Role of biofertilizers and organic fertilizers in growth and productivity Maize (*Zea mays* L.) under constant levels of mineral fertilizers

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Abstract

A field experiment was conducted in one of the fields of Ibn Al-Bitar Vocational Preparatory School, located in Al-Husseiniya sub-district, Karbala Governorate, at 32°N latitude and 44°E longitude, during the fall season of 2024. The experiment was designed using a randomized complete block design (RCBD) in a factorial arrangement with three replications. The first factor included different levels of NPK fertilizer: the full recommended dose, three-quarters of the recommended dose, and half of the recommended dose, denoted as C1, C2, and C3, respectively. The second factor consisted of the following treatments: control, sheep manure at 4 tons ha-1, poultry manure at 4 tons ha-1, sheep manure at 4 tons ha-1 + EM1, poultry manure at 4 tons ha-1 + EM1, and EM1 alone, denoted as O1, O2, O3, O4, O5, and O6, respectively. The results indicated significant differences among the NPK fertilizer levels. The C1 treatment (full recommendation) outperformed other treatments in plant height, leaf area, total chlorophyll content, 500-grain weight, grain yield, and biological yield, with means of 183.83 cm, 4121.8 cm², 0.9505 mg g-1 fresh plant tissue, 195.51 g, 7.633 Mg ha-1, and 19.34 Mg ha-1, respectively. Similarly, organic and biofertilizer treatments showed significant effects, with O4 (sheep manure at 4 tons ha-1 + EM1) demonstrating the highest values for the aforementioned traits, recording 188.33 cm, 4094.5 cm², 1.0129 mg g-1 fresh plant tissue, 206.96 g, 8.833 Mg ha-1, and 21.68 Mg ha-1, respectively. The interaction between factors was also significant, with the C1O4 combination achieving the highest values in all studied traits. These findings suggest that the addition of organic matter, particularly the O4 treatment, resulted in a substantial improvement in maize growth and productivity.

Keywords: Maize, Organic fertilization, Chemical fertilization (NPK), Bioactivator (EM1), Growth and yield indicators.

Introduction

Maize (*Zea mays* L.) is a field crop belonging to the Poaceae family and is considered one of the most important cereal crops worldwide, serving as a primary source for food, animal feed, and industrial applications. Originating from Central America, maize

ranks third in global agricultural importance [1,2]. Its grains contain approximately 72% starch, 4–8% oils, 3% sugars, 15% proteins, 5-8% fiber, and 1.7% ash.[3]
In recent years, increasing attention has been directed towards the application of advanced techniques to enhance field crop production, including maize. Among these techniques are organic farming and biofertilizers. The use of organic fertilizers derived from natural plant or animal sources improves soil properties and enhances crop yield. The addition of organic matter is particularly essential in arid and semi-arid climates, such as in Iraqi soils, as it serves as a crucial source of macro- and micronutrients. Moreover, it plays a significant role in improving soil physical and chemical properties, including permeability, water and air movement, and moisture retention.[4]

Biofertilizers are materials containing beneficial microorganisms that promote plant growth and development. Specific bacterial strains utilize various mechanisms to enhance nutrient uptake, improve soil fertility, and increase crop yields by fixing nitrogen, solubilizing phosphorus and potassium, and producing plant hormones and substances that suppress plant pathogens [5,6]. One such biofertilizer is Effective Microorganisms (EM1), a natural product developed by the Japanese company EMRO and contains a compatible group of beneficial microorganisms such as: lactic acid bacteria, Lactobacillus sp, yeast, and pH. that contribute to enhancing soil fertility and plant health [7]. Studies have shown [8], The use of bio- and organic fertilizers alone or in combination can stimulate microbial activity and increase the availability of nutrients and can be used as an alternative to reduce the consumption of chemical fertilizers. Therefore, through the above, this study aims to know the role of organic fertilization enhanced with bio-fertilizer EM1 in reducing the chemical recommendation of NPK and the interaction between them and the extent of its reflection in some growth and productivity traits of maize.

Materials and Methods

A field experiment was conducted during the autumn season of 2024 in an agricultural field belonging to Ibn Al-Bitar Vocational School, located in Al-Husseiniya district, Karbala Governorate, at coordinates 32°N and 44°E. The experiment was laid out in a randomized complete block design (RCBD) following a factorial arrangement with three replications.

The first factor consisted of different levels of NPK fertilizer application: full recommended dose, three-quarters of the recommended dose, and half of the recommended dose, symbolized by the symbols C1, C2, and C3, respectively. The recommendation that was adopted is the guidance bulletin issued by the Ministry of Agriculture 2006, which included the following levels: N = 320 kg N ha-1, P = 86 kg P ha-1, and K = 66 kg K ha-1. The second factor included six treatments: a control, sheep manure at 4 tons ha-1, poultry manure at 4 tons ha-1, sheep manure at 4 tons ha-1 + biofertilizer (EM1), poultry manure at 4 tons ha-1 + biofertilizer (EM1), and EM1 alone, symbolized by the symbols O1, O2, O3, O4, O5, and O6, respectively .

Chemical fertilizers were applied in two splits: the first dose before planting and the second dose one month after the first dose. Organic fertilizers were applied in a single dose before planting, while EM1 biofertilizer was applied every 10 days from before planting until the pre-flowering stage. The seeds were sown in ridges, with a spacing of 75 cm between ridges and 25 cm between planting holes, resulting in a plant density of 53333 plants per hectare. Additionally, a soil analysis was conducted before planting to determine important chemical and physical properties, and the results were obtained from the laboratories of the Directorate of Agriculture in Karbala Governorate (Table 1).

Organic Matter

Accounted using wet digestion according to the method described in.[9]

Available Nitrogen

Accounted using a Microkjeldal apparatus according to the method described in.[10]

Available Phosphorus

Available phosphorus was measured according to the method of [10] using a device spectrophotometer.

Available Potassium

Accounted using a flame photometer according to the method proposed by.[11]

Table (1): Some chemical and physical traits of field soil before planting.

Trait	Unit	Value
Organic Matter	g kg^{-1} soil	1.43
Available Nitrogen	mg kg^{-1} soil	32.11
Available Phosphorus	mg kg^{-1} soil	11.9
Available Potassium	mg kg^{-1} soil	74.27
Sand	g kg^{-1} soil	300
Silt	g kg^{-1} soil	320
Clay	g kg^{-1} soil	380
Soil Texture		Clay loam

Data recorded

Plant height (cm): Plant height was measured at full flowering for five randomly selected plants from each experimental unit. A measuring tape was used to record the height from the soil surface to the last node of the plant. The average plant height was then calculated.

Leaf area (cm^2): Leaf area per plant was determined for five plants from each experimental unit. The measurement was based on the length of the leaf located below the ear leaf, following the method described in [12]. The average leaf area was then calculated.

Total chlorophyll content (mg g-1 fresh plant tissue): Total chlorophyll content in maize leaves was estimated using the method outlined in [13]. A sample of 200 mg of fresh green leaves was cut with a sterilized scissor and ground in a ceramic mortar with

6 mL of 80% acetone. The extraction process continued until the pellet was colorless. The extract was then separated from the residue using a centrifuge at 1600 rpm for 10 minutes. The supernatant was transferred into opaque tubes to prevent pigment oxidation due to light exposure. The total volume was adjusted with acetone, and a blank sample was prepared containing all experimental reagents except plant tissue. The optical density of the extract was measured using a spectrophotometer at wavelengths of 645 nm and 663 nm. Total chlorophyll content was calculated using the following equation:

Chlorophyll Total = {22.2(D645) + 8.02(D663)} x V/1000xW

500-Grain weight (g): The weight of 500 grain was determined by manually counting 100 grains from each ear, multiplying the count by 5, and weighing them using a precision balance. This measurement was taken from five ears per experimental unit.[14]

Grain yield (Mg ha-1): It was calculated as follows:

Grain yield = Grain yield per plant * Plant density.

Biological yield (Mg ha-1): It was calculated from the dry matter yield for five plants from each experimental unit and then converted to hectares.

Results and Discussion

Plant height (cm)

The results of Table (2) indicate that there are significant differences between the levels of organic and biofertilizers in the plant height trait, as treatment O4 recorded the highest average of 188.33 cm, while the control treatment (O1) recorded the lowest average of 164.39 cm, representing a 14.56% increase. perhaps due to the interaction of organic and biofertilization, which led to an increase in the availability of major and minor nutrients and thus the ability of the root to absorb them from the soil, which leads to an increase in the division and elongation of the stem, which led to an increase in vegetative growth in general and plant height in particular, which is consistent with .[8]

The results of the table also showed significant differences between the levels of chemical fertilizers in the plant height trait, as treatment C1 recorded the highest average of 183.84 cm, while treatment C3 recorded the lowest average of 167.14 cm, representing a 9.99% increase. This may be due to the availability of sufficient and ready NPK nutrients in the soil, which led to their adequate absorption, which was positively reflected on the role of these elements in increasing the division and elongation of the intercalary branches, and thus increasing the height of the plant [15]. As for the interaction, it is noted from the same table that there is a significant interaction between the factors, as the treatment C1O4 outperformed by giving the highest interaction of 195.73 cm, while the treatment C3O1 gave the lowest interaction of 156.57 cm.

Table (2): Effect of chemical fertilization, organic fertilization enhanced with bio activator EM1, and their interaction on the plant height (cm).

Organic and Bio Fertilization	Chemical Fertilization			Means
	C1	C2	C3	
O1	173.17	163.43	156.57	164.39
O2	185.60	179.37	167.80	177.59
O3	182.40	173.97	166.53	174.30
O4	195.73	189.37	179.90	188.33
O5	190.20	186.43	172.00	182.88
O6	175.97	165.70	160.07	167.24
Means	183.84	176.38	167.14	
LSD 0.05	C	O		C*O
	1.835	2.594		4.494

Leaf area (cm^2)

The results of Table (3) indicate that there are significant differences between the levels of organic and bio-fertilizers in the leaf area trait, as treatment O4 recorded the highest average of 4094.5 cm2, while the control treatment O1 recorded the lowest average of 3390.0 cm2, representing a 20.781% increase. This may be attributed to the role of organic fertilizer enhanced with the bio activator (EM1), which affects the readiness and absorption of nutrients, especially nitrogen and phosphorus. The nitrogen element has a significant effect on the process of cell division and expansion, which leads to an increase in leaf area and its great absorption of solar radiation, and thus an increase in the process of photosynthesis [16]. Also, the phosphorus element has a role in cell expansion and division and works to increase the number of root hairs, which leads to the absorption of nutrients and thus an increase in cell division, which increases the leaf area.[17]

The results of the table also showed significant differences between the averages of chemical fertilizers in the leaf area trait, where treatment C1 outperformed with the highest average of 4121.8 cm2, while treatment C3 recorded the lowest average of 3391.3 cm2 and representing a 21.540% increase. The reason may be due to the role of nitrogen, phosphorus and potassium elements and their availability in appropriate proportions for the basic soil conditions that suffer from a lack of nutrients, which led to an increase in the speed of cell growth and division, and thus cell elongation and expansion, which was reflected in an increase in leaf area, and this is consistent with what was reached by [18,19]. As for the interaction, it is noted from the same table that there is a significant interaction between the experimental factors, as treatment C1O4 outperformed by giving the highest interaction, average of 4755.7 cm2, while treatment C3O1 gave the lowest interaction, average of 3004.7 cm2.

Table (3): Effect of chemical fertilization, organic fertilization enhanced with bio activator EM1, and their interaction on the leaf area (cm2).

Organic and Bio Fertilization	Chemical Fertilization			Means
	C1	C2	C3	
O1	3700.8	3464.4	3004.7	3390.0
O2	4008.0	3751.3	3380.8	3713.4
O3	4064.2	3662.5	3426.6	3717.8
O4	4755.7	3874.0	3653.8	4094.5
O5	4352.9	3857.0	3629.1	3946.3
O6	3849.1	3365.0	3252.9	3489.0
Means	4121.8	3662.4	3391.3	
LSD 0.05	C	O		C*O
	43.73	61.84		107.12

Total chlorophyll content (mg g-1 fresh plant tissue)

The results of Table (4) showed that the combinations of organic and bio fertilizers significantly affected the total chlorophyll content of the leaves. It was noted that the treatment O4 gave the highest average of 1.0129 mg g-1 fresh plant tissue, while the control treatment O1 gave the lowest average of 0.6497 mg g-1 fresh plant tissue representing a 55.90% increase. This may be due to the importance of organic fertilization enhanced by the EM1 catalyst in providing nutrients in sufficient quantities, especially nitrogen and magnesium, which form the chlorophyll molecule .[20]

The results also showed significant differences between the levels of chemical fertilizers in the total chlorophyll content of the leaves, as the highest average was recorded at level C1, reaching 0.9505 mg g-1 fresh plant tissue, while level C3 recorded the lowest average of 0.6882 mg g-1 fresh plant tissue representing a 38.11% increase. This may be due to the sufficiency of ready-made NPK fertilizers and then their absorption by the plant and the important role played by these main elements in building the chlorophyll molecule, especially nitrogen, which is associated with magnesium in building the molecule [21]. As for the interaction, the treatment C1O4 achieved the highest interaction, reaching 1.2193 mg g-1 fresh plant tissue, while the treatment C3O1 recorded the lowest interaction, of 0.5683 mg g-1 fresh plant tissue.

Table (4): Effect of chemical fertilization, organic fertilization enhanced with bioactivator EM1, and their interaction on the total chlorophyll content (mg g^{-1} fresh plant tissue).

Organic and Bio Fertilization	Chemical Fertilization			Means
	C1	C2	C3	
O1	0.7417	0.6390	0.5683	0.6497
O2	0.9620	0.8510	0.7273	0.8468
O3	0.9073	0.7590	0.6307	0.7657
O4	1.2193	0.9827	0.8367	1.0129
O5	1.0413	0.8853	0.7553	0.8940
O6	0.8313	0.7527	0.6110	0.7317
Means	0.9505	0.8116	0.6882	
LSD $_{0.05}$	C	O		C*O
	0.02481	0.03509		0.06077

500-Grain weight (g)

The results of Table (5) indicated that there were significant differences between the organic and biofertilizer combinations on the grain weight, as treatment O4 outperformed by giving the highest average of 206.96 g, while the lowest average of 165.51 g in treatment O1 representing a 25.04% increase . The reason may be due to the fact that organic and biofertilizer have a positive effect on the availability of nitrogen and other elements, which has a positive role in the grain filling process [22], and that the nitrogen element works to extend the effective period of grain filling by reducing leaf aging. Bio activator EM1 also plays an important role in the readiness and absorption of phosphorus, which is an essential element in the growth, development, cell division and grain formation [23]. Or it may be due to the superiority of the treatment in leaf area and total chlorophyll (Tables 2 and 3) and their role in increasing the manufactured materials and storing them in the grains.

The results also showed significant differences between the levels of chemical fertilizers in the grain weight trait, as level C1 was superior by giving the highest average of 195.51 g, while level C3 gave the lowest average of 168.69 g representing a 15.89% increase . This may be due to the increased availability of the main elements in the soil when added sufficiently, especially since the soil suffers from a high value of the reaction degree and thus the role of these elements in extending the period of grain filling, or the reason may be due to the increase in the leaf area and total chlorophyll (Tables 2 and 3), which led to an increase in the amount of manufactured materials and their transfer to storage areas in the grains, which increased the weight of the grains. The same table also shows that there are highly significant differences between the interactions of the factors, as treatment C1O4 achieved the highest interaction of 222.97 g, while treatment C3O1 recorded the lowest interaction of 140.40 g.

Table (5): Effect of chemical fertilization, organic fertilization enhanced with bioactivator EM1, and their interaction on the weight of 500 grain (g).Organic and Bio Fertilization Chemical Fertilization Means

Organic and Bio Fertilization	Chemical Fertilization			Means
	C1	C2	C3	
O1	181.93	175.47	140.40	165.51
O2	186.63	191.20	173.43	183.76
O3	196.97	194.30	165.27	185.51
O4	222.97	209.50	188.40	206.96
O5	205.70	194.47	185.37	195.18
O6	178.87	174.00	159.30	170.72
Means	195.51	189.82	168.69	
LSD 0.05	C	O		C*O
	1.502	2.124		3.680

Grain yield (Mg ha^{-1})

The results of Table (6) indicate that there are significant differences between the combinations of organic and biofertilizers on the grain yield. It was noted that treatment O4 recorded the highest average of 8.833 Mg ha-1, while treatment O6 gave the lowest average of 5.601 Mg ha-1 representing a 57.70% increase. The reason is due to the high availability of nutrients, especially nitrogen, as well as the role of organic matter in improving the chemical, physical and biological properties of the soil, which led to stimulating the growth and development of flowering structures, which was reflected in increasing the total grain yield .[24]

The results of the same table showed significant differences between the levels of chemical fertilizers in grain yield, as level C1 was superior by giving the highest average of 7.633 Mg ha-1, while level C3 recorded the lowest average of 6.268 Mg ha-1 representing a 21.77% increase . The reason may be due to the role of the main elements NPK and their presence at a sufficient level to meet the plant's need, which enhanced their role in increasing photosynthesis processes and transferring their products to the grains, which caused an increase in grain yield [25]. Or the reason may be due to the superiority of the treatment in the grain weight trait (Table 4), which was reflected in the increase in grain yield. The results (Table 6) also showed a significant interaction between the study factors, as the highest interaction was in the treatment C1O4 with an average of 9.783 Mg ha-1, while the lowest interaction was in the treatment C3O6 with an average of 4.397 Mg ha^{-1}.

Table (6): Effect of chemical fertilization, organic fertilization enhanced with bioactivator EM1, and their interaction on the grain yield (Mg ha^{-1}).

Organic and Bio Fertilization	Chemical Fertilization			Means
	C1	C2	C3	
O1	6.420	6.100	5.723	6.081
O2	7.607	7.263	6.593	7.154
O3	6.960	6.937	5.693	6.530
O4	9.783	8.943	7.773	8.833
O5	8.630	8.120	7.430	8.060
O6	6.400	6.007	4.397	5.601
Means	7.633	7.228	6.268	
$LSD_{0.05}$	C	O	C*O	
	0.2145	0.3033	0.5254	

Biological yield (Mg ha^{-1})

The results of Table (7) indicated that there were significant differences between the combinations of organic and biofertilizers on the biological yield trait, as treatment O4 outperformed by giving the highest average of 21.68 Mg ha-1, while the lowest average was reached in the control treatment (O1) with an average of 15.75 Mg ha-1, and representing a 37.650% increase. The increase in the biological yield may be due to the combined effect of organic and biofertilizers and their role in improving soil fertility and enhancing the availability of essential nutrients for the plant. Organic fertilizers have the ability to improve the composition of the soil and increase its efficiency in retaining moisture and nutrients, which contributes to enhancing and developing vegetative and root growth. Biofertilizers also improve the absorption of nutrients through the activity of microorganisms in the soil, which is positively reflected in the accumulation of dry matter and thus increasing the biomass of the plant.

The results also showed (Table 7) significant differences between the levels of chemical fertilizers in the biomass yield, as level C1 achieved the highest average of 19.34 Mg ha-1, while level C3 recorded the lowest average of 16.54 Mg ha-1, with representing a 16.92% increase. The reason may be due to the increased availability of the main elements NPK and thus increased absorption by the plant and the role played by the nitrogen element in increasing vegetative growth and the role of potassium in increasing the thickness of the cell walls, which was reflected in the increase in the dry weight of the plant and thus the biological yield [26]. Or the reason may be due to the superiority of the treatment itself in the characteristics of plant height, leaf area and grain yield, which caused an increase in the biological yield (Tables 2, 3 and 6). The results also showed a significant interaction between the studied factors, as the highest interaction was in the treatment C1O4 with an average of 24.00 Mg ha-1, while the lowest interaction was in the treatment C3O6 with an average of 14.46 Mg ha^{-1}.

Table (7): Effect of chemical fertilization, organic fertilization enhanced with bio activator EM1, and their interaction on the biological yield (Mg ha^{-1}).

Organic and Bio Fertilization	Chemical Fertilization			Means
	C1	C2	C3	
O1	16.67	15.59	15.00	15.75
O2	18.78	18.56	16.34	17.89
O3	18.23	17.74	16.36	17.44
O4	24.00	21.69	19.36	21.68
O5	22.01	19.66	17.53	19.73
O6	16.34	16.67	14.64	15.88
Means	19.34	18.32	16.54	
$LSD_{0.05}$	C	O		C*O
	0.548	0.775		1.343

Based on the results of the study, we conclude that adding organic matter its sources to the soil, especially treatment O4, led to a significant This is a discussion, not conclusions. It is better to be brief and rephrased. improvement in the growth and productivity of corn plants. This may be due to the role of organic matter in improving soil properties, which increased its ability to retain water and nutrients, and also enhanced microbial activity that helps in gradually releasing nutrients. At the same time, chemical fertilizer provided essential elements at an appropriate concentration, which contributed to achieving an ideal nutritional balance for the plant. This interaction between organic matter and chemical fertilizer led to improved nutrient absorption and enhanced photosynthesis processes, which positively affected productivity. These results can be used to recommend integrated fertilization practices that combine organic matter and chemical fertilizers to ensure achieving the highest productivity while maintaining soil fertility and sustainability in the long term.

References

1) Revilla, P., Alves, M. L., Andelković, V., Balconi, C., Dinis, I., Mendes-Moreira, P., & Malvar, R. A. (2022). Traditional foods from maize (*Zea mays* L.) in Europe. *Frontiers in Nutrition, 8*, 683399.

2) Al-Maliki, S., Al-Amery, A., Sallal, M., Radhi, A., & Al-Taey, D. K. A. (2021). Effects of arbuscular mycorrhiza and organic wastes on soil carbon mineralisation, actinomycetes, and nutrient content in maize plants (*Zea mays* L.). *Malaysian Journal of Soil Science, 25*, 107–124.

3) Huma, B., Hussain, M., Ning, C., & Yuesuo, Y. (2019). Human benefits from maize. *Scholar Journal of Applied Sciences and Research, 2*(2), 4–7.

4) Wang, J., Sun, N., Xu, M., Wang, S., Zhang, J., Cai, Z., & Cheng, Y. (2019). The influence of long-term animal manure and crop residue application on abiotic and biotic N immobilization in an acidified agricultural soil. *Geoderma, 337*, 710–717.

5) Cai, A., Xu, M., Wang, B., Zhang, W., Liang, G., Hou, E., & Luo, Y. (2019). Manure acts as a better fertilizer for increasing crop yields than synthetic fertilizer by improving soil fertility. *Soil and Tillage Research, 189*, 168–175.

6) Duan, Y., Chen, L., Zhang, J., Li, D., Han, X., Zhu, B., & Huang, P. (2021). Long-term fertilisation reveals close associations between soil organic carbon composition and microbial traits at aggregate scales. *Agriculture, Ecosystems & Environment, 306*, 107169.

7) Osman, S. O., Moustafa, F. M. A., Abd El-Galil, H. A., & Ahmed, A. Y. M. (2011). Effect of yeast and effective microorganisms (EM1) application on the yield and fruit characteristics of Bartamuda date palm under Aswan conditions. *Assiut Journal of Agricultural Sciences, 42*(5), 332–349.

8) Hamad, A. H. A. A., Hamza, M. A., & Hussain, A. K. (2024). Response of maize to bio and organic fertilization and the stages of spraying nano-fertilizer. *5th International Conference of Modern Technologies in Agricultural Sciences, 1371*, 032008. *IOP Publishing*. https://doi.org/10.1088/1755-1315/1371/3/032008

9) Black, C. A. (1965). *Methods of soil analysis: Chemical and microbiological properties*. American Society of Agronomy Inc., Madison, Wisconsin, U.S.A.

10) Page, A. L., Miller, R. H., & Keeney, D. R. (1982). *Methods of soil analysis: Chemical and microbiological properties* (Agronomy Series No. 9). American Society of Agronomy, Madison, Wisconsin, U.S.A., pp. 1–33.

11) Richards, L. A. (1954). *Diagnosis and improvement of saline and alkali soils*. U.S. Department of Agriculture Handbook No. 60.

12) Al-Sahouki, M. M., & Saddam, H. J. (2014). Estimation of leaf area in sorghum based on a single leaf. *Iraqi Journal of Agricultural Sciences, 45*(1), 1–5.

13) McKinney, G. (1941). Absorption of light by chlorophyll solutions. *Journal of Biology, 140*, 315–322.

14) Al-Sahouki, M. M. (1990). *Yellow corn production and improvement*. Ministry of Higher Education and Scientific Research, University of Baghdad, p. 400.

15) Kareem, I., Taiwo, O. S., Kareem, S. A., Oladosu, Y., Eifediyi, E. K., Abdulmaliq, S. Y., & Olalekan, K. (2020). Growth and yield of two maize varieties under the influence of plant density and NPK fertilization. *Journal of Applied Sciences and Environmental Management, 24*(3), 531–536.

16) Al-Lami, S. H. K. (2004). *Effect of seeding rates, nitrogen levels, and herbicide mixture on the growth and yield of bread wheat (Triticum aestivum L.)* (Doctoral dissertation, College of Agriculture, University of Baghdad).

17) Al-Ansari, M. M., Al-Younes, A. H. A., Hasnawi, G. S., & Al-Shamaa, W. S. (2011). *Principles of field crops* (2nd ed.). Ministry of Higher Education and Scientific Research.

18) Ziki, S. J. L., Zeidan, E. M. I., El-Banna, A. Y. A., & Omar, A. E. A. (2019). Influence of cutting date and nitrogen fertilizer levels on growth, forage yield, and quality of Sudan grass in a semiarid environment. *International Journal of Agronomy, 1*.

19) Abera, K., Tana, T., & Takele, A. (2020). Effect of rates and time of nitrogen fertilizer application on yield and yield components of sorghum (*Sorghum bicolor* L. Moench) at Raya Valley, Northern Ethiopia. *International Journal of Plant Breeding and Crop Science, 7*(1), 598–612.

20) Hamad, A. H. A. A., Hamza, M. A., & Hussain, A. K. (2024). Effect of spraying stages with bio-organic and nano-fertilizers on the growth and yield of maize (*Zea mays* L.). *Euphrates Journal of Agricultural Science, 16*(2).

21) Al-Khuzaie, K. H. (2024). Effect of agricultural sulfur levels and application dates on the NPK rate and some growth characteristics during the growth stages of the yellow corn plant (*Zea mays*). *Dijlah Journal of Agricultural Sciences, 2*(1), 8–29.

22) Alkinani, A. H., Jassem, K. A., & Jabail, W. A. (2019). Effect of nitrogen fertilization and number of cuttings on yield components of barley (*Hordeum vulgare* L.). *Journal of Al-Muthanna for Agricultural Sciences, 7*(1).

23) Morsy, M., & Ahmed, A. (2021). Response of two yellow maize hybrids to amino acids, mineral NPK, and nano-fertilizers under Toshka District conditions. *Alexandria Science Exchange Journal, 42*(2), 327–340.

24) El-Shafey, A. I., & El-Hawary, M. M. (2016). Integrated effect of bio-organic and/or nitrogen fertilizer on growth and yield of maize (*Zea mays* L.). *Zagazig Journal of Agricultural Research, 43*(4), 1105–1119.

25) Abdelzaher, M. A., Ibrahim, Z. I., Khalil, F. A., & Mohamed, W. S. (2017). Use of some organic and bio fertilizers as a partial substitution of mineral nitrogen fertilization for corn: The effect on corn yield and N, P, and K uptake. *Assiut Journal of Agricultural Sciences, 48*(1).

26) Alzreejawi, S. A. M., & Al-Juthery, H. W. A. (2020, August). Effect of spraying with nano NPK, complete micro fertilizers, and nano amino acids on some growth and yield indicators of maize (*Zea mays* L.). In *IOP Conference Series: Earth and Environmental Science* (Vol. 553, No. 1, p. 012010). *IOP Publishing*.