

Effect of Integrated Nitrogen and Bio-fertilization on Growth, Yield and Oil traits of Sunflower (*Helianthus annuus* L.)

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Abstract

A field experiment was conducted during the spring and autumn growing seasons of 2025 in the Jalyukhan region to study the effect of five combinations of biofertilizers and nitrogen fertilizers (80 kg N ha⁻¹, 65 kg N ha⁻¹ + Azotobacter, 50 kg N ha⁻¹ + Azotobacter, 35 kg N ha⁻¹ + Azotobacter, and 20 kg N ha⁻¹ + Azotobacter) and three sunflower cultivars (Aqmar, Banam, and Taqah-1) on growth characteristics and yield. The experiment was conducted as a split-plot factorial experiment with a randomized complete block design (RCBD) and three blocks. The results showed significant differences between the combinations in most of the studied traits for both growing seasons. The combination of 35 kg N ha⁻¹ + Azotobacter resulted in the highest average plant height, disc diameter, and oil percentage for both seasons, while the combination of 20 kg N ha + Azotobacter resulted in the highest average chlorophyll content index. Cultivars significantly affected all studied traits. The Taqah-1 cultivar recorded the highest values for plant height, number of leaves, disc diameter, 1000-seed weight, seed yield, oil percentage, and oil yield for both growing seasons, while the Aqmar cultivar recorded the highest value for chlorophyll content index for both growing seasons. There was a significant interaction between the 35 kg N ha⁻¹ + Azotobacter combination and the Taqah-1 cultivar in plant height and oil percentage and 1000-seed weight for both growing seasons.

Keywords: Sunflower, Biofertilization, Cultivars

Introduction

The sunflower (*Helianthus annuus* L.) is considered one of the most important oilseed crops globally, belonging to the Asteraceae family. It is one of the most highly traded crops in international markets, with oil content in its seeds reaching up to 47%. It is regarded as an excellent source of edible oil for human nutrition due to its content of omega-3 fatty acids, in addition to unsaturated fatty acids such as oleic and linoleic acids. Furthermore, it contains essential vitamins, including vitamins A, B, and E [21]. Despite its importance, its productivity remains below the required level, necessitating extensive agricultural and technological improvements, including crop management, particularly nutrition [15].

Nitrogen is a major component of plant cells, playing a vital role in numerous metabolic processes, including respiration,

photosynthesis, and cell division. Plants require nitrogen during the early stages of growth and root formation [17]. The use of biofertilizers has recently become widespread because they reduce the use of mineral fertilizers, which have harmful effects on human health and the environment [14]. Azotobacter bacteria are among the most widely used biofertilizers due to their ability to fix atmospheric nitrogen symbiotically and convert it to ammonium. They represent a natural source of nitrogen in ecosystems and agricultural systems lacking symbiotic nitrogen fixation [26]. Furthermore, they secrete certain growth hormones and vitamins, which improve crop growth and yield. These bacteria fix approximately 30 kg of nitrogen per hectare [1]. This research aims to determine the optimal fertilizer combination and the most suitable cultivar for the region's conditions to ensure maximum sunflower yield. [16] in their study of three biofertilization levels, found

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significant differences between the levels in plant height, number of leaves, head diameter, 1000-seed weight, and oil yield. [20], in their experiment using nine biofertilizer and nitrogen combinations, found significant differences between the combinations in plant height, number of leaves, head diameter, plant yield, and oil percentage. [13] in their study of eleven biofertilizer and nitrogen combinations, found significant differences between the combinations in head diameter, 1000-seed weight, oil percentage, and oil yield. [10], in their experiment with three sunflower cultivars (Ishaqi-1, Flamme, and Lilo), found significant differences between the cultivars in plant height, number of leaves, chlorophyll content, oil percentage, and oil yield. [7] in their study of three sunflower cultivars (Leviathan, Aqmar, and Banam), found significant differences between the cultivars in plant height, chlorophyll content, 1000-seed weight, and plant yield. [2], in an experiment studying two sunflower cultivars (Ishaqi-1 and Ishaqi-2), showed significant differences between the cultivars in disc diameter, oil percentage, and oil yield.

Materials and Methods

The field experiment was conducted during the spring and autumn growing seasons of 2025 to study the effect of a combination of biofertilization and nitrogen fertilization on the growth traits and yield of sunflower cultivars. The experiment was implemented as a factorial experiment within split plots using a randomized complete block design (RCBD) with three blocks. The main blocks included five treatments of biofertilization and nitrogen fertilization, while the subplot included three sunflower cultivars. The number of experimental units was $5 \times 3 \times 3 = 45$ experimental units. Each experimental unit consisted of four rows, 2 m long, with a spacing of 30 cm between plants. A distance of 0.5 m was maintained between experimental units, and a distance of 1 m was maintained between blocks. The treatments were randomly distributed among the

experimental units within each replicate. The experimental field was plowed twice perpendicularly with a disc plow for smoothing and leveling. Planting took place in two seasons: the spring season on 4/30/2025 and the autumn season on 7/16/2025.

Studied Traits: Five plants were randomly selected from each experimental unit to study the following traits:

1. Plant height (cm): Measured from the point where the stem meets the soil to the base of the flower head.
2. Number of leaves (leaves per plant): Counted the total number of leaves plant.
3. Chlorophyll content index (SPAD): Calculated by taking three readings from the bottom, middle, and top of the plant and averaging the reading for each plant.
4. Flower head diameter (cm): Measured using a measuring tape across the center of the flower head.
5. Weight of 1000 seeds (g): After mixing the harvested plants, 1000 seeds were randomly selected from each experimental unit and weighed.
6. Seed yield per plant (g per plant): Weighed the seed yield of five plants and averaged the seed yield in grams per head.
7. Oil content in seeds (%): Estimated using the Soxhlet apparatus and the equation: % oil =

$$\frac{\text{weight befo extraction} - \text{weight after extraction}}{\text{sample weight}} \times 100$$

100

Total sample weight before washing - Sample weight after washing / 2g $\times 100$

8. Oil yield (g plant^{-1}) = Percentage of oil (%) $\times$ Plant seed yield / 100

Statistical Analysis:

Data were statistically analyzed using the Analysis of Variance (ANOVA) method with the Statistical Package for the Social Sciences (SPSS). Means were compared using Duncan's multiple range test at probability levels of 1 and 5% (Al-Rawi and Khalaf-Allah, 2000).

Results and Discussion:

Plant height (cm):

The results shown in Table (1) indicate significant differences in plant height between the fertilizer combinations. The combination of 35 kg N ha⁻¹ + Azotobacter resulted in the highest average height (137.28 and 141.50 cm) for both growing seasons, while the control treatment with a concentration of 80 kg N ha⁻¹ resulted in the lowest average height (126.70 cm). The average height was 128.84 cm for both growing seasons. This may be due to the optimal use of biofertilizers and nitrogen fertilizers, where these fertilizers are characterized by their ability to convert essential nutrients from an unusable form to a usable one. Azotobacter bacteria are characterized by their ability to synthesize growth substances such as indoleacetic acid (IAA) and auxins, which contribute to increased plant height [18]. This result is consistent with [3] and [24]. The cultivar had a significant effect on plant height, as shown in Table (2). The Taqah-1 cultivar gave the highest average height (143.10 and 143.86 cm) for both growing seasons, while the Banam cultivar gave the lowest average height (124.38 and 128.96 cm) for both growing seasons. This is attributed to the genetic variation among cultivars in their response to growth factors, including plant height. The auxins present in the Growing tips play a key role in this process [26]. This finding is consistent with [6,10].

Table (3) shows a significant interaction between the 35 kg N ha⁻¹ + Azotobacter combination and the Taqah-1 cultivar. The highest average plant height (150.53 cm) was recorded for the spring crop, while no significant interaction between fertilization and cultivar was observed for the autumn crop.

Number of leaves (leaves per plant):

Table (1) indicates significant differences between the fertilizer combinations in the number of leaves. The 50 kg N/ha + Azotobacter combination gave the highest average leaf height (26.36 and 25.8 leaves per

plant) for both crops, while the control treatment with a concentration of 80 kg N/ha gave the lowest average leaf height. (21.97 and 20.82 leaves per plant) for both growing seasons. This increase in the traits may be due to the plants' positive response to nitrogen-fixing biofertilizers, in addition to other elements and amino acids, during the growth stage [16]. This result is consistent with [20,24].

Table (2) shows significant differences between the cultivars in the number of leaves. The Taqah-1 cultivar exhibited the highest average for the traits (25.56 and 24.52 leaves per plant) for both growing seasons, while the Banam cultivar exhibited the lowest average (23.00 and 22.32 leaves per plant) for both growing seasons. This variation between the cultivars is attributed to differences in their genetic makeup and their responsiveness to environmental conditions. This result is consistent with [6,10].

Table (3) shows no significant interaction between fertilizer combinations and cultivars in the number of leaves traits for both growing seasons.

Chlorophyll Index (SPAD)

Table (1) shows significant differences between fertilizer combinations for the chlorophyll content index. The 20 kg N/ha combination gave the highest average value (45.79 and 44.04 SPAD) for both growing seasons, while the control treatment with a concentration of 80 kg N/ha gave the lowest average value (41.28 and 38.59 SPAD) for both growing seasons.

Table (2) shows significant differences between cultivars for the chlorophyll content index for both growing seasons. The Aqmar cultivar gave the highest average value (45.88 and 43.96 SPAD) for both growing seasons, while the Taqah-1 cultivar gave the lowest average value (34.33 SPAD) for the spring growing season, and the Banam cultivar had the lowest average value (38.80 SPAD) for the

autumn growing season. This difference between cultivars is attributed to their vegetative growth patterns and their interaction with prevailing environmental conditions. This interaction directly affects the physiological processes of these cultivars, particularly their efficiency in converting and utilizing photosynthetic byproducts for cell growth and elongation, which in turn directly impacts the chlorophyll content in the leaves [9]. This finding is consistent with [7,10] .

Table (3) shows no significant interaction between fertilizer combinations and cultivars in the chlorophyll content index.

Head diameter (cm):

The results in Table (1) show significant differences between fertilizer combinations in the head diameter characteristic. The combination of 35 kg N/ha + Azotobacter resulted in the highest average disc diameter (17.51 and 17.7 cm) for both growing seasons, while the control treatment with 80 kg N/ha yielded the lowest average diameter (14.55 and 13.79 cm) for both growing seasons. The increased disc diameter may be attributed to the adequate supply of mineral nitrogen with the biofertilizer, leading to increased photosynthetic activity through stimulation of cell elongation and division [13]. This finding is consistent with Jonnagorla et al. (2021) and [3].

Table (2) shows significant differences between cultivars in disc diameter for both growing seasons. The Taqah-1 cultivar exhibited the highest average diameter (17.37 and 17.06 cm) for both seasons, while the Banam cultivar exhibited the lowest average diameter (14.76 and 14.95 cm) for both seasons. This variation in disc diameter between cultivars is attributed to genetic factors specific to the cultivars [7]. This finding is consistent with [2,21].

Table (3) indicates no significant interaction between fertilizer combinations and cultivars in disc diameter for both growing seasons.

1000-seed weight (gm):

Table (1) shows significant differences between fertilizer combinations in the 1000-seed weight trait. The combination of 35 kg N ha⁻¹ + Azotobacter resulted in the highest average weight (89.54 and 109.06 g) for both growing seasons, while the control treatment with 80 kg N ha⁻¹ resulted in the lowest average weight (67.73 and 84.99 g) for both growing seasons. The increase in 1000-seed weight may be attributed to the use of mineral nitrogen with biofertilizers as a source of nitrogen-fixing bacteria [19] which promotes crop growth and development. This result is consistent with [13,22] .

Table (2) shows significant differences between the cultivars in the 1000-seed weight trait. The Taqah-1 cultivar exhibited the highest average weight (86.24 and 104.41 g) for both growing seasons, while the Banam cultivar exhibited the lowest average weight (67.49 and 87.11 g) for both growing seasons. This is attributed to the superiority of the Taqah-1 cultivar in the number of leaves (Table 4), which increased photosynthesis and consequently led to increased nutrient storage in the telomere (seeds). This result is consistent with [2,5].

Table (3) indicates a significant interaction between the combination of 35 kg N ha⁻¹ + Azotobacter with the Taqah-1 cultivar in the 1000 seed weight traits, as it recorded the highest average for the traits, which reached (100.76 and 120.35 g) for both seasons, while the comparison treatment with a concentration of 80 kg N ha⁻¹ with the Banam cultivar gave the lowest average for the trait, which reached (57.63 and 77.13 g) for both seasons.

Seed yield per plant (gm):

The results in Table (1) show significant differences between the fertilizer combinations in the plant seed yield traits. The combination

of 35 kg N ha⁻¹ + Azotobacter gave the highest average yield, reaching (112.76 and 126.44 g plant⁻¹) for both growing seasons, while the control treatment with a concentration of 80 kg N ha⁻¹ gave the lowest average yield, reaching (71.41 and 71.76 g plant⁻¹) for both growing seasons. This variation is attributed to the increased disc diameter (Table, 6). This result is consistent with [20] and [25].

Table (2) indicates significant differences between the cultivars in the plant seed yield traits. The Taqah-1 cultivar outperformed others, recording the highest average seed weight in both growing seasons (105.87 and 113.08 g plant⁻¹), while the Banam cultivar recorded the lowest average seed weight (76.23 and 79.53 g plant⁻¹) for both growing seasons. This is attributed to the increased disc diameter (Table 6) . This result is consistent with [21,12]

Table (3) shows a significant interaction between the 35 kg N ha⁻¹ + Azotobacter combination and the Taqah-1 cultivar , which recorded the highest average yield of the traits (132.60 g plant⁻¹) for the spring crop. Conversely, the 65 kg N ha⁻¹ + Azotobacter combination and the Aqmar cultivar gave the lowest average yield of the traits (44.69 g plant⁻¹) in the spring crop. However, there was no significant interaction between the fertilizer combinations and the cultivars in the autumn crop.

Oil content (%):

The results in Table (1) show significant differences between the fertilizer combinations in the oil content for both growing seasons. The combination of 35 kg N ha⁻¹ + Azotobacter gave the highest average oil content for the spring growing season (39.94%), while the combination of 20 kg N ha⁻¹ + Azotobacter gave the highest average oil content for the autumn growing season (37.38%). The control treatment with a concentration of 80 kg N ha⁻¹ gave the lowest

average oil content (33.25% and 33.05%, respectively) for both growing seasons. this attributed to the enhancement of plant growth, productivity, and quality resulting from the application of Azotobacter bacteria. This micro-organism is characterized by its ability to stimulate plant growth through the production of growth-regulating hormones, such as auxins, cytokinins, and gibberellic acid, which subsequently promote nutrient uptake. This result is consistent with [3] and [13].

Table (2) shows significant differences between the cultivars in oil percentage. The Taqah-1 cultivar recorded the highest average oil percentage in both growing seasons (37.68% and 37.75%), while the Banam cultivar recorded the lowest average oil percentage (35.20% and 33.11%). This difference is attributed to the superior cultivar being influenced by prevailing environmental conditions. This result is consistent with [7] and [2].

Table (3) shows a significant interaction between the 35 kg N ha⁻¹ + Azotobacter combination and the Taqah-1 cultivar in oil percentage. This combination gave the highest average oil percentage in both growing seasons (42.25% and 39.50%), while the control treatment with 80 kg N ha⁻¹ and the Banam cultivar gave the lowest average oil percentage (32.03% and 30.66%).

Oil yield per plant (g):

The results in Table (1) indicate significant differences between the fertilizer combinations in oil yield. The combination of 35 kg N ha⁻¹ + Azotobacter gave the highest average yield in both growing seasons (45.22 and 45.38 g plant⁻¹), while the control treatment with a concentration of 80 kg N ha⁻¹ gave the lowest average yield (23.87 and 24.05 g plant⁻¹) for both growing seasons. This is attributed to the increased disc diameter (Table 6), and the

increased oil content in the seeds (Table 13). This result is consistent with [3] and [13].

Table (2) shows significant differences between cultivars in oil yield. The Taqah-1 cultivar exhibited the highest average yield in both growing seasons (40.06 and 42.59 g plant⁻¹), while the Banam cultivar exhibited the lowest average yield (27.13 and 26.45 g

plant⁻¹) for both seasons. This increase is attributed to the higher seed yield per plant (Table 10), and the higher oil content in the seeds (Table 13). This result is consistent with the findings of [6,7] .

Table (3) indicates no significant interaction between fertilizer combinations and cultivars in oil yield in both growing seasons.

Table (1): Effect of fertilizer combination on some studied characteristics of the sunflower.

fertilizer combination	Plant height (cm)	No. of leaves plant ⁻¹	Chlorophyll index (SPAD)	Head diameter (cm)	1000-seed weight	Seed yield (g head ⁻¹)	Oil content (%)	Oil yield (g head ⁻¹)
Spring season								
80 kg N ha ⁻¹	126.70c	21.97c	41.28c	14.55c	67.73c	71.41d	33.25c	23.87d
65 kg N ha ⁻¹ + Azotobacter	130.28bc	23.71b	43.26b	15.75b	71.97bc	83.38c	35.91bc	29.97c
50 kg N ha ⁻¹ + Azotobacter	133.37ab	26.36a	43.43b	16.33b	82.42ab	98.68b	36.58b	36.08b
35 kg N ha ⁻¹ + Azotobacter	137.23a	24.37b	43.69b	17.51a	89.54a	112.76a	39.94a	45.22a
20 kg N ha ⁻¹ + Azotobacter	133.27ab	23.42bc	45.79a	16.15b	73.46bc	88.69bc	36.69b	32.67bc
Autumn season								
80 kg N ha ⁻¹	128.84c	20.82c	38.59c	13.79d	84.99c	71.76d	33.05c	24.05d
65 kg N ha ⁻¹ + Azotobacter	133.51b	23.08b	40.58bc	15.73c	91.52bc	87.39c	35.30b	31.06c
50 kg N ha ⁻¹ + Azotobacter	136.88ab	25.84a	40.93bc	16.80b	100.57ab	105.06b	34.55bc	36.68b
35 kg N ha ⁻¹ + Azotobacter	141.50a	23.42b	42.55ab	17.97a	109.06a	126.44a	35.88a	45.38a
20 kg N ha ⁻¹ + Azotobacter	137.33ab	23.24b	44.04a	15.76c	94.99bc	93.07bc	37.38a	35.14bc

Values followed by different letters within the same column differ significantly from each other according to Duncan's multiple range test.

Table (2): Effect of cultivars on some studied traits of the sunflower.

cultivar s	Plant height (cm)	No. of leaves plant ⁻¹	Chlorophyll index (SPAD)	Head diamete r (cm)	1000- seed weight	Seed yield (g head ⁻¹)	Oil content (%)	Oil yield (g head ⁻¹)
Spring season								
Aqmar	129.06b	23.35b	45.88a	16.05b	77.33b	90.81b	36.55ab	33.49b
Banam	124.38c	23.00b	41.26c	14.76c	67.49c	76.23c	35.20b	27.13c
Taqah-1	143.10a	25.56a	34.33b	17.37a	86.24a	105.87a	37.68a	40.06a
Autumn season								
Aqmar	134.01b	23.01b	43.96a	16.01b	97.15b	97.62b	34.85b	34.34b
Banam	128.96c	22.32b	38.80c	14.95c	87.11c	79.53c	33.11c	26.45c
Taqah-1	143.86a	24.52a	41.25b	17.06a	104.4a	113.08a	37.75a	42.59a

Values followed by different letters within the same column differ significantly from each other according to Duncan's multiple range test.

Table (3): Effect of the interaction between fertilizer combinations and cultivars on some studied traits of the sunflower.

fertilizer combination	cultivars	Plant height (cm)	No. of leaves plant ⁻¹	Chlorophyll index (SPAD)	Head diamete r (cm)	1000- seed weight	Seed yield (g head ⁻¹)	Oil content (%)	Oil yield (g head ⁻¹)
Spring season									
80 kg N ha ⁻¹	Aqmar	126.75 df	21.66	44.20	15.73	67.97c d	75.85f	33.83ef	25.71
	Banam	120.83f	20.91	39.31	12.93	57.03d	48.90g	32.08f	15.73
	Taqah-1	132.53c e	23.33	40.34	15.00	78.21b c	89.49df	33.83ef	30.18
65 kg N ha ⁻¹ + Azotobacter	Aqmar	121.25f	22.41	45.89	15.86	79.38b c	44.69ef	35.41cf	31.45
	Banam	125.00 df	23.33	41.17	14.26	69.54c d	79.50f	32.91ef	26.24
	Taqah-1	144.60a b	25.40	42.72	17.13	66.98c d	81.76f	39.41ab	32.22
50 kg N ha ⁻¹ + Azotobacter	Aqmar	126.33 df	24.75	45.70	15.60	85.36a b	102.03 be	38.66bc	39.66
	Banam	124.66 df	25.66	41.59	15.80	66.46c d	76.40f	36.41be	27.91
	Taqah-1	149.13a	28.66	43.01	17.60	95.43a	117.60a b	34.66ef	40.66
35 kg N ha ⁻¹ +	Aqmar	133.50c d	24.00	46.96	17.13	88.73a b	111.25 bc	38.83bc	43.19

Azotobacter	Banam	127.83 df	23.91	40.62	15.86	79.12b c	94.42cf	38.75bc	36.54
	Taqah-1	150.53a	25.20	43.48	19.53	100.76 a	132.60a	42.25a	55.93
20 kg N ha⁻¹ + Azotobacter	Aqmar	137.50 bc	23.91	46.64	15.93	65.22c d	76.23f	36.00be	27.45
	Banam	123.58e f	21.16	43.64	14.93	65.31c d	81.76f	35.83be	29.25
	Taqah-1	138.73 bc	25.56	47.11	14.26	89.84a b	107.90 bd	38.25b d	41.32
Autumn season									
80 kg N ha⁻¹	Aqmar	121.00	20.33	41.82	14.10	77.24f	67.34	31.25g h	20.96
	Banam	120.33	19.33	35.40	12.77	77.13f	61.18	30.66h	18.79
	Taqah-1	145.20	22.80	38.55	14.50	100.60 bd	86.76	37.25ad	32.42
65 kg N ha⁻¹ + Azotobacter	Aqmar	134.20	22.60	44.64	15.77	93.72ce	88.21	34.25d g	30.18
	Banam	128.53	21.73	37.40	13.99	90.62df	73.49	33.41eh	24.58
	Taqah-1	137.80	24.93	39.70	17.41	90.21df	100.48	38.25ab	38.43
50 kg N ha⁻¹ + Azotobacter	Aqmar	137.40	25.86	44.20	17.33	104.09 bd	106.23	33.25eh	35.46
	Banam	129.26	24.86	37.56	14.99	93.77ce	89.57	31.66fh	28.26
	Taqah-1	144.00	26.80	41.03	18.08	103.87 bd	119.37	38.75a	46.41
35 kg N ha⁻¹ + Azotobacter	Aqmar	141.13	23.26	44.73	17.33	113.42a b	134.50	37.50ad	50.32
	Banam	136.90	22.46	41.68	17.66	93.41ce	99.46	35.16be	34.94
	Taqah-1	146.46	24.53	41.23	18.91	120.35a	145.36	39.50a	50.88
20 kg N ha⁻¹ + Azotobacter	Aqmar	136.33	23.00	44.42	15.55	97.27cd	91.81	38.00ac	34.89
	Banam	129.80	23.20	41.96	15.33	80.66ef	37.95	34.66cg	25.71
	Taqah-1	145.86	23.53	45.25	16.41	107.04a c	113.45	35.00bf	44.84

Values followed by different letters within the same column differ significantly from each other according to Duncan's multiple range test.

Conclusion:

This experiment concludes that the fertilizer combination 35 kg N ha⁻¹ + Azotobacter effectively contributed to improving sunflower productivity, in addition to the superiority of the Taqah-1 cultivar plants in most of the studied traits, including disc diameter, 1000

seed weight, oil percentage, and oil yield, which was reflected positively in increasing the productivity of the sunflower crop under the conditions of the region.

References

- [1] Aasfar, A., Bargaz, A., Yaakoubi, K., Hilali, A., Bennis, I., Zeroual, Y., & Meftah Kadmiri, I. (2021). Nitrogen fixing Azotobacter species as potential soil biological enhancers for crop nutrition and yield stability. *Frontiers in microbiology*, 12, 628379.
- [2] Abbas, H., & Saudi, A. (2026). effect of seeds priming and foliar application with seaweed extract on some yield traits of two sunflower cultivar. *Iraqi Journal of Agricultural Sciences*, 57(3), 812-827.
- [3] Abdelaziz, S. M. (2022). Response of sunflower to biofertilization and diatoms under saline condition. *Egypt J of Appl Sci*, 37, 58-79.
- [4] AL-Abody, M. A. K., Ramadhan, M. N., & Muhsin, S. J. (2021). Effect of Humic acid on the growth, yield components, and yield of three sunflower cultivars (*Helianthus annuus* L.). *Eco. Env. Cons*, 27(2), 548-554..
- [5] Ali, A. H., Sharif, Y. O. N. A., Raheem, A. H., Hussein, A. A. K., & Al-Mafarji, T. R. T. (2025). The effect of phosphorus levels on growth and yield components in sunflower (*Helianthus annuus* L.). *Agricultural Science Digest*, 1-6.
- [6] Al-kakayie, N. A. H., & Al-Juhayshi, W. K. S. Response Of Sunflower Varieties Growth and Yield to Foliar Application with Nano Boron. *Journal of Agricultural Science-16 (2):161-172*.
- [7] KhM, A. R., & Khalaf-Allah, A. M. (2000). Design and analysis of agricultural experiments. Dar Al-Kutub Foundation for Printing and Publishing. University of Mosul. Iraq, 81.
- [8] Al-Shammary, A. M. A., & Akram, Z. H. (2016). The Effect of colchicine concentration and time of tubers Immersion on three genotypes of potatoes (*Solanum tuberosum* L.) I- Some vegetative growth attributes. *Zagazig Journal of Horticultural science*, 43(6), 1939-1951.
- [9] Al-Zaidy, M. K. A., & Al-Hilfy, I. H. (2023, December). Replacing part of the mineral fertilizer by using organic and biological fertilizers in the sunflower. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1262, No. 3, p. 032012). IOP Publishing.
- [10] Bapir, K. A., & Mahmood, B. J. (2022). Response of Two Sunflower (*Helianthus annuus* L.) Genotypes to Foliar Application of Different Nano Fertilizers. *Zanco Journal of Pure and Applied Sciences*, 34(5), 141-153.
- [11] Dasgupta, K., Sardar, S., Roy, A., & Mazumdar, D. (2024). The Effect of Different Doses of Nitrogen and Seed Treatment with Biofertilizers on Growth, Yield and Seed Quality of Sunflower (*Helianthus annuus* L.). *Journal of Advances in Biology & Biotechnology*, 27(10), 1447-1456.
- [12] El-Kholy, M. A., El-Ashry, S., & Gomaa, A. M. (2005). Biofertilization of maize crop and its impact on yield and grains nutrient content under low rates of mineral fertilizers. *J. Appl. Sci. Res*, 1(2), 117-121.
- [13] Elsahookie, M. M. 1994. Sunflower Production and Improvement. Ibaa Center for Agricultural Research. Baghdad. pp: 3
- [14] Fakirah, A. B., Al-Thobhani, M. A., & Al-Aq, M. M. (2017). Effect of plant density and bio-fertilizer on some morphological traits, seed yield and yield components of sunflower (*Helianthus annuus* L.).
- [15] Gul, V., & Kara, K. (2015). Effects of different nitrogen doses on yield and quality traits of common sunflower (*Helianthus annuus*

- L.). *Turkish Journal of Field Crops*, 20(2), 159-165.
- [16] Jonnagorla, L., Singh, V., Tiwari, D., Ali, S. M., & Krishna, B. H. (2021). Effect of levels of nitrogen and biofertilizers on growth and yield of sunflower (*Helianthus annuus* L.). *Inter. J. Curr. Microbiol., Appl. Sci*, 10(01), 2196-2202.
- [17] Keshta, M. M., & El-Kholy, M. H. (1999, May). Effect of inoculation with N₂-fixing bacteria, nitrogen fertilizer and organic manure on sunflower. In *Proc. of the International symposium of biological nitrogen fixation and crop production, Cairo, Egypt* (pp. 11-13).
- [18] Khandekar, S. D., Ghotmukale, A. K., Dambale, A. S., & Suryawanshi, S. B. (2018). Response of Kharif sunflower to biofertilizers and different fertilizer levels. *International Journal of Current Microbiology and Applied Sciences*, 6, 1558-1563.
- [19] Mahmood, H. N. (2021). Efficacy of various NPK application methods on the yield of different sunflower (*Helianthus annuus* L.) genotypes grown during spring seasons. *Applied Ecology and Environmental Research*, 19(1), 491-505.
- [20] Mohammed, A. (2026). growth and productivity sustainability of sunflower by influence of nitrogen fertilization and bacterial biofertilization. *Iraqi Journal of Agricultural Sciences*, 57(1), 183-193.
- [21] Nasralla, A. Y., Al-Hilfy, I. H., Al-Abodi, H. M., Mohammed, O. A., & Mhmood, M. (2014). Effect of spraying some plant extractions and anti-oxidant on growth and yield of sunflower. *Iraqi Journal of Agricultural Sciences*, 45(7), 651-659.
- [22] Rahman, R. H. A., Bakr, A. M. M., and Salama, A. (2020). Effects of NP and Biofertilizers on Growth and Some Yield Attributes of Sunflower *Helianthus Annus* L. *Fields of Interests*, 42.
- [23] Saloum, A. (2025, April). Effect of Mineral and Bio-Fertilizers on the Growth and Productivity of Sunflower (*Helianthus annuus* L.). In *IOP Conference Series: Earth and Environmental Science* (Vol. 1487, No. 1, p. 012092). IOP Publishing.
- [24] Sumbul, A., Ansari, R. A., Rizvi, R., & Mahmood, I. (2020). Azotobacter: A potential bio-fertilizer for soil and plant health management. *Saudi journal of biological sciences*, 27(12), 3634-3640.
- [25] Willston Research Extension Center (2005). Safflower cultivar trials. North Dakota State University. 14120 Hwy 2, Williston, N D 58801-8629. Voice: (701) 774-4315.