# Effect of Azotobacter Inoculation on Growth, Yield, and Oil Quality of Sunflower (Helianthus annuus L.) Cultivars

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**ABSTRACT**
A field experiment was conducted during the spring and autumn seasons of 2025 in Al- 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 traits 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 in both seasons. The combination of 35 kg N ha$^{-1}$ + Azotobacter gave the highest average plant height, number of seeds per disc, seed yield, and oil percentage in both seasons, while the combination of 50 kg N ha$^{-1}$ + Azotobacter gave the highest average disc diameter. Cultivars significantly affected all studied traits. Taqah-1 cultivar recorded the highest values for plant height, stem diameter, number of seeds, 1000-seed weight, seed yield, oil percentage, and oil yield in both seasons. There was a significant interaction between the 35 kg N ha$^{-1}$ + Azotobacter combination and Taqah-1 cultivar in plant height, oil percentage for spring season, number of seeds per disc, and 1000-seed weight for both seasons.

**Keywords**: Sunflower, Azotobacter bacteria, Cultivars, Seed yield, Oil percentage.

## Introduction

The sunflower (Helianthus annuus L.) is one of the most important oilseed crops in the world, belonging to Asteraceae family. Its seeds contain a high percentage of oil, up to 50%, and its feed is rich in protein, fiber, and minerals, making it suitable for animal feed (Lahuf et al., 2019). Furthermore, sunflower fields are of great importance to beekeepers for producing high-quality honey, and the presence of bees contributes to increased pollination success (Lomascolo et al., 2012). In Iraq, it ranks second only to soybeans in terms of oil content (AL-Mali et al., 2020).

Despite its economic importance, its productivity rates remain below potential, necessitating technical and administrative improvements, particularly in crop management and nutrition (Elsahookie, 1994).Nitrogen is one of the most important nutrient factors affecting plant productivity (Alaamer et al., 2022). It is responsible for crop growth and development, and increases the rate of photosynthesis and leaf area, which leads to an increase in net nutrient uptake (Munir et al., 2007), and thus improves seed quality (Ullah et al., 2010).

Biofertilizers are defined as biological inoculators isolated and prepared from specific microorganisms to improve soil properties and increase its fertility by breaking down complex substances within it (Haneef et al., 2014). This stimulates plant growth, increases productivity, and improves quality when applied to seeds or added to the soil. The biofertilizers colonize the root zone (Inamuddin et al., 2021) or the plant's internal structures, promoting growth by providing the plant with readily available nutrients after breaking down raw materials and plant residues present in the soil (Sharma, 2002).This research aims to identify the optimal fertilizer combination and the most suitable cultivar for the region's conditions to ensure maximum sunflower yield.

In their experiment studying nine combinations of biofertilizers and nitrogen fertilizers, Khandekar et al. (2018) found significant differences between the combinations in plant height, stem diameter, number of seeds per disc, plant yield, and oil content. The results of Dasgupta et al. (2024), in their study of eleven combinations of biofertilizers and nitrogen fertilizers, indicated significant differences between the combinations in plant height, 1000-seed weight, and oil yield. The results of Mohammed (2026), in their study of four biofertilizer treatments, showed significant differences in plant height, number of seeds per disc, and 1000-seed weight.The results of Mahmood and Babir (2022), in a study of two sunflower cultivars (Velko and Baroloro), showed significant differences between the cultivars in 1000-seed weight, plant yield, and oil percentage. The results of Ali et al. (2025), in an experiment studying three sunflower cultivars (Taqah-1, Taqah-2, and Jude), indicated significant differences between the cultivars in the number of days from planting to 75% flowering, plant height, stem diameter, number of seeds per disc, 1000-seed weight, and oil yield. Saudi and Abbas (2026) found significant differences between two sunflower cultivars (Ishaqi-1 and Ishaqi-2) in oil percentage and 1000-seed weight.

## Materials and Methods

The field experiment was conducted during the spring and autumn seasons of 2025 to study the effect of a combination of biofertilization and nitrogen fertilization on the growth and yield traits of sunflower cultivars. The experiment was implemented as a factorial experiment within a split-plot design using a randomized complete block design (RCBD) with three plots. The main plots included four treatments of biofertilization and nitrogen fertilization, while the subplots included three sunflower cultivars. The number of experimental units will be 5 x 3 x 3 = 45 experimental units. Each experimental unit consists of four rows, 2 meters long, with a spacing of 30 cm between plants. A distance of 0.5 meters is left between experimental units, and a distance of 1 meter is left between sections. 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 April 30, 2025, and the autumn season on July 16, 2025.The traits studied: Five plants were randomly selected from each experimental unit to study the following traits:

1. Number of days from planting to 50% flowering (days): This trait was calculated based on the number of days from planting to flowering in 50% of the plants in each experimental unit.
2. Plant height (cm): This was measured from the point where the stem meets the soil to the base of the flower disc.
3. Stem diameter (mm): The diameter of the stem was measured at the midpoint of five plants after flowering was complete using a venier micrometer, and the arithmetic mean was calculated.
4. Number of seeds per disc (seed disc$^{-1}$): The total number of seeds (full and empty) was calculated for five discs randomly selected from each experimental unit, and the arithmetic mean was calculated.
5. Weight of 1000 seeds (g): After mixing the harvested plants, 1000 seeds were randomly selected from each experimental unit and weighed.
6. Plant seed yield (g plant $^{-1}$): This is calculated by weighing the seed yield of five plants and then taking the average seed yield in grams per disc.
7. Oil content in seeds (%): Estimated using the Soxhlet apparatus and the equation: % oil = Total sample weight before washing - Sample weight after washing / 2g × 100
8. Oil yield (g disc $^{-1}$) = Percentage of oil (%) × 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

**Number of days from planting to 50% flowering (days)**

Table (1) shows no significant differences in the number of days from planting to 50% flowering for both seasons based on the fertilizer combinations.

Table (2) shows significant differences between cultivars in the number of days from planting to 50% flowering for both seasons, with Taqah-1 cultivar having the lowest average number of days (51.06). The average number of days from planting to 50% flowering was 48.18 days (for both seasons), while Aqmar cultivar exhibited the highest average for the trait (56.33 and 51.06 days) for both seasons. This is attributed to the genetic differences among the cultivars, as well as their varying levels of response to environmental factors. This result is consistent with Ai-Saadi and AL-Hilfy (2023) and Ali et al. (2025).

Table (3) shows no significant interaction between fertilizer combinations and cultivars in the number of days from planting to 50% flowering in either season.

**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 and 128.84 cm) for both seasons. This may be due to the optimal use of biofertilizers and nitrogen fertilizers, as 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 (Jonnagorla et al., 2021). This result is consistent with those of Abdelaziz (2022) and Saloum (2025).

The cultivars had a significant effect on plant height, as shown in Table (2). Taqah-1 cultivar exhibited the highest average height (143.10 and 143.86 cm) in both seasons, while Banam cultivar exhibited the lowest average height (124.38 and 128.96 cm) for both seasons. This is due to the genetic variation among cultivars in their response to growth factors, including plant height. Auxins present in the growing tips play a key role in this process (W.R.E.C., 2005). This result is consistent with those of AL-Zaidy and AL-Hilfy (2023) and Ali et al. (2025).

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

**Stem diameter (cm):**

Table (1) shows significant differences between the fertilizer combinations in stem diameter for both seasons. The 50 kg N ha$^{-1}$ + Azotobacter combination gave the highest average stem diameter (20.34 mm and 17.95 mm) for both seasons, while the control treatment with a concentration of 80 kg N ha$^{-1}$ recorded the lowest average (15.44 mm and 13.68 mm) for both seasons. The increase in stem diameter may be due to the vital role of Azotobacter bacteria in secreting natural growth regulators such as auxins and gibberellins, which promote stem cell division and elongation. This result is consistent with Khandekar et al. (2018) and Alamery and Ahmed (2020).

Table (2) indicates significant differences between cultivars in stem diameter across both seasons. Taqah-1 cultivar exhibited the highest average diameter (19.10 and 17.16 mm) in both seasons, while Banam cultivar exhibited the lowest average diameter (16.28 and 14.14 mm) for the two growing seasons, respectively. This difference is attributed to variations in the genetic material of the cultivars. This result is consistent with Ali et al. (2025) and Mahmood and Hama (2026).

Table (3) shows no significant interaction between fertilizer combinations and cultivars in stem diameter across both seasons.

**Number of seeds per disc**
The results in Table (1) indicate significant differences between the fertilizer combinations in the number of seeds per disc in both seasons. The combination of 35 kg N ha$^{-1}$ + Azotobacter gave the highest average for this trait (1254.70 and 1153.86 seeds .disc $^{-1}$) for the two growing seasons, respectively. In contrast, the control treatment with a concentration of 80 kg N ha$^{-1}$ gave the lowest average for both seasons (1039.07 and 841.209 seeds .disc $^{-1}$). This may be due to the integrated use of nitrogen and biofertilizers, which leads to a significant increase in the number of seeds per disc (Saloum, 2025) as a result of the accumulation of photosynthetic byproducts from the source to the outlet. This result is consistent with Alamery and Ahmed (2020) and Mohammed (2026).
Table (2) shows significant differences between cultivars in the number of seeds in both seasons. Taqah-1 cultivar exhibited the highest average for this trait (1224.82 and 1078.73 seeds .disc $^{-1}$) for both seasons, while Banam cultivar recorded the lowest average for this trait in both seasons (1119.81 and 907.86 seeds .disc $^{-1}$). This is attributed to the increased disc diameter (Table 6). This result is consistent with Smaeili et al. (2022) and Ali et al. (2025).
Table (3) shows a significant interaction between the 35 kg N ha-1 + Azotobacter combination and Taqah-1 cultivar, giving the highest average seed weight (1315.66 seeds .disc $^{-1}$) for the spring season. However, no significant interaction was found between the fertilizer combinations and the Cultivars in the autumn season.

**1000-seed weight (g):**
Table (1) shows significant differences between the fertilizer combinations in the 1000-seed weight trait. The 35 kg N ha$^{-1}$ + Azotobacter combination gave the highest average seed weight (89.54 and 109.06 g) in both seasons, while the control treatment with a concentration of 80 kg N ha$^{-1}$ gave the lowest average seed weight in both seasons (67.73 and 84.99 g). The increase in 1000-seed weight may be attributed to the use of mineral nitrogen with biofertilizers as a source of nitrogen-fixing bacteria (Keshta and El-Kholy, 1999), which promotes crop growth and development. This finding is consistent with Dasgupta et al. (2024) and Mohammed (2026).
Table 2 shows significant differences between cultivars in 1000-seed weight. Taqah-1 cultivar exhibited the highest average weight (86.24 and 104.41 g) for both growing seasons, while Banam cultivar exhibited the lowest average weight (67.49 and 87.11 g) for both seasons. This difference is attributed to the superiority of Taqah-1 cultivar in the number of leaves (Table 4), which increased photosynthesis and consequently led to increased nutrient storage in the seed pellet. This result is consistent with AL-Aboody et al. (2021) and Saudi and Abbas (2026).
Table (3) indicates a significant interaction between the 35 kg N ha-1 + Azotobacter combination and Taqah-1 cultivar in the 1000-seed weight trait, as it recorded the highest average for the trait (100.76 and 120.35 g) in both seasons. In contrast, the control treatment with 80 kg N ha-1 and Banam cultivar gave the lowest average for the trait (57.63 and 77.13 g) in both seasons.

**Seed yield per plant (gm)**
The results in Table (1) show significant differences between the fertilizer combinations in the plant seed yield trait. 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 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 seasons. This variation is attributed to the increased disc diameter (Groll, 6) and the number of seeds per disc (Table, 7). This result is consistent with Khandekar et al. (2018) and Saloum (2025).
Table (2) indicates significant differences between the cultivars in the plant seed yield trait. Taqah-1 cultivar outperformed others, recording the highest average seed weight in both seasons (105.87 and 113.08 g plant$^{-1}$), while 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) and the number of seeds per disc (Table 7). This result is consistent with Mahmood (2021) and Mahmood and Babir (2022).
Table (3) shows that there was a significant interaction between the combination of 35 kg N ha-1 + Azotobacter with Taqah-1 cultivar, which recorded the highest average for the trait, amounting to (132.60 g plant-1) for the spring season, while the combination of 65 kg N ha-1 + Azotobacter with Aqmar cultivar gave the lowest average for the trait, amounting to (44.69 g plant-1) in the spring season, while there was no significant interaction between the fertilizer combinations and the cultivars in the autumn season.

**Oil content (%)**
The results in Table (1) show significant differences in oil content between the fertilizer combinations in both seasons. The combination of 35 kg N ha$^{-1}$ + Azotobacter gave the highest average oil content for the spring season (39.94%), while the combination of 20 kg N ha$^{-1}$ + Azotobacter gave the highest average oil content for the autumn 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) in both seasons. This is attributed to the improved growth, productivity, and quality resulting from the use of Azotobacter bacteria, which are characterized by their ability to stimulate plant growth through the production of growth-controlling hormones such as auxins, cytokinins, and gibberellic acid, which enhance nutrient absorption. This result is consistent with Abdelaziz (2022) and Dasgupta et al. (2024).
Table (2) shows significant differences between the cultivars in oil percentage. Taqah-1 cultivar recorded the highest average oil percentage in both seasons (37.68% and 37.75%), while Banam cultivar recorded the lowest average oil percentage (35.20% and 33.11%) for both seasons. This difference is due to the superior cultivar being influenced by prevailing environmental conditions. This result is consistent with AL-Kakayie and AL-Juhayshi (2024) and a and Abbas (2026).
Table (3) shows a significant interaction between the 50 kg N ha$^{-1}$ + Azotobacter combination and Taqah-1 cultivar in oil percentage. The combination gave the highest average oil percentage in both seasons (42.25% and 38.75%), while the

control treatment with 80 kg N ha$^{-1}$ and Banam cultivar gave the lowest average oil percentage (32.03% and 30.66%) for both seasons.

**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 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 seasons. This is attributed to the increased disc diameter (Table 6), the number of seeds per disc (Table 7), and the increased oil content in the seeds (Table 13). This result is consistent with Abdelaziz (2022) and Dasgupta et al. (2024).

Table (2) shows significant differences between cultivars in oil yield. Taqah-1 cultivar exhibited the highest average yield in both seasons (40.06 and 42.59 g plant$^{-1}$), while 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 number of seeds per disc (Table 7), 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 AL-Kakayie and AL-Juhayshi (2024) and Ali et al. (2025).

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

Conclusion: This experiment demonstrates that the 35 kg N ha$^{-1}$ fertilizer combination + Azotobacter effectively improved sunflower productivity. Furthermore, Taqah-1 cultivar exhibited excelled performance in most of the studied traits, including plant height, number of seeds per disc, 1000-seed weight, oil percentage, and oil yield. This resulted in a positive increase in sunflower yield under the region's conditions.

**Table (1): Effect of Fertilizer Combinations on Some Studied Sunflower Traits.**

| Fertilizer combination | Days to 50% flowering | Plant height (cm) | Stem diameter (cm) | No. seed per disc | 1000-seed weight (g) | Seed yield (g disc$^{-1}$) | Oil content (%) | Oil yield (g disc$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **spring season** | | | | | | | | |
| **80 kg N ha$^{-1}$** | 54.88 | 126.70c | 15.44c | 1039.07c | 67.73c | 71.41d | 33.25c | 23.87d |
| **65 kg N ha$^{-1}$ + Azotobacter** | 55.66 | 130.28bc | 16.90bc | 1159.78b | 71.97bc | 83.38c | 35.91bc | 29.97c |
| **50 kg N ha$^{-1}$ + Azotobacter** | 53.11 | 133.37ab | 20.34a | 1194.31ab | 82.42ab | 98.68b | 36.58b | 36.08b |
| **35 kg N ha$^{-1}$ + Azotobacter** | 54.22 | 137.23a | 18.52ab | 1254.70a | 89.54a | 112.76a | 39.94a | 45.22a |
| **20 kg N ha$^{-1}$ + Azotobacter** | 53.66 | 133.27ab | 17.42bc | 1212.22ab | 73.46bc | 88.69bc | 36.69b | 32.67bc |
| **autumn season** | | | | | | | | |
| **80 kg N ha$^{-1}$** | 50.66 | 128.84c | 13.68c | 841.20d | 84.99c | 71.76d | 33.05c | 24.05d |
| **65 kg N ha$^{-1}$ + Azotobacter** | 51.44 | 133.51b | 15.57b | 954.91c | 91.52bc | 87.39c | 35.30b | 31.06c |
| **50 kg N ha$^{-1}$ + Azotobacter** | 49.55 | 136.88ab | 17.95a | 1043.38b | 100.57ab | 105.06b | 34.55bc | 36.68b |
| **35 kg N ha$^{-1}$ + Azotobacter** | 48.33 | 141.50a | 16.75b | 1153.86a | 109.06a | 126.44a | 35.88a | 45.38a |
| **20 kg N ha$^{-1}$ + Azotobacter** | 49.77 | 137.33ab | 15.75b | 970.83c | 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.**

| cultivars | Days to 50% flowering | Plant height (cm)) | Stem diameter (cm) | No. seed per disc | 1000-seed weight | Seed yield (g disc$^{-1}$) | Oil content (%) | Oil yield (g disc$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **Spring season** | | | | | | | | |
| **Aqmar** | 56.33a | 129.06b | 17.79b | 1171.42b | 77.33b | 90.81b | 36.55ab | 33.49b |
| **Banam** | 55.35a | 124.38c | 16.28c | 1119.81c | 67.49c | 76.23c | 35.20b | 27.13c |
| **Taqah-1** | 51.06b | 143.10a | 19.10a | 1224.82a | 86.24a | 105.87a | 37.68a | 40.06a |
| **autumn season** | | | | | | | | |
| **Aqmar** | 51.06a | 134.01b | 16.08b | 991.91b | 97.15b | 97.62b | 34.85b | 34.34b |
| **Banam** | 50.66a | 128.96c | 14.14c | 907.86c | 87.11c | 79.53c | 33.11c | 26.45c |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Taqah-1** | 48.13b | 143.86a | 17.61a | 1078.73a | 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 sunflower.**

| Fertilizer combination | cultivars | Days to 50% flowering | Plant height (cm) | Stem diameter (cm) | No. seed per disc | 1000-seed weight(g) | Seed yield (g disc$^{-1}$) | Oil content (%) | Oil yield (g disc$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| Spring season | | | | | | | | | |
| **80 kg N ha$^{-1}$** | **Aqmar** | 56.33 | 126.75df | 15.96 | 1112.33c | 67.97cd | 75.85f | 33.83ef | 25.71 |
| | **Banam** | 53.33 | 120.83f | 14.23 | 856.44d | 57.03d | 48.90g | 32.08f | 15.73 |
| | **Taqah-1** | 55.00 | 132.53ce | 16.13 | 1148.44bc | 78.21bc | 89.49df | 33.83ef | 30.18 |
| **65 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 57.33 | 121.25f | 16.46 | 1116.66c | 79.38bc | 44.69ef | 35.41cf | 31.45 |
| | **Banam** | 58.00 | 125.00df | 14.90 | 1141.22bc | 69.54cd | 79.50f | 32.91ef | 26.24 |
| | **Taqah-1** | 51.66 | 144.60ab | 19.33 | 1221.47ac | 66.98cd | 81.76f | 39.41ab | 32.22 |
| **50 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 55.33 | 126.33df | 19.80 | 1195.55ac | 85.36ab | 102.03be | 38.66bc | 39.66 |
| | **Banam** | 54.33 | 124.66df | 18.96 | 1150.55bc | 66.46cd | 76.40f | 36.41be | 27.91 |
| | **Taqah-1** | 49.66 | 149.13a | 22.26 | 1236.93ac | 95.43a | 117.60ab | 34.66ef | 40.66 |
| **35 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 57.66 | 133.50cd | 18.66 | 1254.00ab | 88.73ab | 111.25bc | 38.83bc | 43.19 |
| | **Banam** | 55.33 | 127.83df | 17.23 | 1194.44ac | 79.12bc | 94.42cf | 38.75bc | 36.54 |
| | **Taqah-1** | 49.66 | 150.53a | 19.66 | 1315.66a | 100.76a | 132.60a | 42.25a | 55.93 |
| **20 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 55.00 | 137.50bc | 18.06 | 1178.66bc | 65.22cd | 76.23f | 36.00be | 27.45 |
| | **Banam** | 56.66 | 123.58ef | 16.06 | 1256.40ab | 65.31cd | 81.76f | 35.83be | 29.25 |
| | **Taqah-1** | 49.33 | 138.73bc | 18.13 | 1201.60ac | 89.84ab | 107.90bd | 38.25bd | 41.32 |
| autumn season | | | | | | | | | |
| **80 kg N ha$^{-1}$** | **Aqmar** | 54.66 | 121.00 | 13.66 | 871.11fh | 77.24f | 67.34 | 31.25gh | 20.96 |
| | **Banam** | 49.33 | 120.33 | 13.06 | 790.00h | 77.13f | 61.18 | 30.66h | 18.79 |
| | **Taqah-1** | 48.00 | 145.20 | 14.00 | 862.50fh | 100.60bd | 86.76 | 37.25ad | 32.42 |
| **65 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 52.33 | 134.20 | 16.00 | 939.67ef | 93.72ce | 88.21 | 34.25dg | 30.18 |
| | **Banam** | 50.66 | 128.53 | 13.06 | 814.22gh | 90.62df | 73.49 | 33.41eh | 24.58 |
| | **Taqah-1** | 51.33 | 137.80 | 17.66 | 1110.83ab | 90.21df | 100.48 | 38.25ab | 38.43 |
| **50kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 52.33 | 137.40 | 17.80 | 1021.11ce | 104.09bd | 106.23 | 33.25eh | 35.46 |
| | **Banam** | 50.00 | 129.26 | 15.73 | 955.77df | 93.77ce | 89.57 | 31.66fh | 28.26 |
| | **Taqah-1** | 46.33 | 144.00 | 20.33 | 1153.25ab | 103.87bd | 119.37 | 38.75a | 46.41 |
| **35 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 46.66 | 141.13 | 17.20 | 1185.66a | 113.42ab | 134.50 | 37.50ad | 50.32 |
| | **Banam** | 52.33 | 136.90 | 14.86 | 1068.66bd | 93.41ce | 99.46 | 35.16be | 34.94 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Taqah-1** | 46.00 | 146.46 | 18.20 | 1207.92a | 120.35a | 145.36 | 35.00bf | 50.88 |
| **20 kg N ha$^{-1}$ + Azotobacter** | **Aqmar** | 49.33 | 136.33 | 15.73 | 942.00ef | 97.27cd | 91.81 | 38.00ac | 34.89 |
| | **Banam** | 51.00 | 129.80 | 14.00 | 911.33eg | 80.66ef | 37.95 | 34.66cg | 25.71 |
| | **Taqah-1** | 49.00 | 145.86 | 17.53 | 1059.17bd | 107.04ac | 113.45 | 39.50a | 44.84 |

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

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