# Response Of Sunflower Varieties Growth and Yield to Foliar Application with Nano Boron

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**Abstract**

A field experiment was conducted during the spring season (2022-2023) in two locations: the first in Erbil city (Grdarasha field), and the second in the district of Khabat, located it become west of Erbil province and (37) km far away from the city center, This study was aimed to the growth response and yield of three varieties of sunflower to foliar nutrition with nano boron. The experiment was conducted using a split-plot randomized complete block design (RCBD) with three replicates and two factors, The first factor included four concentrations of nano-boron (0, 1, 2, 3 g/L), besides the second factor included three varieties of sunflower (Leviathan, Aqmar, Banam). The results revealed significant differences between the levels of nano boron fertilizer and varieties in all studied traits. Nano boron recorded the highest averages for plant height, leaf area, chlorophyll content in leaves, head diameter, seed number per disc, 1000-seed weight, seed yield, seed oil percentage, and oil yield at both locations. Additionally, clear significant differences were observed between the doses (2 g/L) and (3 g/L) of fertilizer, where it gave the highest averages. Varieties showed significant differences among them, that Aqmar variety recording the highest averages in most of the studied traits such as seed number per disc, seed yield, oil percentage, and oil yield at both trial locations. on the other hand, Leviathan variety recorded the highest averages in some growth traits such as height and chlorophyll content at the research locations. About the interaction between nano boron fertilizer and varieties, it significantly affected some studied traits. The highest number of seeds per disc, seed yield, and oil yield were obtained from the interaction between the dose (2 g/L) of nano boron with Banam variety, with average yields reaching (1276.97 seeds $disc^{-1}$, 1540 seeds $disc^{-1}$), (158.27 g $disc^{-1}$, 241.41 g $disc^{-1}$), (57.60 g $disc^{-1}$, 92.31 g $disc^{-1}$), respectively.

**Keywords:** Nano boron, Growth, Yield, Nutrition, Sunflower.

## Introduction

Sunflower (*Helianthus annuus* L.) is considered one of the most important oilseeds crops internationally. It belongs to the Asteraceae family also it grades fourth as the major source of vegetable oils that became after palm oil and rapeseed, representing more than 87% of total vegetable oil production **[32]**. Originating from the southwestern United States and Mexico, it was utilized by indigenous populations as a food source **[36]**. Sunflower is one of the most popular crops in global markets, and its oil is valued for containing Omega-3 fatty acids, vitamins B and C, as well as unsaturated fatty acids such as linolenic, linoleic, and oleic acids, ranging from 85% to 91% **[28]**. Sunflower oil contains retinol (vitamin A) and tocopherol (vitamin E), making it one of the healthiest vegetable oils

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consumed by humans. Moreover, some components of sunflower oil are used in the production of soap, detergents, paints, varnishes, plastics, adhesives, agricultural chemicals, surfactants, plastic additives, fabric softeners, industrial lubricants, coatings, and more **[19]**.

Nanotechnology is a modern approach capable of modifying the current synthetic framework used in agricultural systems by enhancing the efficiency of agricultural chemicals and providing solutions to environmental and agricultural problems **[30]**. Foliar fertilization is an effective technique to overcome the deficiency of some essential nutrients in the soil by directly applying nutrients to plant leaves, which may be the most effective method to improve plant growth, health, and productivity **[27]**. Nano boron is one of the essential micronutrients that plays a crucial role as an enzyme activator, carbohydrate transporter, ion absorber, and synthesizer of nucleic acids (DNA and RNA), lignin, cellulose, and proteins **[17]**. It also improves pollen tube growth, and there is a good relationship between boron content in plant tissues and total flower number, non-aborted flower ratio, and seed numbers **[38]**. Enhancing local production relies on the cultivation of new varieties characterized by their high productivity. This depends on several scientific steps, including introducing superior varieties into the country, studying their adaptation to climatic conditions, and selecting the most suitable ones **[21]**. The aim of this study is to determine the optimal concentration of nano boron and identify the suitable sunflower variety for achieving the highest productivity.

**Materials and Methods**

A field experiment was conducted during the spring season (2022-2023) in two locations: the first in Erbil city (Grdarasha field). and the second in the district of Khabat, located west of Erbil province and (37) km far away from the city center, The experimental setup followed a randomized complete block design (RCBD) with split-plot arrangement and three replications. The main plots consisted of four concentrations of nano boron (0, 1, 2, 3 g/L), applied as foliar spray on plants in a single application just before flowering. And other included three varieties of sunflower (Leviathan, Aqmar, Banam).

Field preparation involved plowing the land using a Moldboard plow in orthogonal followed by harrowing and leveling using a Chisel plow. The experimental land was then divided into experimental units according to the design used, and the experimental treatments were randomly allocated to the experimental units. There were 36 experimental units distributed across the three sectors.

Seeds were manually sown in rows within each experimental unit at a depth of 1-3 cm in both locations. Each row was 2 m long, with a distance of 50 cm between rows and 40 cm between plants. Each experimental unit consisted of 4 rows, covering an area of 4 $m^2$ (2 × 2 m). Drip irrigation system was used to ensure uniform water distribution.

Data collected from the field experiment were analyzed using the SAS (Statistical Analysis System) software. Differences between the means of the factors involved in the experiment were tested for significance using the Duncan's multiple range test at the 1% and 5% probability levels, following the method **[12]**.

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## Results and Discussion

### Plant Height (cm):

It is evident from the results in the table below that the dose of nano-boron fertilizer (2 g/liter) significantly outperformed in the plant height attribute for both sites, recording the highest average of (234.06 and 287.08 cm), respectively. In contrast, the control treatment (0 fertilization) recorded the lowest average for the attribute at (184.72 cm). The reason for this might be the effect of boron addition on cell division, expansion, and apex growth **[18]**, which is consistent with the findings of **[1,4]**.

Results in the table below indicate significant differences among varieties in the plant height attribute. Leviathan variety surpassed the others by recording the highest average for the attribute in both research sites (220.74 and 265.75 cm), respectively, while Banam variety recorded the lowest average at (200.20 and 240.36 cm). The variation in response to growth factors, including plant height, is due to the differences in genetic structures, as auxins in apical meristems regulate this attribute, and their activities differ among genetic structures **[37]**, consistent with **[3].**

There was no significant interaction between nano-boron and varieties in the plant height attribute.

### Chlorophyll Content Index (SPAD):

It is observed in the table below that there were significant differences between doses of nano-boron fertilizer, with the dose (2 g/liter) recording the highest average for chlorophyll content in the leaves in both research sites at (40.673 and 43.654 SPAD), respectively, while the comparison treatment (0 fertilization) recorded the lowest average for the attribute at (33.86 and 36.95 SPAD), respectively. This result is consistent with **[4, 15].**

**Leaf Area ($cm^2$):** It is observed in the table below that the fertilizer dose (2 g/liter) of nano-boron significantly outperformed in the leaf area attribute in both research sites, recording averages of (802.20 and 921.25 cm2), respectively, while the control treatment (0 fertilization) recorded the lowest average for the attribute at (494.72 and 496.24 cm2), respectively. This result aligns with **[15, 35]**.

Results also indicate significant differences among varieties in the leaf area attribute, where the Leviathan variety recorded the highest average for the attribute in both research sites (778.07 and 874.95 cm2), respectively, while the Banam variety recorded the lowest average at (551.16 and 619.30 cm2), respectively, consistent with **[9].**

In the interaction between fertilizer and varieties, the interaction between the dose (2 g/liter) of nano-boron fertilizer with the Aqmar variety and the interaction between the dose (3 g/liter) with the Aqmar variety significantly outperformed in the Khubat site, recording (1084.79 and 1028.55 cm2), respectively, while the lowest average for interactions was recorded by the interaction between the dose (2 g/liter) of fertilizer with the Leviathan variety, reaching (371.57 cm2).

The table below also shows that varieties had a significant effect on the chlorophyll content index attribute in the leaves, with the Aqmar variety recording the highest average for the attribute in both research sites (38.34 and 42.82 SPAD), respectively, while the Banam variety gave the lowest average for the attribute (36.45 and 37.84 SPAD), respectively, consistent with **[4].**

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There was no significant interaction effect between the factors on the chlorophyll content index attribute in the research sites.

**Head Diameter (cm):**

The results in the table below indicate significant differences between doses of nano-boron fertilizer, with the dose (3 g/liter) yielding the highest average for the disk diameter attribute in both research sites, reaching (21.32 and 22.88 cm) respectively. In contrast, the control treatment (0 fertilization) recorded the lowest average for the attribute in both sites, at (17.72 and 18.01 cm) respectively. This result is consistent with findings by **[6, 25].**

It is observed in the table below that varieties had a significant effect on the disk diameter attribute, with the Aqmar variety recording the highest average in both research sites (20.68 and 21.09 cm), respectively, while the Leviathan variety gave the lowest average in both sites (18.30 and 19.47 cm), respectively. This result aligns with findings by **[2,5,9].**

There was no significant interaction effect between fertilizer and varieties on the disk diameter attribute.

**Number of Seeds Disc$^{-1}$ (Seed.Disc$^{-1}$):**

It is observed in the table below that the fertilizer dose (3 g/liter) of nano-boron significantly outperformed in both research sites regarding the number of seeds per disk attribute, recording averages of (1042.81 and 1272.05 Seed per Disk-1) respectively, while the control treatment (0 fertilization) recorded the lowest average for the attribute in both sites, at (677.68 and 815.84 Seed per Disk-1) respectively. This result is consistent with findings by **[20, 31].**

Results in the table below also indicate that varieties differed significantly in the number of seeds per disk attribute, with the Aqmar variety recording the highest average in both research sites (1006.26 and 1186.07 Seed per Disk-1) respectively, while the Leviathan variety recorded the lowest average in both sites (729.04 and 905.66 Seed per Disk-1) respectively. This result aligns with findings by **[9, 26].**

In the interaction between fertilizer and varieties, the interaction between the dose (2 g/liter) of nano-boron fertilizer with the Banam variety significantly outperformed in both research sites, reaching (1276.97 and 1540 Seed per Disc$^{-1}$) respectively, while the lowest average for interactions was recorded by the interaction between the dose (2 g/liter) of fertilizer with the Leviathan variety in both research sites, reaching (435.23 and 691.68 Seed per Disc$^{-1}$) respectively

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**1000 Seed Weight (gram):**

The results in the table below indicate that the fertilizer dose (3 g/liter) of nano-boron significantly outperformed in both research sites regarding the 1000 seed weight attribute, recording the highest average of (138.49 and 163.89 grams) respectively, while the control treatment (0 fertilization) recorded the lowest average in both sites, at approximately (27.271 and 135.24 grams) respectively. This result is consistent with findings by **[7,31].**

It is observed in the table below that varieties differed significantly in the 1000 seed weight attribute, with the Leviathan variety recording the highest average in both research sites (155.97 and 166.85 grams) respectively, while the Banam variety recorded the lowest average

in both sites (119.49 and 135.30 grams) respectively. This result aligns with findings by **[2,5].**

In the interaction between fertilizer and varieties, the interaction between the dose (1 g/liter) of nano-boron fertilizer with Banam variety significantly outperformed in both research sites, reaching the highest average in both sites, at (161.32 and 175.60 grams) respectively, while the lowest average for interactions was recorded by the interaction between the dose (2 g/liter) of fertilizer with the Leviathan variety in both research sites, reaching (107.75 and 123.82 grams) respectively

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**Seed yield (g. disc$^{-1}$):**

The results in the table below indicate a significant superiority of the nano-boron fertilizer concentration (3 g/L) in seed yield trait over other concentrations. It recorded the highest averages successively, reaching (141.62 and 206.74 g. disc$^{-1}$) respectively. Conversely, the control treatment (0 fertilization) yielded the lowest average for the trait in both locations, giving (83.10 and 109.47 g disc$^{-1}$) respectively. These results align with findings from **[6,16, 35].**

The results below also demonstrate significant differences among varieties in the seed yield trait. The "Aqmar" variety outperformed others, registering the highest average in both research locations, with (126.26 and 176.87 g. disc$^{-1}$) respectively. On the other hand, the "Banam" variety recorded the lowest average in both locations, with (106.16 and 148.57 g. disc$^{-1}$) respectively. This finding correlates with results from **[8,11].**

About the interaction between fertilizer and varieties, the interaction between a dose of (2 g/L) nano-boron fertilizer and the "Banam" variety showed significant superiority, recording the highest average in both research locations, with (158.27 and 241.41 g. disc$^{-1}$) respectively. Conversely, the lowest averages for interactions were recorded between the fertilization dose of the control treatment (0 fertilization) and the "Leviathan" variety, yielding (67.93 and 105.18 g. disc$^{-1}$) respectively.

**Oil percentage in seeds (%):**

The data in the table below show a clear significant superiority of the (3 g/L) nano-boron fertilizer dose in oil percentage trait over other concentrations. It recorded the highest average, reaching (33.21 and 34.35 %) respectively in both locations. Conversely, the control treatment (0 fertilization) yielded the lowest average for the trait in both locations, with (26.68 and 30.25 %) respectively. These results are consistent with **[23, 29].**

The results below indicate significant differences among varieties in oil percentage trait. The "Aqmar" variety showed the highest average in both research locations, with (33.42 and 36.78 %) respectively, while the "Leviathan" variety recorded the lowest average in both locations, with (24.82 and 25.27 %) respectively. This finding is in line with results from **[10,24].**

There was no significant interaction between fertilization and varieties on oil percentage trait in both research locations

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**Oil yield (g. disc$^{-1}$):**

The results in the table below indicate a significant superiority of the (3 g/L ) nano-boron fertilizer dose in oil yield trait over other concentrations. It recorded the highest average, reaching (47.25 and 71.82 g. disc$^{-1}$) respectively, while the control treatment (0 fertilization) yielded the lowest average, with (22.83 and 33.24 g. disc$^{-1}$) respectively. These results are consistent with those of **[34].**

There were significant differences among varieties in oil yield trait, with the "Aqmar" variety showing the highest average in both research locations, with (42.58 and 65.23 g. disc$^{-1}$) respectively, and the "Leviathan" variety recording the lowest average, with (28.73 and 38.86 g disc$^{-1}$) respectively. This finding aligns with **[13,33]**.

In the interaction, the 2 g/L dose of nano-boron fertilizer showed significant superiority when combined with the "Banam" variety, recording the highest average in both research locations, with (57.60 and 92.31 g. disc$^{-1}$) respectively. Conversely, the lowest averages for interactions were recorded between the fertilization dose of the control treatment (0 fertilization) and the "Leviathan" variety, yielding (14.64 and 23.81 g. disc$^{-1}$) respectively.

**Table (1): Effect of Nano-Boron Concentrations and Varieties on Growth, Yield Traits of Sunflower for Erbil location.**

| | Plant Height (cm) | Leaf Area (cm²) | Chlorophyll Content (SPAD) | Disk Diameter (cm) | Number of Seeds per Disk (seeds/disk) | 1000 Seed Weight (g) | Seed Yield (g/disk) | Oil Percentage in Seeds (%) | Oil Yield (g/disk) |
|---|---|---|---|---|---|---|---|---|---|
| **Leviathan** | 220.74a | 778.07 a | 37.27ab | 18.30b | 729.04c | 155.97 a | 113.66 b | 24.82c | 28.73c |
| **Aqmar** | 210.85b | 637.19 b | 38.34a | 20.68a | 1006.26a | 125.43 b | 126.26 a | 33.42a | 42.58a |
| **Banam** | 200.20c | 551.16 c | 36.45b | 19.50ab | 880.64b | 119.49 c | 106.16 b | 31.22b | 33.84b |
| **0** | 184.72 c | 494.72 c | 33.86c | 17.72c | 677.68c | 127.27 c | 83.10c | 26.68c | 22.83c |
| **1** | 209.11 b | 652.67 b | 37.41b | 18.94b | 872.73b | 131.78 cb | 114.61 b | 29.18B c | 33.35b |
| **2** | 234.06 a | 802.20 a | 40.67a | 19.98b | 894.70b | 136.99 ab | 122.11 b | 30.19ab | 36.77b |
| **3** | 214.50 ab | 672.30 b | 37.48b | 21.32a | 1042.81a | 138.49 a | 141.62 a | 33.21a | 47.25a |

**The values followed by the same alphabetical letter for each parameter and their interactions do not differ significantly from each other.**

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**Table (2): Effect of Nano-Boron Concentrations and Varieties on Growth, Yield Traits of Sunflower for Khabat location.**

| Variety | Plant Height (cm) | | Leaf Area ($cm^2$) | Chlorophyll Content (SPAD) | Head Diameter (cm) | Number of Seeds per Disc (seeds/disc) | 1000 Seed Weight (g) | Seed Yield (g/disc) | Oil Percentage in Seeds (%) | Oil Yield (g/disc) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Leviathan** | 265.75 a | | 874.95 a | 40.29 b | b 19.47 | c 905.66 | 166.85 a | 152.23 b | 25.27 c | 38.86c |
| **Aqmar** | 250.82 b | | 747.55 b | 42.82a | 21.09a | 1186.07a | 146.79 b | 176.87 a | 36.78 a | 65.23a |
| **Banam** | 240.36 c | | 619.30 c | 37.84c | 20.19ab | 1090.34b | 135.30 c | 148.57 b | 35.10 b | 52.65b |
| **0** | 215.96 c | | 496.24 c | 36.95c | 18.01c | 815.84c | 135.24 d | 109.47 c | 30.25c | 33.24c |
| **1** | 240.88 bc | | 725.50 b | 40.25b | 20.00b | 1075.63b | 144.15 c | 152.82 b | 32.26b | 49.05b |
| **2** | 287.08 a | | 921.25 a | 43.65a | 20.11b | 1083.23b | 155.32 b | 167.87 b | 32.67b | 54.87b |
| **3** | 265.34 ab | | 846.07 ab | 40.42b | 22.88a | 1272.05a | 163.89 a | 206.74 a | 34.35a | 71.82a |

**The values followed by the same alphabetical letter for each parameter and their interactions do not differ significantly from each other.**

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**Table (3): The Effect of Interaction between Nano Boron Fertilizer and Varieties on Growth, Yield Traits of Sunflower in Erbil location.**

| | | Plant Height (cm) | Leaf Area ($cm^2$) | Chlorophyll Content (SPAD) | Head Diameter (cm) | Number of Seeds per Disc (seeds/disc) | 1000 Seed Weight (g) | Seed Yield (g/disc) | Oil Percentage in Seeds (%) | Oil Yield (g/disc) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Leviathan** | **0** | 197.13 | 603.66 | 34.49 | 15.46 | 435.23f | 155.89ab | 67.93f | 21.55 | 14.64h |
| | **1** | 188.26 | 488.02 | 34.12 | 19.03 | 863.87cd | 118.16f | 102.12e | 31.18 | 31.92ef |
| | **2** | 168.76 | 392.49 | 32.76 | 18.66 | 733.93e | 107.75g | 79.25f | 27.33 | 21.94g |
| | **3** | 219.93 | 774.90 | 37.01 | 17.83 | 825.13de | 150.52b | 124.12bcd | 23.14 | 28.71f |
| **Aqmar** | **0** | 205.86 | 637.63 | 38.37 | 20.16 | 920.30bcd | 126.53cde | 116.31cde | 33.52 | 38.99cd |
| | **1** | 201.53 | 545.49 | 36.86 | 18.83 | 872.77cd | 118.26f | 103.40e | 30.89 | 32.35ef |
| | **2** | 241.36 | 905.94 | 40.88 | 19.96 | 832.20de | 156.14ab | 129.74bc | 27.53 | 35.67cde |
| | **3** | 237.93 | 794.20 | 41.62 | 21 | 963.90Bc | 132.99c | 128.35bc | 32.58 | 41.81c |
| **Banam** | **0** | 222.90 | 706.46 | 39.52 | 19 | 888cd | 121.86ef | 108.24de | 30.47 | 32.83def |
| | **1** | 224.53 | 827.79 | 36.50 | 19.93 | 823.60de | 161.32a | 132.84bc | 27.05 | 35.90cde |
| | **2** | 211.36 | 628.90 | 39.26 | 22.53 | 1276.97a | 124.05def | 158.27a | 36.40 | 57.60a |
| | **3** | 207.60 | 560.20 | 36.68 | 21.50 | 1027.86b | 130.10cd | 133.76b | 36.19 | 48.25b |

**The values followed by the same alphabetical letter for each parameter and their interactions do not differ significantly from each other.**

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**Table (4): The Effect of Interaction between Nano Boron Fertilizer and Varieties on Growth, Yield Traits of Sunflower in Khabat location.**

| | | Plant Height (cm) | Leaf Area ($cm^2$) | Chlorophyll Content (SPAD) | Head Diameter (cm) | Number of Seeds per Disc (seeds/disc) | 1000 Seed Weight (g) | Seed Yield (g/disc) | Oil Percentage in Seeds (%) | Oil Yield (g/disc) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Leviathan** | **0** | 235.46 | 625.93 ef | 36.88 | 17.80 | 691.68f | 151.94 c | 105.18f | 22.69 | 23.81 f |
| | **1** | 210.26 | 491.21 fg | 39.35 | 18.13 | 885.29e | 129.98 d | 114.89ef | 36.05 | 41.40 e |
| | **2** | 202.13 | 371.57 g | 34.61 | 18.10 | 870.55e | 123.82 d | 108.34f | 32.01 | 34.52 e |
| | **3** | 254.20 | 829.25 bc | 40.34 | 18.76 | 917.63 de | 169.38 ab | 155.45d | 25.41 | 39.38 e |
| **Aqmar** | **0** | 241.06 | 670.80 de | 42.71 | 21.40 | 1134.95 b | 129.84 d | 147.54d | 37.22 | 54.76 f |
| | **1** | 227.36 | 676.46 de | 37.71 | 19.83 | 1174.31 b | 133.23 d | 155.47d | 34.16 | 53.02 c |
| | **2** | 297.06 | 1084.79a | 44.70 | 19.16 | 955.62 cde | 170.50 ab | 162.77cd | 26.05 | 42.36 de |
| | **3** | 288.30 | 1028.55a | 44.75 | 21.30 | 1196.03 b | 170.49 ab | 203.68b | 35.64 | 72.47 b |
| **Banam** | **0** | 275.86 | 650.42 de | 41.51 | 19.86 | 1098.03 bc | 124.97 d | 137.18de | 36.31 | 49.78 cd |
| | **1** | 276.26 | 959.86 ab | 39.25 | 22.16 | 1057.69 bcd | 175.60 a | 185.53bc | 26.93 | 49.88 cd |
| | **2** | 263.66 | 799.63 cd | 44.50 | 23.53 | 1540a | 156.87 bc | 241.41a | 38.21 | 92.31 a |
| | **3** | 256.10 | 778.73 C de | 37.52 | 22.96 | 1218.46b | 159.21 bc | 193.30b | 37.91 | 73.28 b |

**The values followed by the same alphabetical letter for each parameter and their interactions do not differ significantly from each other.**

**Conclusion**:

From this experiment, it can be concluded that foliar application of nano boron fertilizer on certain varieties of sunflower was superior in productivity compared to the control treatment (0 fertilization). It is evident that the Leviathan variety outperformed the other varieties in some growth traits such as plant height and leaf area in both study locations. However, the Aqmar variety excelled significantly in productivity traits such as head diameter, number of seeds per disc, 1000 seed weight, oil percentage in seeds, seed yield, and oil yield in both locations. Regarding the interaction between nano boron fertilizer and varieties, the interaction between the Banam variety and the fertilizer dose (2g/L) showed clear superiority over the other varieties.

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