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RESEARCH ARTICLE

# Weed control methods and micronutrient sprays on weeds and sunflower growth

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## Abstract

An experiment was conducted during the spring seasons of 2022 and 2023 at Agricultural Research Station No. 1, College of Agriculture, University of Anbar, located in Ramadi district, Anbar province, Iraq. The study aimed to evaluate the impact of weed control methods and micronutrient spraying on weed traits and growth characteristics of three sunflower varieties. The experiment followed a randomized completely block design (RCBD) with a split-split plot arrangement and three replications. The main plots included weed control methods (no control, Treflan herbicide treatment and black plastic mulching). At the same time, the sub-plots consisted of three micronutrient spraying treatments (0, first combination and second combination). The sunflower varieties Aqmar, Sakha and Flami included the sub-sub-plots. Results indicated that the mulching treatment significantly reduced weed density and dry weed weight and achieved values of (5.96 and 4.33 plant m$^{-1}$, 11.67 and 8.22 plant m$^{-1}$, 123.97 and 91.02 g plant$^{-1}$) for the two seasons, respectively, while enhancing: plant height, leaf area, stem diameter and chlorophyll index. The second micronutrient spray formulation gave the highest averages for most traits. Among the cultivars, Sakha showed the lowest weed density and dry weed weight, Qamar recorded the tallest plants (189.04 and 211.12 cm) for both seasons and Flame showed superior vegetative growth traits. Significant interactions were observed between the study factors, where the mulching combination and Flamy cultivar gave the highest leaf area, stem diameter and chlorophyll content and the three-way interaction of mulching, the second micronutrient formulation and Flamy cultivar achieved the highest chlorophyll content. and the triple interaction of mulching, second micronutrient combination and Flami variety achieving the highest chlorophyll content. In conclusion, black plastic mulching effectively reduced weed density and improved sunflower growth, with the second micronutrient combination and Flame variety showing the best results.

## Keywords

black plastic mulching; micronutrient spraying; sunflower varieties; weed density reduction

## Introduction

Sunflower (*Helianthus annuus* L.) is among the major oil crops in the world today. Globally, it ranks third, only after soybean and canola, in terms of oil content. Despite this crop's huge importance for Iraq, productivity per unit area has decreased compared to global production. Several reasons are associated with this decline in yield, which includes low productivity of the available varieties due to improper agricultural practices, such as weed control. However, for field crops, weeds incur very heavy losses in yield.

Soil problems in Iraq include the pH level of the soils, which leads to the unavailability of many nutrients that the plant needs to complete its life cycle, particularly micronutrients such as iron, zinc and manganese (1). This necessitates using various methods to increase productivity, such as using newly introduced or recently developed varieties, understanding their performance under weed competition and conditions and controlling them. Weeds are one of the significant challenges and problems this crop faces, as they compete with the crops for the necessary nutrients for growth, especially during the establishment stages (2). Moreover, weed and environmental pollution should be minimized through modern techniques by using black plastic mulching to acquire a rapid and effective response, in addition to providing the plant with the basic micronutrients essential for completing its life cycle, which are added as foliar sprays on the plant to continue its growth and achieve quantitative and qualitative improvements in its yield and increase its production capacity, making it suitable for cultivating crops with high economic returns (3, 4). Based on the above, this study aims to determine the best treatment for weed control, the best concentration of micronutrients, their effects on varieties and their interaction in competing with weeds and improving yield traits and components of the sunflower crop.

## Materials and Methods

A field experiment was conducted during the spring seasons of 2022 and 2023 in Anbar Governorate at Agricultural Research Station No (1), Affiliated with the College of Agriculture - University of Anbar, located in the Ramadi district - Anbar Governorate - Iraq. situated at Longitude: E 43° 32' 65" Latitude: N 33° 45' 37". The objective was to investigate the effect of weed control methods and micronutrient spraying on certain weed traits and growth characteristics of three sunflower varieties. The experiment used a Randomized Complete Block Design (RCBD) with a Split-Split Plot arrangement and three replications. The treatments were randomly distributed in each replicate. The main plots included three weed control treatments (weed-infested, spraying with Treflan herbicide (48 % EC) at the recommended concentration and black nylon mulching (0.8-micron thickness), designated as $M_1$, $M_2$ and $M_3$, respectively. The subplots contained three combinations of micronutrient treatments (0, first and second). Designated as; F0, $F_1$ and $F_2$, respectively. Table 1 displays the concentrations of some micronutrients in the fertilizer used in the study. The spraying was done twice: the first when the plants reached a height of 10 cm and the second at flowering. The sub-subplots included three sunflower varieties (Aqmar, Sakha and Flame). The seeds of these varieties were obtained from the Seed Testing and Certification Authority in Iraq.

Soil preparation activities such as ploughing, smoothing and levelling were performed, followed by soil sampling for physical and chemical analyses before planting (Table 2). The experimental field was then divided into experimental units with dimensions (3 × 3 m), resulting in an area of (9 m$^2$) per unit and a total of 81 units with three replications. Each unit contained five rows with a spacing of 60 cm between rows and 30 cm between plants. The spacing between experimental units was 1 m and between replicates was 2 m. Seeds were hand-planted in rows on 20/3/2022 and 20/3/2023 and the experimental field was irrigated using drip irrigation as needed. Phosphate fertilizer was added to the soil in the form of diammonium phosphate (DAP) (18:46:0) at a rate of (80 kg $P_2O_5$ /ha), mixed with the soil in one dose before planting. Potassium fertilizer was added as potassium sulfate ($K_2O$ 50%) at a rate of (80 kg $K_2O$ ha-1), mixed with the soil in one dose before planting. Nitrogen fertilizer was added in the form of urea at a rate of (160 kg N / ha) in two doses: the first when the plants reached the three-leaf stage and the second at flowering (5). Data were statistically analyzed using GenStat software and the least significant difference (L.S.D) test at a probability level of 0.05 was used to distinguish statistically different means (6).

## Results

### *Weed plant density 60 days after planting*

The results in Table 3 show significant differences between weed control methods in the averages of this trait. The mulching treatment ($M_2$) recorded the lowest weed density, reaching 5.96 and 4.33 plants m$^{-2}$, while the weed-infested treatment ($M_0$) recorded the highest weed density, reaching 36.70 and 36.07 plants m$^{-2}$ in both seasons, respectively. The data from the same Table 4 also showed that the addition of micronutrients has a significant effect on the means of this trait. The second micronutrient combination had the lowest average at 18.04 and 14.70 plants m$^{-2}$, while the control treatment had the highest average concerning this trait, at 22.52 and 19.96 plants / m$^{-2}$ for the two seasons, respectively.

The averages of this trait were significantly affected by the two-way and three-way interactions of the study factors, as shown in Table 2, except for the two-way interaction between weed control methods and micronutrient spraying in the first season. The two-way interaction between weed control methods and

**Table 1.** Composition of micronutrients used in the study

| Combination number | Zinc (Zn) | Iron (Fe) | Manganese (Mn) | Copper (Cu) | Boron (B) |
|---|---|---|---|---|---|
| | | | (mg.L$^{-1}$) | | |
| The first combination | 300.15 | 278.25 | 170.00 | 26.10 | 26.10 |
| The second combination | 600.30 | 556.5 | 340.00 | 52.20 | 52.20 |

**Table 2.** Some physical and chemical properties of the experimental field soil before planting

| Character | | Unit | 2022 | 2023 |
|---|---|---|---|---|
| Soil pH 1:1 | | ——— | 7.12 | 7.14 |
| Electrical conductivity 1:1 | | dS $m^{-1}$ | 2.47 | 1.62 |
| Soil organic matter (SOM | | gm/ $kg^{-1}$ | 5.40 | 5.40 |
| Gypsum ($CaSO_4$) | | % | 5.55 | 4.23 |
| Carbonate minerals ($CaCO_3$) | | % | 10.30 | 10.30 |
| Bulk density | | Mega gm $m^{-3}$ | 1.30 | 1.30 |
| Cation exchange capacity (CEC) | | centimoles per kilogram of soil (cmol/kg) | 23.80 | 23.80 |
| **dissolved positive ions** | $Ca^{2+}$ | milliequivalents per liter (meq $L^{-1}$) | 6.23 | 6.23 |
| | $Mg^{2+}$ | | 7.23 | 3.89 |
| | $Na^{+}$ | | 3.89 | 5.60 |
| | $K^{+}$ | | 6.60 | 1.39 |
| **dissolved negative ions** | $SO_4^{-2}$ | | 6.39 | 7.52 |
| | $CO_3$ | | 1.95 | Nil |
| | $HCO_3^{-}$ | | 2.69 | 1.69 |
| | $Cl^{-}$ | | 5.99 | 6.70 |
| Nitrogen N | | mg $kg^{-1}$ soil | 8.96 | 12.2 |
| Phosphorus P | | | 10.30 | 10.30 |
| Potassium K | | | 90.80 | 130.40 |
| Iron Fe | | | 82.5 | 145.8 |
| Zinc Zn | | | 61.3 | 73.6 |
| Manganese Mn | | | 46.1 | 82.2 |
| **Soil composition** | Sand | gm $kg^{-1}$ soil | 684 | 684 |
| | Silt | | 112 | 112 |
| | Clay | | 204 | 204 |
| **Class** | | **Sandy clay loam** | | |

Analyzed in the laboratories of the College of Agriculture / University of Anbar

**Table 3.** Types of weeds identified in the experimental units for the spring seasons of 2022-2023

| .No .Sr | English name | Scientific name | Family | Type | Life cycle | Degree of density* |
|---|---|---|---|---|---|---|
| 1 | Lambs quartey | *Chenopodium album L.* | Chenopodiaceae | Broadleaf | Perennial | Medium |
| 2 | Wild dock | *Raphanus raphanistrum L.* | Brassicaceae | Broadleaf | Perennial | low |
| 3 | Nut grass | *Cyperus rotaundus L.* | Cyperaceae | Narrow leaf | Annual | Medium |
| 4 | Purslane | *Portulaca oleracea L.* | Portulaceae | Broadleaf | Perennial | Medium |
| 5 | Rough pigeed | *Amaranthus retroflexus L.* | Amaranthaceae | Broadleaf | Perennial | Medium |
| 6 | Field bind weed | *Convolvulus arvensis L.* | Convolvulaceae | Broadleaf | Perennial | Very Dense |
| 7 | Leaved croton | *Chrozphora tinctoria L. Ref* | Euphorbiaceae | Narrow leaf | Perennial | low |
| 8 | Common sow thistle | *Sonchus oleraceus L.* | Compositae | Broadleaf | Perennial | Very low |
| 9 | Bermuda grass | *Cynodon dactylon L.* | Poaceae | Narrow leaf | Annual | Dense |
| 10 | Priekly alhagi | *Alhagi maurorum medic L.* | Papilionaceae | Broadleaf | Annual | Very low |
| 11 | Prickly lettuce | Lactuca virosa | Compositae | Broadleaf | Perennial | Very low |
| 12 | Black nightshade | *Solanum nigrum* L. | Solanaceae | Broadleaf | Perennial | low |
| 13 | Common Reed | *Phragmitis australis* L. | Poaceae | Narrow leaf | Annual | Very low |
| 14 | Johnson grass | *Sorghum halepense* L. | Poaceae | Narrow leaf | Annual | Very low |

**Table 4** .Effect of weed control methods and micronutrient spraying on varieties and their interaction on weed density after 60 days of planting) plants per $m^{-2}$)

| Methods of weed control M | Nutrient compositions F | First Season 2022 Varieties V Aqmar V1 | Sakha V2 | Flame V3 | M * F | Second Season 2022 Varieties V Aqmar V1 | Sakha V2 | Flame V3 | M * F |
|---|---|---|---|---|---|---|---|---|---|
| | F0 | 56.67 | 47.00 | 73.33 | 59.00 | 59.67 | 57.67 | 70.33 | 62.56 |
| M0 | F1 | 55.00 | 44.67 | 65.67 | 55.11 | 53.33 | 50.67 | 52.00 | 52.00 |
| | F2 | 51.00 | 41.00 | 64.67 | 52.22 | 40.00 | 35.67 | 43.33 | 39.67 |
| | F0 | 37.33 | 27.33 | 43.67 | 36.11 | 23.00 | 21.67 | 26.67 | 23.78 |
| M1 | F1 | 31.00 | 21.00 | 39.00 | 30.33 | 19.67 | 18.67 | 19.00 | 19.11 |
| | F2 | 29.00 | 20.33 | 33.67 | 27.67 | 13.00 | 12.67 | 12.00 | 12.56 |
| | F0 | 14.67 | 9.67 | 17.00 | 13.78 | 10.33 | 10.00 | 11.33 | 10.55 |
| | F1 | 13.00 | 6.67 | 15.33 | 11.67 | 8.33 | 7.33 | 9.33 | 8.33 |
| M2 | F2 | 11.33 | 5.00 | 12.33 | 9.55 | 5.67 | 5.33 | 6.33 | 5.78 |
| $LSD_{M*F*V}$ | | | 2.38* | | $LSD_{M*F}$ 1.12** | | 2.56** | | $LSD_{M*F}$ 1.77** |

| M * V | | | | | M * V | | | |
|---|---|---|---|---|---|---|---|---|
| **Methods of weed control** | **Aqmar** | **Sakha** | **Flame** | **Average weed control** | **Aqmar** | **Sakha** | **Flame** | **Average weed control** |
| M0 | 54.22 | 44.22 | 67.89 | 55.45 | 51.00 | 48.00 | 55.22 | 51.41 |
| M1 | 32.44 | 22.89 | 38.78 | 31.37 | 18.56 | 17.67 | 19.22 | 18.48 |
| M2 | 13.00 | 7.11 | 14.89 | 11.67 | 8.11 | 7.55 | 9.00 | 8.22 |
| **$LSD_{M*V}$** | | **1.37**** | | **$LSD_M$ 1.09**** | | **1.48**** | | **$LSD_M$ 0.86**** |

| F * V | | | | | F * V | | | |
|---|---|---|---|---|---|---|---|---|
| **Micronutrient compositions** | **Aqmar** | **Sakha** | **Flame** | **Average** | **Aqmar** | **Sakha** | **Flame** | **Average** |
| F0 | 36.22 | 28.00 | 44.67 | 36.30 | 31.00 | 29.78 | 36.11 | 32.30 |
| F1 | 33.00 | 24.11 | 40.00 | 32.37 | 27.11 | 25.56 | 26.78 | 26.48 |
| F2 | 30.44 | 22.11 | 36.89 | 29.81 | 19.56 | 17.89 | 20.55 | 19.33 |
| $LSD_{F*V}$ | | N.S. | | $LSD_F$ 0.65** | | 1.478** | | $LSD_F$ 1.02** |

| V | | | | V | | |
|---|---|---|---|---|---|---|
| **Varieties** | **Aqmar** | **Sakha** | **Flame** | **Aqmar** | **Sakha** | **Flame** |
| **Average varieties** | **33.22** | **24.74** | **40.52** | **25.89** | **24.41** | **27.81** |
| **$LSD_V$** | | **0.79**** | | | **0.85**** | |

micronutrient spraying significantly affected the combination ($M_2F_2$), with an average of 3.22 plants $m^{-2}$ in the second season alone, compared to the other combinations. The two-way interaction between weed control methods and varieties significantly affected weed density 60 days after germination, with the combination ($M_2V_2$) having the lowest average for this trait, 3.89 and 3.78 plants $m^{-2}$ in both seasons, respectively.

In the two-way interaction between micronutrient combinations and varieties, the combination ($F_2V_2$) had the lowest average, 13.11 and 14.11 plants $m^{-2}$ in both seasons, respectively. Regarding the three-way interaction, the combination ($M_2F_2V_2$) had the lowest average for this trait, 2.33 and 2.67 plants $m^{-2}$ in both seasons, respectively.

### *Weed plant density 90 days after planting*

Table 5 shows significant differences in weed control methods' averages for this trait. The mulching treatment had the lowest average weed density, reaching 11.67 and 8.22 plants $m^{-2}$, significantly lower than other control methods. In contrast, the weed-infested treatment had the highest average for this trait, reaching 55.45 and 51.41 plants $m^{-2}$, respectively, during both study seasons. The same Table shows that the effect of the micronutrient combination on the averages of this trait is exceptionally significant. The second micronutrient combination had the lowest average for this trait, reaching 29.81 and 19.33 plants $m^{-2}$ in both seasons. In contrast, the control treatment had the highest average, reaching 36.30 and 32.30 plants $m^{-2}$ in both seasons.

The results also revealed significant differences between varieties regarding this character's means. The Sakha variety significantly reduced the number of weed plants accompanying the crop when compared to the other varieties, with an average of 24.74 and 24.41 plants $m^{-2}$, compared to the Flami variety, which had the highest average for this character, reaching 40.52 and 27.81 plants $m^{-2}$ in both seasons, respectively. Weed control methods and micronutrient combinations significantly affected this trait's averages. The combination $M_2F_2$ had the lowest average for this trait, with 9.55 and 5.78 plants $m^{-2}$ in both seasons, respectively. The interaction of weed control methods and varieties also significantly impacted weed density 90 days after planting, with the combination $M_2V_2$ having the lowest average for this trait, reaching 7.11 and 7.55 plants per $m^2$ in both seasons. The interaction between micronutrient combinations and varieties greatly impacted the means of this attribute. Only in the second season did the combination $F_2V_2$ produce the lowest mean value of 17.89 plants per square metre. The interaction of the study factors also significantly affected the means of this attribute, with the combination $M_2F_2V_2$ having the lowest mean value, reaching 5.00 and 5.33 plants $m^{-2}$ for both seasons, respectively.

**Table 5 .** Effect of weed control methods and micronutrient spraying on varieties and their interaction on weed density after 90 days of planting) plants per $m^{-2}$)

| | | First Season 2022 | | | | Second Season 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Methods of weed control M** | **Nutrient compositions F** | **Varieties V Aqmar V1** | **Sakha V2** | **Flame V3** | **M * F** | **Varieties V Aqmar V1** | **Sakha V2** | **Flame V3** | **M * F** |
| M0 | F0 | 675.30 | 618.60 | 828.20 | 707.37 | 527.80 | 492.50 | 620.50 | 546.93 |
| | F1 | 598.60 | 568.80 | 672.50 | 613.30 | 522.90 | 427.80 | 567.90 | 506.20 |
| | F2 | 570.10 | 529.20 | 649.10 | 582.80 | 511.60 | 405.10 | 559.30 | 492.00 |
| M1 | F0 | 378.40 | 342.90 | 397.80 | 373.03 | 322.70 | 268.90 | 394.10 | 328.57 |
| | F1 | 303.60 | 259.70 | 262.00 | 275.10 | 283.60 | 243.10 | 321.70 | 282.80 |
| | F2 | 288.10 | 251.40 | 234.10 | 257.87 | 249.40 | 216.30 | 280.70 | 248.80 |
| M2 | F0 | 161.60 | 144.70 | 178.70 | 161.67 | 106.50 | 95.40 | 142.60 | 114.83 |
| | F1 | 111.60 | 90.50 | 124.50 | 108.87 | 76.70 | 67.20 | 117.60 | 87.17 |
| | F2 | 92.00 | 83.10 | 129.00 | 101.37 | 74.20 | 56.90 | 82.10 | 71.07 |
| **$LSD_{M*F*V}$** | | | **21.82**** | | **$LSD_{M*F}$ 21.55**** | | **17.11**** | | **$LSD_{M*F}$ 7.42**** |
| | | | M * V | | | | M * V | | |
| **Methods of weed control** | | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** |
| M0 | | 614.67 | 572.20 | 716.60 | 634.49 | 520.77 | 441.80 | 582.57 | 515.04 |
| M1 | | 323.37 | 284.67 | 297.97 | 302.00 | 285.23 | 242.77 | 332.17 | 286.72 |
| M2 | | 121.73 | 106.10 | 144.07 | 123.97 | 85.80 | 73.17 | 114.10 | 91.02 |
| $LSD_{M*V}$ | | | 12.60** | | $LSD_M$ 25.57** | | 9.88** | | $LSD_M$ 6.51** |
| | | | F * V | | | | F * V | | |
| **Micronutrient compositions** | | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** |
| F0 | | 405.10 | 368.73 | 468.23 | 414.02 | 319.00 | 285.60 | 385.73 | 330.11 |
| F1 | | 337.93 | 306.33 | 353.00 | 332.42 | 294.40 | 246.03 | 335.73 | 292.06 |
| F2 | | 316.73 | 287.90 | 337.40 | 314.01 | 278.40 | 226.10 | 307.37 | 270.62 |
| $LSD_{F*V}$ | | | 12.6** | | $LSD_F$ 12.44** | | 9.88** | | $LSD_F$ 4.29** |
| | | | V | | | | V | | |
| **Varieties** | | **Aqmar** | **Sakha** | **Flame** | | **Aqmar** | **Sakha** | **Flame** | |
| **Average varieties** | | **353.26** | **320.99** | **386.21** | | **297.27** | **252.58** | **342.94** | |
| **$LSD_V$** | | | **7.27**** | | | | **5.70**** | | |

### *Dry weight of weeds*

Table 6 shows the results for the dry weight of weeds. There were significant differences due to the effects of various weed control methods. Mulching resulted in weeds' lowest mean dry weight (123.97 and 91.02 g $m^{-2}$ in both seasons, respectively). In return, the weed-infested treatment produced the most dry weight of weed plants, averaging 634.49 and 515 g $m^{-2}$ for both seasons, respectively.

Table 6 also shows that micronutrient spraying produced significant differences in weed dry weight. The second combination had the lowest average for this trait, with 314.01 and 270.62 g $m^{-2}$, as opposed to the control treatment, which had the highest dry weight of weed plants, with 414.02 and 330.11 g $m^{-2}$ for both seasons, respectively. The table results also show that varieties have a significant effect on the increase in dry weight of weeds that grow alongside them. Compared to the other two varieties, the Sakha variety had the lowest weed spread in the planted plots, with 320.99 and 252.58 g $m^{-2}$ in both seasons, respectively. The Flami variety had the highest average value for this characteristic in both seasons, with 386.21 and 342.94 g $m^{-2}$, respectively. Regarding two-way interactions, Table 6 shows a significant difference between weed control methods and micronutrient combinations. The mulching treatment combination $M_2F_2$ had the lowest dry weight of weeds, at 101.37 g $m^{-2}$ and 71.07 g $m^{-2}$ for the rainy and dry seasons, respectively; on the other hand, the weed-infested $M_0F_0$ had the highest dry weight of weeds, at 707.37 g $m^{-2}$ and 546.93 g $m^{-2}$ for both seasons.

The results in Table 6 also show a significant difference in the two-way interaction of varieties with weed control methods. The $M_2V_2$ mulching treatment with the Sakha variety produced the lowest dry weight of weeds during both seasons, at 106.10 and 73.17 g $m^{-2}$, respectively. In contrast, the weed-infested treatment in the Flami variety $M_0V_3$ produced a high dry weight of weeds (716.60 and 582.57 g $m^{-2}$, respectively) during both study seasons. The findings also revealed a strong two-way interaction between varieties and micronutrients. The Flami variety ($F_0V_3$) had the highest dry weight of weeds (468.23 and 385.73 g $m^{-2}$), while the Sakha variety ($F_0V_2$) had the lowest dry weight of weeds (287.90 and 226.10 g $m^{-2}$ in both seasons).

**Table 6**. Effect of weed control methods and spraying with micronutrients on varieties and their interactions in average dry weight of weeds (g m$^{-2}$)

| Methods of weed control M | Nutrient compositions F | First Season 2022 Varieties V Aqmar V1 | Sakha V2 | Flame V3 | M * F | Second Season 2022 Varieties V Aqmar V1 | Sakha V2 | Flame V3 | M * F |
|---|---|---|---|---|---|---|---|---|---|
| M0 | F0 | 185.83 | 170.06 | 182.81 | 179.57 | 211.51 | 187.03 | 196.70 | 198.41 |
| | F1 | 187.67 | 171.91 | 184.61 | 181.40 | 217.07 | 186.87 | 199.16 | 201.03 |
| | F2 | 189.52 | 173.85 | 185.70 | 183.02 | 217.67 | 195.17 | 207.52 | 206.79 |
| M1 | F0 | 177.39 | 164.39 | 157.59 | 166.46 | 185.75 | 184.00 | 177.58 | 182.44 |
| | F1 | 183.33 | 165.59 | 178.83 | 175.92 | 196.94 | 189.35 | 186.45 | 190.91 |
| | F2 | 185.37 | 170.35 | 179.85 | 178.52 | 207.50 | 193.98 | 190.87 | 197.45 |
| M2 | F0 | 194.92 | 177.55 | 190.48 | 187.65 | 219.23 | 210.14 | 211.80 | 213.72 |
| | F1 | 196.29 | 184.71 | 191.57 | 190.86 | 220.89 | 214.23 | 218.23 | 217.78 |
| | F2 | 201.02 | 195.41 | 195.67 | 197.37 | 223.52 | 218.71 | 219.63 | 220.62 |
| **LSD$_{M*F*V}$** | | | **5.45** | | **LSD$_{M*F}$ 2.29** | | **N.S.** | | **LSD$_{M*F}$ 3.29** |

| | | | | M * V | | | | |
|---|---|---|---|---|---|---|---|---|
| **Methods of weed control** | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** |
| M0 | 187.67 | 171.94 | 184.37 | 181.33 | 215.42 | 189.69 | 201.13 | 202.08 |
| M1 | 182.03 | 166.78 | 172.09 | 173.63 | 196.73 | 189.11 | 184.97 | 190.27 |
| M2 | 197.41 | 185.89 | 192.57 | 191.96 | 221.21 | 214.36 | 216.55 | 217.38 |
| LSD$_{M*V}$ | | 3.15 | | LSD$_M$ 2.46 | | 4.17 | | LSD$_M$ 5.09 |

| | | F * V | | | | F * V | | |
|---|---|---|---|---|---|---|---|---|
| **Micronutrient compositions** | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** |
| F0 | 186.05 | 170.67 | 176.96 | 177.89 | 205.50 | 193.72 | 195.36 | 198.19 |
| F1 | 189.10 | 174.07 | 185.00 | 182.72 | 211.63 | 196.82 | 201.28 | 203.24 |
| F2 | 191.97 | 179.87 | 187.07 | 186.30 | 216.23 | 202.62 | 206.01 | 208.29 |
| LSD$_{F*V}$ | | N.S. | | LSD$_F$ 1.32 | | Ns | | LSD$_F$ 1.90 |

| | | V | | | | V | |
|---|---|---|---|---|---|---|---|
| **Varieties** | **Aqmar** | **Sakha** | **Flame** | | **Aqmar** | **Sakha** | **Flame** |
| **Average varieties** | **189.04** | **174.87** | **183.01** | | **211.12** | **197.72** | **200.88** |
| **LSD$_V$** | | **1.82** | | | | **2.40** | |

Regarding the three-way interactions between the study factors, the effect was significant for this trait. The mulching treatment with the second micronutrient combination and the Sakha variety ($M_2F_2V_2$) gave the lowest dry weight of weeds, with 83.10 and 56.90 g m$^{-2}$ in both seasons, respectively, compared to the weed-infested treatment with the control and the Flami variety ($M_0F_0V_3$), which gave the highest average for this trait, with 828.20 and 620.50 mg L$^{-1}$ in both seasons, respectively.

### *Plant height*

The results of Table 7 indicate significant differences among weed control methods in the plant height trait. The mulching treatment (M2) achieved the highest average, reaching 191.96 and 217.38 cm. In contrast, the spraying with herbicide treatment (M1) recorded the lowest average for this trait, at 173.63 and 190.27 cm for the two seasons, respectively. This superiority may be attributed to mulching the soil surface increased soil moisture content by reducing evaporation, thereby increasing water and nutrient availability for the plant. This improved the moisture and nutrients, which reflected positively on crop growth, increasing the height of plants. The same Table also shows a significant effect of the micronutrient combination on the averages of this trait, wherein the second combination of micronutrient spraying achieved the highest average of 186.30 and 208.29 cm compared to the control treatment, which gave the lowest average for the trait 177.89 and 198.19 cm in both seasons, respectively. It also shows significant differences among varieties about the averages of plant height, where the Aqmar variety recorded a substantial increase in the averages of this trait compared to other varieties, as it recorded an average of 189.04 and 211.12 cm for both seasons, respectively, compared to the Sakha variety, which recorded the lowest average for this trait, at 174.87 and 197.72 cm for both seasons, respectively.

The interaction between weed control methods and micronutrient combinations for this trait was significant at the average level, so the combination ($M_2F_2$) gave the highest average of 197.37 and 220.62 cm compared to other combinations in both seasons, respectively. Also, the interaction between weed control methods and varieties significantly affected the plant height trait, as the combination $M_2V_1$ recorded the highest average for the said trait, attaining 197.41 and 221.21 cm for both seasons, respectively. Further, the triple interaction among the study factors significantly affected the averages of this trait, where the combination $M_2F_2V_1$ achieved the highest average for the said trait, reaching 201.02 cm for the first season only.

**Table 7.** Effect of weed control methods and spraying with micronutrients on varieties and their interactions in plant height (cm)

| Methods of weed control M | Nutrient compositions F | First Season 2022 | | | | Second Season 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Varieties V | | | M * F | Varieties V | | | M * F |
| | | Aqmar V1 | Sakha V2 | Flame V3 | | Aqmar V1 | Sakha V2 | Flame V3 | |
| M0 | F0 | 2901.00 | 2936.00 | 3880.00 | 3239.00 | 3627.00 | 3405.00 | 4448.00 | 3826.67 |
| | F1 | 3527.00 | 3282.00 | 4037.00 | 3615.33 | 4105.00 | 3536.00 | 4643.00 | 4094.67 |
| | F2 | 3951.00 | 3751.00 | 4573.00 | 4091.67 | 4542.00 | 3727.00 | 4809.00 | 4359.33 |
| M1 | F0 | 4043.00 | 3993.00 | 4781.00 | 4272.33 | 4828.00 | 3784.00 | 4976.00 | 4529.33 |
| | F1 | 4480.00 | 4200.00 | 5087.00 | 4589.00 | 4872.00 | 3903.00 | 5130.00 | 4635.00 |
| | F2 | 4506.00 | 4317.00 | 5385.00 | 4736.00 | 4992.00 | 3988.00 | 5242.00 | 4740.67 |
| M2 | F0 | 4784.00 | 4532.00 | 5763.00 | 5026.33 | 5132.00 | 4210.00 | 5357.00 | 4899.67 |
| | F1 | 5161.00 | 4668.00 | 5923.00 | 5250.67 | 5335.00 | 4267.00 | 6454.00 | 5352.00 |
| | F2 | 5615.00 | 4981.00 | 6487.00 | 5694.33 | 5454.00 | 4722.00 | 6655.00 | 5610.33 |
| **$LSD_{M*F*V}$** | | | **N.S.** | | **$LSD_{M*F}$ 145.20**** | | **287.50**** | | **$LSD_{M*F}$ 168.60 **** |

M * V

| Methods of weed control | Aqmar | Sakha | Flame | Average weed control | Aqmar | Sakha | Flame | Average weed |
|---|---|---|---|---|---|---|---|---|
| M0 | 3459.67 | 3323.00 | 4163.33 | 3648.67 | 4091.33 | 3556.00 | 4633.33 | 4093.56 |
| M1 | 4343.00 | 4170.00 | 5084.33 | 4532.44 | 4897.33 | 3891.67 | 5116.00 | 4635.00 |
| M2 | 5186.67 | 4727.00 | 6057.67 | 5323.78 | 5307.00 | 4399.67 | 6155.33 | 5287.33 |
| $LSD_{M*V}$ | | 124.20** | | $LSD_M$ 144.80** | | 166.00** | | $LSD_M$ 116.10** |

F * V

| Micronutrient compositions | Aqmar | Sakha | Flame | Average concentrations | Aqmar | Sakha | Flame | Average concentrations |
|---|---|---|---|---|---|---|---|---|
| F0 | 3909.33 | 3820.33 | 4808.00 | 4179.22 | 4529.00 | 3799.67 | 4927.00 | 4418.56 |
| F1 | 4389.33 | 4050.00 | 5015.67 | 4485.00 | 4770.67 | 3902.00 | 5409.00 | 4693.89 |
| F2 | 4690.67 | 4349.67 | 5481.67 | 4840.67 | 4996.00 | 4145.67 | 5568.67 | 4903.44 |
| $LSD_{F*V}$ | | 124.2** | | $LSD_F$ 83.90** | | 166.00* | | $LSD_F$ 97.40** |

V

| Varieties | Aqmar | Sakha | Flame | | Aqmar | Sakha | Flame | |
|---|---|---|---|---|---|---|---|---|
| **Average varieties** | **4329.78** | **4073.33** | **5101.78** | | **4765.22** | **3949.11** | **5301.56** | |
| **$LSD_V$** | | **71.70**** | | | | **95.80**** | | |

### *Leaf area per plant*

The results of Table 8 indicate significant differences among weed control methods in the trait of leaf area. The mulching treatment (M2) achieved the highest average for this trait, reaching 5323.78 and 5287.33 cm$^2$ per plant, compared to the weedy control treatment (M0), which recorded the lowest leaf area of 3648.67 and 4093.56 cm$^2$ per plant for the two seasons, respectively. This increase is likely due to no competition between weeds and crop plants for essential growth requirements. It significantly impacts the leaf area, especially in the early stages of growth, where overall plant growth is enhanced, promoting leaf growth and increasing size.

The same Table also shows a significant effect of the micronutrient combination on the averages of this trait, as the high concentration of spraying (the second combination) recorded the highest average of 4840.67 and 4903.44 cm$^2$ per plant, compared to the control treatment, which gave the lowest average leaf area (4179.22 and 4418.56 cm$^2$ per plant) for both seasons, respectively. This may be due to the role of micronutrients in increasing plant height, thereby increasing the number of leaves and the leaf area (Table 8). The results of Table 8 show significant differences among varieties in the averages of leaf area, with the Flame variety recording a substantial increase in the averages of this trait compared to other varieties, with an average of 5101.78 and 5301.56 cm$^2$ per plant for both seasons, respectively, compared to the Sakha variety, which recorded the lowest average of 4073.33 and 3949.11 cm$^2$ per plant for both seasons, respectively.

The interaction between weed control methods and micronutrient combinations shows a significant effect on the averages of this trait, with the combination ($M_2F_2$) achieving the highest average of 5694.33 and 5610.33 cm$^2$ per plant for both seasons, respectively, compared to other combinations. Similarly, the interaction between weed control methods and varieties significantly affected leaf area, with the combination ($M_2V_3$) recording the highest average for the trait, reaching 6057.67 and 6155.33 cm$^2$ per plant for both seasons, respectively. The interaction between micronutrient combinations and varieties also recorded the highest averages for the trait (5481.67 and 5568.67 cm$^2$ per plant) for both study seasons, respectively. Additionally, the triple interaction among the study factors significantly affected the averages of this trait, with the combination ($M_2F_2V_3$) achieving the highest average for the trait, reaching 6655.00 cm$^2$ per plant for the second season only.

**Table 8 .** Effect of weed control methods and spraying with micronutrients on varieties and their interactions in leaf area) dm² per plant[-1])

| | | First Season 2022 | | | | Second Season 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Methods of weed control M** | **Nutrient compositions F** | **Varieties V** | | | **M * F** | **Varieties V** | | | **M * F** |
| | | **Aqmar V1** | **Sakha V2** | **Flame V3** | | **Aqmar V1** | **Sakha V2** | **Flame V3** | |
| M0 | F0 | 2901.00 | 2936.00 | 3880.00 | 3239.00 | 3627.00 | 3405.00 | 4448.00 | 3826.67 |
| | F1 | 3527.00 | 3282.00 | 4037.00 | 3615.33 | 4105.00 | 3536.00 | 4643.00 | 4094.67 |
| | F2 | 3951.00 | 3751.00 | 4573.00 | 4091.67 | 4542.00 | 3727.00 | 4809.00 | 4359.33 |
| M1 | F0 | 4043.00 | 3993.00 | 4781.00 | 4272.33 | 4828.00 | 3784.00 | 4976.00 | 4529.33 |
| | F1 | 4480.00 | 4200.00 | 5087.00 | 4589.00 | 4872.00 | 3903.00 | 5130.00 | 4635.00 |
| | F2 | 4506.00 | 4317.00 | 5385.00 | 4736.00 | 4992.00 | 3988.00 | 5242.00 | 4740.67 |
| M2 | F0 | 4784.00 | 4532.00 | 5763.00 | 5026.33 | 5132.00 | 4210.00 | 5357.00 | 4899.67 |
| | F1 | 5161.00 | 4668.00 | 5923.00 | 5250.67 | 5335.00 | 4267.00 | 6454.00 | 5352.00 |
| | F2 | 5615.00 | 4981.00 | 6487.00 | 5694.33 | 5454.00 | 4722.00 | 6655.00 | 5610.33 |
| **$LSD_{M*F*V}$** | | | **N.S.** | | **$LSD_{M*F}$ 145.20**** | | **287.50**** | | **$LSD_{M*F}$ 168.60**** |
| | | | | | | | | M * V | |
| Methods of weed control | | Aqmar | Sakha | Flame | Average weed control methods | Aqmar | Sakha | Flame | Average weed control methods |
| M0 | | 3459.67 | 3323.00 | 4163.33 | 3648.67 | 4091.33 | 3556.00 | 4633.33 | 4093.56 |
| M1 | | 4343.00 | 4170.00 | 5084.33 | 4532.44 | 4897.33 | 3891.67 | 5116.00 | 4635.00 |
| M2 | | 5186.67 | 4727.00 | 6057.67 | 5323.78 | 5307.00 | 4399.67 | 6155.33 | 5287.33 |
| **$LSD_{M*V}$** | | | **124.20**** | | **$LSD_{M}$ 144.80**** | | **166.00**** | | **$LSD_{M}$ 116.10**** |
| | | | F * V | | | | | F * V | |
| **Micronutrient compositions** | | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** |
| F0 | | 3909.33 | 3820.33 | 4808.00 | 4179.22 | 4529.00 | 3799.67 | 4927.00 | 4418.56 |
| F1 | | 4389.33 | 4050.00 | 5015.67 | 4485.00 | 4770.67 | 3902.00 | 5409.00 | 4693.89 |
| F2 | | 4690.67 | 4349.67 | 5481.67 | 4840.67 | 4996.00 | 4145.67 | 5568.67 | 4903.44 |
| $LSD_{F*V}$ | | | 124.2** | | $LSD_{F}$ 83.90** | | 166.00* | | $LSD_{F}$ 97.40** |
| | | | V | | | | | V | |
| **Varieties** | | **Aqmar** | **Sakha** | **Flame** | | **Aqmar** | **Sakha** | **Flame** | |
| **Average varieties** | | **4329.78** | **4073.33** | **5101.78** | | **4765.22** | **3949.11** | **5301.56** | |
| **$LSD_{V}$** | | | **71.70**** | | | | **95.80**** | | |

## *Stem diameter*

Table 9 results indicate significant differences among weed control methods in stem diameter. The mulching treatment ($M_2$) achieved the highest average for this trait, reaching 2.66 and 2.74 mm, compared to the weedy control treatment ($M_0$), which recorded the lowest average stem diameter of 2.14 and 2.38 mm for the two seasons, respectively. The same Table also shows a significant effect of the micronutrient combination on the averages of this trait, with the high concentration of spraying (the second combination) recording the highest average for the trait (2.41 and 2.58 mm), compared to the weed control, which gave the lowest average for the trait (2.14 and 2.38 mm) for both seasons, respectively.

Noticeable differences between the averages of stem diameter among varieties are also noticed in the Table, where the Flami variety proves to have a highly significant increase in the averages of this trait compared with other varieties. The average it obtained was 2.40 and 2.62 mm, whereas the Aqmar variety had the lowest average for this trait, 2.16 and 2.34 mm for both seasons, respectively. This superiority of the Flame variety in this trait may be due to its superior leaf area, as indicated in Table 8. The interaction of weed control methods and micronutrient combinations was highly significant on the averages of this trait in the second season only, where the combination $M_2F_2$ resulted in the highest average for the said trait, reaching 2.88 mm, compared to other combinations. Variety and weed control method interactions, on the other hand, significantly affected stem diameter only in the second season. At the same time, the combination $M_2V_3$ recorded the highest average of 3.00 mm for this trait compared to other combinations. Besides, the interaction of micronutrient combinations and varieties and the triple interaction among the study factors affected stem diameter significantly only in the first season, where the combination $M_2V_3$ resulted in the highest averages for this trait, reaching 2.83 mm. In comparison, the combination $M_2F_2V_3$ reached the highest average of 2.94 mm only in the first season.

## *Chlorophyll content in leaves*

There were significant effects of weed control methods, micronutrient combinations, varieties and their interactions on chlorophyll content, as noted in Table 10, the highest average for this trait was recorded with the mulching treatment, M2, which reached an average of 44.64 and 46.97 mg $g^{-1}$ for the two respective seasons, in comparison with weedy control, M0, that had the lowest average chlorophyll content of 36.02 and 32.62 mg $g^{-1}$ for both seasons, respectively. The same Table also indicates a significant effect of the micronutrient combination on the averages of this trait. The high concentration of spraying recorded the highest average of this trait with values of 42.24 and 42.90 mg $g^{-1}$, while the control treatment gave the lowest average for the trait under research in the case of both seasons: 38.50 and 36.53 mg $g^{-1}$.

**Table 9.** Effect of weed control methods and spraying with micronutrients on varieties and their interactions in stem diameter (cm)

| | | First Season 2022 | | | | Second Season 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Methods of weed control M** | **Nutrient compositions F** | **Varieties V** | | | **M * F** | **Varieties V** | | | **M * F** |
| | | **Aqmar V1** | **Sakha V2** | **Flame V3** | | **Aqmar V1** | **Sakha V2** | **Flame V3** | |
| M0 | F0 | 34.26 | 29.50 | 37.28 | 33.68 | 22.17 | 31.40 | 33.40 | 28.99 |
| | F1 | 36.40 | 32.21 | 39.82 | 36.14 | 31.77 | 33.37 | 36.07 | 33.74 |
| | F2 | 38.98 | 34.96 | 40.73 | 38.23 | 34.20 | 35.57 | 35.63 | 35.13 |
| M1 | F0 | 39.71 | 37.15 | 42.09 | 39.65 | 36.87 | 37.60 | 37.83 | 37.43 |
| | F1 | 40.31 | 37.53 | 42.99 | 40.28 | 39.70 | 39.40 | 39.73 | 39.61 |
| | F2 | 40.90 | 38.36 | 44.32 | 41.19 | 40.90 | 41.50 | 42.70 | 41.70 |
| M2 | F0 | 42.27 | 38.84 | 45.40 | 42.17 | 43.53 | 41.90 | 44.03 | 43.15 |
| | F1 | 42.85 | 39.49 | 50.95 | 44.43 | 44.73 | 45.07 | 47.90 | 45.90 |
| | F2 | 49.48 | 40.06 | 52.37 | 47.30 | 51.83 | 49.27 | 54.47 | 51.86 |
| **$LSD_{M*F*V}$** | | | **1.21**** | | **$LSD_{M*F}$ 0.80**** | | **2.10**** | | **$LSD_{M*F}$ 1.56**** |
| | | | | | | | M * V | | |
| **Methods of weed control** | | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** |
| M0 | | 36.55 | 32.22 | 39.28 | 36.02 | 29.38 | 33.45 | 35.03 | 32.62 |
| M1 | | 40.31 | 37.68 | 43.13 | 40.37 | 39.16 | 39.50 | 40.09 | 39.58 |
| M2 | | 44.87 | 39.46 | 49.57 | 44.64 | 46.70 | 45.41 | 48.80 | 46.97 |
| $LSD_{M*V}$ | | | 0.70** | | $LSD_M$ 0.59** | | 1.21** | | $LSD_M$ 1.17** |
| | | | F * V | | | | F * V | | |
| **Micronutrient compositions** | | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** |
| F0 | | 38.75 | 35.16 | 41.59 | 38.50 | 34.19 | 36.97 | 38.42 | 36.53 |
| F1 | | 39.85 | 36.41 | 44.59 | 40.28 | 38.73 | 39.28 | 41.23 | 39.75 |
| F2 | | 43.12 | 37.79 | 45.80 | 42.24 | 42.31 | 42.11 | 44.27 | 42.90 |
| $LSD_{F*V}$ | | | 0.698** | | $LSD_F$ 0.46** | | 1.21* | | $LSD_F$ 0.90** |
| | | | V | | | | V | | |
| **Varieties** | | **Aqmar** | **Sakha** | **Flame** | | **Aqmar** | **Sakha** | **Flame** | |
| **Average varieties** | | **40.57** | **36.46** | **43.99** | | **38.41** | **39.45** | **41.31** | |
| **$LSD_V$** | | | **0.40**** | | | | **0.70**** | | |

Results of Table 10 indicate significant differences among varieties for the averages of chlorophyll content. The Flame variety recorded a highly significant increase in the averages of this trait compared with other varieties, with an average of 43.99 and 41.31 mg $g^{-1}$ for the two seasons, respectively, which is compared to the lowest averages recorded for this trait for the Sakha and Aqmar varieties, being 36.46 mg $g^{-1}$ and 38.41 mg $g^{-1}$for the two seasons respectively.

The interaction between weed control methods and micronutrient combinations was highly significant on the averages of this trait. $M_2F_2$ combination gave the highest average for this trait, attaining 47.30 and 51.86 mg $g^{-1}$ for both seasons, respectively, than other combinations. The interaction between weed control methods and varieties also showed significant effects on the averages of this trait. Combination $M_2V_3$ gave the highest average for this trait, reaching 49.57 and 48.80 mg $g^{-1}$ in both seasons, respectively. The interaction of micronutrient combinations and varieties also brought about a significant effect on chlorophyll content, where the combination $F_2V_3$ recorded the highest average for the trait of 45.80 mg $g^{-1}$ and 44.27 mg $g^{-1}$ for both seasons of the study, respectively. Also, the interaction among the studied factors in triple was highly significant on the averages of this trait. The combination $M_2F_2V_3$ gave the highest value for the said trait, attaining an average of 52.37 and 54.47 mg $g^{-1}$ in both study seasons, respectively.

## Discussion

As shown in Table 4, there was a significant difference in weed control methods. Weed control with mulching, $M_2$, had the lowest weed density, while the weed-infested treatment, $M_0$, had the highest of 5.96 and 4.33 plants $m^{-2}$ in both seasons. This is attributed to black plastic mulching blocking the light from the weed plants, suppressing them and weakening their growth, positively affecting their demise and reducing their numbers. Mulching reduces the development of weed plants by utilizing solar energy to increase soil temperature, sterilize it and enhance the activity of various soil organisms, thereby reducing weed density (7).

**Table 10.** Effect of weed control methods and spraying with micronutrients on varieties and their interactions in chlorophyll content (mg.g$^{-1}$ fresh weight)

| | | First Season 2022 | | | | Second Season 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Methods of weed control M** | **Nutrient compositions F** | **Varieties V** | | | **M * F** | **Varieties V** | | | **M * F** |
| | | **Aqmar V1** | **Sakha V2** | **Flame V3** | | **Aqmar V1** | **Sakha V2** | **Flame V3** | |
| M0 | F0 | 34.26 | 29.50 | 37.28 | 33.68 | 22.17 | 31.40 | 33.40 | 28.99 |
| | F1 | 36.40 | 32.21 | 39.82 | 36.14 | 31.77 | 33.37 | 36.07 | 33.74 |
| | F2 | 38.98 | 34.96 | 40.73 | 38.23 | 34.20 | 35.57 | 35.63 | 35.13 |
| M1 | F0 | 39.71 | 37.15 | 42.09 | 39.65 | 36.87 | 37.60 | 37.83 | 37.43 |
| | F1 | 40.31 | 37.53 | 42.99 | 40.28 | 39.70 | 39.40 | 39.73 | 39.61 |
| | F2 | 40.90 | 38.36 | 44.32 | 41.19 | 40.90 | 41.50 | 42.70 | 41.70 |
| M2 | F0 | 42.27 | 38.84 | 45.40 | 42.17 | 43.53 | 41.90 | 44.03 | 43.15 |
| | F1 | 42.85 | 39.49 | 50.95 | 44.43 | 44.73 | 45.07 | 47.90 | 45.90 |
| | F2 | 49.48 | 40.06 | 52.37 | 47.30 | 51.83 | 49.27 | 54.47 | 51.86 |
| **LSD$_{M*F*V}$** | | | **1.21**** | | **LSD$_{M*F}$ 0.80**** | | **2.10**** | | **LSD$_{M*F}$ 1.56**** |
| | | | | | | | | M * V | |
| **Methods of weed control** | | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** | **Aqmar** | **Sakha** | **Flame** | **Average weed control methods** |
| M0 | | 36.55 | 32.22 | 39.28 | 36.02 | 29.38 | 33.45 | 35.03 | 32.62 |
| M1 | | 40.31 | 37.68 | 43.13 | 40.37 | 39.16 | 39.50 | 40.09 | 39.58 |
| M2 | | 44.87 | 39.46 | 49.57 | 44.64 | 46.70 | 45.41 | 48.80 | 46.97 |
| LSD$_{M*V}$ | | | 0.70** | | LSD$_M$ 0.59** | | 1.21** | | LSD$_M$ 1.17** |
| | | | F * V | | | | | F * V | |
| **Micronutrient compositions** | | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** | **Aqmar** | **Sakha** | **Flame** | **Average concentrations** |
| F0 | | 38.75 | 35.16 | 41.59 | 38.50 | 34.19 | 36.97 | 38.42 | 36.53 |
| F1 | | 39.85 | 36.41 | 44.59 | 40.28 | 38.73 | 39.28 | 41.23 | 39.75 |
| F2 | | 43.12 | 37.79 | 45.80 | 42.24 | 42.31 | 42.11 | 44.27 | 42.90 |
| LSD$_{F*V}$ | | | 0.698** | | LSD$_F$ 0.46** | | 1.21* | | LSD$_F$ 0.90** |
| | | | V | | | | | V | |
| **Varieties** | | **Aqmar** | **Sakha** | **Flame** | | **Aqmar** | **Sakha** | **Flame** | |
| **Average varieties** | | **40.57** | **36.46** | **43.99** | | **38.41** | **39.45** | **41.31** | |
| **LSD$_V$** | | | **0.40**** | | | | **0.70**** | | |

Regarding the cultivars, the lowest number of weed plants was in the Sakha variety, while 24.30 and 17.78 plants m$^{-2}$ were recorded with the prevailing variety of Flami in both seasons, respectively. This could be because the Sakha variety, because of its morphological and genetic nature, combined with vegetative mass, acquired the ability to compete with the weeds for the different growth requirements, thus reducing the density of the competing weeds. Furthermore, the competitive ability of varieties and the associated weed plants could also lead to this difference in the effects of the varieties on the numerical density of weed plants. Research indicates varieties may differ in competitive ability with associated weed plants (8, 9).

Significant differences in weed control methods were observed in Table 5. The average weed density was the lowest with the mulching treatment, at 11.67 and 8.22 plants m$^{-2}$, while it was the highest in the weed-infested at 55.45 and 51.41 plants m$^{-2}$ in both seasons. This could be due to the effect of mulching in suppressing or killing the weed plants accompanying crop growth, therefore reducing their density. Research indicates that using weed control methods significantly decreased the density of weed plants growing various crops (2, 10).

The varietal differences were highly significant. The variety Sakha significantly reduced the number of weed plants to 24.74 and 24.41 plants m$^{-2}$ compared with the variety Flami, which recorded the highest averages of 40.52 and 27.81 plants m$^{-2}$ in both seasons, respectively. This could be due to the competitive ability of the Sakha variety resulting from morphological and physiological characteristics that made it compete with weeds and reduce their density after 60 days, as shown in Table 2, hence reducing their numbers after 90 days of planting. The result confirms the difference in growth nature and development ability among sunflower varieties, which could be reflected in their competitiveness with accompanying weed plants (11, 12, 13).

The results of the dry weight of weeds are presented in Table 6. A significant difference was observed in weed control methods. Mulching recorded the lowest mean dry weight of weeds, 123.97 and 91.02 g m -2 in both seasons, respectively. Weed-infested treatment noted the highest dry weight with an average of 634.49 and 515 g m$^{-2}$ for both seasons. This might be because the black polyethene mulch affected weed plant growth by reducing or preventing the amount of light reaching the plants, harming their photosynthesis process and ultimately reducing their dry weight. Research indicates that mulch treatment resulted in weakened growth, reduced number, or death of weeds, affecting their dry weight negatively (14, 15).

Table 6 shows a significant interaction of micronutrient spraying on weed dry weight. The second combination showed the minimum average dry weight of

314.01 and 270.62 g $m^{-2}$ in both seasons, respectively and the control treatment showed the maximum under both seasons at 414.02 and 330.11 g $m^{-2}$. It also represents the results of weed dry weight: the lowest was presented by the Sakha variety with 320.99 and 252.58 g $m^{-2}$ and the highest value obtained was by the Flami variety with 386.21 and 342.94 g $m^{-2}$ in both seasons. This may be attributed to the potential of these varieties to compete against weed plants, besides utilizing the necessary growth requirements to its advantage, which is reflected positively by the lower numbers of weed plants, causing a decrease in dry weight. Research indicates that varieties differ in their competitive ability, with weed plants accompanying them, giving rise to differences in dry weight.

Table 7 shows significant differences in plant heights among weed control methods. The highest averages, 191.96 and 217.38 cm were recorded with the mulching treatment, $M_2$ and the lowest, 173.63 and 190.27 cm, were recorded with the herbicide treatment, M1, in both seasons. Likely, the increase in the plant height with mulching can be attributed to higher water content in the soil and, hence, increased availability of water and nutrients for better crop growth. Research indicates an increase in crop plant height due to the absence of weed plants in control methods (18, 19). Table 7 also added that micronutrient combinations have a highly significant effect on plant height. The second micronutrient combination spraying increased the highest average to 186.30 and 208.29, while the control had the lowest average of 177.89 and 198.19 cm in both seasons, respectively. This may be attributed to micronutrients, especially zinc, which synthesize tryptophan and produce growth hormones like IAA, responsible for cell division and cell elongation of the stem internodes, resulting in increased plant height. Research indicates that micronutrient spraying on different crops increases the height of the plants.

Table 7 shows that there are also significant differences in plant height among varieties. In addition to the Aqmar variety, which had the highest average in both seasons, the Sakha variety had the lowest in both seasons. It can also result from the nature of the cultivar, which is genetically determined and reflected in its response to environmental conditions. It resulted in cell division and elongation and increased plant height. Research indicates significant differences between the varieties of sunflowers and other crops regarding plant height.

According to Table 8, the largest leaf areas of 5323.78 and 5287.33 $cm^2$ per plant were obtained with mulching ($M_2$), while the smallest, 3648.67 and 4093.56 $cm^2$ per plant, was obtained with the weedy control ($M_0$) in the two seasons, respectively. Explanations for the large leaf areas noted with mulching could be a reduced struggle for growth resources. Research indicates that the absence of weed competition in control methods had clear effects on the leaf area of plants (25, 26).

It is also shown in the Table that the high micronutrient concentration obtained the largest leaf area of 4840.67 and 4903.44 $cm^2$ per plant compared to the control, which received the smallest of 4179.22 and 4418.56 $cm^2$ per plant. This may be an improvement due to micronutrients raising plant height and number of leaves, increasing the leaf area (24, 27, 28).

Table 8 reveals that the Flame variety had the largest leaf area (5101.78 and 5301.56 $cm^2$ per plant) compared to the Sakha variety, which had the smallest leaf area (4073.33 and 3949.11 $cm^2$ per plant) across both seasons. The difference among varieties in this trait is due to the genetic nature of the varieties and their response to prevailing environmental conditions. Research indicates the variations among muti-crop varieties in leaf areas.

According to Table 9, $M_2$ produced the most prominent stem diameter of 2.66 and 2.74 mm compared to the weedy control, $M_0$, which produced the most minor stem diameter of 2.14 and 2.38 mm for two seasons. This increase could be due to the lower density of weed plants in the mulching treatment, reducing competition for growth requirements thereby increasing the efficiency of the plant's carbon assimilation process. This led to more cell divisions in the stem, reflected in the increased stem diameter in that treatment. Research indicates that the absence of weed competition in control methods for crop plants led to increased stem diameter in sesame plants (31).

Also, Table 9 indicates that the high micronutrient concentration achieved the largest stem diameter of 2.41 and 2.58 mm compared to the control treatment, which recorded the smallest with a stem diameter of 2.14 and 2.38 mm over the two seasons. The increase in stem diameter is attributed to micronutrients' role in synthesising the amino acid tryptophan, which is involved in forming IAA from auxins that stimulate cell division and expansion lengthwise and widthwise, thereby increasing stem diameter (5). In this regard, researchers found significant differences in the average stem diameter of sunflower crops with the addition of zinc (32, 33).

Table 9 shows Flame had the highest diameter of the stem, with values of 2.40 and 2.62 mm, whereas Aqmar had the smallest, with values of 2.16 and 2.34 mm. The superiority of Flame in terms of stem diameter could be related to its higher leaf area, as shown in Table 8. Therefore, this positively reflected the increase in products of the carbon assimilation process, stimulating the stem cells to divide along the length and width, hence the increased stem diameter. Research has reported that significant differences in stem diameter among sunflower varieties have been found.

Table 10 also indicates that the highest chlorophyll content of 44.64 and 46.97 mg $g^{-1}$ was recorded by $M_2$ (mulching), while the weedy control, $M_0$, had the lowest with 36.02 and 32.62 mg $g^{-1}$ in both seasons. This increase in chlorophyll content might be attributed to the fact that weed control methods of mulching eliminated weeds that generally compete with crop plants for essential requirements of growth, resulting in enhanced vegetative growth, evidenced by increased plant height and leaf area as shown in Tables 7 and 8, reflecting positively on the chlorophyll content of leaves. Research indicates that weed control and reduced competition with crop plants significantly increased the vegetative growth indicators, increasing leaf chlorophyll content.

Table 10 also shows that the high concentration of micronutrients resulted in the highest chlorophyll content. This increase could be attributed to the role and importance these micronutrients play in plant physiological processes, including iron, which participates in the formation of the compounds α-aminolevulinic acid and protochlorophyllide, essential elements in the pathway of chlorophyll synthesis (5). Table 10 shows that the Flame variety had the highest chlorophyll content during both seasons. In contrast, the lowest values were reported for the varieties Sakha and Aqmar across both seasons. These differences between varieties could result from their different genetic makeup and the varying environmental factors to which they responded. This result agrees with previous findings, which reported the varieties to have significantly different effects on this trait (37, 38).

## Conclusion

Mulching ($M_2$) contributed to weeds' significantly lower density and dry weight, which accounted for higher plant height, leaf area and stem diameter compared to the treatment with weedy control (M0). Enhanced micronutrient concentration enhanced more physiological processes and increased chlorophyll content, leaf area and stem diameter. Out of the varieties, the Flame variety proved to be superior in leaf area, stem diameter and chlorophyll content, perhaps due to inherent good genetic makeup and competitive ability. Effective weed control, application of micro-nutrients and variety selection play an essential role in optimizing the propagation and harvest of sunflowers.

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## Authors' contributions

JD conceptualized and designed the experiment, supervised the research and contributed to data collection and interpretation. BS assisted in the experimental setup performed data analysis and contributed to manuscript preparation. AA contributed to fieldwork execution, provided technical support and assisted in drafting and reviewing the manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors declare no conflicts of interest related to this study.

**Ethical issues:** None

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