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RESEARCH ARTICLE

Response of Yield and its Components for Three Cultivars of Sunflower to Weeding and Micronutrient Spraying Treatments

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ABSTRACT

A field experiment was conducted during the spring season of 2022 and 2023 at Agricultural Research Station No. (1), College of Agriculture, University of Anbar, located in the Ramadi district, Anbar Governorate, Iraq, to investigate the effect of weeding treatments and micronutrient spraying on the dry weight of weeds, yield, and its components for several sunflower cultivars. A randomized complete block design (R.C.B.D) with a split-split plot arrangement was used, with three replications. The main plots included the control treatment, Treflan herbicide treatment, and mulching treatment. Micronutrient spraying treatments with three concentrations (0, first concentration, second concentration) were distributed in the sub-plots, while the cultivars (Aqmar, Sakha, and Flame) were assigned to the sub-sub-plots. The results indicated that the mulching treatment significantly outperformed in all studied traits, achieving the highest averages for disk diameter, fertility percentage, number of seeds per disk, 1000-seed weight, and total seed yield. The highest concentration of micronutrient spraying (second concentration) also recorded the highest averages for all studied traits, including yields of 5.59 and 5.87 tons per hectare for both seasons, respectively. The cultivars, the Flame cultivar achieved the highest averages in disk diameter (19.26 and 20.17 cm), fertility percentage (86.35% and 82.58%), number of seeds per disk (1418.49 and 1334.91 seeds per disk), 1000-seed weight (78.90 and 79.65 g), and total seed yield (6.22 and 6.38 tons per hectare) for both seasons.

INTRODUCTION

Sunflower (*Helianthus annuus* L.), is an important oil crop, which is ranks third after soybean and sorghum in oil content globally (Al-Refai and Shaker, 2019; Jessup et al., 2020). Despite the great importance of this crop in Iraq, its productivity per unit area has decreased compared to global production. This decline is due to several reasons, including the low productivity of the cultivars available to farmersresulting from faulty farming methods. Such as inadequate weed control, which causes significant losses in the productivity of field crops. Additionally, there are some issues related to Iraqi soils, such as; soil pH, which leads to the unavailability of many nutrients needed by the plant to complete its life cycle, including micronutrients like iron, zinc, and manganese. Therefore, adopting numerous methods to enhance productivity is essential, including utilizing newly introduced or developed high-yielding cultivars and understanding their performance under weed competition and

weed control conditions. This can contribute to determining the growth trajectory and yield. Weeds present one of the most significant obstacles and challenges facing this crop, as they compete with the crop plants for essential growth requirements, particularly during the early stages of growth (Daba and Sharma, 2018).

Therefore, it is essential to employ modern techniques that reduce weeds and environmental pollution, such as using black plastic mulching to achieve a rapid and effective response. Morever, providing the plant with essential micr-onutrients required for completing its life cycle is crucial. The micro-nutrients can be used as foliar sprays to ensure continued growth and achieve quantitative and qualitative improvements in its yield. Depend on the above, this study was aimed to identify the best weed control treatment and the optimal concentration of micronutrients, as well as their effect on cultivars and their interaction in weed competition, to improve the yield and its component of the sunflower crop.

MATERIALS AND METHODS

A field experiment was conducted during the spring season of 2022 and 2023 at Agricultural Research Station No. (1), College of Agriculture - University of Anbar, located in Ramadi District, Anbar Governorate, Iraq. The coordinates are E43.32.65 longitude and N33.45.37 latitude. The study aimed to determine the effect of weed treatments and micronutrient foliar spraying on the yield and its components of three sunflower cultivars. The experiment was applied using the Randomized Complete Block Design (R.C.B.D) with a Split-Split Plot arrangement, and with three replications. The treatments were randomly distributed within each replicate. The main plots included three weed treatments: weedy treatment, spraying with the herbicide Treflan (48% EC) at the recommended concentration, and black nylon mulch (0.8 microns thick), denoted as M1, M2, and M3, respectively. The subplots included three concentrations of micronutrient fertilizer (0, the first concentration, and the second concentration), denoted as F0, F1, and F2. Table 1 shows the concentration of some micronutrients contained in the fertilizer used in the study. The spraying was done twice: the first when the plant reached a height of 10 cm, and the second at flowering. The sub-sub-plots included three sunflower cultivars: Aqmar, Sakha, and Flammy. Soil preparation operations, including plowing, smoothing, and leveling, were carried out. A soil sample was taken to analysis some physical and chemical properties, before planting (Table 2). Afterward, the experimental field was divided into experimental units with dimensions of 3×3 meters, resulting in an area of 9 m^2 per unit, and a total of 81 units with three replications. Each experimental unit contained five rows, with a distance of 60 cm between rows and 30 cm between plants. The distance between experimental units was 1 meter, and the distance between replications was 2 meters. The seeds were sown manually in rows on 20/3/2022 and 20/3/2023. The experimental field was irrigated using drip irrigation as needed. Phosphate fertilizer in the form of ammonium phosphate (DAP) (18:46:0) was added to the soil at a rate of 80 kg P_2O_5 ha^{-1}, mixed with the soil in a single application before planting. Potassium fertilizer in the form of potassium sulfate (50% K_2O) was supplied at a rate of 80 kg K_2O ha^{-1}, also mixed with the soil in a single application before sowing. Nitrogen fertilizer was supplied in the form of urea at a rate of 160 kg N ha^{-1} in two applications: the first when the plants reached the three-leaf stage and the second at the flowering stage (Ali *et al.*, 2014).

The data were statistically analyzed using the Genstat program, employing the Least Significant Difference (L.S.D) test at a significance level of 0.05 to distinguish between different statistical means (Al-Rawi and Khalaf Allah, 1980).

Table 1: Concentrations of micronutrients used in the study.

Concentration (mg/L)	Zinc (Zn)	Iron	Manganese (Mn)	Copper (Cu)	Boron (B)

		(Fe)			
First	300.15	278.25	170	26.1	26.1
Second	600.3	556.5	340	52.2	52.2

Table 2: Physical and chemical properties of the experimental field soil before planting

Property		Unit	2022	2023
Soil Reaction (1:1 pH)		-	7.12	7.14
Electrical Conductivity (1:1 EC)		dS m^{-1}	2.47	1.62
Soil Organic Matter (SOM)		g kg^{-1}	5.40	5.40
Gypsum (Ca SO4)		%	0.81	
Carbonate Minerals (CaCO3)		%	10.3	10.3
Bulk Density		Mg m^{-3}	1.3	1.3
Cation Exchange Capacity (CEC)		cmol kg^{-1} soil	23.8	23.8
Cationic ions	Ca2+	meq L^{-1}	6.23	6.23
	Mg2+		7.23	3.89
	Na+		3.89	5.60
	K+		6.6	1.39
Anionic ions	SO4-2		2.39	7.52
	CO3		1.95	Nil
	$HCO3^-$		2.69	1.69
	Cl^-		5.99	6.70
Available Nitrogen (N)		mg kg^{-1} soil	8.96	12.2
Available Phosphorus (P)			10.3	10.30
Available Potassium (K)			90.8	130.40
Available Zinc (Zn)			21.6	20.00
Soil separates	Soil Separates: Sand	g kg^{-1} soil	684	684

	Soil Separates: Silt		112	112
	Soil Separates: Clay		204	204
Textural Class		Sandy Clay Loam		Sandy Clay Loam Loam

RESULTS AND DISCUSSION

Disk Diameter (cm):

The results in Table (3) show that the mulching treatment (M2) recorded the highest average disk diameter at 19.74 and 19.57 cm, compared to the weedy treatment, with the lowest average of 15.87 and 17.61 cm for the two seasons, respectively. The reason for the increased disk diameter in the mulching treatment may be attributed to the role of mulching in eliminating and suppressing weeds, preventing of weeds to obtaining essential growth requirments such as light, water, and mineral nutrients. This positively reflected in the increased disc diameter. This result agrees with the findings of Kumar et al. (2018), who found that mulching treatment led to an increase in the disk diameter of the sunflower crop.

The results also indicate that increasing the concentrations of micronutrient sprays significantly enhanced disc diameter. The highest concentration (second level) resulted in the largest average diameters of 18.44 cm and 19.05 cm, compared to other concentrations, where the control concentration was recorded the lowest average in the disc diameter of 16.93 and 18.21 cm for the two seasons, respectively. This increasing can be attributed to the vitol role of micronutrients in enhancing the photosynthesis apparatus activity, thereby providing more nutrients to the developing discs. This results in increased cell division and expansion within the disk, leading to a larger disk diameter. These findings are consistent with those of Surhead et al. (2015), who observed similar effects with the addition of manganese, Ahmed (2016), who reported increased disk diameters with the addition of chelated iron, and Al-Shalah (2020), who found similar results with the application of nano zinc on sunflowers.

The results show that the Flammy cultivar achieved the highest average disc diameter of 19.26 cm and 20.17 cm, significantly differing compared with other cultivars. In contrast, the Sakha cultivar scored the lowest average disc diameter of 16.31 cm and 17.47 cm for the two seasons, respectively. The difference in disc diameter between cultivars is likely due to variations in their genetic structure

And their ability to exploit environmental conditions to enhance this trait. These findings are consistent with those of Atiya and Kazem (2017), Tawfiq (2019), Demir (2019), and Rehman (2019), who also found significant differences in disc diameter averages among different sunflower cultivars. The results indicated significant interaction between weed control treatments and cultivars in terms of disc diameter. The mulching treatment with the Flammy cultivar (M2V3) produced the highest average disc diameter of 21.66 cm and 21.55 cm, compared to the weedy treatment with the Sakha cultivar (M0V2), which had the lowest average of 14.53 cm and 16.39 cm for the two seasons, respectively. The results also show significant differences between weed control treatments and micronutrient concentrations. The mulching treatment with the second concentration (M2F2) achieved the highest average disc diameter of 20.87 cm and 20.16 cm for the two seasons, respectively, while the weedy treatment with the control concentration (M0F0) recorded the lowest average of 15.06 cm and 17.14 cm for the two seasons, respectively.

The results revealed significant three-way interaction; the mulching treatment with the second concentration for the Flammy cultivar (M2F2V3) resulted in the highest average disk diameter of 23.21 cm and 22.64 cm for both seasons, respectively. In contrast, the weedy treatment with the

control concentration for the Sakha cultivar (M0F0V2) recorded the lowest average disc diameter of 13.71 cm and 15.95 cm for both seasons, respectively.

Table 3: Effect of weed control treatments and micronutrient sprays on cultivars and their interactions on disk diameter (cm)

First Season 2022							Second Season 2023					
Weed treatments M	**Fert. Conc. F**	**Cultivars V**			**M * F**		**Cultivars V**			**M * F**		
		Aqmar	**Sakha**	**Flammy**			**Aqmar**	**Sakha**	**Flammy**			
M0	F0	14.96	13.71	16.50	15.06		16.99	15.95	18.49	17.14		
	F1	16.25	14.75	17.29	16.10		17.39	16.17	19.03	17.53		
	F2	16.70	15.13	17.57	16.47		17.99	17.05	19.44	18.16		
M1	F0	17.02	15.37	18.66	17.02		18.11	17.38	19.90	18.46		
	F1	17.54	15.93	18.88	17.45		18.44	18.10	19.92	18.82		
	F2	17.97	16.53	19.44	17.98		18.52	17.84	20.16	18.84		
M2	F0	18.42	17.39	20.31	18.71		18.58	18.10	20.38	19.02		
	F1	19.24	18.27	21.45	19.65		18.93	18.06	21.61	19.53		
	F2	19.71	19.69	23.21	20.87		19.27	18.56	22.64	20.16		
LSD_{M*F*V}		0.53*			LSD_{M*F}	0.36**	0.48**			LSD_{M*F}	0.20**	
M * V							M * V					
Weed treatments		Aqmar	Sakha	Flammy	Weed mean		Aqmar	Sakha	Flammy	Weed mean		
M0		15.97	14.53	17.12	15.87		17.45	16.39	18.99	17.61		
M1		17.51	15.94	18.99	17.48		18.36	17.78	19.99	18.71		
M2		19.13	18.45	21.66	19.74		18.93	18.24	21.55	19.57		
LSD_{M*V}		0.31**			LSD_{M}	0.11**	0.28**			LSD_{M}	0.30**	
F * V							F * V					
Micronutrient conc.		Aqmar	Sakha	Flammy	Conc. mean		Aqmar	Sakha	Flammy	Conc. mean		
F0		16.80	15.49	18.49	16.93		0.28**	17.15	19.59	18.21		
F1		17.68	16.32	19.21	17.73		0.28**	17.44	20.19	18.63		
F2		18.13	17.12	20.07	18.44		0.28**	17.82	20.75	19.05		
LSD_{F*V}		N.S.			LSD_{F}	0.21**	N.S.			LSD_{F}	0.12**	
V							V					
cultivars		Aqmar	Sakha	Flammy			Aqmar	Sakha	Flammy			
Mean cultivars		17.54	16.31	19.26			18.24	17.47	20.17			
LSD_{V}		0.18**					0.16**					

Fertility Rate (%)

The results showed that the mulching treatment (M2) achieved the highest average fertility rate of 93.85% and 89.49%, compared to the weedy treatment, which is recorded the lowest average fertility rates of 70.70% and 71.79% at two seasons, respectively (Table 4). The reason for the higher averages in the mulching treatment may be attributed to the prevention of weed competition with crop plants for water, light, and nutrients. This positively influenced the physiological processes within the plant and the transfer of manufactured materials to the developing flowers, which, in turn, reflected positively on the fertility rate of flower set. This result aligns with the findings of Daba and Sharma (2018), who observed that weed control treatments led to a significant increase in the fertility rate.

The results indicate that the fertility rate significantly increased with higher concentrations of micronutrient sprays. The highest concentration (second level) achieved the highest average fertility rates of 83.29% and 85.04% for the two seasons, respectively, while the control concentration recorded the lowest average fertility rates of 80.85% and 78.67% for the two seasons, respectively. The increase in fertility rate may be attributed to the addition of essential micronutrients that play a vitol role in the biological processes within the plant, including zinc, which enhances fertility and the vitality of pollen grains, leading to the formation of healthy and viable pollen. This positively impacts the flower set and subsequently increases the fertility rate (Hassanein, 2020). This finding is consistent with the results of AL-Doori and Al-Dulaimy (2014), who found significant differences in fertility rate averages with the addition of various elements to sunflower plants

The results indicated significant differences among the cultivars in terms of fertility rate. The Flammy cultivar recorded the highest averages for this trait (86.35% and 82.58%), followed by the Sakha cultivar, which achieved averages of 79.43% and 81.34%. The Sakha cultivar did not differ significantly from the Aqmar cultivar in the first season only. Meanwhile, the Aqmar cultivar recorded the lowest fertility rates, with averages of 79.44% and 80.64% for both seasons, respectively. This variation can be attributed to the genetic differences among the cultivars and their ability to benefit from the surrounding environmental conditions. This result is consistent with findings from other researchers who reported significant differences in fertility rates among different cultivars of sunflower crops (Al-Sibaihi, 2019).

The interaction between weed treatments and micronutrient fertilization treatments significantly affected the fertility rate. The treatment with mulching and the second concentration (M2F2) recorded the highest average fertility rates of 95.66% and 90.67% for both seasons, respectively, while the untreated control with the control concentration (M0F0) recorded the lowest fertility rates of 67.70% and 65.03% for both seasons, respectively. Additionally, the results indicated a significant interaction between weed treatments and cultivars affecting the fertility rate at the first season only. The treatment with mulching and the Flammy cultivar (M2V3) recorded the highest average fertility rate of 94.76%, while the untreated control with the Aqmar cultivar (M0V1) recorded the lowest average fertility rate of 69.20%. The results showed a significant interaction between cultivars and concentrations in the average of this trait in the second season only. The Flammy cultivar with the second concentration (V3F2) achieved the highest average fertility rate of 85.79%, while the Sakha cultivar with the control treatment (V2F0) recorded the lowest average fertility rate of 78.01%.

Results also revealed a significant three-way interaction between the study factors; the Flammy cultivar under the mulching treatment with the second concentration (M2F2V3) achieved the highest average fertility rates of 97.17% and 91.92% for both seasons, respectively. In contrast, the Aqmar cultivar under the untreated control with the control concentration (M0F0V1) recorded the lowest average fertility rate of 66.29% in the first season. In the second season, the Sakha cultivar under the

untreated control with the control concentration (M0F0V2) recorded the lowest average fertility rate of 63.56%

Table 4: The effect of weed treatments and foliar spray with micronutrients on cultivars and their interactions on fertility percentage (%)

First Season 2022						Second Season 2023			
Weed treatments M	**Fert. Conc. F**	**Cultivars V**			**M * F**	**Cultivars V**			**M * F**
		Aqmar	**Sakha**	**Flammy**		**Aqmar**	**Sakha**	**Flammy**	
M0	F0	66.29	66.90	69.91	67.70	67.56	63.56	63.98	65.03
	F1	69.52	70.79	73.13	71.15	65.81	69.37	75.67	70.28
	F2	71.79	72.52	75.44	73.25	79.76	80.21	80.16	80.04
M1	F0	78.25	74.02	90.59	80.95	81.72	81.65	83.68	82.35
	F1	74.39	74.55	91.33	80.09	82.24	83.13	83.86	83.08
	F2	75.09	75.36	92.44	80.96	83.28	84.69	85.28	84.42
M2	F0	93.30	93.59	94.82	93.90	88.16	88.82	88.91	88.63
	F1	91.98	91.67	92.29	91.98	87.72	90.04	89.76	89.17
	F2	94.33	95.48	97.17	95.66	89.53	90.57	91.92	90.67
LSD_{M*F*V}		2.09**			LSD_{M*F} 1.36**	1.68**			LSD_{M*F} 0.93**
M * V						M * V			
Weed treatments		Aqmar	Sakha	Flammy	Weed mean	Aqmar	Sakha	Flammy	Weed mean
M0		69.20	70.07	72.83	70.70	71.04	71.05	73.27	71.79
M1		75.91	74.64	91.45	80.67	82.41	83.16	84.27	83.28
M2		93.20	93.58	94.76	93.85	88.47	89.81	90.20	89.49
LSD_{M*V}		1.21**			LSD_{M} 1.47**	N.S.			LSD_{M} 0.86**
F * V						F * V			
Micronutrient conc.		Aqmar	Sakha	Flammy	Conc. mean	Aqmar	Sakha	Flammy	Conc. mean
F0		79.28	78.17	85.11	80.85	79.15	78.01	78.86	78.67

F1	78.63	79.00	85.58	81.07		78.59	80.85	83.10	80.84	
F2	80.40	81.12	88.35	83.29		84.19	85.16	85.79	85.04	
LSD_{F*V}	N.S.			LSD_F	0.78**	0.97**			LSD_F	0.53**
V						V				
cultivars	Aqmar	Sakha	Flammy			Aqmar	Sakha	Flammy		
Mean cultivars	79.44	79.43	86.35			80.64	81.34	82.58		
LSD_V	0.70**					0.56**				

Number of seeds per disc (seeds disc^{-1})

The results showed that the mulching treatment (M2) significantly increased the number of seeds per disk, with an average of 1416.08 and 1338.80 seeds per disc, compared to other treatments (Table 5). The weedy treatment recorded the lowest averages, 1248.43 and 1128.72 seeds disc^{-1}, for both seasons, respectively. The superior performance of the mulching treatment in this trait may be attributed to its superior performance in disk diameter and fertility rate (Tables 3 and 4), leading to an increased number of seeds disc^{-1}. Additionally, this treatment reduced the number of competing weeds, thereby enhancing the growth indicators of the crop plants and subsequently increasing the number of seeds disc^{-1}. This result is consistent with the findings of several researchers who observed differences in the number of seeds for various crops when using different weed control treatments (Meleta *et al.,* 2018; Dulaimy and El-Fahdawi, 2020; Singh *et al.,* 2019; Ozkil et al., 2022).

The results indicate an increase in averages with higher concentrations of micronutrient sprays. The second concentration recorded the highest values for this trait, with 1357.07 and 1273.44 seeds disc^{-1}, while the control treatment recorded the lowest values, with 1303.63 and 1192.36 seeds disc^{-1}. This may be attributed to the superior performance of the high concentration spray treatment in disk diameter and fertility rate (Tables 3 and 4), leading to an increase in the number of seeds disc^{-1}. Additionally, the role of micronutrients in regulating plant hormones, which encourage the growth of reproductive organs and increase the number of flower structures and thus fertilization and seed number also contributes to this increase (Eskandari, 2011; Uludag et al., 2018). This finding aligns with other studies that found significant differences in the averages of this trait due to the effect of micronutrient sprays (Al-Doori, 2014; Farokhi *et al.,* 2015; Adeleke et al, 2020; Hamad and Sallume, 2021; Okab and Abed, 2023).

The cultivars significantly differed in the number of seeds disc^{-1}. The Flammy cultivar achieved the highest average of 1418.49 and 1334.91 seeds disk^{-1}, while the Sakha cultivar recorded the lowest average of 1234.52 and 1117.49 seeds disk^{-1} for both seasons, respectively. The variation among cultivars in this trait may be attributed to their different efficiencies in utilizing available environmental factors to enhance growth and yield, including the number of seeds disc^{-1}. This finding is consistent with the results of several researchers, including Al-Sibaihi (2019), Kushwaha *et al*., (2019), and Abdulkafoor et al., (2023), who also reported significant differences among cultivars in seed number for other crops.

The results indicate that the interaction between weed treatments and cultivars significantly affected the number of seeds disk^{-1}. The mulching treatment with the Flammy cultivar (M2V3) achieved the

highest average number of seeds per disk, with 1518.03 and 1435.77 seeds disk^{-1}, compared to other interaction treatments. In contrast, the Sakha cultivar under the control treatment (M0V2) recorded the lowest averages of 1146.97 and 1008.63 seeds disk^{-1} for both seasons, respectively. Additionally, the result indicates a significant interaction between cultivars and spray concentrations. The Flammy cultivar with the second concentration spray (F2V3) recorded the highest average number of seeds disk^{-1}, with 1435.97 and 1355.77 seeds disk^{-1}, while the Sakha cultivar under the control treatment (M0F0) recorded the lowest averages of 1214.30 and 1070.27 seeds disk^{-1} for both seasons, respectively. Moreover, Table 5 shows significant differences in the interaction between weed treatments and micronutrient spray concentrations in the number of seeds per disc for the second season only. The mulching treatment with the second concentration (M2F2) achieved the highest average of 1388.17 seeds disk^{-1}, while the weedy treatment with the control concentration (M0F0) recorded the lowest average of 1074.67 seeds disc^{-1} in the second season only.

The results showed significant three-way interaction in the number of seeds disc^{-1}. The mulching treatment with the high concentration and the Flammy cultivar (M2F2V3) recorded the highest average number of seeds disc^{-1}, with 1529.40 and 1459.70 seeds disc^{-1} for both seasons, respectively. In contrast, the weedy treatment with the control concentration and the Sakha cultivar (M0F0V2) recorded the lowest averages of 1131.70 and 950.10 seeds disc^{-1} for both seasons, respectively.

Table 5: Effect of weed treatments and micronutrient spraying on cultivars and their interactions on the number of seeds per disk (seeds disc^{-1})

First Season 2022							Second Season 2023				
Weed treatments M	**Fert. Conc. F**	**Cultivars V**			**M * F**		**Cultivars V**			**M * F**	
		Aqmar	**Sakha**	**Flammy**			**Aqmar**	**Sakha**	**Flammy**		
M0	F0	1228.30	1131.70	1306.30	1222.10		1029.90	950.10	1244.00	1074.67	
	F1	1242.50	1146.40	1328.70	1239.20		1114.30	1021.80	1249.10	1128.40	
	F2	1341.60		1347.60	1284.00		1217.90	1054.00	1277.40	1183.10	
M1	F0	1293.80	1204.40	1392.20	1296.80		1256.40	1080.50	1292.10	1209.67	
	F1	1297.50	1214.40	1406.60	1306.17		1275.20	1126.20	1314.10	1238.50	
	F2	1340.40	1240.20	1430.90	1337.17		1284.20	1132.80	1330.20	1249.07	
M2	F0	1366.30	1306.80	1502.90	1392.00		1299.80	1180.20	1398.20	1292.73	
	F1	1390.20	1306.60	1521.80	1406.20		1341.80	1215.30	1449.40	1335.50	
	F2	1423.30	1397.40	1529.40	1450.03		1408.30	1296.50	1459.70	1388.17	
LSD_{M*F*V}		30.29**			LSD_{M*F}	N.S.	39.93**			LSD_{M*F}	22.73**
M * V							M * V				
Weed treatments		Aqmar	Sakha	Flammy	Weed mean		Aqmar	Sakha	Flammy	Weed mean	

M0	1270.80	1146.97	1327.53	1248.43		1120.70	1008.63	1256.83	1128.72	
M1	1310.57	1219.67	1409.90	1313.38		1271.93	1113.17	1312.13	1232.41	
M2	1393.27	1336.93	1518.03	1416.08		1349.97	1230.67	1435.77	1338.80	
LSD_{M*V}	17.49**			LSD_M	9.41**	23.05**			LSD_M	15.55**
F * V						F * V				
Micronutrient conc.	Aqmar	Sakha	Flammy	Conc. mean		Aqmar	Sakha	Flammy	Conc. mean	
F0	1296.13	1214.30	1400.47	1303.63		1195.37	1070.27	1311.43	1192.36	
F1	1310.07	1222.47	1419.03	1317.19		1243.77	1121.10	1337.53	1234.13	
F2	1368.43	1266.80	1435.97	1357.07		1303.47	1161.10	1355.77	1273.44	
LSD_{F*V}	17.49*			LSD_F	11.43**	23.05**			LSD_F	13.12**
V						V				
Cultivars	Aqmar	Sakha	Flammy			Aqmar	Sakha	Flammy		
Mean cultivars	1324.88	1234.52	1418.49			1247.53	1117.49	1334.91		
LSD_V	10.10**					13.31**				

Weight of 1000 Seeds (g):-

The results indicate a significant effect of weed treatments on the weight of 1000 seeds (Table 6). The mulching treatment (M2) recorded the highest average weight of 1000 seeds (80.82 g and 79.03 g) compared to other treatments, with the weedy treatment (M0) recording the lowest average weight of 1000 seeds (70.23 g and 72.16 g) for both seasons, respectively. The increase in the weight of 1000 seeds can be attributed to the superior vegetative growth traits in the mulching treatment, which enhances the plant's efficiency in photosynthesis and the transfer of manufactured products from the source to the sink, these results in greater dry matter accumulation and, consequently, increased seed weight. This finding aligns with Al-Mohammadi (2020), who noted that the reduction in seed weight in sesame crops was due to the accompanying weeds.

The result shows a significant increase in the weight of 1000 seeds with higher concentrations of micronutrient sprays. The second concentration recorded the highest average weight of 76.43 g and 77.65 g, compared to the control treatment, which is recorded the lowest average weight of 74.21 g and 73.96 g for both seasons, respectively. The increase in the weight of 1000 seeds due to micronutrients may be attributed to their role in enhancing vegetative growth indicators, thus increasing the plant's ability to capture and absorb more light. This positively impacts the production of manufactured materials and facilitates the transfer of nutrients from the source to the sink, accumulating in the seeds and consequently increasing their weight. This finding aligns with other studies that found significant differences in seed weight when sprayed with various micronutrients

on several field crops (Farokhi et al., 2015; Menajid *et al.,* 2021; Hasan *et al.,* 2023; Abdulkafoor *et al.,* 2023; Ji et al,2023).

The cultivars significantly differed in the weight of 1000 seeds. The Flammy cultivar achieved the highest average weight (78.90 g and 79.65 g), followed by the Aqmar cultivar, which recorded averages of 77.12 g and 75.84 g. In contrast, the Sakha cultivar recorded the lowest averages of 69.00 g and 71.67 g for both seasons, respectively. This variation in seed weight among cultivars may be attributed to their different genetic compositions, superior vegetative traits, and varying efficiencies in transferring photosynthetic products from the source to the sink (seeds). This finding is consistent with several researchers who reported that crop cultivars differ in their vegetative traits and seed weights (Al-Temimi and Abed, 2016; Erdogdu *et al.,* 2018; Karpov *et al.,* 2021; Pacanoski and Mehmeti, 2021; Ahmed and Abdulkafoor, 2023; Li, et al, 2024).

The results showed a significant two-way interaction between weed treatments and micronutrient fertilization treatments in the weight of 1000 seeds. The mulching treatment with the second concentration (M2F2) recorded the highest average weight of 77.82 g, while the weedy treatment with the control concentration (M0F0) recorded the lowest average weight of 75.68 g in the first season only. Regarding the interaction between weed treatments and cultivars, the mulching treatment with the Flammy cultivar (M2V3) achieved the highest average weight of 84.82 g, compared to the weedy treatment with the Sakha cultivar (M0V2), which recorded the lowest average weight of 63.72 g in the second season only. The results also indicate a significant interaction between cultivars and micronutrient spray concentrations. The Flammy cultivar with the second concentration (F2V3) achieved the highest average weight of 79.98 g and 82.44 g, while the Sakha cultivar with the control treatment (F0V2) recorded the lowest averages of 66.55 g and 69.35 g for both seasons, respectively.

Regarding the three-way interaction among the study factors, the Flammy cultivar under the mulching treatment with the second concentration (M2F2V3) recorded the highest average weight of 86.65 g, while the Sakha cultivar under the weedy treatment with the control concentration (M0F0V2) recorded the lowest average weight of 63.18 g in the first season only.

Table 6: Effect of weed treatments and micronutrient spraying on cultivars and their interactions on the weight of 1000 seeds (g)

First Season 2022						Second Season 2023			
Weed treatments M	Fert. Conc. F	Cultivars V			M * F	Cultivars V			M * F
		Aqmar	Sakha	Flammy		Aqmar	Sakha	Flammy	
M0	F0	74.40	63.18	74.19	70.59	71.91	64.78	72.77	69.82
	F1	70.09	63.85	75.19	69.71	72.02	69.40	74.20	71.87
	F2	70.77	64.13	76.25	70.38	74.76	71.18	78.42	74.79
M1	F0	77.33	67.33	78.00	74.22	74.55	70.21	78.72	74.49
	F1	74.00	67.00	75.00	72.00	75.86	72.13	79.69	75.89
	F2	78.00	72.00	77.03	75.68	76.51	73.95	82.04	77.50

M2	F0	81.33	69.13	83.01	77.82		78.11	73.06	81.52	77.56	
	F1	83.67	75.76	84.81	81.41		79.18	74.81	82.58	78.86	
	F2	84.45	78.60	86.65	83.23		79.69	75.47	86.87	80.68	
LSD_{M*F*V}		3.73			LSD_{M*F}	2.08	N.S.			LSD_{M*F}	N.S
M * V							M * V				
Weed treatments		Aqmar	Sakha	Flammy	Weed mean		Aqmar	Sakha	Flammy	Weed mean	
M0		71.75	63.72	75.21	70.23		72.90	68.45	75.13	72.16	
M1		76.44	68.78	76.68	73.97		75.64	72.10	80.15	75.96	
M2		83.15	74.50	84.82	80.82		78.99	74.45	83.66	79.03	
LSD_{M*V}		N.S.			LSD_M	0.77	0.93**			LSD_M	0.33**
F * V							F * V				
Micronutrient conc.		Aqmar	Sakha	Flammy	Conc. mean		Aqmar	Sakha	Flammy	Conc. mean	
F0		77.69	66.55	78.40	74.21		74.86	69.35	77.67	73.96	
F1		75.92	68.87	78.33	74.37		75.69	72.11	78.82	75.54	
F2		77.74	71.58	79.98	76.43		76.99	73.53	82.44	77.65	
LSD_{F*V}		2.154			LSD_F	1.20	0.93**			LSD_F	0.67**
V							V				
cultivars		Aqmar	Sakha	Flammy			Aqmar	Sakha	Flammy		
Mean cultivars		77.12	69.00	78.90			75.84	71.67	79.65		
LSD_V		1.24**					0.54**				

Total Seed Yield (Mg ha-1):

The results showed that the mulching treatment gave the highest average seed yield of 6.09 and 6.24 Mg ha^{-1}(Table 7), compared to the weedy treatment, which recorded the lowest average yield of 4.45 and 5.07 Mg ha^{-1} for both seasons, respectively. The increase in seed yield with the mulching treatment can be attributed to its superior performance in yield components such as disk diameter, number of seeds per disc, and weight of 1000 seeds (Tables 5 and 6), thereby increasing the yield per unit area. This finding is consistent with Singh et al. (2019) and Alam *et al.* (2021), who found that using weed control treatments increases the yield of plants per unit area

The results indicate a significant effect of micronutrient spray concentrations on seed yield. The second concentration recorded the highest average yield of 5.59 and 5.87 Mg ha^{-1}, significantly surpassing the other concentrations. The control concentration recorded the lowest average seed yield of 4.93 and 5.46 Mg ha^{-1} for both seasons, respectively. The increase in seed yield with higher micronutrient spray concentrations may be attributed to their effect on enhancing several traits, such as disc diameter, number of seeds per disk, and weight of 1000 seeds (Tables 3, 5, and 6), which positively impacted the total yield. This finding aligns with Baraich et al. (2016), Hatami (2017), Sallume et al. (2023), and Hasan et al. (2023), who reported a significant effect of micronutrient sprays on increasing seed yield per unit area.

The cultivars showed significant differences in average seed yield (Table 7). The Flammy cultivar recorded the highest average yield of 6.22 and 6.38 Mg ha^{-1}, while the Sakha cultivar recorded the lowest average yield of 4.23 and 5.16 Mg ha^{-1} for both seasons, respectively. The superior performance of the Flammy cultivar in seed yield may be attributed to its excellence in yield components (Tables 3 and 6). This result is consistent with the findings of several researchers, including Guteta et al. (2020), Karpov et al. (2021), AL-Behadili, and Abed (2021) and Abdulkafoor et al. (2023), who reported differences in seed yield per unit area among different cultivars of sunflower, sesame, and flax.

The results showed significant two-way interaction between weed treatments and cultivars. The mulching treatment with the Flammy cultivar (M2V3) recorded the highest average yield of 6.98 and 7.10 Mg ha^{-1}, compared to the weedy treatment with the Sakha cultivar (M0V2), which recorded the lowest average yield of 3.28 and 4.76 Mg ha^{-1} for both seasons, respectively.

The results showed a significant two-way interaction between concentrations and cultivars in the second season only. The second concentration with the Flammy cultivar (F2V3) recorded the highest average yield of 6.70 Mg ha^{-1}, compared to the control treatment with the Sakha cultivar (F0V2), which recorded the lowest average yield of 5.09 Mg ha^{-1}. Additionally, the results indicated significant differences between weed treatments and concentrations in the averages of this trait. The mulching treatment with the second concentration (M2F2) recorded the highest average yield of 6.67 Mg ha-1, compared to the weedy treatment with the control concentration (M0F0), which recorded the lowest average yield of 4.25 Mg ha^{-1} in the first season only.

The results revealed a significant three-way interaction among the study factors. The mulching treatment with the Flammy cultivar at the second concentration (M2F2V3) recorded the highest average total seed yield of 7.62 and 7.59 Mg ha^{-1} for both seasons, respectively. In contrast, the weedy treatment with the Sakha cultivar at the control concentration (M0F0V2) recorded the lowest average seed yield of 2.98 and 4.63 Mg ha^{-1} for both seasons, respectively.

Table 7: Effect of weed treatments and micronutrient spraying on cultivars and their interactions on total seed yield (Mg ha^{-1})

First Season 2022						Second Season 2023			
Weed treatments M	Fert. Conc. F	Cultivars V			M * F	Cultivars V			M * F
		Aqmar	Sakha	Flammy		Aqmar	Sakha	Flammy	
M0	F0	4.14	2.98	5.63	4.25	4.69	4.63	5.23	4.85
	F1	4.49	3.27	5.52	4.43	4.87	4.69	5.60	5.05

	F2	4.66	3.57	5.79	4.68	4.95	4.96	6.03	5.31
M1	F0	4.94	3.99	5.68	4.87	5.08	5.00	6.35	5.47
	F1	5.17	4.32	6.10	5.20	5.29	5.21	6.43	5.64
	F2	5.46	4.53	6.32	5.43	5.54	5.17	6.48	5.73
M2	F0	5.77	4.60	6.67	5.68	5.81	5.65	6.70	6.06
	F1	6.20	4.95	6.66	5.93	5.95	5.39	6.99	6.11
	F2	6.51	5.87	7.62	6.67	6.34	5.78	7.59	6.57
LSD_{M*F*V}		0.35**			LSD_{M*F} 0.17**	0.21**			LSD_{M*F} N.S.
M * V						M * V			
Weed treatments		Aqmar	Sakha	Flammy	Weed mean	Aqmar	Sakha	Flammy	Weed mean
M0		4.43	3.28	5.65	4.45	4.84	4.76	5.62	5.07
M1		5.19	4.28	6.03	5.17	5.30	5.13	6.42	5.62
M2		6.16	5.14	6.98	6.09	6.03	5.60	7.10	6.24
LSD_{M*V}		0.20**			LSD_{M} 0.21**	0.12**			LSD_{M} 0.11**
F * V						F * V			
Micronutrient conc.		Aqmar	Sakha	Flammy	Conc. mean	Aqmar	Sakha	Flammy	Conc. mean
F0		4.95	3.86	5.99	4.93	5.19	5.09	6.09	5.46
F1		5.29	4.18	6.09	5.19	5.37	5.10	6.34	5.60
F2		5.54	4.66	6.57	5.59	5.61	5.30	6.70	5.87
LSD_{F*V}		N.S.			LSD_{F} 0.10**	0.12**			LSD_{F} 0.13**
V						V			
cultivars		Aqmar	Sakha	Flammy		Aqmar	Sakha	Flammy	
Mean cultivars		5.26	4.23	6.22		5.39	5.16	6.38	
LSD_{V}		0.12**				0.07**			

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