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Effect of Floret Removal on Seed Yield and Quality of Some Safflower Genotypes

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ABSTRACT

A field experiment was conducted at the Grdarasha site (Latitude 36. 10116 N and Longitude 44.00925) during the 2023–2024 growing season to investigate the effects of genotype and floret removal timing on safflower *(Carthamus tinctorius L.*) performance. The study involved two experimental factors: the first comprised nine safflower genotypes (Rabeey 500, G218, Chwarqurna, Shamela, Local Mosul, G-2018, Al-Mais, Nap, and Gilla), while the second included three floret removal treatments, namely removal at three days after the initiation of flowering, removal at nine days after flowering initiation, and a control treatment without floret removal. The experiment was arranged in a 9 × 3 factorial scheme using a Randomized Complete Block Design (RCBD) with three replications. A wide range of quantitative and qualitative traits was evaluated to assess the response of the tested genotypes to the imposed treatments. The mentioned factors showed a positive role in safflower growth, yield and medical properties, it is clear from the results that the highest increment plant height (145.76 and 138.03) cm recorded for V4, Number of capitula per plant-1 19.04 and 18.85 obtained in V8 and V4, Number of seed capitula-1 29.77 resulted in V4, additionally Seed index(10.70,10.35,10.23 and 10.13) g recorded for V8, V4, V5 and V9) respectively finally Seed yield were recorded for (V8, V4, V5 andV9) with values (1.60,1.55,1.53,1.52) t ha-1 respectively. The highest values for most of the harvesting time were acquired in the first harvest time, number of capitula per plant-1, seed index, and seed yield with values 17.70,11.07 g,1.66 t ha-1, respectively. The interaction between genotype and floret removal timing exhibited pronounced effects on oil composition, where the V2H2 treatment combination resulted in a significant increase in oil content, reaching 35.24%. Moreover, the interaction treatment V9H2 recorded the highest values for major fatty acids, including oleic, linoleic, linolenic, palmitic, stearic, and arachidonic acids, indicating its superior biochemical performance. Hierarchical cluster analysis (dendrogram) classified the relationships treatments into three distinct clusters based on their degree of similarity, reflecting underlying patterns of variation among treatments. Furthermore, Principal Component Analysis (PCA) revealed the relationships among variables through vector orientation, where the angles between vectors represent the strength and direction of correlations; for example, palmitic acid was closely associated with V7H2, while linoleic acid showed the strongest association with V7H3, indicating positive correlations between these variables and their respective treatment combinations.

***Keywords*:** *Carthamus tinctorius L.*, Flower removal, Plant growth, Crop yield, Oil quality.

INTRODUCTION

Safflower (*Carthamus tinctorius L.*), a member of the family Asteraceae, is an ancient oilseed crop believed to have originated in the Mediterranean basin. It is characterized as a highly branched, herbaceous annual species with a thistle-like morphology and predominantly self-pollinating reproductive system, reflecting its evolutionary adaptation to diverse agroecological conditions.[1]. Safflower (Carthamus tinctorius L.) is a multifunctional crop with diverse applications, including its use as bird seed [2], and it is widely valued for its nutritional attributes and medicinal properties. It is considered an economically important species cultivated for oil production as well as for pharmaceutical and industrial purposes. Morphologically, safflower develops primary, secondary, and tertiary branches, each terminating in a globular inflorescence (capitulum) bearing florets that range in color from yellow to

orange and red [3].In recent years, particularly in the developed countries, safflower has attracted important attention due to its edibility and medicinal values [4].

Safflower oil is one of the highest quality vegetable oils, containing oleic acid and linoleic acid [5]. There is a significant variation in safflower oil content, yield and fatty acid composition, which is influenced by genetic factors, location, season, temperature, agronomic practices, time of planting, and plant density [6] and [7]. Safflower oil is characterized by a high proportion of unsaturated fatty acids, particularly the essential polyunsaturated linoleic acid (70–87%) and the monounsaturated oleic acid (11–80%), traits that are critically important for enhancing safflower productivity and quality [8], as well as for alternative applications such as biogas production from safflower straw [9]. The typical fatty acid profile of safflower oil comprises 6–8% palmitic acid, 2–3% stearic acid, 16–20% oleic acid, and 71–75% linoleic acid [10]. Furthermore, Sarkees and Mahmood [11] reported that genetic variation among genotypes significantly affects both oil content and fatty acid composition, underscoring the importance of genotype selection in safflower improvement programs.

Safflower cut flowers are typically harvested at a developmental stage when petals have emerged and are visible on the majority of capitula, generally when the florets are approximately one-quarter to one-half open, since immature buds exhibit limited post-harvest opening capacity; under optimal handling conditions, freshly cut flowers can maintain their quality and aesthetic value for up to 10 days [3, 12]. The timing of harvest represents a critical agronomic factor in safflower production systems, as it directly influences both qualitative and quantitative attributes, including the accumulation of red and yellow pigments, which may require differential harvesting schedules depending on the intended end use, particularly in contrast to seed production objectives. Notably, previous findings indicate that repeated or regular floret harvesting does not exert a detrimental effect on final seed yield, highlighting the crop's resilience and potential for dual-purpose utilization. In this context, the present study was designed to comprehensively evaluate the effects of varying harvest times on key vegetative growth parameters, yield components, and overall seed yield across nine distinct safflower genotypes, under the specific pedoclimatic conditions of Erbil.

Materials And Methods

Locations of the Studied Area

The current study was conducted at the experimental farm of College of Agricultural Engineering Sciences at Grdarasha with GPS reading: Lat. 36° 06' 44".8 N and Long. 44° 00'44.4" E; and elevation 420 meters above sea level (masl), which is about 8 km to the southwest of Erbil city during the growing season of 2023 - 2024.

Seed sources:

The nine safflower varieties utilized in the study were sourced from multiple reputable research institutions to ensure genetic diversity and representativeness. Specifically, the NAP, Shamla, Local Mosul, and G-218 varieties were obtained from the Sulamani Research Center, while Rabeey 500, Gilla, G-2018, and Al-Mais were procured from the Askykalalk (Xabat) Institute. Additionally, the Chwarqurna variety was provided by Raparen University, thereby encompassing a wide spectrum of locally adapted genotypes for comprehensive evaluation under experimental conditions.

Land preparation

The experimental field was meticulously prepared through chisel plowing to a depth of 25 cm, followed by harrow-disking 48 hours prior to sowing, ensuring a well-aerated and uniform seedbed conducive to optimal germination and early plant development. To characterize the edaphic conditions of the study site, representative soil samples were collected from the 0–30 cm plow layer, air-dried, and subsequently passed through a 2 mm sieve to obtain a homogenous fraction suitable for laboratory analysis. These samples were then subjected to comprehensive physical and chemical analyses to determine key soil properties, including texture, nutrient content, pH, and organic matter, providing a foundational understanding of the soil environment in which the safflower varieties were cultivated, as summarized in Table 1.

Table 1. Some soil physical and chemical properties of the studied field before planting *

Soil Property		Unit	Average value
Particle size distribution	Sand	($g\ kg^{-1}$)	100.25
	Silt		515.00
	Clay		384.75
Textural class		lining cell	
pH		7.53	

$CaCO_3$		(g kg^{-1})	26.91
Total N	(ppm)	89.17	
AVailable P	mg kg^{-1}	4.67	
K	cmolc $liter^{-1}$	0.12	
Organic Matter	g kg-1	9.60	

* [13]

The primary Purpose of this study was to evaluate the performance and variability of safflower (Carthamus tinctorius L.) genotypes under the agro-climatic conditions of Kurdistan, Iraq, with respect to key physical traits, oil content, and physicochemical properties of seed oil, and to elucidate the relationships among these parameters to facilitate efficient genotype selection aimed at enhancing oil yield in safflower breeding programs. For this purpose, the experimental field was systematically subdivided into three blocks, each further partitioned into nine plots, with a 1 m buffer zone between blocks to allow for movement and 0.5 m separation between plots to minimize edge effects. The study was arranged as a factorial experiment in a Randomized Complete Block Design (RCBD) with three replicates, encompassing two factors: the first factor consisted of nine safflower varieties—V1 = Rabeey 500, V2 = G-218, V3 = Chwarqurna, V4 = Shamela, V5 = Local Mosul, V6 = G-2018, V7 = Al-Mais, V8 = NAP, and V9 = Gilla—while the second factor represented floret harvesting time, including H1 = 3 days, H2 = 9 days after initiation of flowering, and H3 = control (without floret removal), initiated when the majority of plants reached principal growth stage 6 (flowering) according to the BBCH scale [14]. In total, 27 plots were established, each measuring 2 m in length with five planting rows spaced 40 cm apart and intra-row spacing of 15 cm, achieving a plant density of 166,700 plants ha^{-1} [15]. Fertilization was applied at sowing on 15th November, consisting of 120 kg N ha^{-1} as urea (46% N), 120 kg P_2O_5 ha^{-1} as triple superphosphate (46%), and 100 kg K ha^{-1} as KCl (52%). Throughout the growing season, detailed meteorological data were recorded to contextualize environmental influences on safflower growth and productivity, as summarized in Table 2.

Table2. Meteorological data for Grdmala and Grdarasha fields during 2023-2024

Months	Rainfall	Minimum temp.	Maximum temp.	Relative humidity
	mm	℃		%
November	79	2.19	30.17	62.97
December	59.8	2.26	22.65	71.95
January	77.5	-0.06	19.67	73.48
February	121.2	-1.98	20.68	68.49
March	61.2	- 2.20	25.69	61.19
April	59.80	6.76	36.1	49.59
May	46.10	8.44	41.32	39.80
June	zero	49.64	15.96	14.91
July	zero	44.79	21.75	16.32

To avoid drought stress to the crop, it was irrigated to supplement natural rainfall during periods with no rainfall whenever time 75% of the available water was depleted. The crops were manually weeded on occasions during the growing season. All other cultural practices were followed according to standard recommendations for the locality. fungal disease was controlled using (Proplant, Pilarstin, Himex, Topsin, and Reval).

Safflower traits Determination

The measurement was done at principal growth stage 3: Stem elongation (main shoot) according to the BBCH scale [14].

Plant height (cm) was measured from the soil surface to the apex of six randomly selected plants from the inner two rows of each plot, and the mean value was calculated for each treatment, while the number of branches per plant was similarly recorded and averaged. Chlorophyll content was assessed using the SPAD (Soil Plant Analysis Development) method at 120 days after sowing, corresponding to the elongation stage, with a handheld chlorophyll meter (Atleaf CHL STD), taking readings from mature leaves at the lower, middle, and upper canopy positions of six labeled plants, resulting in a total of 30 measurements per experimental unit according to [16]. The number of capitula per plant was determined by manually counting the flower heads of the six labeled plants, and the mean was calculated. For seed number per capitulum, seeds were separated from 15 randomly selected capitula from the same six plants, manually cleaned, and counted to determine the average. Seed mass was determined by weighing one thousand seeds and expressing the result in grams. Finally, seed yield was measured by harvesting and weighing seeds from individual plants in grams and converting the data to kg ha^{-1} for each experimental unit.

Statistical Analysis

The data were statistically analyzed according to the technique of analysis of Factorial experiment.(ANOVA) for randomized complete block design (RCBD) using IBM SPSS program version (26) the mean comparison was full filled according to Duncan's multiple range test at the level of significant 0.05 for the field data. The comparison between locations was done using F-test [17].

Cluster analysis was conducted between safflower varieties using XLSTAT- premium program to obtain homogenous groups by agglomerative hierarchical clustering (AHC) to show the similarity between them.

Results

Plant height (cm)

The observed variation in plant height among safflower varieties, with V4 and V9 reaching the maximum values of 145.76 cm and 138.03 cm and V3 exhibiting the minimum of 118.10 cm, underscores the significant influence of genetic factors on vegetative growth, corroborating the findings of Gürsoy et al. [18] who reported that both genotype and environmental conditions strongly affect plant stature. Environmental factors, particularly higher rainfall and cooler temperatures during the flowering period, likely enhanced nutrient and water availability, thereby promoting greater vegetative development across all genotypes [4]. The analysis of two-factor interactions revealed that floret harvesting timing further modulated plant height, with the tallest and shortest plants recorded in the V4 × H1 and V3 × H3 treatments, respectively, indicating that early or delayed floret removal can differentially influence resource allocation between vegetative and reproductive organs. The wider range of plant heights across interaction treatments, from 79.03 cm in V1 × H4 to 101.83 cm in V2 × H3, suggests that certain genotype–harvest time combinations may optimize vegetative growth, which could have downstream effects on yield components and overall productivity. These results highlight the importance of integrating genotype selection with management practices, such as precise timing of floret harvesting, to maximize vegetative development and potentially enhance seed yield in safflower cultivation.

Table 3. Effect of safflower varieties, floret harvesting and their interactions on plant height(cm)

Varieties		H_1	H_2	H_3	Means of varieties
Rabeey 500	(V_1)	130.18abc	133.56 abc	130.44 abc	131.40a-d
G-218	(V_2)	126.23 abc	122.78 abc	116.26bc	121.75cd
Chwarqurna	(V_3)	125.61 abc	115.04c	113.64c	118.10d
Shamela	(V_4)	148.26a	146.64b	142.38 abc	145.76a
Local mosil	(V_5)	139.44 abc	132.76 abc	131.50 abc	134.57abc
G -2018	(V_6)	124.85 abc	125.43 abc	120.89 abc	123.72bcd
Al-mais	(V_7)	128.81 abc	124.19 abc	122.87 abc	125.29bcd
Nap	(V8)	137.80 abc	130.11 abc	124.46 abc	130.79a-d
Gilla	(V_9)	141.92 abc	138.55 abc	133.62 abc	138.03a
Mean of harvest		133.68a	129.90a	126.3a	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Number of branches plant^{-1}

The data presented in Table 4 indicate that the number of branches per plant was significantly influenced by safflower genotype, with V1 producing the highest average number of branches (8.68), whereas V3 and V7 exhibited the lowest values of 5.79 and 6.14, respectively, highlighting the strong genetic control over branching capacity. This variation aligns with previous findings by Bardhi et al. [19], who reported that safflower varieties exert a significant effect on branch number, and is further supported by Mohammadi and Tavakoli [20], who emphasized that cultivar origin can influence not only branch number but also capitulum formation and flower coloration. Although differences in floret harvesting time did not result in statistically significant changes in branch number, the highest average was observed under the first harvesting time, corroborating observations reported by [21] that early intervention can promote vegetative proliferation. Analysis of genotype × harvesting time interactions revealed a broad range in branch number, from 4.27 in V6 × H3 to 10.75 in V1 × H3, demonstrating that specific combinations of variety and harvest management can optimize branching. These results suggest that both inherent genetic potential and the timing of floret harvesting interact to modulate vegetative architecture, which is likely to influence assimilate allocation and, ultimately, reproductive success and seed yield in safflower.

Table 4. Effect of safflower varieties, floret harvesting and their interactions on number of branch plant^{-1}

Varieties		H_1	H_2	H_3	Means of varieties
Rabeey 500	(V_1)	7.22b-f	8.06a-e	10.75a	8.68a
G-218	(V_2)	7.48a-f	8.1a-e	5.75b-f	7.11abc
Chwarqurna	(V_3)	4.67ef	5.11c-f	7.59a-f	5.79c
Shamela	(V_4)	7.44a-f	7.00b-f	7.85a-e	7.43abc
Local mosil	(V_5)	7.05b-f	8.61abc	5.08def	6.91abc
G -2018	(V_6)	9.05ab	6.67b-f	4.27f	6.66bc
Al-mais	(V_7)	6.52b-f	5.85b-f	6.05b-f	6.14c
Nap	(V8)	8.58a-d	8.17a-e	8.50a-d	8.41ab
Gilla	(V_9)	7.83a-e	6.54b-f	6.23b-f	6.87abc
Mean of harvest		7.32a	7.13a	6.90a	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Chlorophyll content (SPAD)

The results presented in Table 5 demonstrate that chlorophyll content, as measured by SPAD values, was significantly influenced by both safflower genotype and floret harvesting time. Among the nine varieties, V8 exhibited the highest chlorophyll content (62.77 SPAD), whereas V2 recorded the lowest value (55.67 SPAD), indicating substantial genetic variation in leaf pigmentation and photosynthetic potential. Floret harvesting time also had a pronounced effect, with the highest chlorophyll levels observed in the control treatment without floret removal (H3, 63.65 SPAD) and the lowest in early harvesting at three days (H1, 55.67 SPAD), suggesting that early floret removal may temporarily reduce leaf chlorophyll accumulation, possibly due to altered source–sink dynamics and stress-induced senescence. Moreover, the interaction between genotype and harvesting time further amplified these differences, with V8 × H3 achieving the maximum SPAD value of 71.52 and V3 × H1 the minimum of 52.23, highlighting that specific genotype × management combinations can optimize photosynthetic capacity. These findings emphasize the importance of both inherent varietal traits and agronomic practices in regulating chlorophyll content, which in turn may influence assimilate production, vegetative vigor, and ultimately seed yield in safflower cultivation.

Table 5. Effect of safflower varieties, floret harvesting and their interactions on Chlorophyll content(SPAD)

Varieties		H1	H2	H3	Means of varieties
Rabeey 500	(V_1)	53.64ijk	58.20e-k	62.73cde	58.19de
G-218	(V_2)	52.99jk	55.66f-k	58.36e-k	55.67e
Chwarqurna	(V_3)	52.23k	58.53d-j	64.62bcd	58.46cde
Shamela	(V_4)	59.18d-j	58.31e-k	59.18d-j	58.89bcd
Local mosil	(V_5)	57.03e-k	62.29cde	67.37abc	62.23ab
G -2018	(V_6)	57.49e-k	59.19d-j	60.59d-g	59.09bcd
Al-mais	(V_7)	59.84d-i	57.03e-k	59.91d-h	58.92bcd
Nap	(V8)	53.90j-k	62.89cde	71.52a	62.77a
Gilla	(V_9)	54.70g-k	61.71c-f	68.54ab	61.65abc
Mean of harvest		55.67c	59.31b	63.65a	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Number of capitula plant^{-1}

The number of capitula per plant, a key determinant of safflower seed yield, was significantly influenced by both genotype and floret harvesting time, as presented in Table 6. Among the varieties, V8, V4, and V9 exhibited the highest values, with V8 reaching a maximum of 19.04 capitula per plant, while V3 produced the fewest (9.54), reflecting the strong genetic control over reproductive architecture. These findings are consistent with the observations of Soleymani et al. [22], who reported substantial variation in capitula number among diverse safflower genotypes. Floret harvesting time also exerted a significant effect, with the highest values recorded under early harvesting (H1 = 17.70) and slightly lower but statistically comparable values in H2 (14.73) and H3 (14.53), corroborating prior reports that timing of flower removal can modulate capitula development [4]. Interaction effects further highlighted the combined influence of genotype and harvest timing, with V9 × H1 producing the greatest number of capitulacapitula (23.69) and V3 × H1 the lowest (7.61), demonstrating that specific genotype × management combinations can optimize reproductive output. These results align with the findings of Kizil et al. [4] and other studies [23], emphasizing that both genetic potential and agronomic practices, such as the timing of floret removal, are critical for maximizingcapitula formation and, consequently, potential seed yield in safflower.

Table 6. Effect of safflower varieties, floret harvesting, and their interactions on the number of capitula plant^{-1}

Varieties		H_1	H_2	H_3	Means of varieties
Rabeey 500	(V_1)	14.95a-g	10.18d-g	16.33a-g	13.82abc
G-218	(V_2)	16.71a-g	16.44a-g	13.99a-g	15.71ab
Chwarqurna	(V_3)	7.61g	9.45efg	11.56c-g	9.54c
Shamela	(V_4)	21.80ab	16.20a-g	18.54a-f	18.85a
Local mosil	(V_5)	20.59abc	18.00a-f	12.91b-g	17.17ab
G -2018	(V_6)	19.33a-e	16.78a-g	13.50a-g	16.54ab
Al-mais	(V_7)	14.20a-g	13.72a-g	8.89 fg	12.27bc
Nap	(V8)	20.45abc	16.72a-g	19.93a-d	19.04a
Gilla	(V_9)	23.69a	15.06a-g	15.11a-g	17.95a
Mean of harvest		17.70a	14.73b	14.53b	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Seed index (g)

The results presented in Table 7 indicate that safflower varieties exhibited significant differences in seed index, reflecting the influence of genetic factors on seed size and weight. The highest thousand-seed weights were recorded in V8, V4, V5, and V9, with values of 10.70 g, 10.35 g, 10.23 g, respectively, whereas V3 produced the lowest seed index at 3.83 g, highlighting the substantial varietal variation consistent with findings reported by Kizil et al. [4], who observed clear differences in thousand-seed weight across multiple cultivars over a two-year period. Floret harvesting time also significantly affected seed index, with the first harvesting time (H1) resulting in the highest average seed weight (11.07 g) and the control (H3) producing the lowest (5.49 g), suggesting that early floret removal may enhance assimilate partitioning toward seed development. Furthermore, the interaction between genotype and harvesting time amplified these effects, with V5 × H1 and V8 × H1 achieving the maximum seed index (17.05 g and 16.88 g, respectively), while V3 × H1 recorded the minimum value (2.74 g), indicating that specific genotype × harvest time combinations can optimize seed mass. These findings corroborate previous reports [23], emphasizing that both genetic potential and precise management of floret harvesting are critical for improving seed size, which is a key yield-contributing trait in safflower production.

Table 7. Effect of safflower varieties, floret harvesting, and their interactions on seed index (g)

Varieties		H_1	H_2	H_3	Means of varieties
Rabeey 500	(V_1)	7.20cde	10.12a-e	6.96cde	8.09abc
G-218	(V_2)	10.36a-e	11.00a-e	8.13b-e	9.83ab
Chwarqurna	(V_3)	2.74e	3.82de	4.92de	3.83c
Shamela	(V_4)	16.14ab	8.52b-e	6.38de	10.35a
Local mosil	(V_5)	17.05a	9.16a-e	4.48de	10.23a
G -2018	(V_6)	11.70a-d	7.68cde	4.51de	7.96ab
Al-mais	(V_7)	6.58de	5.45de	4.59de	5.54bc
Nap	(V8)	16.88a	10.31a-e	4.90de	10.70a
Gilla	(V_9)	10.95a-e	14.92abc	4.53de	10.13a
Mean of harvest		11.07a	9.00a	5.49b	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Number of seed capitula^{-1}

The results presented in Table 8 demonstrate that the number of seeds per capitulum was significantly influenced by safflower genotype, with V4 exhibiting the highest value (29.77 seeds) and V7 the lowest (21.58 seeds), likely reflecting the superior adaptability and genetic potential of V4 under the experimental conditions. These findings are consistent with previous reports by Ahmed [24, 25], who highlighted the strong influence of varietal genetics on reproductive traits in safflower. In contrast, floret harvesting time did not exert a statistically significant effect on this trait, indicating that seed set per capitulum is relatively stable across different harvest management practices. However, the interaction between genotype and harvesting time revealed marked variability, with the highest number of seeds per capitulum observed in V8 × H1 (35.29 seeds) and the lowest in V2 × H1 (17.95 seeds), underscoring that specific combinations of genotype and floret removal timing can optimize reproductive output. These results suggest that while inherent genetic factors predominantly determine seed number per capitulum, strategic management of floret harvesting can further enhance this trait in selected varieties, contributing to improved seed yield potential.

Table 9. Effect of safflower varieties, floret harvesting, and their interactions on the number of seed capita^{-1}

Varieties		H_1	H_2	H_3	Means of varieties
Rabeey 500	(V_1)	23.91a-d	24.38b-d	24.67a-d	24.32abc
G-218	(V_2)	17.95d	25.95a-d	23.33b-d	22.41c
Chwarqurna	(V_3)	28.47a-d	29.84abc	29.93abc	29.42ab
Shamela	(V_4)	32.02ab	25.29a-d	32.00ab	29.77a
Local mosil	(V_5)	30.60abc	23.18b-d	25.11a-d	26.30abc
G -2018	(V_6)	23.00b-d	24.29a-d	22.47b-d	23.25bc
Al-mais	(V_7)	25.11a-d	19.49c-d	20.13c-d	21.58c
Nap	(V8)	35.29a	20.00c-d	27.27a-d	27.52abc
Gilla	(V_9)	27.15a-d	25.58a-d	29.31a-d	27.35abc
Mean of harvest		27.06a	24.22a	26.03a	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Seed yield *M*g ha^{-1}

The paramount economic parameter for assessing treatment superiority over others is seed yield. As delineated in Table 9. revealed that seed yield was affected significantly by the safflower varieties and time of floret harvesting and their interactions. The analysis of data revealed that significant differences occurred on seeds yield Mg ha-1 due to differences in safflower varieties.V8 exhibited superiority in seed yield, although there is no significant differences between V8,V4,V5 and V9 with values (1.60,1.55,1.53 and 1.52) kg ha-1 . The V8 variety offered 1.80 time more compared to the V3 variety, which obtained the lowest value 0.57 Mg ha-1. The increase in yield may be attributed to the presence of a greater number of primary branches.as shown in Table 4, the observed distinctions can be attributed to the inherent genetic potential of the safflower varieties, coupled with variations in the responsiveness of certain cultivars during the seed-filling stage (from flowering to maturity) to temperature fluctuations recorded across different locations [26]. on this trait between the harvesting times, the highest value 1.66 and 1.50 was recorded for H1 and H2 while the lowest value 0.82 Mg ha-1 recorded for H3. The presented result was in line with Kajo and Al-Souda [27]. In addition, the interaction among the studied factors had significant effects on seed yield, the highest value recorded in (2.56 and 2.53) Mg ha-1 obtained from the interaction treatments V5*H1 and V8*H1 respectively. Samancı and Özkaynak [28] reported that the effect of genotypes on seed yield and oil content was greater than that of environment. This result wasn't similar with [23], who obtained (varieties x florets removal interaction) indicated no differential effects of on grain yield.

Table 9. Effect of safflower varieties, floret harvesting and their interactions on seed yield *M*g ha^{-1}

Varieties		H_1	H_2	H_3	Means of varieties
Rabeey 500	(V_1)	1.08c-e	1.52a-e	1.04c-e	1.21ab
G-218	(V_2)	1.55a-e	1.65a-e	1.22b-e	1.48ab
Chwarqurna	(V_3)	0.41e	0.57de	0.74de	0.57c
Shamela	(V_4)	2.42ab	1.28b-e	0.96de	1.55a
Local mosil	(V_5)	2.56a	1.37a-e	0.67de	1.53a
G -2018	(V_6)	1.75a-d	1.15c-e	0.68de	1.20ab
Al-mais	(V_7)	0.99de	0.82de	0.69de	0.83bc
Nap	(V8)	2.53a	1.55a-e	0.74de	1.60a
Gilla	(V_9)	1.64a-e	2.24abc	0.68de	1.52a
Mean of harvest		1.66a	1. 50a	0.82b	

Values with different letters indicate significant differences at 5% according to Duncan's multiple-range test

Oil content (%)

The data presented in Fig. 1 indicate significant variation in seed oil content among safflower varieties, with V8 and V2 exhibiting the highest oil concentrations (29.91% and 29.12%, respectively), whereas V5 recorded the lowest value (23.22%), highlighting the strong influence of genetic factors on oil accumulation. These findings are consistent with Moatshe et al. [8], who reported that oil content in safflower is determined by an interplay of genotype, environmental conditions, agronomic practices, growing season, and geographical location. Floret harvesting time also significantly affected oil content, with the second harvesting (H2) producing the highest average oil concentration (29.12%) and the control (H3) the lowest (24.05%), corroborating the observations of Kajo and Al-Souda [27] regarding the critical role of harvesting management in modulating oil accumulation. Furthermore, analysis of the genotype × harvesting time interaction revealed that V2 × H2 achieved the maximum oil content (35.24%), whereas V4 × H1 recorded the minimum (21.50%), demonstrating that specific combinations of variety and harvest timing can

optimize oil yield. These results underscore the importance of integrating both genetic selection and precise floret harvesting strategies to maximize oil content in safflower cultivation..

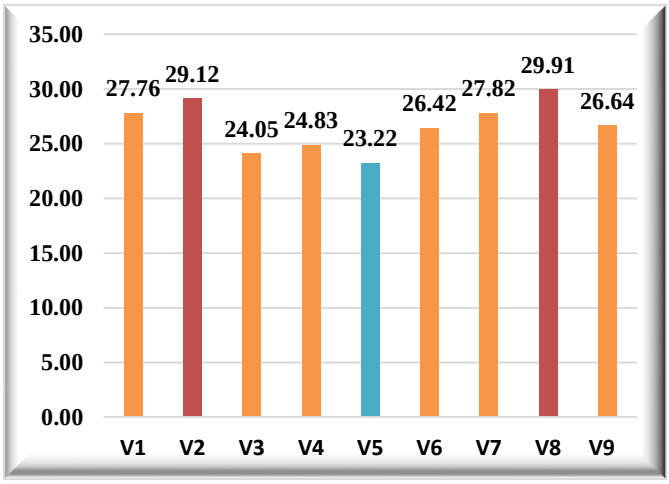

Fig 1. Effect of safflower varieties on oil %

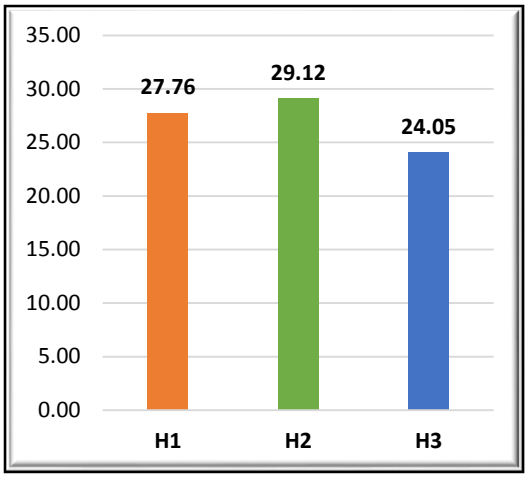

Fig 2. Effect of harvesting time on oil %

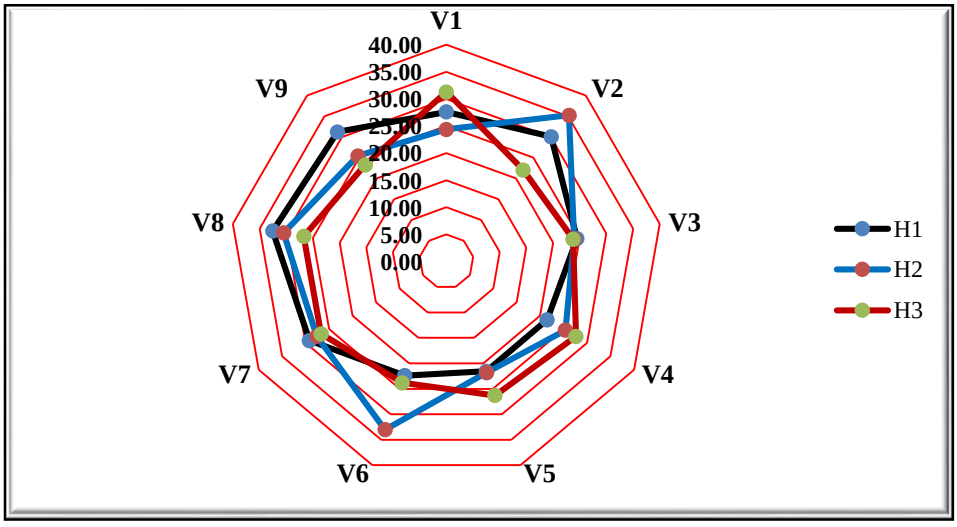

Fig 3. Interaction effect of safflower varieties and harvesting time on Oil%

Table 10. The interaction effect of safflower varieties, floret harvesting time oil and fatty acids%							
Treatments		Oleic	Lenolic	Lenolinic	Stearic	Palmatic	Arachidonic
	%						
V_1H_1	27.6	12.08	16.78	3.66	6.39	1.52	0.69
V_2H_1	30.08	12.22	17.00	3.90	6.56	1.77	0.78
V_3H_1	24.46	11.41	16.12	3.12	6.05	1.14	0.42
V_4H_1	21.50	11.70	16.33	3.40	6.20	1.34	0.55
V_5H_1	21.56	12.98	18.00	4.80	7.25	2.29	1.18
V_6H_1	22.40	12.42	17.52	4.15	6.77	1.93	0.90
V_7H_1	29.18	13.00	18.25	5.00	7.55	2.40	1.36
V_8H_1	32.54	12.65	17.80	4.50	6.90	2.10	1.05
V_9H_1	31.22	13.32	18.40	5.33	7.79	2.69	1.55
V_1H_2	24.38	12.18	17.11	3.90	6.90	1.70	0.70
V_2H_2	35.24	12.44	17.35	4.35	7.30	1.99	0.89
V_3H_2	23.96	12.89	17.69	4.80	7.68	2.15	1.00
V_4H_2	25.36	13.28	17.90	5.05	7.99	2.47	1.18
V_5H_2	21.80	13.60	18.36	5.55	8.25	2.68	1.39
V_6H_2	33.04	13.90	18.66	5.89	8.60	2.99	1.60
V_7H_2	27.58	14.39	18.90	6.00	8.89	3.25	1.88
V_8H_2	30.48	14.64	19.15	6.25	9.15	3.49	2.00
V_9H_2	25.42	14.90	19.55	6.49	9.66	3.66	2.35
V_1H_3	31.30	12.65	17.22	3.98	7.00	1.70	0.73
V_2H_3	22.04	12.90	17.50	4.22	7.44	1.90	0.84
V_3H_3	23.74	11.80	16.68	3.50	6.45	1.22	0.49
V_4H_3	27.64	12.00	16.94	3.77	6.80	1.52	0.61
V_5H_3	26.30	13.90	18.40	4.90	8.44	2.58	1.28
V_6H_3	23.82	13.22	17.88	4.50	7.89	2.18	0.99
V_7H_3	26.70	14.30	18.74	5.15	8.70	2.77	1.49
V_8H_3	26.72	13.68	18.00	4.77	8.05	2.39	1.16
V_9H_3	23.28	14.66	18.90	5.50	8.93	2.90	1.76
Average	26.64	13.08	17.82	3.66	2.25	1.52	1.14

Cluster Analysis

The cluster analysis of the 27 safflower genotype × floret harvesting treatment combinations, as illustrated in Table 11 and Figure 4, classified the interactions into three distinct clusters based on similarity in oil content and fatty acid composition. Cluster 1 comprised nine treatment combinations, cluster 2 included 17 combinations, and cluster 3 was represented solely by the V2 × H2 interaction, indicating its unique biochemical profile compared to other treatments. The dendrogram, constructed using oil percentage and fatty acid data (Table 10), highlighted mean values of 26.64%, 13.08%, 17.82%, 2.25%, 7.61%, 4.68%, and 1.14% for oil, oleic, linoleic, linolenic, palmitic, stearic, and arachidonic acids, respectively, illustrating the variation in lipid composition across the treatments. The vertical line in the dendrogram effectively demarcates the degree of similarity among clusters, reflecting that V2 × H2 possesses a distinct combination of high oil content and favorable fatty acid profile, which may be exploited for targeted breeding or industrial applications. These findings underscore the utility of multivariate clustering approaches in identifying superior genotype × management combinations with optimal oil quality traits, providing a framework for the strategic selection of safflower varieties for enhanced oil productivity.

Table. Classifying the treatment combination into clusters1

Class1	V_1H_1	V_2H_1	V_7H_1	V_8H_1	V_9H_1	V_6H_2	V_8H_2	V_1H_3	V_4H_3
Class2	V_3H_1	V_4H_1	V_5H_1	V_6H_1	V_1H_2	V_3H_2	V_4H_2	V_5H_2	
	V_7H_2	V_9H_2	V_2H_3	V_3H_3	V_5H_3	V_6H_3	V_7H_3	V_8H_3	V_9H_3
Class3	V_2H_2								

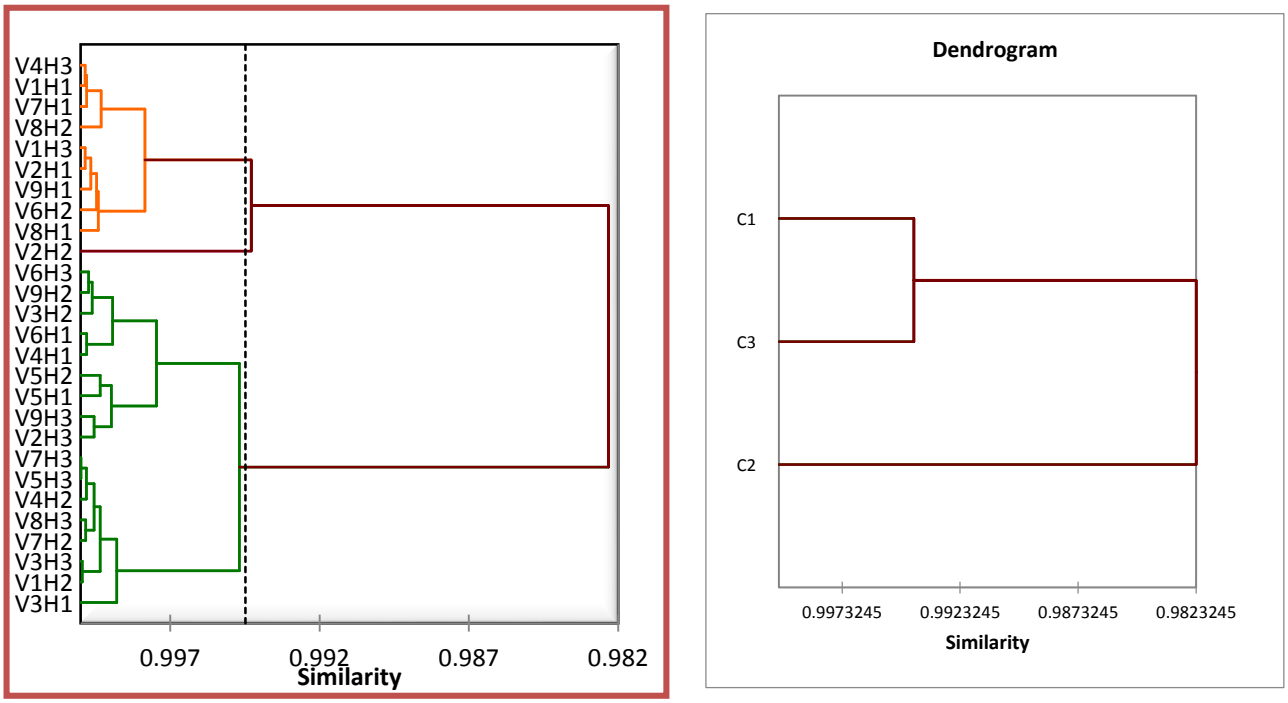

Figure 4. Dendrogram for the cluster of oil and safflower fatty acids (%)

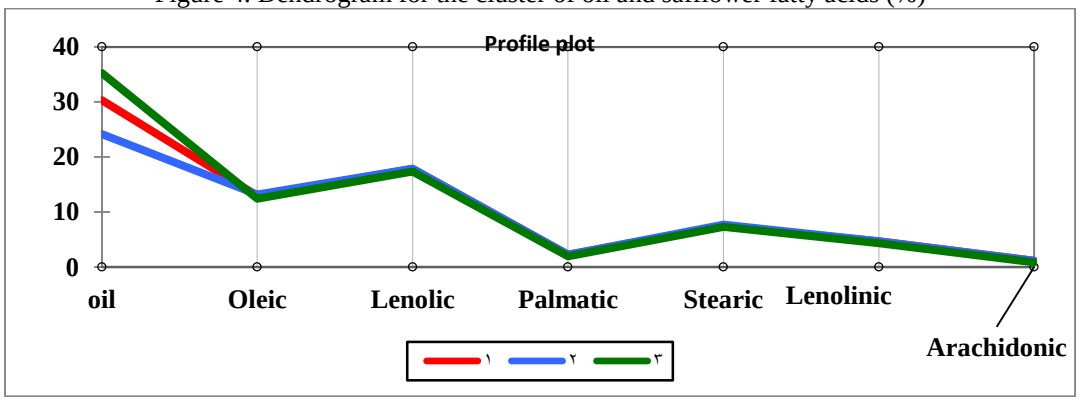

Figure 5. Shows the profile plot oil and fatty acids

Table 12 presents the proximity matrix, which quantifies the degree of similarity and dissimilarity among the measured oil quality traits across the safflower genotype × floret harvesting combinations. The matrix values provide insight into how closely related or divergent specific fatty acids and oil content are in their responses. The highest proximity value (0.989) indicates a pronounced dissimilarity between linolenic and palmitic acids, suggesting that these two components vary independently across the treatments and are likely influenced by different metabolic or genetic factors. In contrast, the lowest value (0.087) highlights a strong similarity between oil content and oleic acid, implying a positive association in which increases in oleic acid are generally accompanied by higher overall oil percentages. These results emphasize that certain fatty acids, such as oleic, are closely linked with total oil accumulation, whereas others, like linolenic and palmitic acids, may respond differently to varietal and management influences, providing critical information for targeted selection and breeding strategies aimed at improving both oil

Table 12. Correlation matrix (Pearson (n)):

Variables	oil	Oleic	Lenolic	Palmatic	Stearic	Lenolinic	Arachidonic
oil	1						
Oleic	0.087	1					
Lenolic	0.150	0.969	1	1			
Palmatic	0.182	0.961	0.981	1			
Stearic	0.090	0.983	0.956	0.958	1		
Lenolinic	0.182	0.937	0.971	0.989	0.945	1	
Arachidonic	0.166	0.943	0.969	0.986	0.934	0.975	1

quantity and quality in safflower.

Eigenvalues:

Table 13. The eigenvalue and the variability among the genotypes

	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	5.845	0.985	0.098	0.033	0.025	0.010	0.005
Variability (%)	83.493	14.072	1.394	0.472	0.361	0.138	0.070
Cumulative %	83.493	97.565	98.959	99.431	99.792	99.930	100.000

Table 13. and Figure 6. explain that for F a great influence on variability, since their values were higher than one which was 83.493, and the cumulative variability was 68.45 and 89.95 % while the eigenvalues for other fertilizer were less than one or can be neglected. After F1 the slope of the scree plot will decrease then an approach zero (Figure 7), which means the effects of F2to F7 are very low and can be neglected.

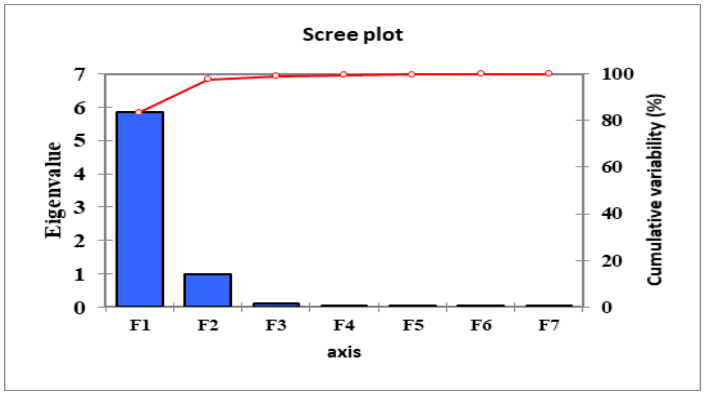

Figure 6. Shows the decrease in slope for the scree plot after F2

Figure 7. explains the vectors for the studied traits. The angles between vectors explain the correlation between them. The decrease in angle value to < 90◦ means an increase in positive correlation coefficient value and if the angle approached zero the correlation coefficient value approaches 1.00; if the angle is °90 that means the correlation coefficient equals zero. If it is °180, it means the correlation (r = -1) or open-angle between two variables decreases to a negative correlation between them. However, if the angle between two variables is less than °90, it means a positive correlation coefficient. The length of the vector explains the value of loading factors.
The combination treatments in Figure () are merged and give a different explanation. For the variables close to the

center, there will not be significant differences between them, for example in linoleic acids is the closest variable to V_7H_3, and the palmitic acid with V_7H_2 is closer. If any of the variables are close, meaning there are positive reactions between them, and the other side has a negative reaction to the first one. The first two axes for four clusters were significant (eigenvalues ≤ 90) and contributed to 97.56 % of total variance, and were mainly correlated to F1, F2.

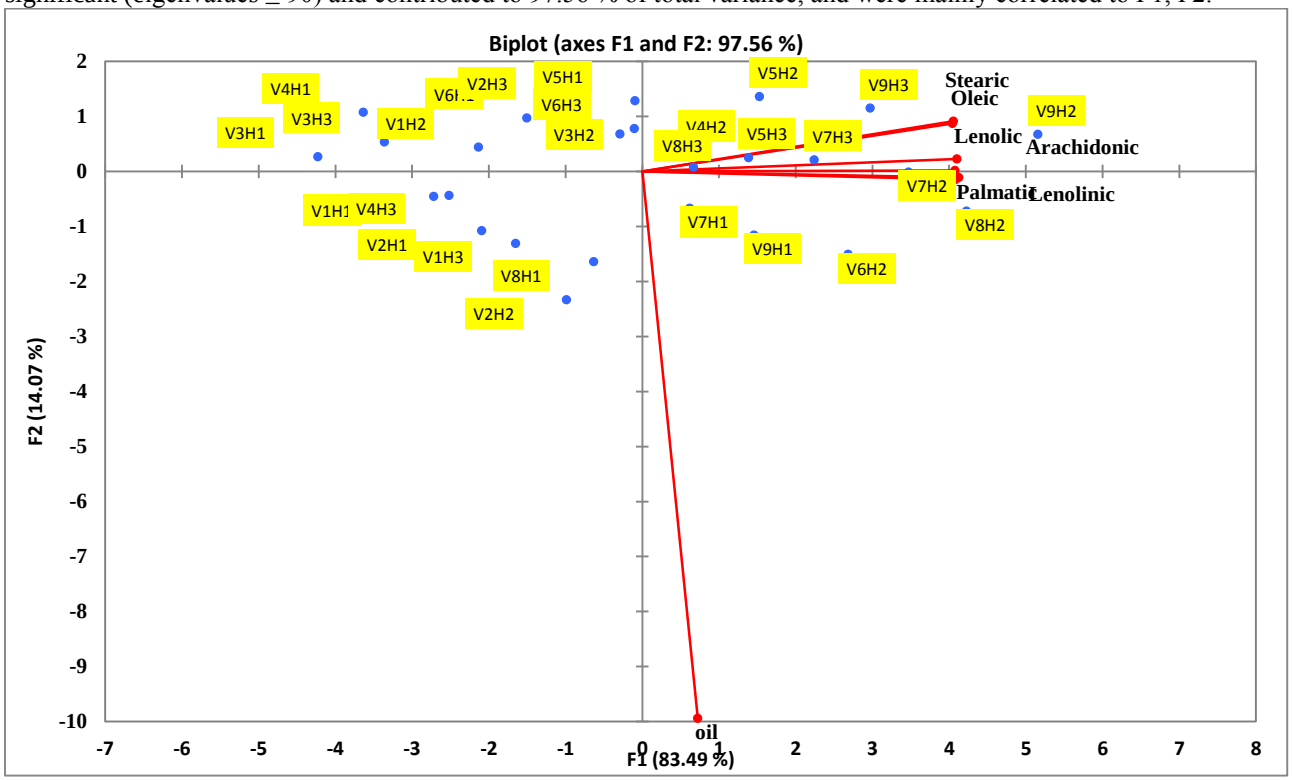

Fig 7. The vectors for the safflower varieties and floret harvesting times

Conclusion

This study demonstrates that significant genetic variation exists among safflower *(Carthamus tinctorius L.)* varieties, resulting in pronounced differences in growth parameters, yield components, and chemical composition. Among the nine genotypes evaluated, V4, V8, and V9 consistently exhibited superior performance across multiple traits, including plant height, number of branches, capitula formation, seed index, and oil content, indicating their high potential for both agronomic productivity and oil quality. These findings underscore the importance of genotype selection as a key determinant for optimizing safflower performance under the agro-climatic conditions of Kurdistan, Iraq.In addition, the timing of floret harvesting was shown to influence certain physiological and biochemical traits without adversely affecting overall seed yield or oil content. Early floret harvesting, in particular, allowed for simultaneous utilization of florets for commercial or ornamental purposes while maintaining seed and oil productivity, thereby maximizing the overall economic value of the crop. Collectively, these results provide a strong basis for integrating varietal selection with targeted harvest management to enhance both the quantitative and qualitative outputs of safflower, supporting its dual-purpose use for seed oil production and floret harvesting in sustainable cropping systems.

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تأثير إزالة الزهيرات على إنتاجية وجودة بذور بعض تراكيب العصفر

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الخلاصة
أُجريت دراسة ميدانية في منطقة گرده رەشه خلال موسم النمو 2023-2024. شملت التجربة عاملين: الأول هو تسعة أصناف من العصفر، وهي: ربيع 500، و***G218***، جوارقورنه، وشاميلا، وموصل المحلي، و***G-2018***، والميس، وناب، وجيلا. أما العامل الثاني فهو ثلاثة أوقات لحصاد الأزهار: 1. بعد ثلاثة أيام من بدء الإزهار، 2. بعد تسعة أيام من بدء الإزهار، 3. مجموعة ضابطة (بدون حصاد الأزهار). أُجريت تجربة عاملية (9 × 3) باستخدام تصميم القطاعات العشوائية الكاملة ***(RCBD).***ودُرست في هذه التجربة العديد من المعايير الكمية والنوعية. أظهرت العوامل المذكورة دورًا إيجابيًا في نمو العصفر وإنتاجيته وخصائصه الطبية، ويتضح من النتائج أن أعلى زيادة في ارتفاع النبات (145.76 و138.03) سم سُجلت للصنف***V4*** ، وعدد البذور لكل نبات 19.04 و18.85 في الصنفين ***V8*** و***V4***، وعدد البذور لكل نبات 29.77 في الصنف***V4*** ، بالإضافة إلى مؤشر البذور (10.70، 10.35، 10.23، و10.13) غرام سُجل للأصناف***V8*** ، ***V4***، ***V5***، و ***V9***على التوالي، وأخيرًا سُجلت إنتاجية البذور للأصناف***V8)*** ، ***V4***، ***V5***، و ***(V9***بقيم (1.60، 1.55، 1.53، 1.52) طن/هكتار على التوالي. سُجّلت أعلى القيم خلال معظم فترات الحصاد في الحصاد الأول، حيث بلغت 17.70 غرام، و11.07 غرام لكل نبتة، و1.66 طن/هكتار على التوالي، وذلك بالنسبة لعدد البذور في النبات الواحد، ومؤشر البذور، وإنتاجية البذور أدى الجمع بين المعاملات ***V2H2*** إلى زيادة محتوى الزيت بنسبة 35.24%، بينما حققت المعامله التفاعلية ***V9H2*** أعلى قيمة لحمض الأوليك، وحمض اللينوليك، وحمض اللينولينيك، وحمض البالمتيك، وحمض الستيريك، وحمض الأراكيدونيك. صنّف تحليل التجميع أو مخطط التفرع المعاملات التفاعلية إلى ثلاث مجموعات بناءً على التشابه بينها. يُظهر تحليل المكونات الرئيسية (***PCA)***الزوايا بين المتجهات، مما يُفسّر الارتباط بينها؛ فعلى سبيل المثال، حمض البالمتيك أقرب إلى ***V7H2***، وحمض اللينوليك أقرب إلى ***V7H3***، مما يعني وجود تفاعلات إيجابية بينهما.

الكلمات المفتاحية: : االعصفر إزالة الأزهار، نمو النبات، إنتاجية المحصول، جودة الزيت.