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Influence of Genotype and Planting Date on Seed Yield and it's Components in Sunflower (Helianthus Annuus L.)

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ABSTRACT
Two key factors, sunflower genotypes and planting dates, significantly impact sunflower seed production. This study examines the relationship between sunflower yield and its components. (split-plot design) was used with three replications across two seasons at the Qlyasan location in 2024. The subplot treatments included planting dates in spring (March 15, April 4, and 24) and summer (July 1, 21, and August 10). The main plot treatments consisted of four sunflower genotypes (BAROLO RO, VELKO, DEA, and LOCAL). Results revealed notable differences among genotypes in seed yield, with the BAROLO RO genotype producing the highest seed yield (3094.573 and 3237.292 kg ha-1) respectively in both seasons. For planting dates, April 4 and July 1 yielded the highest seed yield (2939.483 kg ha-1 and 2607.640 kg ha-1) in spring and summer, respectively. The results revealed a positive and highly significant relationship between seed yield and full seed weight (r = 0.930) during the spring season. The correlation between seed yield and other characters, such as stem diameter, head diameter, head weight, and full seed weight, showed a highly significant and positive correlation (r = 0.857, r = 0.962, r = 0.955, and r = 0.967) in the summer season. Path coefficient analysis helps break down the correlation into direct and indirect effects. The highest positive direct effect was (1.485; 0.441) for 1000-seed weight, and head weight in spring and summer. The highest indirect effect was 1.492 for head diameter, mediated by the number of full seeds plant-1, and 0.416 for full seed weight, as indicated by head weight during the spring and summer seasons. Results suggest that selecting based on head diameter, head weight, 1000-seed weight, full-seed weight, and the number of full seeds per plant will be more effective in improving yield.

***Keywords*:** Sunflower, Planting Date, Sunflower Genotype, Correlation, Path Analysis.

INTRODUCTION
Sunflower (*Helianthus annuus* L.) is an important oilseed crop worldwide valued for its various uses in food, health products, and industry [1]. The crop's ability to adapt to different climates and soil conditions supports its widespread cultivation [1]**.** Despite its importance, many countries struggle with low sunflower yields, prompting plant breeders to develop higher-yielding varieties [2]. Global sunflower cultivation covers approximately 29.8 million hectares, producing about 55.23 million tons of seeds and 21.63 million tons of oil annually [3],[4]. One of the most controversial decisions in sunflower production is determining the best planting date [5]. As a crop grown in the temperate zone, sunflowers have shown adaptability to changes in the environmental conditions. However, factors like the date of sowing and seasonal weather have a significant impact on sunflower production potential. To put it another way, the timing of the sowing and the seasonal weather are thought to be limiting factors for seed production and its components [6].

Sunflower cultivars, varieties, and hybrids are grown on farms in our semi-arid region from early spring through late summer. Several studies have examined how planting dates affect the yield and yield components of sunflower genotypes. From these studies, [7] reported that the amount and distribution of temperature during the growing season, along with the timing, duration, and severity of drought, significantly influence yield levels, 1000-seed weight, and germinability. Hence, [5] demonstrated that the April planting date, among those in May, June, and July, produced the highest yield potential.

Sunflower genotypes exhibited significant variation in yield and yield attributes, as reported by [8] and [9]. However, regions like Tunisia face production constraints due to low yields from traditional varieties, which require evaluating genetic resources for improved cultivars [9]**.** In addition, [11] found that the hybrid record surpassed the other hybrids in most of the studied yield and quality characters. [12] reported that the oil content in sunflower seeds was highly significantly affected by year, planting date, hybrids, and most interactions between these factors.

Information on how yield components relate to overall yield is needed [13]. One of the fundamental statistical methods for examining relationships between characteristics is the analysis of the simple correlation coefficient [14]. Correlation

coefficients show the relationship between the independent variable and the dependent variable, which can be either positive or negative [15]. Many researchers have used correlation and path coefficient analyses to examine the relationship between seed yield and other related components [16],[17], and [18]. Correlation analysis reveals the relationship between morphological traits and achene yield per plant. It can be partitioned into genetic and phenotypic correlations when the genetic association is stronger than the phenotypic correlation, and environmental effects do not significantly influence the relationship [19]. Additionally, [20] noted that path analysis can be used to gather more information about causes and identify both direct and indirect effects of causal components on the outcome.
This study aimed to determine the performance of genotypes and the impact of spring and summer planting dates, as well as to analyze the relationships and patterns between yield components and sunflower yield.

Materials and methods

The College of Agricultural Engineering Sciences at the University of Sulaimani conducted experiments with Qlyasan, a research station affiliated with the university (latitude: 35° 34′ 17″ N, longitude: 45° 22′ 00″ E, altitude: 757 masL). Two consecutive seasons were conducted in spring and summer of 2024, using a (Split-plot design) with three replications to assess the performance of four sunflower genotypes (SG): G1= BAROLO RO, G2= VELKO, G3= DEA, and G4= LOCAL. The researchers implemented these genotypes in the main plots and arranged with (CRBD), with three (PD) planting dates for each season arranged in the subplots: D1 = March 15, D2 = April 4, and D3 = April 24 for spring, and D1 = July 1, D2 = July 21, and D3 = August 10 for summer. Each replication included 12 experimental subplots. The subplot size was 5.4 m² and consisted of three rows spaced 0.60 m apart, with plants spaced 0.30 m apart within each row. Sunflower seeds were planted in a line at a depth of 3 to 5 cm. The climate is semi-arid, characterized by hot, dry summers and cold, wet winters. Researchers thinned seedlings to one plant per hole after germination. The recommended nitrogen fertilizer, in the form of urea, was applied in two equal doses: one when the plant had four true leaves and the other before flowering at a rate of 60 kg ha^{-1}. The researcher performed hand weeding and irrigation as needed. Then, after pollination, covered sunflower heads with a screen to protect them from bird attacks. Data were collected for PH (plant height cm), SD (stem diameter cm), HD (head diameter cm), HW (head weight g), EHW (empty head weight g), FSW (full seed weight g), ESW (empty seed weight g), # FS (number of full seeds $plant^{-1}$, 1000 SW (1000 seed weight g), K% (kernel percentage) and SY (seed yield kg ha^{-1}), from five randomly selected plants.

Results

The data in Table 1 display the performance of the genotypes for the studied characteristics during the spring and summer seasons. The differences among genotypes are highly significant for all characteristics studied, except for empty head weight and empty seed weight, which showed significant responses in the spring season and not significant effect for kernel percent. Genotype G1 demonstrated the best performance in terms of stem diameter, full seed weight, empty seed weight, number of full seeds $plant^{-1}$ and seed yield. Meanwhile, G2 exhibited the highest values for plant height, head diameter, head weight, empty head weight, and 1000 seed weight. Notably, G4 had the lowest values for almost all studied characteristics.
During the summer, the differences between genotypes are highly significant for head weight, empty head weight, full seed weight, the number of full seeds $plant^{-1}$, and seed yield. Significance was also observed for head diameter, empty seed weight, and 1000 seed weight, while the other characteristics were not significant. G1 shows the highest values for all significant characters, while G4 has the lowest values across all characteristics. A combined analysis of variance presented in Table 2 indicated that planting dates influenced the characteristics studied during the spring and summer seasons. In spring, the effect of planting dates was highly significant for plant height, head weight, full seed weight, empty seed weight, 1000 seed weight, and seed yield. Additionally, this effect was significant for stem diameter, and empty head weight; however, it was not significant for the other characteristics. The second planting date (D2) produced the highest values for significant characters, except for the empty seed weight, which recorded its maximum during the spring season with late planting (D3). Regarding the summer season, the influence of planting dates on head weight, full seed weight, and 1000 seed weight was significantly high. Although this influence was significant for empty head weight, empty seed weight, and seed yield, planting dates did not significantly affect the other attributes. The first planting date (D1) produced the highest significant values for the response variables, whereas D3 displayed the lowest significant values. The planting date of April 4 (D2) yielded the heaviest head weight (84.549 g) and the highest seed yield (2939.483 kg ha^{-1}) during the spring season. In contrast, the lowest seed yield recorded in any season was (2194.500 kg ha^{-1}) by D3 during the spring season. The data presented in Table 3 indicate the effects of the interaction between genotypes and planting dates on the characteristics studied during the spring and summer seasons. In spring, the interaction effect was highly significant for plant height, stem diameter, empty head weight, and empty seed weight, while it was significant for head weight. The interaction between G2 and D1 demonstrated maximum values for plant height and stem diameter, reaching 160.070 cm and 2.243 cm, respectively. In contrast, the interaction between G2 and D2 produced a maximum head weight of 104.649 g. The interaction of G3 with D2 showed the highest value for empty head weight, at 39.903 g. The interaction of G1 with D3 exhibited the maximum weight of empty seeds at 3.685 g. During spring, the lowest interaction values for the signified characters were between G4 and D2 and D3, except for empty seed weight, which was noted between G2 and D1. The table illustrates the interaction between genotypes and planting dates during the

summer season. Head diameter, head weight, full seed weight, number of full seeds plant^{-1}, and seed yield exhibited a highly significant response to this interaction effect. While stem diameter responded significantly to this effect, the other characteristics showed a non-significant response. The maximum values for stem diameter, head diameter, head weight, full seed weight, number of full seeds plant^{-1}, and seed yield were noted from the interaction between G1 and D2, with 1.638 cm, 15.970 cm, 95.471 g, 61.067 g, 1143.700, and 3392.680 kg ha^{-1}, respectively. G4 and D3 had the lowest interaction values for all the most significant characteristics.

Table 4 presents the correlation coefficients obtained between seed yield and all pairs of study characteristics during the spring season. The seed yield exhibited a highly significant and positive correlation with full seed weight (r = 0.930). In contrast, this characteristic showed a significant and positive correlation with head weight (r = 0.703). These results suggest that selection for full seed weight is also associated with higher seed yield in sunflower genotypes. A significant, positive correlation was observed between plant height and the number of full seeds per plant (r = 0.680). A highly significant negative correlation was observed between head diameter and the number of full seeds per plant (r = -0.808). Finally, the number of full seeds per plant showed a significant and positive correlation with 1000 seed weight (r = 0.709). The correlation coefficients among all pairs of study characteristics obtained during the summer season are presented in Table 5. Seed yield exhibited a highly significant positive correlation with stem diameter, head diameter, head weight, and full seed weight (r = 0.857, 0.962, 0.955, and 0.967, respectively). Additionally, seed yield showed a significant positive correlation with empty head weight and empty seed weight (r = 0.717 and 0.704, respectively). Conversely, a very strong negative correlation was found between this trait and the number of full seeds per plant (r = -0.795), and a significant positive correlation was observed between plant height and stem diameter (r = 0.670). Stem diameter showed a highly significant positive association with head diameter, head weight, and full seed weight (r = 0.758, 0.831, and 0.778, respectively). It also revealed a significant positive correlation with empty head weight and empty seed weight (r = 0.631 and 0.660). A highly significant positive correlation was found between head diameter with both head weight and full seed weight (r = 0.919 and 0.940). However, it also showed a significant positive correlation with empty head weight and empty seed weight (r = 0.726 and 0.685, respectively). In contrast, the correlation between head diameter and the number of full seeds per plant was highly significant but negative (r = -0.828). Head weight is associated with a highly significant positive correlation to empty head weight, full seed weight, and empty seed weight (r = 0.883, 0.943, and 0.778, respectively). Conversely, the correlation between head weight and the number of full seeds per plant is highly significantly negative (r = -0.819). The characteristic empty head weight exhibited a highly significant positive correlation with full seed weight and empty seed weight (r = 0.746 and 0.738, respectively). However, it is significantly negative in terms of the number of full seeds per plant (r = -0.716). Full seed weight demonstrated a significant positive correlation with empty seed weight (r = 0.639). However, it showed a highly significant negative correlation with the number of full seeds per plant (r = -0.822). Path coefficient analysis reveals distinct connections and the relative importance of the characteristics examined. It clarifies the correlations and accurately illustrates how the studied traits contribute to the dependent variable. Researchers analyzed the direct and indirect effects of various factors on sunflower seed yield over two seasons, considering these effects as the basis for selection to improve yield. In the spring season, as shown in Figure 1, among the variables, 1000 seed weight (1.485) had the most potent positive direct effect on seed yield, while the number of full seeds plant^{-1} (-1.846) had the lowest negative and worthless direct effect. The number of filled seeds per plant influenced the maximum positive and negative indirect effect (1.492; -1.309) effects of head diameter and 1000 seed weight on seed yield. The data presented in Figure 2 for the summer season show that head weight (0.441) has the strongest positive direct impact on seed yield. In contrast, empty head weight has the most significant adverse direct effect (-0.263). Additionally, full seed weight through head weight (0.416) has the strongest positive indirect effect. Meanwhile, the number of full seeds through head weight (-0.361) shows the strongest adverse indirect effect.

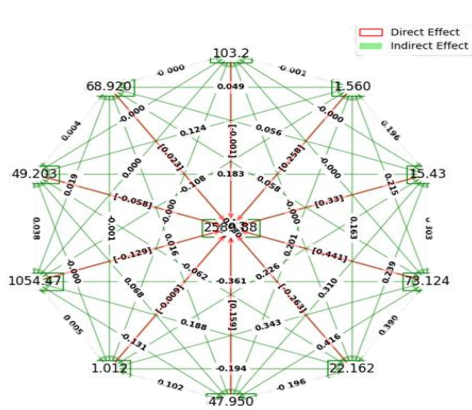

Figure 1: Direct and indirect effects on seed yield and the studied character during the spring season

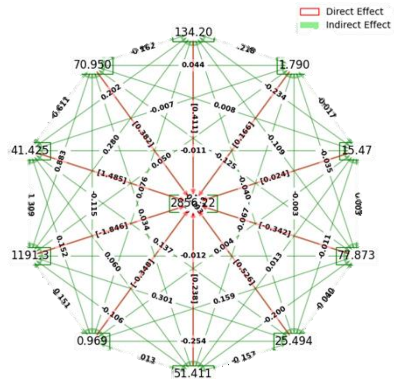

Figure 2: Direct and indirect effects on seed yield and the studied character during the summer season

Table 1: Effect of sunflower genotypes on the studied characters during both seasons

SG	PH	SD	HD	HW	EHW	FSW	ESW	# FS	1000 SW	K%	SY
					Spring Season						
G1	138.378	2.031	15.811	84.909	27.412	55.700	1.797	1281.333	43.098	71.74	3094.573
G2	149.956	1.996	15.833	85.520	30.936	53.469	1.114	1191.689	45.700	70.02	2970.582
G3	146.200	1.840	14.444	74.556	28.766	44.665	1.125	1064.089	41.773	71.44	2481.449
G4	127.800	1.540	13.422	50.163	19.497	29.373	1.293	839.044	33.630	68.47	1631.868
LSD 0.05	6.346**	0.159**	1.156**	14.313**	6.547*	7.804**	0.434*	133.385**	4.137**	N. S	676.795**
					Summer Season						
G1	96.844	1.530	15.733	90.816	31.576	58.270	0.971	1025.983	56.647	72.36	3237.292
G2	100.044	1.517	15.189	73.948	26.294	46.696	0.958	900.778	52.439	73.73	2594.290
G3	101.756	1.465	14.022	55.695	18.755	36.094	0.846	789.011	45.858	71.30	2005.287
G4	98.156	1.450	13.511	51.939	18.547	32.740	0.653	749.358	43.617	73.52	1818.910
LSD 0.05	N. S	N. S	1.300*	7.898**	5.305**	5.817**	0.189*	68.083**	7.390*	N. S	413.674**

LSD value for sunflower genotypes at $P \leq 0.01$ = Highly Significant $**$, LSD value at $P \leq 0.05$ = Significant $*$, N. S. = Staticaly Non Significant

Table 2: Effect of planting dates on the studied characters during both seasons.

PD	PH	SD	HD	HW	EHW	FSW	ESW	# FS	1000 SW	K%	SY
						Spring Season					
D1	143.200	1.907	14.458	71.204	25.287	44.997	0.921	1061.400	40.581	70.30	2499.870
D2	146.220	1.914	15.450	84.549	30.393	52.909	1.247	1164.667	45.222	70.05	2939.483
D3	132.330	1.734	14.725	65.608	24.279	39.500	1.829	1056.050	37.348	70.91	2194.500
LSD 0.05	5.561**	0.158*	N.S.	9.769**	4.435*	5.958**	0.342**	N.S.	4.189**	N.S.	409.455**
						Summer Season					
D1	98.780	1.522	14.992	74.768	26.762	46.936	1.070	890.358	53.602	71.10	2607.640
D2	99.730	1.471	14.500	65.641	23.024	41.785	0.832	854.233	48.067	73.13	2321.432
D3	99.080	1.479	14.350	63.891	21.593	41.629	0.669	854.254	46.252	73.96	2312.761
LSD 0.05	N.S.	N.S.	N.S.	5.587**	3.241*	3.330**	0.266*	N.S.	3.666**	N.S.	257.916*

LSD value for sunflower planting dates at $P \leq 0.01$ = Highly Significant **, LSD value at $P \leq 0.05$ = Significant * , N.S. = Staticaly Non Significant

Table 3: The interaction effects between sunflower genotypes and planting dates during both seasons.

SG & PD		PH	SD	HD	HW	EHW	FSW	ESW	# FS	1000 SW	K %	SY
						Spring Season						
G1	D1	135.330	1.803	15.000	68.459	17.006	50.651	0.802	1176.400	41.446	68.87	2814.030
	D2	136.730	2.070	15.930	97.217	32.461	63.853	0.903	1358.500	48.170	71.27	3547.460
	D3	143.070	2.220	16.500	89.051	32.768	52.599	3.685	1309.100	39.678	75.10	2922.220
G2	D1	160.070	2.243	14.530	81.386	30.101	50.563	0.723	1022.800	50.120	70.10	2809.110
	D2	156.200	2.067	17.400	104.649	36.434	66.621	1.594	1360.500	49.324	69.63	3701.240
	D3	133.600	1.677	15.570	70.524	26.274	43.224	1.026	1191.700	37.657	70.33	2401.390
G3	D1	153.800	1.997	14.530	77.033	27.527	48.299	1.206	1175.100	39.678	71.21	2683.370
	D2	159.930	1.990	14.400	91.439	39.903	50.563	0.974	1030.000	49.467	71.63	2809.150
	D3	124.870	1.533	14.400	55.196	18.869	35.132	1.195	987.130	36.174	71.48	1951.830
G4	D1	123.600	1.583	13.770	57.939	26.514	30.473	0.952	871.270	31.080	71.00	1692.970
	D2	123.000	1.530	14.070	44.892	12.773	30.601	1.518	909.600	33.925	67.67	1700.080
	D3	127.800	1.507	12.430	47.660	19.203	27.045	1.411	736.270	35.883	66.73	1502.550
LSD 0.05		11.121**	0.315**	N.S.	19.538*	8.870**	N.S.	0.685**	N.S.	N.S.	N.S.	N.S.
						Summer Season						
G1	D1	101.600	1.573	15.530	89.194	31.501	56.494	1.199	965.000	59.563	71.50	3138.640
	D2	95.930	1.638	15.970	95.471	33.337	61.067	1.067	1143.700	52.665	72.45	3392.680
	D3	93.000	1.380	15.700	87.785	29.890	57.249	0.647	969.220	57.713	73.14	3180.560

G2	D1	92.000	1.437	14.680	74.381	27.532	46.045	0.805	777.730	59.990	71.10	2558.100
	D2	104.400	1.509	15.900	71.423	24.054	46.311	1.058	940.000	49.137	72.45	2572.920
	D3	103.330	1.615	15.000	76.041	27.297	47.732	1.013	984.600	48.189	77.63	2651.850
G3	D1	98.470	1.517	14.370	64.693	24.704	38.924	1.066	820.770	46.891	71.52	2162.500
	D2	100.070	1.367	12.720	46.746	16.765	29.205	0.776	652.400	45.762	71.86	1622.560
	D3	106.730	1.523	15.000	55.646	14.797	40.153	0.696	893.870	44.925	70.52	2230.800
G4	D1	102.670	1.583	15.400	70.803	23.310	46.283	1.210	997.930	47.963	70.26	2571.320
	D2	98.530	1.371	13.430	48.907	17.940	30.555	0.428	680.800	44.707	75.77	1697.560
	D3	93.270	1.396	11.700	36.092	14.390	21.381	0.321	569.330	38.182	74.54	1187.850
LSD 0.05		N.S.	0.212*	1.116**	11.174**	N.S.	6.659**	N.S.	183.864**	N.S.	N.S.	515.832**

LSD value for the interaction between sunflower genotypes and planting dates at $P \leq 0.01$ = *Highly Significant* $**$, *LSD value at* $P \leq 0.05$ = *Significant* $*$, *N.S.* = *Staticaly Non Significant*

Table 4**:** Simple correlation among all pairs of characters during the spring season.

Characters	SY	PH	SD	HD	HW	EHW	FSW	ESW	# FS	1000 SW	K%
SY	1.000										
PH	-0.315	1.000									
SD	-0.264	0.530	1.000								
HD	0.491	-0.569	-0.101	1.000							
HW	0.703*	-0.266	-0.213	0.127	1.000						
EHW	-0.208	-0.097	-0.019	-0.467	0.117	1.000					
FSW	0.930**	-0.416	-0.404	0.556	0.585	-0.298	1.000				
ESW	-0.056	0.185	0.248	0.163	-0.465	-0.483	-0.055	1.000			
# FS	-0.331	0.680*	0.304	-0.808**	0.035	0.573	-0.445	-0.435	1.000		
1000 SW	0.381	0.492	-0.044	-0.458	0.504	0.261	0.254	-0.438	0.709*	1.000	
K%	0.244	-0.395	0.264	0.314	0.366	-0.176	0.142	0.332	-0.478	-0.411	1.000

$**$ *Significant at* 0.01 *probability level*; $*$ *Significant at* 0.05 *probability level*

Table 5**:** Simple correlation among all pairs of characters during the summer season.

Characters	SY	PH	SD	HD	HW	EHW	FSW	ESW	# FS	1000 SW	K%
SY	1.000										
PH	0.447	1.000									
SD	0.857**	0.670*	1.000								
HD	0.962**	0.366	0.758**	1.000							
HW	0.955**	0.360	0.831**	0.919**	1.000						
EHW	0.717*	0.168	0.631*	0.726*	0.883**	1.000					
FSW	0.967**	0.350	0.778**	0.940**	0.943**	0.746**	1.000				
ESW	0.704*	0.237	0.660*	0.685*	0.778**	0.738**	0.639*	1.000			
# FS	-0.795**	-0.083	-0.418	-0.828**	-0.819**	-0.716*	-0.822**	-0.518	1.000		
1000 SW	0.464	0.434	0.478	0.555	0.392	0.235	0.427	0.047	-0.296	1.000	
K%	0.254	0.007	0.189	0.171	0.132	-0.112	0.098	0.085	-0.149	-0.069	1.000

$**$ *Significant at* 0.01 *probability level*; $*$ *Significant at* 0.05 *probability level*

Discussion

The study demonstrated a significant effect of sunflower genotypes. Notably, genotype G1 outperformed all other genotypes in terms of seed yield and most of the characteristics studied during both seasons. The differences among genotype values may arise from how each genotype responds to varying seasonal conditions. The largest head diameter and the number of full seeds per plant resulted in the highest seed production during the spring and summer seasons. [21] suggested that identifying sunflower genotypes suitable for the region would create opportunities to obtain high-yielding and high-quality products, as the soil, environment, and climatic factors of their growing region are key in determining seed yield and oil content. However, [22] found that the same cultivar excelled in terms of seed number per disc and seed yield across different seasons. In our study, different sunflower genotypes produced plants with varied growth and yield characteristics, consistent with the results of [23] and [24]. Additionally, [25] recorded a high variation among 25 sunflower genotypes.

The study revealed a significant influence of sunflower planting dates; therefore, the increase in seed yield depends on the planting date. Especially, D2 and D1 during the spring and summer seasons lead to a rise in head weight, full seed weight, and 1000-seed weight, ultimately resulting in the highest seed yield in both seasons. Our study reveals that D2 (April planting date) yielded the highest seed yield compared to the other dates. Planting dates, especially in April, can significantly influence seed yield in semi-arid regions with limited growing seasons [24],[26]. Furthermore, our results, consistent with those of [27], indicate that for planting dates in April and May, April yields the highest full seed weight and 1000 seed weight, ultimately resulting in the maximum seed yield. From this, it is clear that the planting date is one of the most important agricultural practices to study, particularly its impact on promising sunflower hybrids.

The interaction effect of G1 with D2 during the summer season was significantly notable. This significance was evident through increases in stem diameter, head diameter, head weight, full seed weight, and the number of full seeds plant^{-1} when compared to other combinations of sunflower genotypes and planting dates. The larger head size of the G1 (Barolo RO) genotype, combined with the second planting date (D2), resulted in the highest yield of sunflowers; this may be significantly influenced by plant genetics and temperature, as noted by [28]. Furthermore, the interaction between planting date and cultivar significantly influenced plant height, head diameter, and seed yield [29].

The correlation coefficient between seed yield and several studied traits was highly significant and positive in both consecutive seasons. The selection of stem diameter, head diameter, head weight, and full seed weight demonstrated a highly significant and positive correlation with seed yield, indicating a strong inherent relationship between these traits and higher sunflower seed yield. [30] found that the seed weight of sunflowers had a significant correlation with seed yield. However, in the literature, similar positive significant correlations are observed between seed yield and these characteristics [30]. Generally, sunflower plants with larger head diameters tend to have heavier heads and greater seed weights per plant, as shown by [32], [33],[34],[35],[36] and [37], making head diameter a valuable criterion for improving achene yield in sunflower. On the other hand, [38] demonstrated that most traits exhibit higher genetic correlation coefficients than their corresponding phenotypic correlation coefficients, as the relationship was influenced by environmental factors at the phenotypic level, resulting in lower phenotypic correlation coefficients.

This study showed that increasing the weight of 1000 seeds and sunflower heads would improve seed yield. Therefore, selecting genotypes with high seed yields would be more effective if it involved choosing the heaviest 1000 seeds and heads. Path coefficient analysis showed that 1000-seed weight and head weight have the most potent positive direct effects on seed yield. A notable direct influence on achene yield was exerted by 100 achene weights [39]. This study's results align with those of [40], who found that 1000-seed weight has a positive effect on grain yield. Conversely, head diameter and full seed weight exhibited the highest positive indirect effects on seed yield through the number of full seeds and head weight. These indirect effects occur via the number of full seeds plant^{-1} and head weight, which our study identified as the most crucial yield components across consecutive seasons. The results align with [41]. These results suggest that selection should focus on head diameter and full seed weight. When making decisions, both direct and indirect effects through intermediary variables must be considered, as strong indirect effects can significantly influence outcomes [42].

Conclusion

Sunflower performance is affected by genotype and planting date. Planting date is a management practice used to maximize yield. Our results generally indicate that the sunflower genotype Barolo RO produces the best crop growth and seed yield when planted on April 4th in the spring and July 1st in the summer in the region. The result demonstrates that genotypes can be particularly useful for analyzing environmental factors, such as planting dates. The increased yield was mainly due to a larger head diameter, higher seed weight, and a greater number of seeds per plant. Highly significant positive correlations were found between seed yield and stem diameter, head diameter, head weight, and full seed weight in our study, suggesting that sunflower genotypes have higher seed yield. Path coefficient analysis distinguished the direct and indirect effects of yield components on sunflower seed yield. Researchers found that head weight and 1000-seed weight are key seed yield components that should be used as selection criteria in sunflower production. Additionally, head diameter and full seed weight can serve as indirect selection criteria to improve seed yield.

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تأثير التراكيب الوراثية ومواعيد الزراعة على إنتاج البذور ومكوناته لدوار الشمس (Helianthus annuus L.)

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الخلاصة

تؤثر عوامل رئيسية، وهي التراكيب الوراثية لدوار الشمس ومواعيد الزراعة، بشكل كبير على إنتاج بذور دوار الشمس. تبحث هذه الدراسة العلاقة بين محصول دوار الشمس ومكوناته. أُستخدم تصميم القطع المنشقة بثلاثة مكررات خلال موسمين في موقع قلياسان عام ٢٠٢٤. شملت القطع المنشقة مواعيد الزراعة في الربيع (١٥ آذار، ٤ نيسان، و٢٤ نيسان) وفي الصيف (١ تموز، ٢١ تموز، و١٠ آب). تضمنت القطع الرئيسية أربعة أصناف من دوار الشمس (***Barolo Ro***، ***VELKO***، ***DEA*** و***LOCA***). أظهرت النتائج وجود فروقات معنوية بين الأصناف في حاصل البذور، حيث حقق صنف ***BAROLO RO*** أعلى حاصل بذور (٣٠٩٤,٥٧٣ كغ/هـ و٣٢٣٧,٢٩٢ كغ/هـ) في كلا الموسمين. أما بالنسبة لمواعيد الزراعة، فقد حقق ٤ نيسان و١ تموز أعلى حاصل البذور (٢٩٣٩,٤٨٣ كغ/هـ و٢٦٠٧,٦٤٠ كغ/هـ) في الربيع والصيف على التوالي. كشفت النتائج عن وجود علاقة إيجابية عالية المعنوية بين حاصل البذور ووزن البذور الممتلئة (معامل ارتباط = ٠,٩٣٠) خلال موسم الربيع. كما أظهر الارتباط بين حاصل البذور وصفات أخرى، مثل قطر الساق، وقطر الراس، ووزن الراس، ووزن البذور الممتلئة، علاقة معنوية (معامل ارتباط = ٠,٨٥٧، ٠,٩٦٢، ٠,٩٥٥، و٠,٩٦٧) في موسم الصيف. ساهم تحليل معامل المسار في تفكيك الارتباط إلى تأثيرات مباشرة وغير مباشرة. حيث سجل وزن الألف بذرة ووزن الراس أعلى تأثير مباشر إيجابي (١,٤٨٥؛ ٠,٤٤١) في الربيع والصيف على التوالي. بينما كان أعلى تأثير غير مباشر (١,٤٩٢) لقطر الراس من خلال عدد البذور الممتلئة لكل نبات، و(٠,٤١٦) لوزن البذور الممتلئة من خلال وزن الراس خلال موسمي الربيع والصيف. تشير النتائج إلى أن الاختيار المعتمد على قطر الرأس، ووزن الرأس، ووزن الألف بذرة، ووزن البذور الممتلئة، وعدد البذور الممتلئة لكل نبات سيكون أكثر فعالية في تحسين المحصول.

الكلمات المفتاحية: عباد الشمس، تاريخ الزراعة، النمط الوراثي لعباد الشمس، الارتباط، تحليل المسار.