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Genetic Analysis of F_3 and F_4 Generations from Two Bread Wheat Crosses under Optimum and Late Sowing Dates

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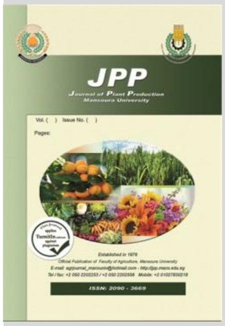

ABSTRACT

This Research was performed to assess the relative response to the selection in F_3, and F_4 generation of two bread wheat crosses under optimum (15November), and late (15 December) sowing date using pedigree selection methods. The findings showed that the selected families or genotypes under study exhibited genetic diversity for the studied traits. Significant differences were found among the parents, F_3 and F_4 families for most of the studied characters under both sowing dates. The means of studied characters of parents, F_3 and F_4 families decreased under the late sowing date. The extent of genetic variance among F_3 and F_4 families was higher than that among families, and plants within families and the equivalent environmental variance in most traits. The additive genetic variance components were greater than corresponding dominance for most of the studied traits. The broad sense heritability estimates were high for all the studied traits in both F_3 and F_4 families, while the values of narrow sense heritability, ranged from low to moderate for most of the studied traits under both sowing dates. The final selection identified four superior families from each cross recorded higher grain yield than their respective parents and exhibited days to maturity within the range of their respective parents, with significant or non-significant differences and will be further evaluated in the next season as F_5 families to select the best-performing lines with the highest grain yield with early maturity.

Keywords: *Bread wheat, sowing dates, Heritability*

INTRODUCTION

Bread wheat is a crucial cereal crop produced globally, serving as a key export and strategic commodity (Kumar et al 2013).

The date of sowing is a critical factor influencing the crop's phonological development and the efficient conversion of biomass into economic yield. Wheat yield is particularly sensitive to late sowing, as it often encounters high temperatures during the grain filling stage, ultimately resulting in decreased yields. Late sowing can result from various factors, such as preceding crops like potatoes or onions. This delay can cause grain yield reductions ranging from 33 to 54%, primarily as a result of heat stress during the stages of grain filling, which resulting aberrant or shriveled grains and reduces total yield.

Genetic variation is essential for manipulating new characters during breeding programs. Genetic variability is necessary for plant breeder to rapidly and successfully improve crops since a diverse population might provide superior genotypes (Holme et al., 2019).

Historically, breeders have selected superior individuals based on phenotypic traits, as indicators of breeding value that reflects the expected performance of their progeny. To enhance the accuracy of breeding value estimation, pedigree-based predictions have been incorporated (Piepho et al., 2008).The success of selection breeding methods for improving quantitative traits relies on the degree of the genetic variation in the segregating population, and the type of gene action. Additionally, the amount of genetic variation within and between families across generations significantly influences the timing and method of selection. Various biometric analyses have been used to estimate these variations (.Mather and Jinks, 1982, Kearsey and Pooni, 1996, and Hallauer et al, 2010).

Local climate and micrometeorological variations are crucial in determining optimal sowing dates for specific locations, as the relationship between maximum temperatures and sowing date provides valuable predictions for growth period in different wheat growing regions (French et al., 1979). Previous studies indicated the importance of understanding the wheat crop responses to weather changes to assess the effect of seasonally temperature variations, also predict yield dependency on temperature increases (Kalra et al., 2008).

This research aims to study the genetic behavior of specific traits in F_3 and F_4 families derived from two bread wheat crosses evaluated during optimal, and delayed sowing. Besides, identifying high-yielding families with early maturing and examining the genetic variability in F_3 and F_4 under early and late sowing dates to facilitate effective selections for yield and earliness improvement.

MATERIALS AND METHODS

This current research was carried out at the research farm of Sakha Agricultural Research Station over three growing seasons from 2021/2022 to 2023/2024 under optimal and late sowing dates. The study involved two crosses: the first was Sakha 96 × Line 1, and the second was Line 2 × Line 3. The pedigrees of the four parents are presented in Table 1. The recorded highest and lowest temperatures at Sakha Agricultural Research Station from November to May of the 2022/2023 and 2023/2024 growing seasons are presented in Fig.1.

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Table 1. Pedigree, selection history, and earliness of maturity of the wheat genotypes used in the study.

Genotypes	Pedigree and selection history	Earliness
P_1 (Sakha 96)	MINO /6/ SAKHA 12 /5/ KVZ // CNO 67 / PJ 62 /3/ YD "S" / BLO "S" /4/ K 134 (60) / VEE. S.16869-010S-07S-1S-2S-0S.	Early
P_2 (Line 1)	CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /3/ 2*KAUZ /4/ HAAMA-11. S. 16276 -018S-010S-3S-0S.	Moderate
P_3 (Line 2)	SIDS1/ ATTILA. // GOUMRIA-17. S. 16498-042S-013S-21S -0S	Early
P_4 (Line 3)	SITTA/CHIL//IRENA /6/ GIZA 168 /5/ MAI "S" / PJ // ENU "S" /3/. KITO / POTO. 19 // MO / JUP /4/ K 134 (60) / VEE.. S. 16616 -018S -015S-2S -0S.	Moderate

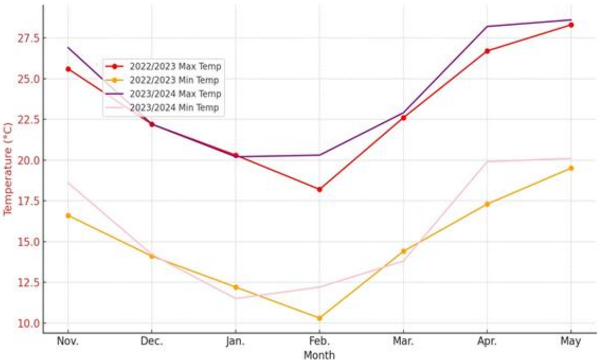

Fig. 1. Recorded highest, and lowest temperatures throughout the study seasons of 2022/2023 and 2023/2024 from (November to May).

During the 2021/2022 growing season, 60 individual plants from the F_2 generation, selected for high yield and early maturity based on previous studies were grown as F_3 families in the 2022/2023 season. These families were sown on two planting dates: November 15th (optimal sowing date), and December 15th (delayed planting date).

In 2023/2024 growing season 40 superior F_3 families were selected and grown as F_4 families under the same two sowing dates.

The study employed a randomized complete block design (RCBD) with three replications for each sowing date. In the F_3 generation, each cross comprised of 62 rows per replicate: one row for each parents (P_1 and P_2) and 60 rows for the F_3 families (one row per family). For the F_4 generation, each cross consisted of 42 rows per replicate: one row for each parents, and 40 rows for the F_4 families.

In both the F_3 and F_4 generations each row was three meters long, spaced 30 cm apart. The grains were spaced 20 cm within rows, averaging fifteen individual plants per row. Five plants per replicate were sampled from each F_3 and F_4 family and from each parent totaling 15 plants per family or parent.

The recorded traits for the parents and both F_3 and F_4 families included days to heading (DH), days to maturity (DM), grain filling period (GFP), grain filling rate(GFR), number of kernels per spike **(**K/S**)**, number of spikes per plant **(S/P)**, 100-kernels weight (100KWT) and grain yield per plant (GY/P). All other recommended agronomic practices for wheat production in the study region were followed.

Statistical analysis and genetic parameters:

Analysis of data was carried out using Microsoft Excel's features. The variances of the basic generations for every cross, involving the four populations (P_1, P_2, F_3, and F_4) were analyzed on both plot mean, and single levels using the methodology suggested by Hallauer et al..(2010), as presented in Table 2.

Table 2. Analysis of variance for F_3 and F_4 families.

Source of variance	DF	Mean squares	Expected mean squares
Replications (R)	r-1		
Among Families (F)	f-1	M_1	$\sigma^2_e + \sigma^2_{wg} + n\sigma^2_1 + nr\sigma^2_{F3,F4}$
R × F (Error)	(r-1)(f-1)	M_2	$\sigma^2_e + \sigma^2_{wg} + n\sigma^2_I$
Plants within Families	(n-1) rf	M_3	$\sigma^2_e + \sigma^2_{wg}$

where r, f and n are the number of replications, F_3, and F_4 families and plants within every family,. respectively. M_1, M_2 and M_3 refer the mean squares for F_3 and F_4 families, replications × F_3 and F_4 families and the plants within the F_3 and F_4 families. Meanwhile, σ^2_e represents the average within plot variances of non-segregating generations calculated as $(VP_1 + VP_2 + VF_1)/3$...

Additionally, σ^2_{wg} equal to the genetic variance among plants within F_3 and F_4 families. Moreover, σ^2_I reflects the environmental effect on plots of the F_3 and F_4 families. Meanwhile, σ^2 F_3, F_4 indicate the genetic variance among F_3 and F_4 families.

F test was conducted to assess whether the differences among F_3 and F_4 families were significant; if,

$$\sigma^2_{F3,F4} = (M_1 - M_2)/rn = \sigma^2_A + 1/4\sigma^2_D \text{ and}$$

$$\sigma^2_{wg} = M_3 - \sigma^2_e = 1/2\sigma^2_A + 1/2\,\sigma^2_D.$$

Where, σ^2_A and σ^2_D denote the additive and dominance variances, respectively

$$\sigma^2_A = 2/3\,(2\sigma^2_{F3,F4} - \sigma^2_{wg})$$

$$\sigma^2_D = 4(\sigma^2_{F3,F4} - \sigma^2_A).$$

In addition, the heritability in the (h^2_b), and (h^2_n) for F_3 and F_4 generations were estimated as following:

$$h^2_b = (\sigma^2_A + 1/4\sigma^2_D) / (\sigma^2_A + 1/4\sigma^2_D + E_2) \times 100 \text{ and}$$

$$h^2_n = (\sigma^2_A) / (\sigma^2_A + 1/4\sigma^2_D + E_2) \times 100. \text{ Where, } E_2 = (M_2 - M_3)/n.$$

RESULTS AND DISCUSSION

Analysis of variance.

The analysis revealed highly significant differences among genotypes for all the studied traits in both F_3 and F_4 generations under optimal and late sowing dates in the two studied crosses (Tables 3, 4, 5 and 6). These results suggest a considerable genetic variation among the selected families or genotypes concerning the traits under study, suggesting a higher potential for response to selection in the progenies of these crosses. Similar findings were reported by Saleh (2017), Aglan and Farhat (2014), Darwish *et al* (2018), and Abdallah *et al* (2019), who noted a large variability for various traits among wheat genotypes.

Mean performance of wheat genotypes

The mean value of the parents and their F_3 and F_4 families and a range of F_3 and F_4 families means for the studied traits in the two crosses under optimum and late sowing dates, are presented in Tables 7, 8, 9 and 10.

The optimal sowing date exhibited higher mean values for all traits in the parents, F_3 and F_4 families compared to the late sowing date. These results may be due to the favorable temperatures conditions during the different growth stages under the optimum date of sowing, which facilitated an adequate grain filling period and, enhanced the net assimilation rate. Similar outcomes were reported by Aglan and Farhat (2014) and Sharshar *et al* (2020).

Table 3. Analysis of variance for days to heading (DH), days to maturity (DM), grain filling period (GFP) and grain filling rate (GFR) in F_3 families of the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Source of variation	DF	DH		DM		GFP		GFR	
			OS	LS	OS	LS	OS	LS	OS	LS
C1	Replication (R)	2	3.64	4.71	13.92	51.7	34.39	317.14	3.62	3.22
	Among F_3 families (F)	59	190.24**	530.33**	92.80**	151.77**	507.30**	463.20**	4.06**	2.11**
Sakha 96 × Line 1	R × F (Error)	118	1.29	16.73	6.25	12.2	49.82	23.09	0.30	0.15
	Plants within F_3 families	720	15.18	36.04	7.92	9.17	35.94	40.34	0.31	0.2
	T test between the two parents		**	**	**	*	**	ns	**	**
C2	Replication (R)	2	3.68	17.65	8.7	36.24	3.95	0.25	0.12	0.27
	Among F_3 families (F)	59	322.74**	265.96**	93.36**	100.29**	494.60**	414.73**	2.89**	4.23**
Line 2 × Line 3	R × F (Error)	118	13.06	64.83	6.04	13.87	14.37	28.54	0.14	0.13
	Plants within F_3 families	720	21.76	15.33	6.36	6.96	33.53	34.46	0.21	0.37
	T test between the two parents		**	**	**	**	**	**	**	ns

***and ** significant at 0.05 and 0.01 levels of probability, respectively**

Table 4. Analysis of variance for days to heading (DH), days to maturity (DM), grain filling period (GFP) and grain filling rate (GFR) in F_4 families of the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Source of variation	DF	DH		DM		GFP		GFR	
			OS	LS	OS	LS	OS	LS	OS	LS
C1	Replication (R)	2	207.30	188.90	107.20	9.30	22.80	113.10	0.30	0.5
	Among F_4 families (F)	39	366.80**	240.20**	199.60**	223.60**	212.60**	158.20**	0.60**	0.60**
Sakha 96 × Line 1	R × F (Error)	78	35.80	29.90	6.30	0.90	15.10	17.60	0.02	0.00
	Plants within F_4 families	480	7.50	7.30	4.40	8.50	5.90	5.30	0.00	0.00
	T test between the two parents		**	**	**	*	**	**	**	**
C2	Replication (R)	2	43.58	50.78	8.01	17.75	3.67	3.57	0	0.16
	Among F_4 families (F)	39	595.08**	637.62**	273.23**	130.11**	245.06**	244.88**	3.55**	3.06**
Line 2 × Line 3	R × F (Error)	78	8.83	8.72	10.21	7.77	5.08	7.2	0.06	0.04
	Plants within F_4 families	480	16.17	20.02	6.65	4.72	6.57	9.11	0.07	0.08
	T test between the two parents		**	**	**	**	ns	**	**	**

***and ** significant at 0.05 and 0.01 levels of probability, respectively**

Table 5. Analysis of variance for plant height (PH), number of kernels per spike (K/S), number of spikes per plant (S/P), 100-kernel weight (100KWT), and grain yield per plant (GY/P) in F_3 families of the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Source of variation	DF	PH		K/S		S/P		100 KWT		GY/P	
			OS	LS	OS	OS	LS	OS	LS	LS	OS	LS
C1	Replication (R)	2	36.52	381.4	64.41	0.56	20.46	43.09	2.63	3.43	94.41	130.53
	Among F_3 families (F)	59	107.65**	383.2**	2345.52**	2293.03**	458.18**	754.59	9.67**	8.34**	2195.44**	1496.42**
Sakha 96×Line 1	R × F (Error)	118	12.52	12.2	93.57	456.98	26.95	72.96	0.69	0.83	144.57	133.58
	Plants within F_3 families	720	11.63	33.6	194.67	160.32	36.28	85.82	0.67	0.83	162.24	125.89
	T test between the two parents		**	**	**	**	**	**	**	*	**	**
C2	Replication (R)	2	126.75	111.81	81.84	117.63	104.87	15.48	1.56	1.61	22.43	99.36
	Among F_3 families (F)	59	1526.56**	1432.18**	2289.07**	2027.51**	562.48**	528.37**	11.83**	8.21**	2497.06**	4741.28**
Line 2 × Line 3	R × F (Error)	118	76.22	82.85	146.71	231.88	61.82	48.43	0.76	0.87	64.31	159.98
	Plants within F_3 families	720	87.57	90.52	185.71	170.86	61.38	55.51	0.79	0.68	222.38	499.64
	T test between the two parents		**	**	**	**	**	**	**	ns	**	**

***and ** significant at 0.05 and 0.01 levels of probability, respectively**

Table 6. Analysis of variance for plant height (PH), number of kernels per spike (K/S), number of spikes per plant (S/P), 100-kernel weight (100KWT), and grain yield per plant (GY/P) in F_4 families of the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Source of variation	DF	PH		K/S		S/P		100 KW		GY/P	
			OS	LS	OS	OS	LS	OS	LS	LS	OS	LS
C1	Replication (R)	2	163.5	100.3	73.6	84.8	562.5	508.9	1.3	3.7	165.4	238.4
	Among F_4 families (F)	39	829.5**	761.2**	535.4	535.4**	661.8**	221.2**	8.2**	5.4**	571.8**	594.5**
Sakha 96 × Line 1	R × F (Error)	78	69	32.9	8.7	11.2	20.1	9.7	0.5	0.5	11.5	19.5
	Plants within F_4 families	480	21.3	24.1	10.6	18.1	31.3	13.4	0.3	0.3	20.5	26.9
	T test between the two parents		**	**	**	**	**	**	ns	ns	**	**
C2	Replication (R)	2	78.78	127.39	65.1	43.56	365.65	386.53	0.13	0.62	60.55	8.73
	Among F_4 families (F)	39	777.73**	721.46**	700.61**	778.88**	339.69**	224.12**	11.31**	6.79**	804.42**	796.21**
Line 2 × Line 3	R × F (Error)	78	15.78	24.11	10.97	14.8	14.66	12.77	0.15	0.08	19.46	19.06
	Plants within F_4 families	480	19.91	23.11	18.51	22.81	19.29	20.22	0.41	0.38	30.43	41.08
	T test between the two parents		**	**	**	**	ns	**	**	**	**	**

***and ** significant at 0.05 and 0.01 levels of probability, respectively**

Table 7. Means of parents and their F_3 families, and the reduction percentage (R%) due to late sowing for days to heading (DH) , days to maturity (DM), grain filling period (GFP), and grain filling rate (GFR) in the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Population	DH			DM			GFP			GFR		
	OS	LS	R. %	OS	LS	R. %	OS	LS	R. %	OS	LS	R. %
P_1 (Sakha 96)	75.60	67.33	21.34	134.87	130.60	3.17	58.87	39.73	32.51	1.61	1.30	19.25
P_2 (Line 1)	89.60	73.13	18.38	135.73	130.93	3.54	54.40	39.73	27.97	2.13	1.64	23.00
P_3 (Line 2)	86.21	71.76	16.67	133.73	131.13	1.94	50.53	41.27	18.33	2.20	1.40	36.36
P_4 (Line 3)	89.53	76.40	14.67	139.60	136.33	2.34	52.53	42.80	18.52	1.88	1.38	26.60
C1 (mean) Sakha 96 × Line 1	86.20	72.90	15.43	135.40	132.30	2.29	49.6	33.4	32.66	2.3	1.70	26.09
Min	73	64		127	128		37.0	21.10		1.23	1.10	
Max	90	87		142	144		58.3	41.90		3.70	2.50	
C2 (mean) Line 2 × Line 3	91.2	75.7	17.00	139.90	135.40	3.20	52.10	44.90	13.82	2.00	1.60	20.00
Min	73	66		130	130		35.60	35.70		1.20	0.60	
Max	96	80		147	143		65.30	57.70		2.90	2.50	

Table 8. Means of parents and their F_4 families, and the reduction percentage (R%) due to late sowing for days to heading (DH), days to maturity(DM), grain filling period (GFP), and grain filling rate (GFR) in the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Population	DH			DM			GFP			GFR		
	OS	LS	R. %	OS	LS	R. %	OS	LS	R. %	OS	LS	R. %
P_1 (Sakha 96)	74.50	67.30	9.70	135.10	130.6	3.40	52.20	46.6	10.7	1.44	1.31	9.02
P_2 (Line 1)	79.60	73.10	8.10	134.60	130.90	2.70	47.10	41.0	12.9	1.43	1.35	5.59
P_3 (Line 2)	86.00	71.70	16.70	134.00	131.10	2.00	48.50	34.7	28.3	2.10	1.68	20
P_4 (Line 3)	89.50	76.40	14.70	139.60	136.10	2.50	48.10	33.3	30.7	1.85	1.52	17.8
C1 (mean) Sakha 96 × Line 1	87.50	78.40	10.40	138.30	135.00	2.4	45.50	37.40	17.80	1.60	1.3	18.75
Min	66.	68		130	126		38.80	32.50		0.90	0.90	
Max	94	90		150	147		60.00	50.50		1.90	2.40	
C2 (mean) Line 2 × Line 3	105.00	98.80	5.90	147.30	140.30	4.80	29.80	26.00	12.80	2.30	1.50	37.80
Min	84	82		134	127		20.50	18.50		0.90	0.70	
Max	116	110		157	148		47.70	38.30		4.30	3.10	

Table 9. Means of parents and their F_3 families, and the reduction percentage (R%) due to late sowing for plant height (PH) , number of kernels per spike (K/S), number of spikes per plant (S/P), 100-kernel weight (100KWT), and grain yield per plant (GY/P) in two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Population	PH			K/S			S/P			100KWT			GY/P		
	OS	LS	R%	OS	LS	R%	OS	LS	R%	OS	LS	R%	OS	LS	R%
P_1 (Sakha 96)	103.67	93.00	10.29	55.33	48.20	12.89	24.60	19.13	22.24	5.18	4.12	20.46	72.25	63.64	11.92
P_2 (Line 1)	87.00	69.00	20.69	50.00	45.53	8.94	28.07	22.33	20.45	4.68	3.85	17.74	59.69	56.54	5.28
P_3(Line 2)	97.67	76.67	21.50	59.40	52.40	11.78	41.00	25.00	39.02	5.06	4.86	5.14	69.27	66.42	4.11
P_4(Line 3)	103.67	82.00	20.90	62.73	56.27	10.30	38.60	22.40	41.97	4.86	4.80	0.62	75.51	60.73	19.57
C1 (mean) Sakha 96 × Line 1	121.2	101.3	16.42	59.0	47.6	19.32	27.00	20.90	22.59	5.40	4.30	25.93	83.90	75.80	9.65
Min	70	65		20	27		17	10		2.00	1.70		56.00	52.60	
Max	130	120		84	75		39	34		6.50	6.00		102.5	92.30	
C2 (mean) Line 2 × Line 3	95.80	76.40	20.25	60.8	57.6	5.26	31.80	26.80	15.72	4.90	4.00	12.24	94.00	70.10	25.43
Min	77	60		40	36		19	16		1.60	1.60		45.00	38.70	
Max	114	93		89	80		43	38		7.00	6.50		120.10	98.20	

Table 10. Means of parents and their F_4 families, and the reduction percentage (R%) due to late sowing for plant height (PH), number of kernels per spike (K/S), number of spikes per plant (S/P), 100-kernel weight (100KWT), and grain yield per plant (GY/P) in two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Population	PH			K/S			S/P			100KWT			GY /P		
	OS	LS	R%	OS	LS	R%	OS	LS	R%	OS	LS	R%	OS	LS	R%
P_1 (Sakha 96)	103.70	93.00	9.40	54.50	45.30	16.80	22.50	19.10	15.40	5.10	4.40	12.90	72.20	61.00	15.5
P_2 (Line 1)	86.10	69.30	19.50	51.70	44.10	14.80	27.10	24.30	10.30	4.70	4.30	8.40	61.10	58.70	4.00
P_3(Line 2)	97.70	76.30	21.80	62.10	50.70	18.40	40.40	25.30	37.30	5.10	4.80	6.10	73.50	68.00	7.50
P_4(Line 3)	102.60	80.70	22.20	60.30	54.00	10.40	39.10	22.40	42.80	4.90	4.50	8.40	78.00	59.40	23.90
C1 (mean) Sakha 96 × Line 1	111.4	102.4	8.1	70.50	62.30	11.80	33.30	18.80	43.50	4.70	4.40	6.70	63.10	53.50	15.20
Min	95	75		58	47		11	9		2.00	2.00		48.50	44.30	
Max	135	115		85	74		41	31		5.50	5.30		74.30	74.70	
C2 (mean) Line 2 × Line 3	93.0	84.7	8.9	57.80	51.30	11.20	36.20	25.00	30.90	4.00	3.50	12.90	65.80	39.30	40.30
Min	75	70		46	37		20	11		2.50	2.00		50.30	28.30	
Max	110	105		70	68		44	33		7.00	5.60		78.70	53.70	

For parents, the data indicated that the first parent (Sakha 96) had the earliest heading date in the F_3 generation, with averages of 75.60 and 67.33 days, and in the F_4 generation, with averages of 74.50 and 67.30 days under both sowing dates, respectively. Furthermore, first parent had the earliest maturity date for the F_3 generation under late sowing was 130.60 days, and similarly for the F_4 generation, with average of 130.6 days. Additionally, first parent recorded the shortest grain filling period in the F_3 generation under late sowing date with an average of 39.73 days. In contrast, third parent (Line 2) had the earliest days to maturity in the F_3 and F_4 generations under optimal sowing date, averaging 133.73 and 133.90 days, respectively. Also, third parent showed the shortest grain filling period for the F_3 generation under optimal sowing date with average 50.53 days, while second parent (Line 1) showed the shortest grain filling period in the F_3 generation under late sowing, averaging 39.73 days, and in the F_4 generation under optimal sowing, averaging 47.10 days. Fourth parent (Line 3) had the lowest grain filling period in the F_3 generation under optimum sowing date, with an average of 50.53 days.

The third parent, (Line 2) exhibited the highest grain filling rate in the F_3 generation under optimal sowing with value of 2.20 and in the F_4 generation under both sowing dates with values 2.1 and 1.68 respectively, while the second parent (Line 1) demonstrated high grain filling rate under late sowing in the F_3 generation with value of 1.64.

The first parent (Sakha 96) produced the tallest plants in the F_3 generation, with averages of 103.67 cm and 93 cm, and in the F_4 generation, with averages of 103.70 and 93.00 cm under optimal and late sowing, respectively.

The fourth parent (Line 3) exhibited high values numbers for kernels per spike in F_3 generation under both optimal and late sowing dates, averaging 62.73 and 56.27 kernels, respectively, and high average of 54.00 kernels in the F_4 generation under late sowing. Moreover Line 3 recorded high grain yield per plant in the F_3 and F_4 generations under optimal sowing, with averages of 75.98 and 78.03 g, respectively.

The third parent (Line 2) showed high numbers of spikes per plant in F_3 generation under both optimal and late sowing dates, with average of 41 and 25 spikes, respectively, and highest average (40.4spikes) in the F_4 generation under optimal sowing, Additionally, Line 2 achieved the greatest number of kernels per spike in the F_4 generation under optimal sowing date with an average of 62.1 kernels. It also ranked highest 100-kernel weight in the F_3 generation recording 5.06 and 4.86 g and in the F_4 generation, with an average 5.10 and 4.80 g under each sowing date, respectively. Furthermore, it recorded high values in grain yield per plant in both the F_3 and F_4 generations under late sowing with averages of 66.42 and 68 g, respectively.

Regarding the F_3 and F_4 families, the first cross (Sakha 96 × Line 1) exhibited the earliest heading and maturity dates in both generations under both optimal and late sowing dates. In the F_3 generation, days to heading were 86.20 days under the optimal sowing date and 72.90 days under the late sowing date, while days to maturity were 135.40 days and 132.30 days, respectively. In the F_4 generation, days to heading were 87.50 days under optimal sowing date, and 78.40 days under delayed sowing date, whereas days to maturity were 138.30 days and 135.00 days under optimal and late planting date, respectively, additionally, the first cross showed the shortest grain filling period and the highest grain filling rate in F_3 generation under both sowing dates with values of 49.60 days under the optimal sowing date and 33.40 days under the late sowing date for grain filling period, while, grain filling rate reached 2.30 and 1.70, respectively.

Furthermore, the first cross recorded the tallest plant in both F_3 and F_4 generations under the two planting dates with heights of 121.20 and 101.3 cm in F_3 generation under both optimum and late planting date, respectively and 114.40 cm and 102 cm under both sowing dates in F_4 generation, respectively. It also produced the greatest number of kernels per spike in F_4 generations across with values 70.50 kernels under the optimal sowing date and 62.3 kernels under late sowing date. In addition, the first cross achieved the highest 100-kernel weight in both generations under both sowing dates reaching 5.4 g under optimal sowing date and 4.3 g under delayed sowing date in the F_3 generation and 4.7 and 4.4 g under both sowing date in F_4 generation, Moreover, this cross produced the greatest grain yield per plant under late planting date with values 75.8 and 53.5 in F3 and F4 generations, respectively

The second cross (Line 2 × Line 3) showed the shortest grain filling period in F_4 generation with values of 29.80 days and 26.00 days under optimum and late planting dates, respectively. It also recorded the highest grain filling rate with averages of 2.30 and 1.50 under both optimal and delayed sowing dates, respectively. Moreover, this cross produced the highest number of spikes per plant in both F_3 and F_4 generations with values of 31.8 spikes and 26.8 spikes in F_3under both sowing date, respectively while in the F_4 generation, it reached 36.2 spikes and 25.0 spikes under both sowing date respectively, Additionally, it achieved high values for number of kernels per spike in the F_3 generation recording 60.8 kernels and 57.6 kernels under optimal and late planting dates, respectively, Furthermore, the second cross recorded high grain yield per plant under optimal sowing dates in both F_3 and F_4 generation with averages of 94.0g and 65.80g respectively.

The F_3 family means exceeded the highest corresponding parent in the first cross for plant height, the number of spikes per plant, 100-kernel weight, and grain yield per plant under both sowing dates, as well as the number of kernels per spike under optimal sowing. The F_4 generation surpassed the greatest parent for plant height, the number of kernels per spike under both dates of sowing, and the number of spikes per plant under optimal sowing. In the second cross, the F_3 family means exceeded the highest parent for the number of spikes per plant under late sowing, and grain yield per plant under each sowing date. For the F_4 generation, the plant height was higher than the highest parent under late sowing. This suggests the presence of transgressive segregation, where recombination of parental genes results in offspring with superior traits compared to both parents

Conversely, the F_4 family means were less than the lowest corresponding. parent in the first cross for grain yield per plant under delayed planting date. In the second cross, the F_3 generation was lower than the lowest corresponding parent for plant height under optimal planting, the number of spikes per plant under optimal sowing, and 100-kernel weight under late sowing. Meanwhile, the F_4 generation was lower than the lowest parent for plant height and the number of spikes per plant under optimal sowing, 100-kernel weight, and grain yield per plant under both sowing dates. This reduction in performance could be due to the segregation of unfavorable alleles or the disruption of favorable gene combinations, leading to a decline in these traits. Additionally, the F_3 family means aligned with the largest parent for the number of kernels per spike in the first cross under late planting and in the second cross under both dates of sowing. These findings emphasize the complex nature of genetic inheritance and the interaction between genetic and environmental factors. The presence of transgressive segregation, both positive and negative, indicates that careful selection is necessary to capture desirable traits while minimizing the expression of undesirable ones.

Low Reduction in F_3 generation was observed in in days to heading, and 100-kernels weight for the fourth parent (Line 3), the third parent (Line 2) exhibited a low reduction in days to maturity, and grain filling period, while the first parent (Sakha 96) displayed a low reduction in grain filling rate and plant height, the second parent (Line 1) recorded low reduction values in number of kernels per spike and the number of spikes per plant and the third parent (Line 2) showed low reduction in grain yield per plant. In the F_4 generation, the second parent (Line 1) exhibited low reduction percentage for days to heading, grain filling rate, the number of spikes per plant, and grain yield per plant in, the third parent (Line 2) showed a low reduction in days to maturity and 100-kernel weight, the first parent (Sakha 96) in grain filling period and plant height, and the fourth parent (Line 3) in number of kernels per spike.

The first cross (Sakha 96 × Line 1) showed low reduction in F_3 generation for Days to heading, Days to maturity, plant height and grain yield per plant, while the second cross recorded low reduction percentage in grain filling period, grain filling rate, number of kernels per spike, number of spike per plant and 100kernel weight. Regarding F_4 generation the first cross exhibited lower reduction percentage for days to maturity, grain filling rate, plant height ,100kernel weight and grain yield per plant, in contrast the second cross recorded low reduction in days to heading, grain filling period, number of kernels per spike and number of spikes per plant. These results suggest that both selected parents and their respective hybrids exhibit variable levels of tolerance to late sowing stress.

In addition to average values, presenting the minimum and maximum helps to better understand the phenotypic variation observed among families. Awide range between these values indicates high genetic diversity, which plays an important role in improving selection efficiency and identifying promising families under both sowing dates.

Genetic and environmental variances:

The genetic and environmental variance components among families and among plants within families in the F_3 and F_4 generations for all traits in the two crosses under the optimal and late sowing date are illustrated in Tables 11, 12, 13 and 14.

In the F_3 and F_4 generation the genetic variance among families exceeded the corresponding environmental variance for all studied traits under both optimal and late sowing date, except for grain filling rate in the F_3 generation under optimal sowing date in the first cross.

Table 11. Genetic (σ^2G) and environmental (σ^2E) variance components among F_3 families, and among plants within F_3 families, for days to heading (DH), days to maturity (DM), grain filling period (GFP) and grain filling rate (GFR) in the two bread wheat crosses under the optimum (OS) and late (LS) sowing dates.

Crosses	Source		DH		DM		GFP		GFR	
			OS	LS	OS	LS	OS	LS	OS	LS
C1	Among F_3	σ2G	12.60	34.24	5.77	9.31	30.50	29.34	0.02	0.13
Sakha 96 × Line 1	families	σ2E	1.83	1.18	1.17	0.81	0.83	2.64	0.09	0.02
	Among plants	σ2G	13.35	34.86	6.75	8.79	35.10	37.70	0.23	0.18
	within F_3 families	σ2E	0.09	1.12	0.42	0.38	3.32	1.54	0.02	0.01
C2	Among F_3	σ2G	20.65	13.41	5.82	5.76	32.02	25.75	0.18	0.27
	families	σ2E	0.87	0.53	0.45	0.47	3.20	3.76	0.03	0.04
Line 2 × Line 3	Among plants	σ2G	21.13	14.80	5.91	6.49	30.33	30.7	0.18	0.33
	within F_3 families	σ2E	0.63	4.32	0.40	0.92	0.96	1.90	0.01	0.01

Table 12. Genetic (σ^2G) and environmental (σ^2E) variance components among F_4 families, and among plants within F_4 families, for days to heading (DH), days to maturity (DM), grain filling period (GFP) and grain filling rate(GFR) in the two bread wheat crosses under the optimum (OS) and late (LS) sowing dates.

Crosses	Source		DH		DM		GFP		GFR	
			OS	LS	OS	LS	OS	LS	OS	LS
C1	Among F_4	σ^2G	22.10	14.00	12.90	14.80	13.20	9.40	0.030	0.039
	families	σ^2E	0.80	1.20	0.50	0.40	1.00	0.40	0.003	0.002
Sakha 96 × Line 1	Among plants	σ^2G	6.70	6.10	4.00	8.10	4.80	4.90	0.017	0.024
	within F_4 families	σ^2E	2.40	2.00	0.40	0.10	1.00	1.20	0.001	0.002
C2	Among F_4	σ^2G	39.10	41.90	17.50	8.20	16.00	15.80	0.2	0.20
	families	σ^2E	0.60	0.50	0.50	0.60	0.50	0.60	0.00	0.00
Line 2 × Line 3	Among plants	σ^2G	15.50	19.50	6.20	4.10	6.00	8.50	0.10	0.10
	within F_4 families	σ^2E	0.60	0.60	0.70	0.50	0.30	0.50	0.00	0.00

Table 13. Genetic (σ^2G) and environmental (σ^2E) variance components among F_3 families and among plants within F_3 families for plant height (PH), number of kernels per spike (K/S), number of spikes per plant(S/P), 100-kernel weight (100KW) and Grain yield per plant (GY/P) in the two bread wheat crosses under the optimum (OS) and late (LS) sowing dates.

Crosses	Source		PH		K/S		S/P		100KW		GY /P	
			OS	LS	OS	LS	OS	LS	OS	LS	OS	LS
C1	Among F_3	σ^2G	6.34	90.26	150.1	122.4	28.75	45.44	0.6	0.5	136.7	90.86
	families	σ^2E	5.83	5.36	19.62	30.47	5.9	10.95	0.09	0.18	19.54	14.9
Sakha 96 × Line 1	Among plants	σ^2G	5.8	92.73	175.1	149.2	30.39	74.87	0.58	0.65	142.7	111
	within F_3 families	σ^2E	0.83	1.73	6.24	11.15	1.8	4.86	0.05	0.06	9.64	8.91
C2	Among F_3	σ^2G	96.69	89.96	142.8	119.7	33.38	32	0.74	0.49	162.2	305.4
	families	σ^2E	5.95	6.19	9.78	14.16	11.27	7.49	0.08	0.2	8.98	22.15
Line 2 × Line 3	Among plants	σ^2G	81.62	84.33	178.2	156.7	50.11	48.03	0.71	0.48	213.4	477.5
	within F_3 families	σ^2E	5.08	5.52	7.52	15.46	4.12	3.23	0.05	0.06	4.29	10.67

Table 14. Genetic (σ^2G) and environmental (σ^2E) variance components among F_4 families and among plants within F_4 families for plant height (PH), number of kernels per spike (K/S), number of spikes per plant(S/P), 100-kernel weight (100KW) and Grain yield per plant (GY/P) in the two bread wheat crosses under the optimum (OS) and late (LS) sowing dates.

Crosses	Source		PH		K/S		S/P		100KW		GY /P	
			OS	LS	OS	LS	OS	LS	OS	LS	OS	LS
C1	Among F_4	σ^2G	50.7	48.60	35.10	34.90	42.80	14.10	0.50	0.30	37.40	38.30
	families	σ^2E	0.80	0.60	0.70	0.80	4.10	3.90	0.10	0.10	2.80	3.50
Sakha 96 × Line 1	Among plants	σ^2G	20.50	23.50	9.80	17.30	27.20	9.50	0.20	0.20	17.60	23.40
	within F_4 families	σ^2E	4.60	2.20	0.60	0.70	1.30	0.60	0.00	0.00	0.80	1.30
C2	Among F_4	σ^2G	50.80	46.50	46.00	50.90	21.70	14.10	0.70	0.40	52.30	51.80
	families	σ^2E	0.50	1.50	2.90	0.90	7.80	11.40	0.10	0.10	3.90	13.00
Line 2 × Line 3	Among plants	σ^2G	19.40	21.60	15.60	21.90	11.50	8.80	0.30	0.30	26.60	28.10
	within F_4 families	σ^2E	1.10	1.60	0.70	1.00	1.00	0.90	0.00	0.00	1.30	1.30

Additionally, the genetic variance among plants within families in both F_3 and F_4 generation was greater than the corresponding environmental variance for all the studied traits under both sowing dates in the two studied crosses. This indicates that the observed phenotypic differences are largely attributed to genetic factors, suggesting that effective selection for these traits could lead to significant genetic improvement through successive generations.

The genetic variance among F_3 families under optimal sowing date was greater than that under late sowing for most traits, except for days to heading, days to maturity, plant height and number of spikes per plant in the first cross, and grain yield per plant in the second cross. A similar trend was observed in the F_4 families, except for days to heading, number of kernels per spike in the second cross, and days to maturity in the first cross. This trend suggests that optimal sowing date provides a more stable environment that enhances the expression of genetic differences, facilitating more effective selection.

Conversely, environmental variance among F_3 families was generally higher under late sowing for most traits, excluding days to heading in the first and second cross, days to maturity, grain filling rate, plant height, grain yield per plant in the first cross, as well as number of spike per plant in the second cross.. This trend was reversed among F_4 families, where environmental variance was higher under optimal sowing for most traits, except for days to heading in the first cross, days to maturity, grain filling period in the second cross, plant height, number of spike per plant and grain yield per plant in the second cross. These findings indicate that the optimal sowing date generally provides a more consistent and favorable environment for expressing genetic differences among plants within families, thereby improving the efficiency of selection. In contrast, the greater environmental variance observed under late sowing date, suggests increased environmental stress, which may obscure genetic variability and reduce selection accuracy.

Regarding genetic variance among plants within families in F_3, late sowing exceeded the optimum sowing for most traits except for grain filling rate and grain yield in the first and second cross, days to heading, number of spikes per plant and 100kernel weight in the second cross and number of kernels per spike in the first and second cross. A similar trend was observed in the F_4 generation except for, days to heading and days to maturity in the second cross, number of spike per plant in both crosses.

Environmental variance among plants within families in F_3 was generally greater under late sowing for most traits, except days to maturity, grain filling period and grain yield in the first cross and number of spikes per plant in the second cross. A similar pattern was observed in F_4 except for days to heading, plant height and number of spikes per plant in the first cross and days to maturity in both crosses.

The genetic variances among plants within families were greater than among the F_3 families for all studied traits under both sowing dates in both crosses, except for days to maturity in the first cross under late sowing date, grain filling period in the second cross under optimum sowing date, plant height under optimal sowing date in the first cross and under both sowing dates in the second cross. This suggests that individual plant selection within families in F_3 could capture more genetic diversity and enhance the potential for genetic improvement through selection.

On the other hand, the genetic variance among plants within families was approximately equal to the variance among families in the F_3 generation for grain filling period in the second cross under optimal sowing date, and for 100-

kernel weight in both the first and second crosses under the same sowing date. This balance of genetic variance suggests that genetic diversity for these traits is similarly distributed within and among families, indicating that selection at either level within or among families may be equally effective. Therefore, breeders can adopt a flexible selection strategy depending on available resources and breeding goals at this early generation.

In contract, in F_4 generation, the genetic variances among families exceeded that within families for all studied traits under both planting dates in both crosses, indicating that the selection would be more efficient among families than within families in this generation. These results demonstrated that in the F_3 generation the greater within-family variance supports the effectiveness of early-generation selection among individual plants, while in F_4 generation the increased among-family variance suggests the value of selecting superior families, thereby enhancing genetic gain and selection accuracy.

These results were similar to those obtained by Aglan and Farhat (2014), Darwish et al (2018), Moreover Saleh (2017) found that genotypic variance was approximately equivalent to the corresponding phenotypic for days to heading. Khalil et al (2017) reported that genetic variance for spikes m^{-2} and 100-kernel weight was lower than environmental variance under normal sowing date, while the genetic variance for grains per spike and grain yield was greater than environmental variance.

Genetic variance components, heritability and expected genetic advance

Data presented in Tables 15, 16 , 17 and 18 revealed that the additive variance components surpassing the dominance variance for most traits under study in both F_3 and F_4 generation under both dates of sowing, reveals that additive effects were more significant in the inheritance of these traits, however, exceptions were observed in the F_3 generation for grain filling period, grain filling rate , number of spikes per plant under delayed planting date in the first cross, number of kernels per spike under late sowing date in the second cross, number of spikes per plant and grain yield per plant in the second cross under both sowing dates, regarding F_4 dominance effects were more significant for number of spikes per plant in the first cross under both planting dates, grain yield in the first cross under late planting date, number of spikes per plant and 100kernel weight in the second cross under late sowing date, suggesting that dominance gene action may play a significant influence in controlling these traits, while the dominance variance equals to the additive variance for grain filling rate under late planting in the first cross, this suggest that both genetic effects contributed equally to the expression of this trait under the specific environmental condition of late sowing.

Table 15. Estimates of additive (σ^2A) and dominance (σ^2D) variances, heritability in broad (h^2b) and narrow senses (h^2n) based on F_3 families means for days to heading (DH), days to maturity (DM), grain filling period (GFP) and grain filling rate (GFR) in the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Parameters	DH		DM		GFP		GFR	
		OS	LS	OS	LS	OS	LS	OS	LS
C1	σ^2A	7.90	22.41	3.19	6.55	17.26	13.99	0.18	0.06
	$1/4\sigma^2D$	4.70	11.83	2.58	2.76	13.23	15.35	0.07	0.07
Sakha 96 × Line 1	$h^2(b)$	99.32	96.84	93.26	91.96	90.18	95.02	92.6	92.73
	$h^2(n)$	62.26	63.39	51.58	64.69	51.05	45.3	67.81	40.47
C2	σ^2A	13.44	8.01	3.82	3.35	22.47	13.86	0.12	0.15
	$1/4\sigma^2D$	7.20	5.39	2.00	2.41	9.55	11.89	0.06	0.13
Line 2 × Line 3	$h^2(b)$	95.95	75.62	93.53	86.17	97.09	93.12	95.12	96.90
	$h^2(n)$	62.47	45.20	61.41	50.17	68.14	50.13	63.69	51.70

Table 16. Estimates of additive (σ^2A) and dominance (σ^2D) variances, heritability in broad (h^2b) and narrow senses (h^2n) based on F_4 families means for days to heading (DH), days to maturity (DM), grain filling period (GFP) and grain filling rate (GFR) in the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Parameters	DH		DM		GFP		GFR	
		OS	LS	OS	LS	OS	LS	OS	LS
C1	σ^2A	22.73	12.60	13.21	11.64	12.72	7.58	0.03	0.03
Sakha 96 × Line 1	$1/4\sigma^2D$	6.03	7.51	3.65	11.35	5.27	6.72	0.02	0.03
	$h^2(b)$	90.13	86.38	94.95	98.13	89.77	89.92	93.02	93.74
	$h^2(n)$	71.23	54.11	74.40	49.70	63.46	47.66	56.86	42.74
C2	σ^2A	36.57	36.41	17.21	6.78	15.31	12.66	0.24	0.19
	$1/4\sigma^2D$	18.05	25.00	6.49	5.47	6.71	11.66	0.07	0.10
Line 2 × Line 3	$h^2(b)$	97.81	98.22	95.35	91.47	96.14	95.58	98.31	98.84
	$h^2(n)$	65.48	58.23	69.23	50.63	66.85	49.76	76.00	64.88

Table 17. Estimates of additive (σ^2A) and dominance (σ^2D) variances, heritability in broad (h^2b) and narrow senses (h^2n) based on F_3 family means for plant height (PH), number of kernels per spike(K/S), number of spike per plant(S/P), 100-kernel weight (100KW) and Grain yield per plant (GY/P), in the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Parameters	PH		K/S		S/P		100KW		GY /P	
		OS	LS	OS	LS	OS	LS	OS	LS	OS	LS
C1	σ^2A	4.59	58.53	83.47	63.75	18.07	10.67	0.41	0.23	87.16	47.14
	$1/4\sigma^2D$	1.75	31.73	66.66	58.65	10.68	34.77	0.19	0.27	49.56	43.71
Sakha 96 × Line 1	$h^2(b)$	88.37	98.12	96.01	80.07	94.12	90.33	92.87	90.03	93.41	91.07
	$h^2(n)$	64.00	63.62	53.38	41.71	59.17	21.22	63.72	42.24	59.55	47.26
C2	σ^2A	74.51	63.72	71.64	55.15	11.09	10.64	0.51	0.33	73.98	88.90
	$1/4\sigma^2D$	22.18	26.24	71.19	64.56	22.28	21.35	0.23	0.16	88.20	216.5
Line 2 × Line 3	$h^2(b)$	95.01	94.22	93.59	88.56	89.01	90.83	93.59	89.46	97.42	96.63
	$h^2(n)$	73.21	66.74	46.94	40.80	29.59	30.22	65.01	60.69	44.44	28.12

Table 18. Estimates of additive (σ^2A) and dominance (σ^2D) variances, heritability in broad (h^2b) and narrow senses (h^2n) based on F_4 family means for plant height (PH)), number of kernels per spike (K/S), number of spike per plant(S/P), 100-kernel weight (100KW) and Grain yield per plant (GY/P), in the two bread wheat crosses under optimum (OS) and late (LS) sowing dates.

Crosses	Parameters	PH		K/S		S/P		100KW		GY/P	
		OS	LS	OS	LS	OS	LS	OS	LS	OS	LS
C1	σ^2A	47.09	41.22	36.98	29.28	29.85	9.3	0.51	0.26	32.19	27.67
	$1/4\sigma^2D$	24.14	30.85	7.97	22.98	40.13	14.31	0.18	0.25	22.78	34.11
Sakha 96 × Line 1	$h^2(b)$	92.96	96.28	97.17	97.2	92.79	83.77	81.91	82.88	93.85	92.82
	$h^2(n)$	61.45	55.07	79.94	54.46	39.58	32.99	60.59	41.99	54.95	41.57
C2	σ^2A	48.36	40.37	45.7	46	17.36	9.96	0.64	0.3	43.2	41.01
	$1/4\sigma^2D$	21.81	27.73	15.88	26.85	15.84	12.96	0.45	0.44	35.7	38.86
Line 2 × Line 3	$h^2(b)$	97.79	95.64	94.42	97.48	79.16	65.18	94	88.78	93.87	84.83
	$h^2(n)$	67.39	56.69	70.08	61.56	41.39	28.33	55.18	36.17	51.4	43.56

The prevalence of additive variance in most traits suggests that selection could be effective starting from early generations. However, traits showing dominance variance, particularly under late sowing conditions, may require alternative breeding approaches such as delayed selection. The variability in gene action across F_3 and F_4 generations also highlights the dynamic nature of genetic expression, possibly due to segregation and recombination. Therefore, continuous evaluation of genetic patterns across generations is essential to guide effective selection and breeding strategies. Similar outcomes were reported by Darwish et al. (2018). On the other hand, Aglan, and Farhat (2014) found that the dominance variance was greater than the additive variance.

The broad-sense heritability estimates h^2 (b) was high for all studied traits across both F_3 and F_4 generations. In the F_3 generation, under optimal sowing date, the heritability values ranged from 88.37 for plant height in the first cross to 99.32 for days to heading in the first cross. Under late planting date, values ranged from 80.07 for number of kernels per spike in the first cross to 98.12 for plant height in the first cross. In the F4 generation h^2 (b) values under optimal sowing date, ranged from 79.16 for number of spikes per plant in the second cross to 98.31 for grain filling rate in the second cross, and from 65.18 for the number of spikes per plant in the second cross to 98.84 for grain filling rate in the second cross under late sowing date. These findings indicate that studied traits are primarily determined by genetic factors with minimal environmental influence, suggesting that selection could contribute to significant genetic improvement. These results are in agreement with Khalil et al. (2017), who stated that broad-sense heritability was medium to high under normal and late sowing. Similarly, Khamees et al. (2021), observed high heritability for most traits, while Olbana et al. (2021) reported moderate heritability estimates for number of spikes per plant, grain filling period, plant height, and number of kernels per spike.

On the other hand, the narrow-sense heritability $h^2(n)$ estimates were relatively low to mederate for most traits in both generations and across both sowing dates. In the F_3 generation, under optimal sowing date, narrow sense heritability ranged from 29.59 for number of spikes per plant in the second cross to 73.21 for plant height in the second cross, while under late sowing date, it ranged from 21.22 for number of spikes per plant in the first cross to 66.74 for plant height in the second cross.

In the F_4 generation under optimal sowing date, $h^2(n)$ values varied between 39.58 for number of spike per plant in the first cross to 79.94 for number of kernels per spike in the first cross. Under delayed planting date, the values varied between 28.33 for number of spikes per plant in the second cross to 64.88 for grain filling rate in the second cross. The relatively low $h^2(n)$ values reflect increased environmental variance and reduced additive genetic contribution, while the high and medium heritability estimates show the significance of the additive genetic component in the inheritance of these traits making selection more efficient.

The narrow-sense heritability in the optimal sowing date was higher than under the late sowing date for most traits in both F_3 and F_4 generation. This indicates that additive genetic variance was more effectively expressed under favorable growing dates, enhancing the potential response to selection, except for days to heading and days to maturity in the first cross in F_3 generation where heritability was relatively higher under late sowing. This suggests that these particular traits may be less influenced by environmental stress during late sowing and retain stable genetic control. These findings are supported by Aglan and Farhat (2014) who reported medium to high narrow-sense heritability for days to heading and plant height under late sowing date. Similarly, Sharshar et al. (2020) found that narrow-sense heritability values were moderate for the most traits.

Selected F_4 families

The means of selected F_4 families based on days to maturity and grain yield per plant under both optimum and late sowing dates are shown in Table 19.

Table 19. Mean values of the selected F_4 families for days to maturity (DM) and grain yield per plant (GY/P) in the two bread wheat crosses under the optimum (OS) and late (LS) sowing dates.

Crosses	Family No.	DM		GY/P	
		OS	LS	OS	LS
C1 Sakha 96 × Line 1	28	136	130	75.34	63.4
	6	135	131	78.14	68.32
	17	137	130	84	70.4
	33	135	132	90.24	72.8
	37	132	128	58.7	57
	Sakha96	134.87	130.60	72.21	61.00
	Line 1	135.73	130.93	61.10	58.70
	L.S.D	3	3.5	5	4.5
C2 Line 2 × Line 3	27	137	134	78.5	68
	3	140	136	81.4	70
	24	139	137	82.7	67
	18	141	135	85.2	72
	34	131	128	70	56
	Line 2	134.00	131.10	73.50	68.00
	Line 3	139.60	136.10	78.00	59.4
	L.S.D	4	4	6	6

The final selection identified five families from each cross, totaling ten F_4 families. Among them, four families per cross recorded higher grain yield than their respective parents. These families exhibited days to maturity within the range of their respective parents, with significant or non-significant differences, indicating that improved yield was not associated with any extension or reduction in the maturity period.

These families will be further evaluated in the next season as F_5 families to select the best-performing lines with the highest grain yield while maintaining stable maturity periods. However, Family 37 in the first cross and family 34 in the second cross matured earlier than their respective parents but produced lower yields, indicating an inverse relationship between earliness and productivity (Abd El-Rady, 2021; Singh et al 2024; Dadrasiet al., 2024). Therefore these families are recommended for inclusion in breeding programs focused on enhancing grain yield in early-maturing.

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التحليل الوراثي في الجيلين الثالث والرابع لهجينين من قمح الخبز تحت ميعادي الزراعه الأمثل والمتأخر

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الملخص

أجريت هذه الدراسة في المزرعة البحثية بمحطة البحوث الزراعية بسخا، مركز البحوث الزراعية مصر خلال ثلاثة مواسم زراعية (2022/2021، 2023/2022، و2024/2023) بهدف دراسة الإستجابة النسبية للإنتحاب في الجيلين الثالث والرابع في هجينين من قمح الخبز بإستخدام طريقة الإنتخاب بسجل النسب تحت ظروف ميعاد الزراعة العادي (15 نوفمبر) والمتأخر(15 ديسمبر). وقد أظهرت النتائج وجود تباين وراثي واضح بين العائلات المنتخبة وفروق معنوية بين الآباء وعائلات الجيلين الثالث الرابع لمعظم الصفات تحت كلا ميعادي الزراعة، وبصفة عامة تناقصت متوسطات الاباء وعائلات الجيلين الثالث والرابع تحت ميعاد الزراعة المتأخر. كان التباين الجيني سواء بين العائلات أو داخل العائلات أكبر من التباين البيئي المقابل في كل من الجيل الثالث والرابع لمعظم الصفات المدروسة تحت كلا ميعادي الزراعة، وكان التباين المضيف أعلي من التباين السيادي في كل من الجيل الثالث والرابع لمعظم الصفات المدروسة. سجلت درجة التوريث بالمعنى الواسع قيماً مرتفعة في كل الصفات المدروسة في الجيلين الثالث والرابع تحت كلا ميعادي الزراعة, بينما كانت درجة التوريث بالمعني الضيق منخفضة الي متوسطه في الجيلين الثالث والرابع لمعظم الصفات المدروسة تحت كلا ميعادي الزراعه. بناء على محصول الحبوب وتاريخ النضج تم إختيار خمس عائلات من كل هجين منها أربع عائلات ذات إنتاجية محصول أعلي من الأباء وسيتم تقييم هذه العائلات كجيل خامس وإنتخاب الأفضل من حيث الصفات المحصولية بالاضافه الي ذلك ، وجدت عائله مبكره النضج مقارنة بالاباء من كل هجين لكنها حققت أقل انتاجية في المحصول مما يدل علي الاعلاقه العكسيه بين التبكير والانتاجية.