International Journal of Agricultural and Natural Sciences
E-ISSN: 2651-3617 18(3): 315-331, 2025
doi:10.5281/zenodo.18067332
Research Article

ASSESSMENT OF SOME SESAME GENOTYPES AND THEIR CROSSES FOR PERFORMANCE, COMBINING ABILITY, AND HETEROSIS OF KEY AGRONOMIC TRAITS

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(Received 1st September 2025; accepted 15th November 2025)

ABSTRACT: To identify superior sesame genotypes and hybrid combinations that can enhance key agronomic traits, especially seed yield, six genetically distinct parental lines, M_2A_{24}, B-$_{42}$, local-$_{131}$, H-$_{46}$, H-$_{102}$ F-$_{13}$, and H-$_{102}$ were crossed using a half diallel mating design at the Ismailia Agricultural Research Station in Egypt during the summer of 2023, producing 15 F1 hybrids. These parental lines and their hybrids were then evaluated in the field during the 2024 and 2025 summer seasons using a randomized complete block design with three replications. Analysis of variance for key agronomic traits in sesame across two seasons revealed highly significant differences among genotypes, parents, and hybrids, indicating substantial genetic variability and the presence of both additive and non-additive genetic effects. Days to 50% flowering ranged from 51.89 to 74.52 days, plant height from 83.21 to 179.20 cm, capsule length from 3.63 to 4.86 cm, number of branches per plant from 5.74 to 7.67, 1000-seed weight from 2.82 to 3.77 g, seed weight per plant from 28.01 to 37.48 g, and seed oil content from 52.69% to 59.21 % in the sesame hybrids. Hybrids such as P4 × P5 and P5 × P6 consistently outperformed parents in yield-related traits and oil content, demonstrating strong hybrid vigor. The Baker ratio for additive effects was moderate to high for most traits (0.78 for days to 50% flowering, 0.69 for plant height), supporting the predominance of additive gene action, though some traits showed greater non-additive influence. Significant general combining ability (GCA) and specific combining ability (SCA) effects were observed, guiding the selection of superior parents and cross combinations. Hybrids like P1 × P5, P2 × P3, and P3 × P6 combined early flowering, optimal plant height, and longer capsules, making them promising for yield improvement. Heterosis and potence ratio values confirmed strong dominance effects in key crosses, with P2 × P5 and P3 × P5 excelling in earliness and plant height, and P4 × P5 in number of branches, seed weight, and oil content. These results highlight the importance of selecting hybrids with high per se performance, strong combining ability, and significant heterosis for breeding programs aiming to enhance sesame yield and oil quality.

Keywords: *Combining ability, half diallel, heterosis, mean performance, sesame*

INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the world's oldest and most valuable oilseed crops, prized for its high oil content, nutritional value, and adaptability to tropical and subtropical climates. Globally, sesame is in increasing demand due to its use in healthy foods and its positive effects on human health, as it is rich in nutrients, antioxidants, minerals, and vitamins [1, 2]. In Egypt, sesame cultivation is economically significant, with its oil being notable for its stability, taste, and long shelf life [3]. Despite its importance, the expansion of sesame cultivation in Egypt and worldwide faces challenges such as limited mechanization, traditional farming methods, and environmental stresses [2, 3]. To meet the rising demand and adapt to climate change, there is a pressing need to develop and introduce new, high-yielding, and resilient sesame varieties [4]. Recent research in Egypt has focused on breeding genotypes that are stable and productive under changing climatic conditions, using advanced modeling to predict their performance [4].

The study of combining ability using Griffing's half diallel method is crucial for improving key agronomic traits in sesame, as it helps breeders identify superior parents and cross combinations for yield and related characteristics. Research consistently shows that both general combining ability (GCA) and specific combining ability (SCA) variances are significant for most yield and yield-attributing traits, indicating the importance of both additive and non-additive gene actions in trait inheritance [5, 6, 7, 8]. Identifying parents with high GCA, such as TKG-22, LOCAL, and G-1, enables the selection of lines that reliably transmit desirable traits like high seed yield and early maturity to their offspring [9, 10, 6, 7, 11, 8]. Meanwhile, crosses with high SCA, such as G-1 x IC-204025 and JTS-8 x TKG-22, are valuable for exploiting hybrid vigor and improving specific traits in breeding programs [6, 7, 11]. The predominance of non-additive gene action for many traits suggests that hybridization and selection in segregating generations can be effective strategies for genetic improvement [8, 11, 12]. Additionally, the presence of significant genetic variability among parents and hybrids underscores the potential for further yield and quality enhancement in sesame through targeted breeding [6, 5, 8]. Overall, these findings provide a scientific foundation for developing high-yielding, stable sesame varieties, which are essential for meeting the growing demand for this important oilseed crop [9, 10, 7, 8, 13].

Hybrid vigor, or heterosis, is a crucial concept in sesame (*Sesamum indicum* L.) breeding, as it can significantly enhance yield and other agronomic traits compared to parental lines. Studies have shown that evaluating hybrid performance at both the mid-parent and better-parent levels provides valuable insights into the potential of specific crosses to outperform their parents, with some hybrids exhibiting mid-parent heterosis values as high as 87% and notable heterobeltiosis for seed yield and related traits[14, 15]. The potence ratio, which measures the degree of dominance in hybrid performance, further helps breeders understand the genetic mechanisms underlying heterosis and guides the selection of parents for hybridization[16, 17, 8]. Identifying parents with high general combining ability (GCA) and hybrids with high specific combining ability (SCA) is essential for maximizing hybrid vigor and improving seed yield and oil content in sesame [8, 14, 17]. The exploitation of non-additive gene action, as indicated by GCA/SCA ratios less than one, underscores the importance of hybrid breeding strategies in this crop [8, 17]. Overall, harnessing hybrid vigor through careful selection of parental lines and understanding potence ratios can accelerate the development of elite sesame varieties with superior yield and adaptability, addressing the challenges of low productivity and environmental stresses [14, 8, 17, 15].

This study was based on the hypothesis that key agronomic traits in sesame are controlled by both additive and non-additive genetic effects, which can be effectively analyzed using the half diallel Griffing method. Therefore, the main objectives were: (1) to evaluate the performance of selected sesame genotypes and their hybrids for important agronomic traits; (2) to estimate general combining ability (GCA) and specific combining ability (SCA) to identify superior parents and cross combinations; (3) to determine the relative importance of additive versus non-additive gene action in trait inheritance; (4) to assess heterosis over mid-parent and better parent values for yield and related traits; (5) to calculate the potence ratio to understand the degree of dominance; (6) to provide insights for breeding strategies aimed at improving yield and other desirable traits; (7) to identify promising parental lines for future hybridization programs; (8) to recommend superior hybrid combinations for further evaluation; (9) to contribute to the genetic improvement of sesame through informed selection; and (10) to enhance understanding of the genetic architecture underlying key agronomic traits in sesame.

MATERIALS AND METHODS

Plant materials

Six genetically distinct parental sesame genotypes, M_2A_{24} (P1), B-$_{42}$ (P2), local-$_{131}$ (P3), H-$_{46}$ (P4), H-$_{102}$ F-$_{13}$ (P5) and H-$_{102}$ (P6), were crossed using a half diallel mating design (excluding reciprocals) at the Ismailia Agricultural Research Station, Egypt, during the summer of 2023, resulting in 15 F1 hybrid combinations. These breeding materials originated from the Oil Crops Research Department, Field Crops Research Institute, ARC, Egypt.

Experimental design and cultural practices

The field evaluation of sesame parents and their F1 crosses was carried out during the summer seasons of 2024 and 2025 using a randomized complete block design (RCBD) with three replications. Each experimental plot consisted of two ridges, each 5 meters long and 60 centimeters wide, with individual plants spaced 10 centimeters apart.

Sesame seeds from both parent plants and their F1 crosses were manually sown in neighboring plots. After germination, the sesame seedlings were thinned to retain only one plant per hill on one side of the ridge, ensuring optimal plant spacing and reducing competition among seedlings, which is important for maximizing yield and uniform growth. All other cultivation practices, such as irrigation, fertilization, and pest management, were carried out according to the guidelines recommended by the Oil Crops Research Department, Field Crops Research Institute, ARC, Egypt, which are designed to support healthy crop development and improve productivity.

Data collection

To collect data on sesame plant traits, ten plants were randomly selected from each plot to measure average plant height (cm), fruiting zone length (cm), capsule length (cm), number of branches per plant, 1000-seed weight (g), and seed weight per plant (g), with seed weights adjusted to 15.5% moisture. Days to 50% flowering were recorded for each plot. Seed oil content (%) was determined after drying seeds at 70°C for 48 hours, using the Soxhlet extraction method with diethyl ether, following [18] guidelines.

Statistical analysis

Statistical analysis of combining ability and gene action in plant breeding typically involves methods using [19] approach for evaluating general (GCA) and specific combining ability (SCA) across seasons, and [20] method for partitioning dominance effects into components (b1, b2, b3) to better understand the genetic control of traits across seasons. The Baker ratio is used to assess the relative importance of additive versus non-additive gene action, with higher values indicating a greater role for additive effects. Heterosis, or hybrid vigor, is calculated as the percentage increase of F1 hybrids over their mid-parent or better-parent values, providing a measure of hybrid performance.

The potence ratio is a genetic parameter used to determine the type and degree of dominance in the inheritance of traits, as described by [21, 22]. It is calculated using the formula: Potence ratio (P) = (F1 - MP) / (HP - MP), where F1 is the mean of the first filial generation, MP is the mean of the two parents, and HP is the mean of the higher parent. A potence ratio of +1 indicates complete dominance, while values between -1 and +1 (excluding zero) suggest partial dominance. A value of zero means there is no dominance, and values greater than +1 or less than -1 indicate over-dominance. The sign of the ratio shows which parent’s traits are dominant. GenStat 16 was employed to diallel analysis, estimation of general and specific combining ability, and calculation of heterosis and potence ratio, making it a standard choice in plant breeding research.

RESULTS AND DISCUSSION

Analysis of variance

Table 1 presents the analysis of variance (ANOVA) for several key agronomic traits in sesame, including days to 50% flowering, plant height, fruiting zone length, capsule length, number of branches per plant, 1000-seed weight, seed weight per plant, and seed oil content, measured across two seasons. The results showed highly significant differences among genotypes, parents, and crosses for all traits, indicating substantial genetic variability. This variability was crucial for breeding programs aiming to improve yield and related traits, as it suggested the presence of heritable differences that can be exploited through selection.

Table 1. *Mean squares of the six sesame parents and their F_1 crosses for earliness, yield, and its attributes across the 2024 and 2025 summer seasons*

Source of variance	df	Days to 50%flowering		Plant height		Fruiting zone length		Capsules length	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Replications	2	10.22	18.53	180.54	281.82	10.46	1.74	0.02	0.01
Genotypes	20	132.81**	189.35**	471.17**	1088.34**	72.57**	107.82**	0.62**	2.26**
Parents (P)	5	78.23**	293.34**	1188.36**	950.70**	156.40**	88.10**	0.42**	0.26**
Crosses (C)	14	118.92**	133.47**	247.81**	902.66**	26.79**	82.48**	0.43**	0.18**
P *V* C	1	600.16**	451.63**	12.29	4376.08**	294.26**	561.30**	4.41**	41.23**
Error	40	15.74	12.97	76.32	95.90	4.83	3.05	0.02	0.05
Source of variance	**df**	**Number of branches/plants**		**1000-seed weight**		**Seed weight/plant**		**Seed oil content**	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Replications	2	0.10	0.04	0.02	0.02	3.102	4.040	0.87	0.15
Genotypes	20	1.72**	5.68**	0.39**	1.17**	35.007**	117.718**	19.20**	28.77**
Parents (P)	5	1.24**	0.75**	0.27**	0.69**	17.390**	77.670**	5.82**	19.24**
Crosses (C)	14	1.03**	0.44**	0.25**	0.11**	25.270**	10.600**	14.81**	5.92*
P *V* C	1	13.75**	103.63**	2.99**	18.55**	259.407**	1817.607**	147.47**	396.30**
Error	40	0.09	0.13	0.03	0.03	2.520	1.813	1.61	2.52

*, ** refers to significant at 5% and highly significant at 1%, respectively

The significant differences between parents and crosses, as well as the parent versus cross (P *vs* C) contrasts, highlight the potential for hybrid vigor and the importance of both additive and non-additive genetic effects. Traits such as plant height, number of branches, capsule length, 1000-seed weight, and seed oil content are particularly important, as they are strongly associated with seed yield and oil productivity in sesame and have been identified as key selection criteria in previous research for yield improvement [23, 24, 25, 26, 27]. The significant genetic variation observed for these traits supports their use in breeding programs to develop high-yielding and high-oil-content sesame varieties.

Mean performance

Table 2 presents data on several sesame genotypes and their hybrids, showing clear differences in days to 50% flowering, plant height, fruiting zone length, and capsule length across two seasons. Genotype P3 flowered earliest (57.57–63 days) and had the tallest plants in the first season (191.82 cm), but plant height dropped sharply in the second season (90.77 cm), indicating strong environmental influence. Hybrids generally showed improved or intermediate values, P2 × P3 had early flowering (51.89–59.75 days), moderate plant height (142.58–154.36 cm), and the longest capsule length (4.23–4.61 cm), suggesting hybrid vigor for some traits.

Table 2. *Mean performance of six parental sesame genotypes and their 15 F_1 cross combinations for days to 50%flowering, plant height, fruiting zone length, and capsule length across the 2024 and 2025 summer seasons*

Genotypes	Days to 50%flowering		Plant height		Fruiting zone length		Capsules length	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P1	74.48	69.73	167.32	137.20	36.14	38.72	3.65	2.85
P2	71.88	61.91	173.80	131.30	45.09	34.27	3.79	2.27
P3	63.00	57.57	191.82	90.77	55.78	23.57	3.84	1.97
P4	73.40	55.03	134.14	111.04	38.59	30.24	2.88	2.44
P5	76.87	39.97	149.73	100.62	43.62	26.43	3.20	2.20
P6	67.33	53.65	166.13	109.34	49.82	31.32	3.56	2.40
LSD 5%	1.69	1.53	3.72	4.17	0.94	0.74	0.06	0.10
LSD 1%	2.26	2.05	4.98	5.58	1.25	1.00	0.08	0.13
P1 × P2	69.07	67.20	174.88	128.48	52.39	37.10	4.13	4.19
P1 × P3	63.87	54.02	156.52	122.42	48.17	36.28	4.01	4.10
P1 × P4	70.80	65.79	179.20	83.21	54.95	23.06	3.71	4.30
P1 × P5	72.32	70.05	175.96	152.81	53.73	44.87	4.15	4.18
P1 × P6	71.67	58.16	164.62	143.54	50.31	40.08	3.89	3.89
P2 × P3	59.75	51.89	154.36	142.58	52.96	41.07	4.61	4.23
P2 × P4	74.27	55.64	166.62	130.31	50.60	37.60	3.82	4.61
P2 × P5	53.25	61.69	163.26	138.20	48.83	35.62	4.17	3.95
P2 × P6	56.72	61.91	158.78	154.65	47.35	44.70	3.65	3.95
P3× P4	63.43	55.25	162.70	126.95	48.50	36.61	3.73	3.99
P3× P5	65.60	71.55	167.74	138.33	49.99	39.75	3.98	4.09
P3× P6	56.72	61.77	145.34	132.84	43.38	38.26	4.65	4.00
P4 × P5	63.43	74.52	160.11	137.09	48.34	34.79	4.86	3.76
P4 × P6	61.48	60.90	155.19	133.97	47.18	38.75	3.63	4.38
P5 × P6	62.57	63.22	157.38	112.00	47.68	31.98	4.11	4.61
LSD 5%	2.67	2.43	5.89	6.60	1.48	1.18	0.10	0.15
LSD 1%	3.58	3.25	7.88	8.83	1.98	1.57	0.13	0.20

Notably, fruiting zone length and capsule length tended to decrease in the second season for most genotypes, likely due to environmental stress or less favorable growing conditions. Some hybrids, such as P1 × P5 and P4 × P5, maintained high capsule lengths (up to 4.86 cm), which is desirable for yield. Overall, the results highlight substantial genetic variability and the potential for selecting superior genotypes or hybrids with early flowering, increased plant height, and longer capsules, all of which are important for enhancing sesame yield and adaptation to diverse environments.

Table 3 presents data on several sesame genotypes and their hybrids, evaluating four key traits: number of branches per plant, 1000-seed weight (g), seed weight per plant (g), and seed oil content (%), across two seasons. The parental genotypes (P1–P6) generally showed lower values for these traits compared to their hybrids. The highest number of branches per plant among parents was 6.09 (P3, first season), while hybrids like P2 × P3 and P4 × P5 reached 7.28 and 7.67, respectively. Similarly, 1000-seed weight and seed weight per plant were higher in hybrids, with P4 × P5 achieving 3.77 g and 37.48 g, respectively, in the first season. Oil content also peaked in hybrids, with P4 × P5 reaching 58.33 % in the first season, compared to a maximum of 54.54 % among parents (P2).

Table 3. *Mean performance of six parental sesame genotypes and their 15 F_1 cross combinations for number of branches/plant, 1000-seed weight, seed weight/plant and seed oil content across the 2024 and 2025 summer seasons*

Genotypes	Number of branches/plant		1000-seed weight		Seed weight/plant		Seed oil content	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P1	5.10	4.21	2.83	2.08	27.21	20.80	50.98	54.23
P2	5.98	4.01	2.94	2.93	28.11	29.82	54.54	54.30
P3	6.09	2.80	2.95	1.57	29.33	15.35	54.36	52.32
P4	4.57	3.91	2.27	1.92	22.66	19.02	54.08	50.74
P5	4.89	3.54	2.34	1.74	25.88	17.18	52.27	51.84
P6	5.84	3.85	2.74	1.88	28.49	18.63	53.29	47.50
LSD 5%	0.13	0.15	0.07	0.07	0.68	0.57	0.54	0.68
LSD 1%	0.17	0.21	0.10	0.10	0.91	0.77	0.72	0.91
P1 × P2	6.53	6.63	3.20	3.26	31.88	32.36	58.40	58.66
P1 × P3	6.35	6.49	3.11	3.19	31.01	31.78	58.16	57.22
P1 × P4	5.88	6.80	2.88	3.34	28.59	33.23	53.92	57.23
P1 × P5	6.57	6.61	3.22	3.25	32.07	32.26	58.19	57.56
P1 × P6	6.16	6.16	3.02	3.03	29.94	30.04	56.40	56.40
P2 × P3	7.28	6.69	3.58	3.28	35.55	32.65	59.21	57.89
P2 × P4	6.06	7.28	2.97	3.58	29.56	35.55	55.51	58.48
P2 × P5	6.59	6.25	3.24	3.07	32.17	30.52	58.64	57.28
P2 × P6	5.78	6.23	2.83	3.06	28.20	30.43	53.04	57.10
P3× P4	5.92	6.31	2.90	3.09	28.78	30.81	54.10	54.27
P3× P5	6.29	6.47	3.09	3.18	30.72	31.59	57.63	59.09
P3× P6	7.34	6.33	3.60	3.11	35.84	30.91	57.03	57.99
P4 × P5	7.67	5.96	3.77	2.93	37.48	29.07	58.33	54.63
P4 × P6	5.74	6.92	2.82	3.39	28.01	33.71	52.69	59.01
P5 × P6	6.51	7.26	3.20	3.57	31.78	35.45	58.37	57.82
LSD 5%	0.20	0.24	0.12	0.12	1.07	0.91	0.85	1.07
LSD 1%	0.27	0.33	0.16	0.16	1.43	1.21	1.14	1.43

These results indicate significant heterosis, where hybrids outperform parents in yield-related traits and oil content. Such traits, number of branches, 1000-seed weight, seed yield per plant, and oil content are strongly correlated with overall yield and are recommended as selection criteria for breeding programs aiming to improve sesame productivity and oil quality [28, 25, 29, 30, 31, 32]. The results align with research showing that these traits have high heritability and genetic advance, making them effective targets for direct selection in sesame improvement [25, 33, 31].

Half diallel's analyses

Table 4 presents the analysis of variance for several agronomic and yield-related traits in sesame, focusing on the effects of general combining ability (GCA, additive effects) and specific combining ability (SCA, non-additive effects) using Griffing's and Jones' methods. Highly significant differences were observed for most traits, including days to 50% flowering, plant height, fruiting zone length, capsule length, number of branches per plant, 1000-seed weight, seed weight per plant, and seed oil content, indicating substantial genetic variability and the presence of both additive and non-additive genetic effects. The significance of GCA for most traits suggests that additive gene action plays a major role, which is favorable for selection and breeding programs, while significant SCA values indicate the importance of specific cross combinations and dominance effects.

Table 4. *Half diallel's analyses with Griffing method 2 model 1 (1956) and Jones (1965) for all studied traits across the 2024 and 2025 summer seasons*

SOV Griffing	SOV Jones	Df	Days to 50%flowering 1st	Days to 50%flowering 2nd	Plant height 1st	Plant height 2nd	Fruiting zone length 1st	Fruiting zone length 2nd	Capsules length 1st	Capsules length 2nd
GCA	a	5	66.44**	32.01*	172.39**	248.92**	11.70**	22.22**	0.14**	0.06**
	b1	1	200.05**	150.54**	4.10	1458.69**	98.09**	187.10**	1.47**	13.74**
	b2	5	20.59**	134.75**	394.61**	319.24**	56.65**	29.48**	0.10**	0.04
	b3	9	27.80**	30.89*	33.56	328.46**	4.88*	30.36**	0.17**	0.09**
SCA	b	15	36.88**	73.48**	151.95**	400.73**	28.35**	40.52**	0.23**	0.98**
	Total	20	44.27**	63.12**	157.06**	362.78**	24.19**	35.94**	0.21**	0.75**
	Error	40	5.25	4.32	25.44	31.97	1.61	1.02	0.01	0.02
	Baker ratio		0.78	0.47	0.69	0.55	0.45	0.52	0.55	0.11

SOV Griffing	SOV Jones	Df	Number of branches/plant 1st	Number of branches/plant 2nd	1000-seed weight 1st	1000-seed weight 2nd	Seed weight/plant 1st	Seed weight/plant 2nd	Seed oil content 1st	Seed oil content 2nd
GCA	a	5	0.39**	0.20**	0.07**	0.14**	7.70**	15.81**	4.19**	4.07**
	b1	1	4.58**	34.54**	1.00**	6.18**	86.47**	605.87**	49.16**	132.10**
	b2	5	0.26**	0.08	0.07**	0.09**	4.08*	10.81**	7.01**	3.32**
	b3	9	0.40**	0.21**	0.10**	0.05*	9.78**	5.09**	2.54**	2.52**
SCA	b	15	0.63**	2.46**	0.15**	0.47**	12.99**	47.05**	7.14**	11.43**
	Total	20	0.57**	1.89**	0.13**	0.39**	11.67**	39.24**	6.40**	9.59**
	Error	40	0.03	0.04	0.01	0.01	0.84	0.60	0.54	0.84
	Baker ratio		0.55	0.14	0.50	0.38	0.54	0.40	0.54	0.42

Note: "GCA and SCA of Griffing (1956)" and "a=additive effects, b=total non-additive (dominance) effects, b1=mean deviation of F1's from their mid-parents, b2=test if there is equal or unequal distribution among parents and b3=detect existence of unique dominance of each F1, i.e., presence of considerable amount of heterotic effect specific to some crosses of Jones (1965) modification",*, ** significant at 0.05 and 0.01 level of probability, respectively

The Baker ratio, which measures the relative importance of additive versus non-additive effects, ranged from moderate to high for most traits (0.78 for days to 50% flowering, 0.69 for plant height), supporting the predominance of additive effects, though some traits like capsule length and oil content in the second season showed lower ratios, highlighting a greater influence of non-additive effects. These findings align with recent research emphasizing the importance of both additive and non-additive genetic variance in improving sesame yield, as well as the key role of traits such as plant height, capsule length, number of branches, and seed weight in determining yield potential [24, 25, 26, 27]. The significant mean squares for b1, b2, and b3 components further indicate the presence of heterosis and unequal parental contributions, which can be exploited in hybrid breeding. Overall, the results suggest that both selection for additive traits and exploitation of specific cross combinations are effective strategies for enhancing sesame yield and quality [24, 25, 27].

General combining ability (GCA) effects

Fig. 1 presents the general combining ability (GCA) effects of six sesame parental genotypes (P1–P6) for key agronomic and yield traits, with significance levels indicating the strength of genetic influence. Significant positive or negative GCA values reveal which parents contribute favorably or unfavorably to each trait. For example, P1 and P3 show highly significant positive effects for early flowering (days to 50% flowering), suggesting they can be used to breed earlier-maturing varieties, while P4 and P6 have significant negative effects, indicating later flowering. For plant height, P1 and P2 generally increase height, while P4 and P6 decrease it, with several effects being highly significant. Traits like fruiting zone length, capsule length, number of branches, and 1000-seed weight also show significant variation among parents, highlighting the presence of substantial genetic diversity and the potential for selection. High heritability and significant GCA effects for traits such as capsule length, branches per plant, and seed yield per plant suggest these are largely controlled by additive genetic factors and can be improved through direct selection in breeding programs [34, 35, 31, 33]. The significant differences among parental lines for most traits confirm the presence of genetic variability, which is essential for effective breeding [24, 31, 27]. Notably, traits with high heritability and genetic advance, such as capsule length and branches per plant, are particularly promising for genetic improvement [35, 31, 33]. Overall, the results support the use of these parental lines in breeding programs to enhance yield and related traits in sesame, with the significant GCA effects guiding the choice of parents for crossing [34, 35, 31, 33].

Specific combining ability effects

Table 5 presents the performance of various sesame hybrids (crosses) for key agronomic traits, days to 50% flowering, plant height, fruiting zone length, and capsule length across two growing seasons. Desirable hybrids are those that combine early flowering, optimal plant height, longer fruiting zones, and longer capsules, as these traits are linked to higher yield and better adaptability. The cross P1 × P5 showed significantly earlier flowering in the second season, increased plant height and fruiting zone length in both seasons, and consistently longer capsules, making it a promising hybrid for yield improvement. Similarly, P2 × P3 and P3 × P6 demonstrated favorable results for capsule length and fruiting zone length, which are important for seed yield. Recent research confirms that selecting hybrids with superior performance in these traits, especially those showing high heterosis and specific combining ability, is effective for developing high-yielding sesame varieties [14, 36, 37, 38].

Additionally, the use of diallel analysis and combining ability studies helps breeders identify the best parental combinations for these traits [39, 40, 14, 38]. Therefore, hybrids like P1 × P5, P2 × P3, and P3 × P6 are recommended for further breeding and commercial cultivation due to their desirable agronomic profiles across seasons [14, 36, 38, 37].

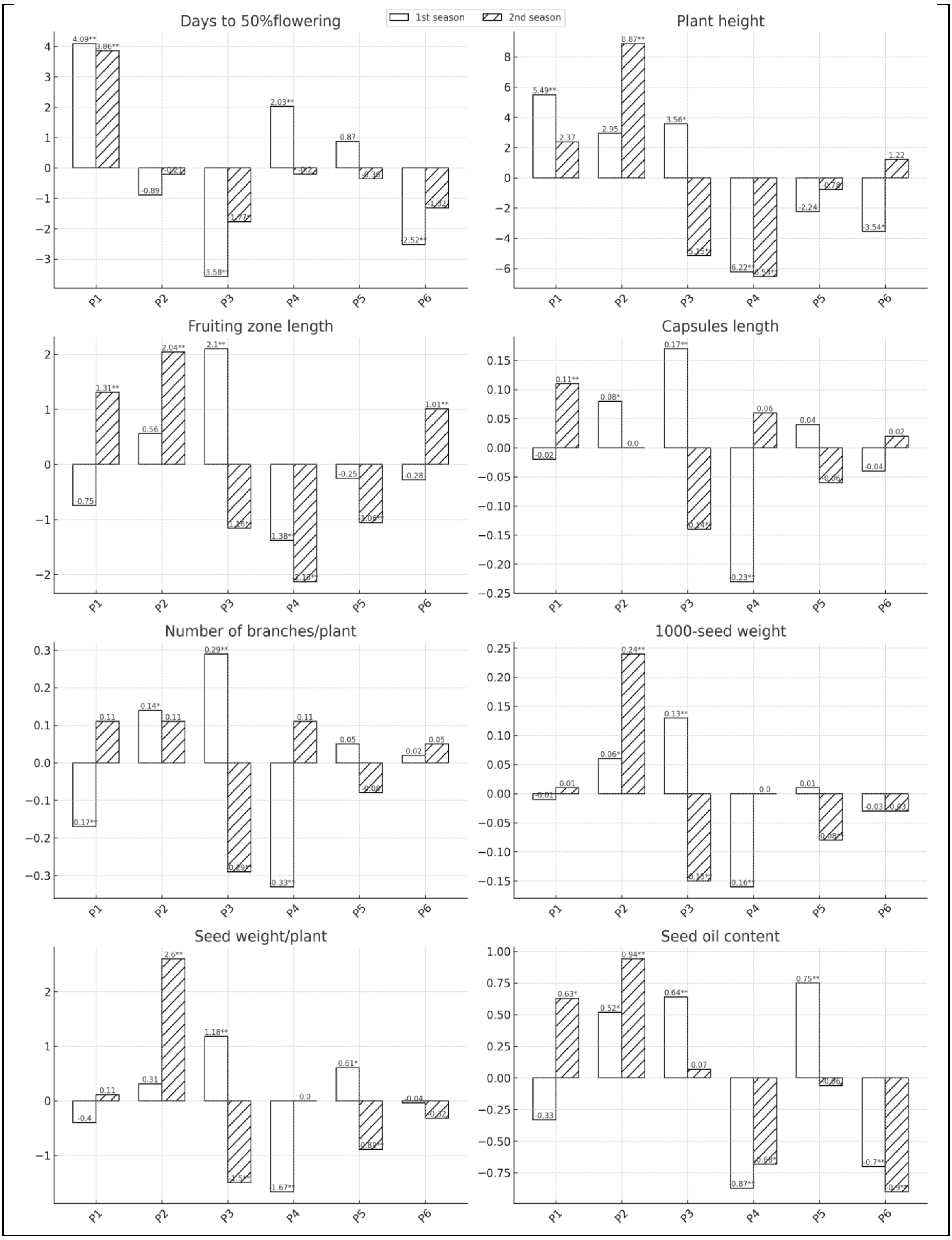

Fig. 1. *General combining ability effects of six parental sesame genotypes for all studied traits across the 2024 and 2025 summer seasons*

**, ** refers to significant at 5% and highly significant at 1%, respectively*

Table 5. *Specific combining ability effects of 15 F_1 cross combinations for days to 50%flowering, plant height, fruiting zone length and capsules length across the 2024 and 2025 summer seasons*

Crosses	Days to 50%flowering		Plant height		Fruiting zone length		Capsules length	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P1 × P2	-0.41	3.00	3.31	-9.31*	4.31**	-1.72*	0.16*	0.44**
P1 × P3	-2.93	-8.61**	-15.65**	-1.35	-1.43	0.65	-0.04	0.49**
P1 × P4	-1.60	1.59	16.80**	-39.18**	8.82**	-11.60**	0.05	0.50**
P1 × P5	1.08	6.00**	9.59*	24.66**	6.47**	9.14**	0.22**	0.49**
P1 × P6	3.81*	-4.92**	-0.46	13.39**	3.08**	2.28**	0.04	0.11
P2 × P3	-2.06	-6.67**	-15.28**	12.31**	2.04*	4.71**	0.46**	0.73**
P2 × P4	6.85**	-4.49**	6.76	1.42	3.16**	2.22**	0.07	0.91**
P2 × P5	-13.00**	1.71	-0.57	3.55	0.26	-0.84	0.14*	0.37**
P2 × P6	-6.15**	2.89	-3.76	18.00**	-1.19	6.18**	-0.30**	0.29**
P3× P4	-1.30	-3.31*	2.24	12.08**	-0.47	4.42**	-0.11	0.43**
P3× P5	2.03	13.14**	3.31	17.71**	-0.11	6.49**	-0.14*	0.65**
P3× P6	-3.47*	4.32**	-17.80**	10.21*	-6.69**	2.93**	0.61**	0.48**
P4 × P5	-5.75**	14.53**	5.45	17.85**	1.71	2.50**	1.14**	0.12
P4 × P6	-4.31*	1.88	1.83	12.73**	0.59	4.40**	-0.01	0.66**
P5 × P6	-2.06**	4.35**	0.04**	-15.00*	-0.05**	-3.44**	0.21**	1.01**
LSD Sij 5%	3.39	3.08	7.46	8.36	1.88	1.49	0.13	0.18
LSD Sij 1%	4.53	4.12	9.98	11.19	2.51	2.00	0.18	0.25
LSD sij-sik 5%	6.12	5.56	13.48	15.12	3.39	2.70	0.24	0.33
LSD sij-sik 1%	8.19	7.44	18.04	20.23	4.54	3.61	0.32	0.44
LSD sij-skl 5%	5.67	5.15	12.48	14.00	3.14	2.50	0.22	0.31
LSD sij-skl 1%	7.59	6.89	16.71	18.73	4.20	3.34	0.30	0.41

*, ** refers to significant at 5% and highly significant at 1%, respectively

Table 6 shows significant differences among sesame hybrids for number of branches per plant, 1000-seed weight, seed weight per plant, and seed oil content across two growing seasons, highlighting the importance of both additive and non-additive genetic effects in these traits. Desirable hybrids for a high number of branches include P4 × P5 and P5 × P6, which also excel in seed weight and oil content, indicating strong hybrid vigor and adaptability. For 1000-seed weight, P4 × P5 and P5 × P6 again stand out, while P2 × P3 and P3 × P6 are notable for their high seed yield and oil content, especially in the second season. These results suggest that hybrids such as P4 × P5, P5 × P6, and P3 × P6 are particularly promising for breeding programs aiming to improve yield and oil quality under varying environmental conditions. Recent research supports the strategy of selecting hybrids with superior specific combining ability for these traits, as they tend to perform well across seasons and environments, and emphasizes the value of focusing on number of branches, seed weight, and oil content in selection criteria for sesame improvement (41, 13, 14, 5]. Additionally, studies confirm that hybrids with high per se performance and strong combining ability, such as those identified in the table, are ideal candidates for further development and commercial cultivation due to their stability and high productivity [42, 14, 5].

Table 6. *Specific combining ability effects of 15 F_1 cross combinations for number of branches/plant, 1000-seed weight, seed weight/plant and seed oil content across the 2024 and 2025 summer seasons*

Crosses	Number of branches/plant		1000-seed weight		Seed weight/plant		Seed oil content	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P1 × P2	0.41**	0.67**	0.12	0.12	1.81*	1.03	2.54**	1.30
P1 × P3	0.08	0.93**	-0.03	0.45**	0.07	4.54**	2.18**	0.74
P1 × P4	0.23	0.84**	0.03	0.45**	0.50	4.49**	-0.54	1.50*
P1 × P5	0.54**	0.83**	0.20**	0.44**	1.70*	4.42**	2.10**	1.20
P1 × P6	0.16	0.25	0.03	0.16*	0.23	1.62**	1.76**	0.88
P2 × P3	0.69**	1.12**	0.36**	0.30**	3.90**	2.92**	2.37**	1.09
P2 × P4	0.09	1.31**	0.04	0.45**	0.76	4.32**	0.19	2.43**
P2 × P5	0.25	0.48**	0.14	0.03	1.09	0.19	1.70**	0.61
P2 × P6	-0.53**	0.33*	-0.23**	-0.03	-2.22**	-0.47	-2.45**	1.28
P3× P4	-0.19	0.75**	-0.09	0.36**	-0.89	3.68**	-1.34*	-0.92
P3× P5	-0.19	1.09**	-0.06	0.53**	-1.23	5.34**	0.57	3.29**
P3× P6	0.88**	0.83**	0.47**	0.41**	4.54**	4.10**	1.41*	3.03**
P4 × P5	1.81**	0.18	0.90**	0.13	8.38**	1.33*	2.78**	-0.42
P4 × P6	-0.10	1.02**	-0.01	0.54**	-0.44	5.41**	-1.41*	4.80**
P5 × P6	0.29**	1.54**	0.20**	0.80**	1.05**	8.04**	2.65**	2.99**
LSD Sij 5%	0.25	0.31	0.15	0.14	1.36	1.15	1.08	1.36
LSD Sij 1%	0.34	0.42	0.19	0.19	1.81	1.54	1.45	1.81
LSD sij-sik 5%	0.45	0.56	0.26	0.26	2.45	2.08	1.96	2.45
LSD sij-sik 1%	0.61	0.75	0.35	0.34	3.28	2.78	2.62	3.28
LSD sij-skl 5%	0.42	0.52	0.24	0.24	2.27	1.92	1.81	2.27
LSD sij-skl 1%	0.56	0.70	0.33	0.32	3.04	2.57	2.42	3.04

*, ** refers to significant at 5% and highly significant at 1%, respectively

Relative heterosis and heterbeltiosis as well as potence ratio

Table 7 presents data on heterosis and potence ratio for days to 50% flowering and plant height in various sesame hybrids across two growing seasons. For earliness (fewer days to 50% flowering), crosses such as P2 × P5 (MP = -28.40**, BP = -25.92**) and P2 × P6 (MP = -18.52**, BP = -15.77**) showed the strongest negative mid-parent and better-parent heterosis, indicating these hybrids are highly desirable for early flowering. For plant height, hybrids like P3 × P5 (MP = 44.56**, BP = 52.41**) and P1 × P5 (MP = 28.51**, BP = 51.87**) exhibited significant positive heterosis, making them preferred for increased plant height. The potence ratio (P) values, such as 8.48 for P2 × P5 and 3.9 for P3 × P6 in days to flowering, and 3.54 for P1 × P6 and 3.16 for P2 × P3 in plant height, further confirm strong dominance effects in these crosses. Recent studies emphasize that hybrids with high heterosis and favorable potence ratios for these traits can be effectively used to improve sesame yield and adaptability, as both earliness and plant height are positively associated with yield potential and agronomic performance [14, 43, 44]. Therefore, hybrids like P2 × P5 and P3 × P5 are recommended for breeding programs targeting early flowering and taller plants, supported by their significant heterosis and potence ratio values.

The Table (8) shows significant heterosis and potence ratio values for key yield traits in sesame hybrids across two growing seasons, highlighting the most desirable crosses for fruiting zone length and capsule length.

Table 7. *Relative heterosis (MP) and heterbeltiosis (BP) as well as potence ratio (P) of 15 F_1 cross combinations for days to flowering and plant height across the 2024 and 2025 summer seasons*

Crosses	Days to 50%flowering						Plant height					
	1st			2nd			1st			2nd		
	MP	P	BP	MP	P	BP	MP	P	BP	MP	P	BP
P1 × P2	-5.63	3.17	-3.92	2.10	-0.35	8.55**	2.53	-1.33	4.52	-4.30	1.96	-2.15
P1 × P3	-7.09*	0.85	1.38	-15.13**	1.58	-6.17*	-12.84*	1.88	-6.45	7.40	-0.36	34.87**
P1 × P4	-4.25	5.80	-3.54	5.47*	-0.46	19.55**	18.89**	-1.72	33.59**	-32.96**	3.13	-25.06**
P1 × P5	-4.44	2.82	-2.91	27.71**	-1.02	75.27**	11.00	-1.98	17.52*	28.51**	-1.85	51.87**
P1 × P6	1.07	-0.21	6.44	-5.72*	0.44	8.41**	-1.26	3.54	-0.91	16.44*	-1.46	31.28**
P2 × P3	-11.40**	1.73	-5.16	-13.14**	3.62	-9.86**	-15.56*	3.16	-11.19	28.41**	-1.56	57.08**
P2 × P4	2.24	-2.14	3.32	-4.85	0.82	1.10	8.22	-0.64	24.21**	7.55	-0.90	17.36*
P2 × P5	-28.40**	8.48	-25.92**	21.11**	-0.98	54.35**	0.93	-0.12	9.04	19.18**	-1.45	37.35**
P2 × P6	-18.52**	5.67	-15.77**	7.15**	-1.00	15.39**	-6.58	2.91	-4.42	28.53**	-3.13	41.44**
P3× P4	-6.99*	0.92	0.69	-1.87	0.83	0.39	-0.17	0.01	21.29**	25.82**	-2.57	39.87**
P3× P5	-6.20*	0.63	4.13	46.72**	-2.59	79.02**	-1.78	0.14	12.03	44.56**	-8.65	52.41**
P3× P6	-12.97**	3.90	-9.97**	11.07**	-3.14	15.13**	-18.79**	2.62	-12.51	32.77**	-3.53	46.35**
P4 × P5	-15.57**	6.75	-13.58**	56.88**	-3.59	86.45**	12.81*	-2.33	19.36**	29.54**	-6.00	36.25**
P4 × P6	-12.62**	2.93	-8.69*	12.07**	-9.48	13.51**	3.37	-0.32	15.69*	21.58**	-27.98	22.53**
P5 × P6	-13.22**	2.00	-7.08*	35.05**	-2.40	58.17**	-0.35	0.07	5.11	6.69	-1.61	11.31
LSD 5%	5.67		6.55	5.15		5.94	12.48		14.42	14.00		16.16
LSD 1%	7.59		8.76	6.89		7.95	16.71		19.29	18.73		21.62

Where P refers to relative potency of the gene set; *, ** refers to significant at 5% and highly significant at 1%, respectively

For fruiting zone length, crosses such as P1 × P4 (MP: 47.05**, BP: 42.39**) and P1 × P5 (MP: 34.72**, BP: 23.18**) exhibited strong mid-parent and better-parent heterosis, indicating their potential for yield improvement. Similarly, for capsule length, P4 × P5 (MP: 59.92**, BP: 51.99**) and P3 × P6 (MP: 25.58**, BP: 20.95**) showed high heterosis values, making them promising for breeding programs. The potence ratio (P) values, especially when positive and significant, further confirm the dominance of non-additive gene action in these traits, supporting the exploitation of hybrid vigor in sesame breeding [17, 45]. Recent studies emphasize that hybrids with high specific combining ability and significant heterosis, such as those identified here, are ideal for selection and further testing in multi-environment trials to enhance yield and its components [17, 46, 45, 47]. The results align with modern research, which recommends focusing on hybrids with both high per se performance and strong heterotic effects for sustainable yield improvement in sesame [46, 37].

Table 9 shows significant differences among sesame hybrids for the number of branches per plant and 1000-seed weight across two growing seasons, highlighting strong hybrid vigor (heterosis) for these traits. The cross P4 × P5 exhibited the highest number of branches per plant (62.27 in the first season, 56.92 for the best parent), indicating superior hybrid performance and a high potency ratio, which suggests dominance or overdominance gene action. For 1000-seed weight, P3 × P5 and P5 × P6 were among the top performers (92.42 and 96.82 in the first season, with best parent values of 82.79 and 89.25), making them desirable for breeding programs targeting seed size improvement. The potence ratio (P) values, such as 18.25 for P4 × P5 and 24.2 for P5 × P6, further confirm the strong hybrid vigor and the potential for these crosses to outperform their parents. Recent research supports the importance of selecting hybrids with high numbers of branches and greater 1000-seed weight, as these traits are positively correlated with seed yield and are largely controlled by additive genetic effects, making them reliable targets for selection and improvement in sesame breeding programs [41, 48, 14, 49, 50].

Table 8. *Relative heterosis (MP) and heterbeltiosis (BP) as well as potency ratio (P) of 15 F_1 cross combinations for fruiting zone length and capsule length across the 2024 and 2025 summer seasons*

Crosses	Fruiting zone length						Capsules length					
	1st			2nd			1st			2nd		
	MP	P	BP	MP	P	BP	MP	P	BP	MP	P	BP
P1 × P2	28.97**	2.63	16.17**	1.66	0.27	-4.18**	10.91**	5.81	8.86**	63.62**	5.61	46.96**
P1 × P3	4.81**	0.23	-13.63**	16.48**	0.68	-6.32**	7.11**	2.80	4.46**	70.02**	3.85	43.85**
P1 × P4	47.05**	14.37	42.39**	-33.14**	-2.70	-40.45**	13.55**	1.15	1.58**	62.62**	8.11	50.96**
P1 × P5	34.72**	3.70	23.18**	37.73**	2.00	15.87**	21.24**	3.21	13.72**	65.35**	5.08	46.52**
P1 × P6	17.05**	1.07	0.99	14.44**	1.37	3.50*	7.81**	6.04	6.44**	47.89**	5.63	36.30**
P2 × P3	5.00**	0.47	-5.06**	42.01**	2.27	19.83**	20.75**	31.26	19.96**	99.25**	14.18	86.22**
P2 × P4	20.94**	2.69	12.22**	16.55**	2.65	9.70**	14.59**	1.07	0.84**	95.56**	26.23	88.69**
P2 × P5	10.10**	6.08	8.30**	17.34**	1.34	3.92**	19.18**	2.26	9.87**	76.63**	49.67	73.94**
P2 × P6	-0.23	-0.05	-4.96**	36.31**	8.06	30.43**	-0.78**	-0.25	-3.83**	68.97**	24.12	64.27**
P3× P4	2.80	0.15	-13.04**	36.06**	2.91	21.04**	11.09**	0.78	-2.79**	80.60**	7.59	63.27**
P3× P5	0.59	0.05	-10.38**	59.00**	10.29	50.38**	12.92**	1.41	3.47**	95.86**	17.56	85.72**
P3× P6	-17.83**	-3.16	-22.23**	39.42**	2.79	22.16**	25.58**	6.67	20.95**	82.75**	8.41	66.38**
P4 × P5	17.60**	2.88	10.82**	22.77**	3.38	15.03**	59.92**	11.48	51.99**	61.92**	11.95	53.94**
P4 × P6	6.74**	0.53	-5.29**	25.90**	14.84	23.74**	12.84**	1.22	2.11**	80.76**	103.00	79.35**
P5 × P6	2.06	0.31	-4.29*	10.75**	1.27	2.11	21.79**	4.10	15.64**	100.10**	22.75	91.67**
LSD 5%	3.14		3.63	2.50		2.88	0.22		0.26	0.31		0.35
LSD 1%	4.20		4.86	3.34		3.86	0.30		0.34	0.41		0.47

Where P refers to the relative potency of the gene set; *, ** refers to significant at 5% and highly significant at 1%, respectively

High heritability and genetic advance for these traits have also been reported, reinforcing the value of these hybrids for future varietal development [41, 50, 51]. Therefore, hybrids like P4 × P5 and P5 × P6 are recommended for their superior performance in both number of branches and seed weight, supported by their high potence ratios and consistent results across seasons.

Table 10 shows significant differences among sesame hybrids for seed weight per plant and seed oil content across two growing seasons, highlighting strong hybrid vigor (heterosis) for these traits. Notably, the cross P4 × P5 exhibited the highest seed weight per plant (54.43** in the first season and 60.61** in the second) and high oil content (9.68** and 6.51**), making it a highly desirable hybrid for both yield and oil quality. Other promising crosses include P3 × P6 and P5 × P6, which also demonstrated high values for both traits in both seasons. The potence ratio (P) values, especially when highly significant (P4 × P5: 8.2 and 11.95 for seed weight, 5.69 and 6.09 for oil content), indicate strong dominance effects and the presence of non-additive gene action, which is consistent with recent research emphasizing the importance of non-additive genetic variance in sesame hybrid performance [8, 13, 5]. These findings align with modern studies that recommend selecting hybrids with high specific combining ability and significant heterosis for improving both seed yield and oil content in sesame breeding programs [52, 8]. The results also support the use of hybrids with high potency ratios and significant mean parent and better parent heterosis as key candidates for future breeding efforts [13, 5, 7].

Table 9. *Relative heterosis (MP) and heterbeltiosis (BP) as well as potence ratio (P) of 15 F_1 cross combinations for number of branches/plant and 1000-seed weight across the 2024 and 2025 summer seasons*

Crosses	Number of branches/plant						1000-seed weight					
	1st			2nd			1st			2nd		
	MP	P	BP	MP	P	BP	MP	P	BP	MP	p	BP
P1 × P2	17.91**	2.24	9.19**	61.44**	25.16	57.59**	10.94**	6.09	8.98**	29.98**	1.77	11.15**
P1 × P3	13.57**	1.52	4.28**	85.17**	4.26	54.32**	7.70**	3.85	5.59**	74.92**	5.30	53.25**
P1 × P4	21.74**	3.96	15.41**	67.61**	18.81	61.80**	12.81**	1.17	1.71**	67.02**	16.99	60.68**
P1 × P5	31.60**	15.23	28.92**	70.62**	8.22	57.12**	24.39**	2.58	13.65**	69.99**	7.83	56.04**
P1 × P6	12.58**	1.84	5.39**	52.74**	12.11	46.37**	8.22**	5.04	6.49**	52.56**	10.60	45.36**
P2 × P3	20.56**	22.18	19.45**	96.40**	5.47	66.95**	21.58**	105.78	21.33**	45.75**	1.51	11.81**
P2 × P4	14.89**	1.11	1.30**	83.78**	72.59	81.68**	13.91**	1.10	1.08**	47.36**	2.28	22.03**
P2 × P5	21.25**	2.12	10.18**	65.77**	10.67	56.15**	22.68**	2.02	10.30**	31.63**	1.24	4.88**
P2 × P6	-2.17**	-1.85	-3.30**	58.64**	30.64	55.66**	-0.22	-0.07	-3.53**	27.26**	1.25	4.55**
P3× P4	11.10**	0.77	-2.82**	87.94**	5.32	61.30**	11.06**	0.86	-1.63**	77.30**	7.54	60.81**
P3× P5	14.64**	1.34	3.31**	103.97**	8.96	82.77**	16.92**	1.48	4.93**	92.42**	17.56	82.79**
P3× P6	22.95**	10.93	20.42**	90.20**	5.72	64.28**	26.42**	7.27	21.98**	80.41**	8.70	65.14**
P4 × P5	62.27**	18.25	56.92**	59.89**	11.95	52.26**	63.28**	42.55	60.89**	59.91**	11.95	52.27**
P4 × P6	10.37**	0.85	-1.68**	78.22**	103.00	76.88**	12.55**	1.35	2.97**	78.19**	77.00	76.40**
P5 × P6	21.35**	2.40	11.45**	96.27**	22.63	88.26**	25.86**	3.30	16.72**	96.82**	24.20	89.25**
LSD 5%	0.42		0.49	0.52		0.60	0.24		0.28	0.24		0.28
LSD 1%	0.56		0.65	0.70		0.81	0.33		0.38	0.32		0.37

Where P refers to relative potency of the gene set, *, ** refers to significant at 5% and highly significant at 1%, respectively

Table 10. *Relative heterosis (MP) and heterbeltiosis (BP) as well as potence ratio (P) of 15 F_1 cross combinations for seed weight/plant and seed oil content across the 2024 and 2025 summer seasons*

Crosses	Seed weight/plant						Seed oil content					
	1st			2nd			1st			2nd		
	MP	P	BP	MP	P	BP	MP	P	BP	MP	p	BP
P1 × P2	15.25**	9.34	13.40**	27.84**	1.56	8.51**	10.69**	3.17	7.08**	8.09**	125.38	8.02**
P1 × P3	9.69**	2.58	5.73**	75.82**	5.02	52.76**	10.43**	3.25	7.00**	7.41**	4.12	5.51**
P1 × P4	14.67**	1.61	5.08**	66.89**	14.94	59.73**	2.65**	0.90	-0.30	9.04**	2.72	5.53**
P1 × P5	20.81**	8.35	17.88**	69.87**	7.33	55.09**	12.71**	10.15	11.32**	8.52**	3.78	6.13**
P1 × P6	7.52**	3.25	5.09**	52.35**	9.51	44.40**	8.18**	3.70	5.84**	10.87**	1.64	3.99**
P2 × P3	23.79**	11.23	21.22**	44.56**	1.39	9.48**	8.73**	51.87	8.55**	8.59**	4.61	6.60**
P2 × P4	16.43**	1.53	5.15**	45.57**	2.06	19.20**	2.21*	5.22	1.78	11.33**	3.34	7.69**
P2 × P5	19.15**	4.64	14.43**	29.87**	1.11	2.35*	9.80**	4.61	7.51**	7.93**	3.42	5.48**
P2 × P6	-0.35	-0.51	-1.02	25.58**	1.11	2.02	-1.62	-1.39	-2.76*	12.18**	1.82	5.16**
P3× P4	10.73**	0.84	-1.85	79.32**	7.42	62.00**	-0.22	-0.88	-0.48	5.31**	3.48	3.73**
P3× P5	11.27**	1.81	4.74**	94.20**	16.68	83.82**	8.10**	4.14	6.02**	13.46**	29.41	12.94**
P3× P6	23.97**	16.63	22.21**	81.93**	8.47	65.89**	5.95**	5.97	4.91**	16.19**	3.35	10.84**
P4 × P5	54.43**	8.20	44.82**	60.61**	11.95	52.86**	9.68**	5.69	7.85**	6.51**	6.09	5.38**
P4 × P6	9.51**	0.83	-1.70	79.07**	77.00	77.25**	-1.86*	-2.51	-2.58*	20.13**	6.10	16.29**
P5 × P6	16.89**	3.52	11.53**	97.97**	24.20	90.27**	10.58**	11.03	9.53**	16.42**	3.76	11.54**
LSD 5%	2.27		2.62	1.92		2.22	1.81		2.09	2.27		2.62
LSD 1%	3.04		3.51	2.57		2.97	2.42		2.80	3.04		3.51

Where P refers to the relative potency of the gene set; *, ** refers to significant at 5% and highly significant at 1%, respectively

CONCLUSION

In conclusion, the research demonstrates substantial genetic variability among sesame genotypes and their hybrids for key agronomic and yield-related traits, such as days to 50% flowering, plant height, capsule length, number of branches, 1000-seed weight, seed yield per plant, and oil content. This variability is crucial for breeding programs, as it enables the selection and development of superior varieties with higher yield and better adaptation to environmental stresses. Both additive and non-additive genetic effects were significant, with traits like capsule length and number of branches showing high heritability and genetic advance, making them reliable targets for selection. Hybrids such as P4 × P5 and P5 × P6 consistently outperformed their parents, exhibiting strong hybrid vigor (heterosis) and high potency ratios, especially for yield and oil content. The results also highlight the importance of specific combining ability and the exploitation of hybrid vigor in breeding strategies.

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