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Assessment of Genetic Diversity, Correlation and Path Coefficients Analysis in Sesame (*Sesamum indicum* L.)

Khin Mu Aye[1,2], Tanee Sreewongchai[1,*], Chalermpol Phumichai[1], Weerachai Mathayatthaworn[1], Orawan Kumdee[3], Yingluck Ratanapongsai[3], Rattigan Kaedphol[4]

[1]*Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand*
[2]*Oilseed Crops Research Section, Department of Agricultural Research, NayPyiTaw 15013, Myanmar*
[3]*Agricultural Research and Technology Transfer Center, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand*
[4]*National Corn and Sorghum Research Center, Faculty of Agriculture, Kasetsart University, Nakhon Ratchasima 30320, Thailand*

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ABSTRACT

Knowledge of variability, correlation and path coefficient analysis is essential for crop improvement procedures. In this study, 54 sesame genotypes were planted in a randomized complete block design with three replications to analyze genetic diversity, correlation and path analysis in sesame. Eleven characters were collected and analyzed. The analysis of variance indicated a significant variation among the genotypes for 11 characters. Days to 50% flowering, days to maturity, height of first capsule bearing node, number of primary branches per plant, capsule length, capsule width, number of seeds per capsule and 1000 seed weight revealed high heritability values. Moderate heritability values were observed for plant height, number of capsules per plant and seed yield per plant. The number of primary branches per plant, number of capsules per plant and number of seeds per capsule were strongly correlated with seed yield per plant. Moreover, path coefficient analysis demonstrated that number of primary branches per plant (0.493), number of capsules per plant (1.833) and number of seeds per capsule (0.448) had a positive direct effect on seed yield. These traits may serve as selection criteria for increasing the yield of sesame.

Keywords: Direct effect; Heritability; Indirect effect; Seed yield; Sesame

***Corresponding author:** agrtns@ku.ac.th
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1. Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop belonging to the order Tubiflorae and the family Pedaliaceae. It is widely used in daily life for a variety of purposes from use in food to cosmetics. The sesame seed provides various useful components such as antioxidants, vitamins, healthy fat, dietary fiber, moisture, energy, carbohydrates and minerals. The seed contains 53% oil, 20% protein, 38% oleic acid and 46% linoleic acid [1]. Although sesamum species can be adapted to a wide range of environmental conditions, its seed yield is quite low compared to that of other oilseed species [2]. The productivity can be affected by various factors, such as climate conditions, drought stress, pests, diseases and a lack of high-yielding varieties [3-5]. In the case of crop improvement programs, the development of additional high-yielding varieties with a wide range of adaptations provides more options for sesame cultivation with enhanced productivity.

For crop improvement efforts, crop yield is a crucial selection characteristic. It is a complex trait controlled by many genes and highly influenced by a variety of environmental factors. The factors of crop variety and yield-contributing traits also have their part influencing crop yield [6]. Accordingly, yield can be effectively increased by improving yield components. Assessment of genetic diversity is a foundational step for any crop improvement program. Heritability is essential knowledge for crop improvement based on selection, as it explains the magnitude of the transmissibility of traits from parents to their progeny [7]. The information on the degree and nature of the correlation between yield and its related traits can help breeders to make better selection choices in their plant breeding programs [8,9]. The selection process is an effective method for crop development efforts that can be carried out using path coefficient analysis as a tool to partition correlation coefficients of yield-contributing traits to direct and indirect effects on seed yield [9, 10]. Hence, the purposes of this study were to evaluate diversity, correlation and path analysis in sesame based on seed yield and its traits.

2. Materials and Methods

2.1 Experimental site, plant materials, experimental layout and crop management

A field experiment was conducted in the summer of 2023 at the National Corn and Sorghum Research Center (Suwan Farm), Kasetsart University, Thailand. For this study, 54 sesame genotypes were used (Table 1). The 54 genotypes were raised in a randomized complete block design (RCBD) with three replications. Each experiment plot contained four rows, each 2 m long, with a plant spacing of 0.1 × 0.7 m^2. The recommended dose of NPK fertilizer (15-15-15) of 187.5 kg per hectare was applied at land preparation and 30 days after sowing. Irrigation was applied the day after planting, then every 7 days until the harvesting period. Two weeks before harvesting, irrigation was restricted. Other recommended agricultural practices, such as thinning, weeding, and pest and disease control measures, were followed throughout the study period as necessary.

2.2 Data collection

Measurements were collected on five random plants from the middle rows of each replication for plant height (PH), height of first capsule bearing node (HFCBN), number of primary branches per plant (NPBPP), number of capsules per plant (NCPP), capsule length (CL), capsule width (CW), number of seeds per capsule (NSPC), thousand seed weight (TSW) and seed yield per plant (SYPP). Days to 50% flowering (DTFPF) and days to maturity (DTM) were recorded on a per plot basis. All measurements were recorded according to the descriptor for sesame [11].

2.3 Statistical analysis

The analysis of variance and descriptive statistics for 11 traits were calculated using Statistical Tool for Agricultural Research (version 2.0.1, IRRI). Broad-sense heritability, correlation and path coefficient analyses were estimated using R package (version 4.3.1). Heritability in broad-sense was calculated using the formula of Burton and Devane [12]. Heritability was categorized as low (<30%), moderate (31–60%) and high (>61%) according to Johnson et al. [7]. The phenotypic and genotypic correlation coefficients were estimated, as suggested by Singh and Chaudhary [13]. They were categorized as weak (< ± 0.3), moderate (± 0.3 to ± 0.7) and strong (± 0.7 to ± 1), as suggested by Oladosu et al. [14]. Path coefficient analysis was calculated by the formula used by Dewey and Lu [10].

Table 1. List of sesame genotypes used in the study.

No.	Genotype	Source	No.	Genotype	Source
1	Yoesein	OSCRS, Myanmar	28	Samonenet (Bawlakhe)	OSCRS, Myanmar
2	Hnanni (25/160)	OSCRS, Myanmar	29	Samonenet (Myintmyattawwin)	OSCRS, Myanmar
3	Hnanyin (60)	OSCRS, Myanmar	30	Samonenet (75)	OSCRS, Myanmar
4	Ztutkalay	OSCRS, Myanmar	31	Pyithawthar	OSCRS, Myanmar
5	Hnanni (Seinsarpin)	OSCRS, Myanmar	32	Shanmalay	OSCRS, Myanmar
6	Kwayhleni	OSCRS, Myanmar	33	Theikpanhnannet	OSCRS, Myanmar
7	Rathekyaw	OSCRS, Myanmar	34	YSS 05014	OSCRS, Myanmar
8	Seinpatlel	OSCRS, Myanmar	35	Sinyadanar 3	OSCRS, Myanmar
9	Shwekyaungty	OSCRS, Myanmar	36	Sinyadanar 14	OSCRS, Myanmar
10	Magway 7/9	OSCRS, Myanmar	37	Magway 1/13	OSCRS, Myanmar
11	Potepyae	OSCRS, Myanmar	38	MT 03	OSCRS, Myanmar
12	Sinyadanar 6	OSCRS, Myanmar	39	Sinyadanar 5	OSCRS, Myanmar
13	Majantaw	OSCRS, Myanmar	40	Kasetsart 18	KU, Thailand
14	Phyuma	OSCRS, Myanmar	41	Kasetsart 21	KU, Thailand
15	Bapan	OSCRS, Myanmar	42	Ubon Ratchathani 2	KU, Thailand
16	Hnanphyu (Linkhay)	OSCRS, Myanmar	43	Maha Sarakham 60	KU, Thailand
17	Chongkyaw	OSCRS, Myanmar	44	Ubon Ratchathani 3	KU, Thailand
18	Shwedasote	OSCRS, Myanmar	45	Ubon Ratchathani 1	KU, Thailand
19	Shwekyetou	OSCRS, Myanmar	46	Ubon Ratchathani 2	KU, Thailand
20	Setletphyu	OSCRS, Myanmar	47	Ubon Ratchathani 3	KU, Thailand
21	China	OSCRS, Myanmar	48	Cplus 1	KU, Thailand
22	Sinyadanar 4	OSCRS, Myanmar	49	C plus 2	KU, Thailand
23	Sinyadanar 8	OSCRS, Myanmar	50	KUAOX 25	KU, Thailand
24	Sinyadanar 12	OSCRS, Myanmar	51	CM 53	KU, Thailand
25	Managermyo	OSCRS, Myanmar	52	Kunming 1	KU, Thailand
26	Gwanet	OSCRS, Myanmar	53	India 3	India
27	Teelonenet	OSCRS, Myanmar	54	India 4	India

Note: OSCRS = Oilseed Crop Research Section; KU = Kasetsart University.

3. Results and Discussion

3.1 Analysis of variance

The analysis of variance revealed highly significant differences among genotypes at $p < 0.01$ for all 11 traits (Table 2). The analysis of variance depicted the presence of a sufficient scope for variation among the 54 sesame genotypes. Hence, the evaluated varieties can support variation by crossing among them for future generations. These results agree with the reports of Gogoi and Sarma [15] and Kumar et al. [16].

Table 2. Analysis of variance for eleven yield and yield components in sesame.

Traits	Genotype mean square (df = 53)	Error mean square (df = 106)
Days to 50% flowering	6.6415**	1.0059
Days to maturity	33.666**	4.177
Plant height (cm)	328.58**	76.89
Height of first capsule bearing node (cm)	231.98**	17.89
Number of primary branches per plant	8.2887**	0.5830
Number of capsules per plant	5704.70**	1443.90
Capsule length (cm)	0.23489**	0.02445
Capsule width (cm)	0.033731**	0.002314
Number of seeds per capsule	448.92**	47.90
Thousand seed weight (g)	0.35705**	0.03153
Seed yield per plant (g)	87.0670**	33.851

Note: ** = significant at $p < 0.01$; df = degrees of freedom.

3.2 Descriptive statistic and heritability

The values of minimum, maximum, overall mean, standard deviation, coefficient of variation, broad-sense heritability and distribution for all traits are described in Table 3 and Fig. 1. The minimum and maximum values from 54 genotypes for days to 50% flowering were 39 and 47 days, respectively, while those for days to maturity were 97 and 107 (days), plant height were 116.52 and 163.93 (cm), height of first capsule bearing node were 11.93 and 48.73 (cm), number of primary branches per plant were 0 and 7, number of capsules per plant were 81 and 286, capsule length were 3.11 and 4.26 (cm), capsule width were 0.71 and 1.17 (cm), number of seeds per capsule were 54 and 118, thousand seed weight were 1.65 and 3.79 (g) and seed yield per plant were 9.45 and 33.55 (g). The mean performance of sesame genotypes for yield and its components is described in Table 3.

Table 3. Minimum and maximum mean values, overall mean values, standard deviation (SD), coefficients of variation (CV) and broad-sense heritability (Hbs) for 11 traits in 54 genotypes.

Traits	Minimum		Maximum		Mean±SD	CV (%)	Hbs (%)
	Value	Cultivar	Value	Cultivar			
Days to 50% flowering	39.00	Sinyadanar 8	47.00	Hnanphyu (Linkhay)	42.44±1.49	2.36	65.05
Days to maturity	97.00	Hnanyin (60)	107.00	Ubon Ratchathani 2	101.76±3.35	2.01	70.16
Plant height (cm)	116.52	Hnanni (Seinsarpin)	163.93	KUAOX 25	136.96±10.47	6.40	52.18
Height of first capsule bearing node (cm)	11.93	MT 03	48.73	Sinyadanar 6	30.88±8.79	13.70	79.96
Number of primary branches per plant	0.00	KUAOX 25	7.00	Potepyae	3.96±1.66	19.27	81.59
Number of capsules per plant	81.00	KUAOX 25	286.00	Hnanphyu (Linkhay)	169.81±43.61	22.38	55.77
Capsule length (cm)	3.11	Teelonenet	4.26	Shwekyetou	3.54±0.28	4.42	77.78
Capsule width (cm)	0.71	Shanmalay	1.17	Sinyadanar 12	0.81±0.11	5.69	83.33
Number of seeds per capsule	54.00	Kasetsart 18	118.00	Sinyadanar 12	69.30±12.23	9.99	73.62
Thousand seed weight (g)	1.65	Hnanphyu (Linkhay)	3.79	Kuming 1	3.14±0.35	5.65	78.57
Seed yield per plant (g)	9.45	Kasetsart 21	33.55	Hnanphyu (Linkhay)	21.68±5.39	26.84	34.39

Broad-sense heritability values for 11 traits ranged from 34.39% (seed yield per plant) to 83.33% (capsule width). High heritability (>61%) was reported by capsule width, number of primary branches per plant, height of first capsule bearing node, thousand seed weight, capsule length, number of seeds per capsule, days to maturity and days to 50%

flowering. This finding indicates that the environmental effect has a small influence on the expression of these traits and high heritability. Therefore, simple selection may be effective for the improvement of these traits based on their phenotypic values. Similar findings have been reported in a number of studies [16-20]. The number of capsules per plant, plant height and seed yield per plant showed moderate heritability values (31-60%). This finding indicates that selection based on these traits would be fairly challenging because there is a considerable environmental effect on these traits. These results are further supported by previous studies [16, 21, 22].

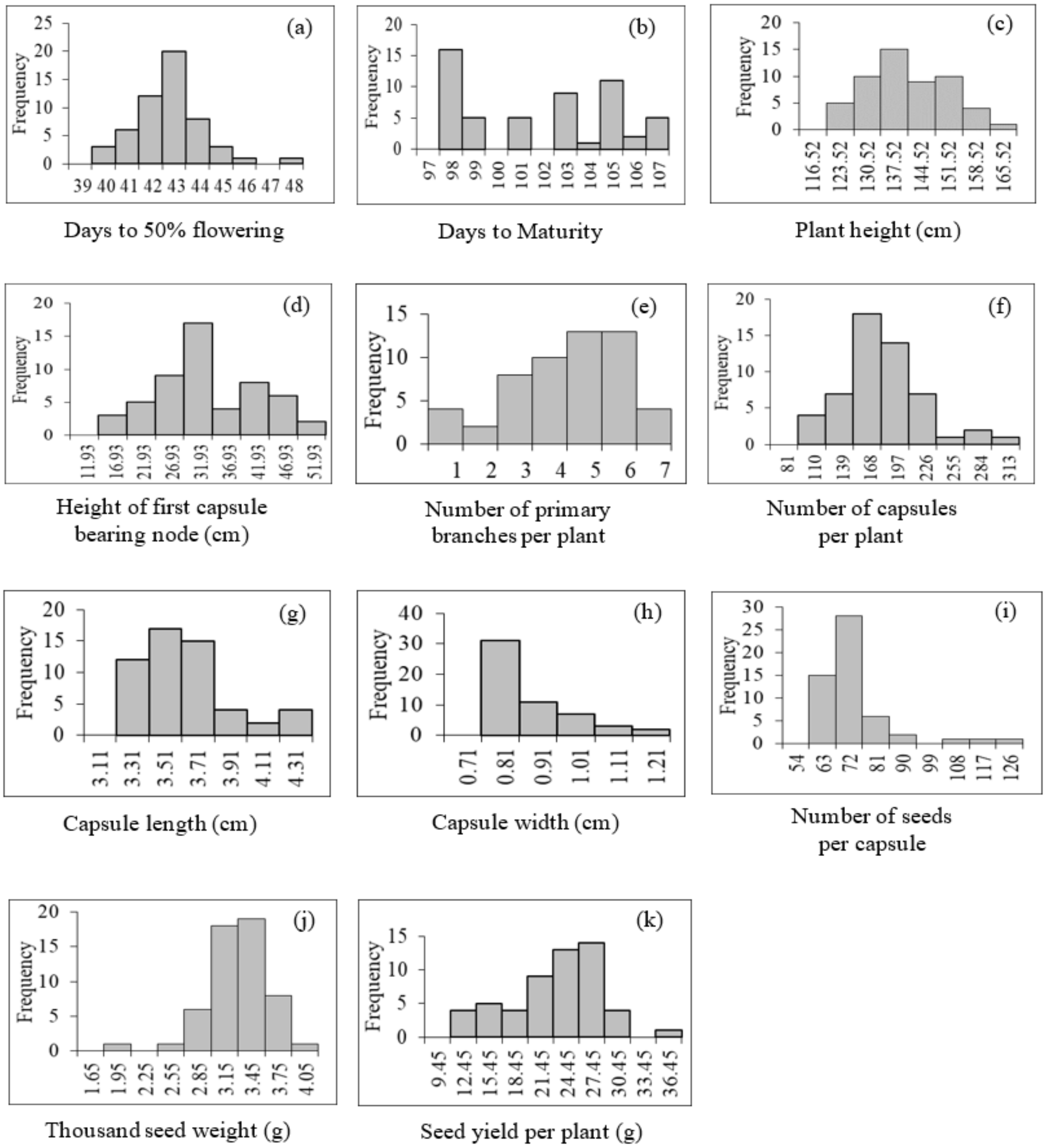


Fig. 1. Frequency distribution of eleven traits (a–k) in 54 sesame genotypes.

3.3 Phenotypic and genotypic correlation coefficients analysis

The partition of correlation coefficients at the phenotypic and genotypic levels for eleven traits is described in Table 4. In most situations, the genotypic correlation coefficient was higher than the phenotypic correlation coefficient, showing that there is a strong genetic association between two characters, but the phenotypic value is lessened by the major environmental interaction. Similar findings have been revealed in other studies [16, 23-26]. Some cases of a higher phenotypic correlation coefficient were found in this study. These cases from the present study indicate that the apparent association of two characters is not only due to genes but also to the influence of environment, which is in agreement with other studies [16, 17, 27]. The phenotypic and genotypic correlation analysis revealed a significant positive association of seed yield per plant with number of capsules per plant (0.699**; 0.744**), number of primary branches per plant (0.542**; 0.791**), height of first capsule bearing node (0.313**; 0.647**), number of seeds per capsule (0.274**; 0.339*) and days to 50% flowering (0.179*; 0.449**). These traits are all positively correlated with seed yield.

The phenotypic and genotypic correlation analysis indicated an important role of 3 traits: number of primary branches per plant, number of capsules per plant and number of seeds per capsule; these traits were positively correlated with seed yield. This result is supported by previous studies that reported a high number of branches, capsules and seeds increases yield [16, 23, 26, 28]. Hence, selection based on these 3 traits could bring an effective improvement to sesame yield. Notably, the positive correlation between the height of first capsule bearing node and days to 50% flowering implies that plants with an elongated time to first capsule bearing node are likely late blooming, consistent with other reports [15, 16].

On the contrary, seed yield revealed a significant negative correlation with days to maturity (-0.365**; -0.517**), capsule length (-0.285**; -0.557**), capsule width (-0.255**; -0.498**) and thousand seed weight (-0.183*; -0.416**). The result implies that seed yield can be enhanced when the values of these 4 traits are low. Similarly to the reports by Patel et al. [26] and Sumathi and Muralidharan [29], in this study, seed yield was negatively correlated with capsule length and capsule width. For this reason, the selection of small capsule trait possibly increases seed yield.

3.4 Path coefficient analysis

The direct and indirect effects of yield-contributing traits on seed yield at the phenotypic level are described in Table 5 and Fig. 2. The number of capsules per plant (0.713) was revealed to be the strongest positive direct contribution to seed yield, whilst the number of seeds per capsule (0.337), thousand seed weight (0.297), plant height (0.254) and number of primary branches per plant (0.149) showed slightly positive direct contributions. This indicates the importance of these traits in the selection for seed yield. On the other hand, days to 50% flowering (-0.005), days to maturity (-0.202), height of first capsule bearing node (-0.137), capsule length (-0.064) and capsule width (-0.054) all had negatively direct contributions to seed yield.

The genotypic path coefficient analysis is described in Table 6 and Fig. 3. Seed yield obtained the largest positive direct contribution from number of capsules per plant (1.833). Similarly, thousand seed weight (0.796), capsule width (0.559), number of primary branches per plant (0.493), number of seeds per capsule (0.448) and plant height (0.379) had a positive direct effect as well. Days to 50% flowering (-0.278), days to maturity (-0.041), height of first capsule bearing node (-0.674) and capsule length (-0.071) had a negative direct effect on seed yield.

Phenotypic and genotypic correlation coefficients were separated by path coefficient analysis to calculate the direct and indirect effects of yield components on seed yield. The number of capsules per plant and number of seeds per capsule had a strong effect directly on seed yield per plant, in agreement with other studies [16, 24, 28]. In addition, a positive direct contribution from plant height, number of primary branches per plant and thousand seed weight on yield has been observed [16, 28, 30, 31]. The number of primary branches per plant, number of capsules per plant and number of seeds per capsule had strong positive direct-effect and correlation with seed yield per plant in this study. In this case, direct selection via these traits would provide an effective improvement of sesame yield. Similar results have been reported in other studies [16, 24, 28, 30].

Table 4. Phenotypic (above) and genotypic (below) correlation coefficients among seed yield and its related traits in sesame.

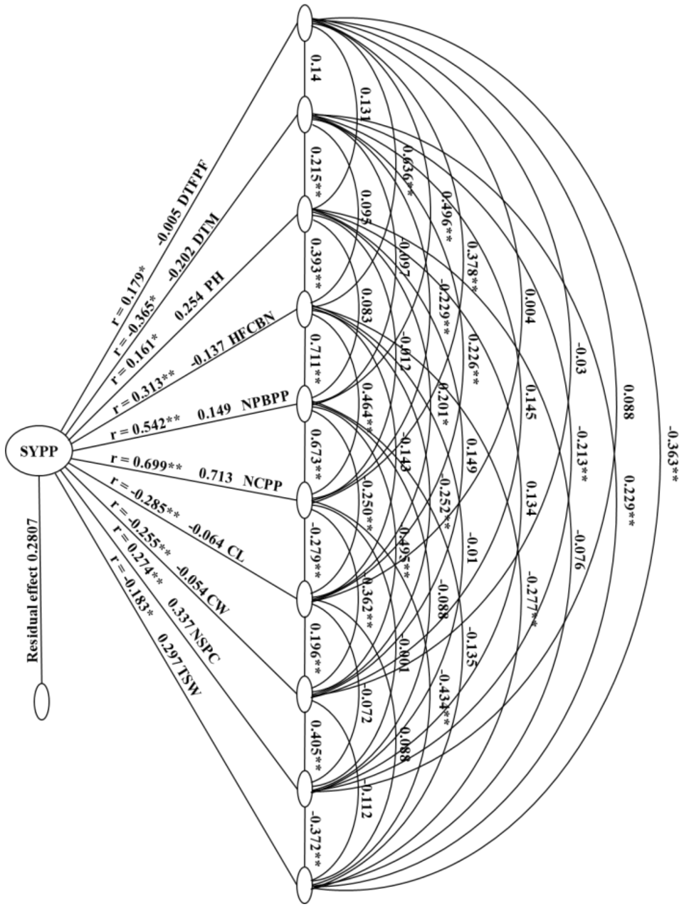
Traits	DTFPF	DTM	PH	HFCBN	NPBPP	NCPP	CL	CW	NSPC	TSW	SYPP
DTFPF	1	0.14	0.131	0.636**	0.496**	0.378**	0.004	-0.03	0.088	-0.363**	0.179*
DTM	0.207	1	0.215**	0.095	-0.097	-0.229**	0.226**	0.145	-0.213**	0.229**	-0.365**
PH	0.470**	0.482**	1	0.393**	0.083	-0.012	0.201*	0.149	0.134	-0.076	0.161*
HFCBN	0.915**	0.124	0.522**	1	0.711**	0.464**	-0.143	-0.252**	-0.01	-0.277**	0.313**
NPBPP	0.633**	-0.114	0.183	0.834**	1	0.673**	-0.250**	-0.495**	-0.088	-0.135	0.542**
NCPP	0.656**	-0.394**	-0.02	0.757**	0.813**	1	-0.279**	-0.362**	-0.001	-0.434**	0.699**
CL	-0.008	0.357**	0.257	-0.162	-0.315*	-0.371**	1	0.196*	-0.072	0.088	-0.285**
CW	-0.042	0.202	0.222	-0.285*	-0.615**	-0.621**	0.291*	1	0.405**	-0.112	-0.255**
NSPC	0.121	-0.263	0.151	-0.029	-0.124	-0.017	-0.12	0.545**	1	-0.372**	0.274**
TSW	-0.467**	0.367**	-0.125	-0.321*	-0.188	-0.600**	0.057	-0.149	-0.483**	1	-0.183*
SYPP	0.449**	-0.517**	0.005^{ns}	0.647**	0.791**	0.744**	-0.557**	-0.498**	0.339*	-0.416**	1

Note: * and ** = significant at $p < 0.05$ and $p < 0.01$, respectively; ns = non-significant.
DTFPF = days to 50% flowering; DTM = days to maturity; PH = plant height; HFCBN = height of first capsule bearing node; NPBPP = number of primary branches per plant; NCPP = number of capsules per plant; CL = capsule length; CW = capsule width; NSPC = number of seeds per capsule; TSW = thousand seed weight; SYPP = seed yield per plant.

Table 5. Direct (diagonal) and indirect (off-diagonal) effects of yield-contributing traits on seed yield at phenotypic level.

Traits	DTFPF	DTM	PH	HFCBN	NPBPP	NCPP	CL	CW	NSPC	TSW	Phenotypic correlation with yield
DTFPF	**-0.005**	-0.028	0.033	-0.087	0.074	0.270	-0.0002	0.002	0.030	-0.108	0.179*
DTM	-0.001	**-0.202**	0.054	-0.013	-0.015	-0.163	-0.015	-0.008	-0.072	0.068	-0.365**
PH	-0.001	-0.043	**0.254**	-0.054	0.012	-0.009	-0.013	-0.008	0.045	-0.022	0.161*
HFCBN	-0.003	-0.019	0.100	**-0.137**	0.106	0.331	0.009	0.014	-0.003	-0.082	0.313**
NPBPP	-0.003	0.020	0.021	-0.098	**0.149**	0.480	0.016	0.027	-0.030	-0.040	0.542**
NCPP	-0.002	0.046	-0.003	-0.064	0.100	**0.713**	0.018	0.019	-0.0002	-0.129	0.699**
CL	-0.00002	-0.046	0.051	0.020	-0.037	-0.199	**-0.064**	-0.011	-0.024	0.026	-0.285**
CW	0.0002	-0.029	0.038	0.035	-0.074	-0.258	-0.013	**-0.054**	0.136	-0.035	-0.255**
NSPC	-0.0005	0.043	0.034	0.001	-0.013	-0.0004	0.005	-0.022	**0.337**	-0.110	0.274**
TSW	0.002	-0.046	-0.019	0.038	-0.020	-0.310	-0.006	0.006	-0.125	**0.297**	-0.183*
Residual	0.2807										

Note: * = significant correlated at $p < 0.05$; ** = significant correlated at $p < 0.01$.
DTFPF = days to 50% flowering; DTM = days to maturity; PH = plant height; HFCBN = height of first capsule bearing node; NPBPP = number of primary branches per plant; NCPP = number of capsules per plant; CL = capsule length; CW = capsule width; NSPC = number of seeds per capsule; TSW = thousand seed weight; SYPP = seed yield per plant.



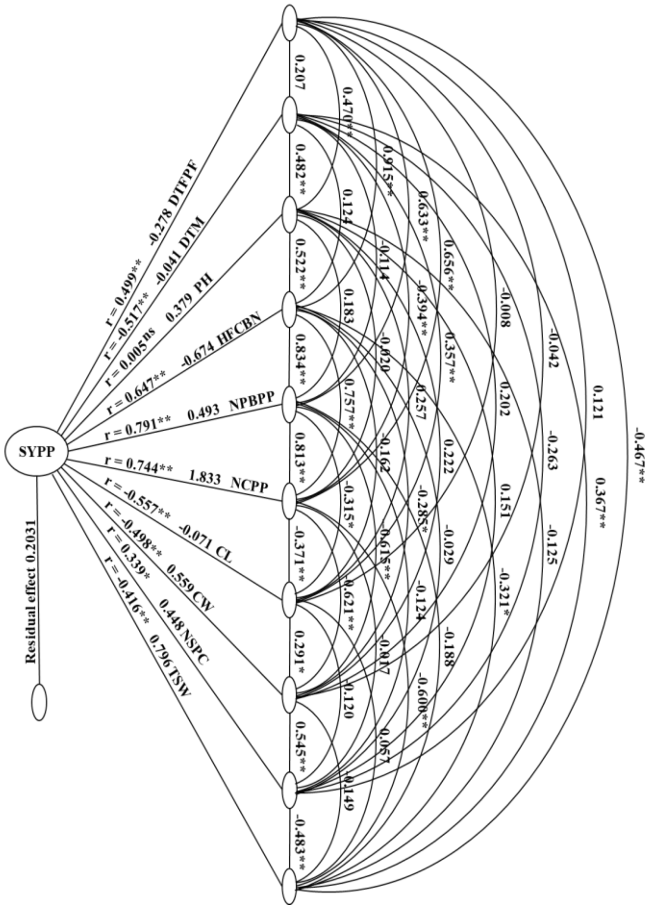
Note: * and ** = significant at $p < 0.05$ and $p < 0.01$, respectively.
DTFPF = days to 50% flowering; DTM = days to maturity; PH = plant height; HFCBN = height of first capsule bearing node; NPBPP = number of primary branches per plant; NCPP = number of capsules per plant; CL = capsule length; CW = capsule width; NSPC = number of seeds per capsule; TSW = thousand seed weight; SYPP = seed yield per plant.

Fig. 2. Phenotypic path coefficient diagram of 10 observed agronomic traits in sesame.

Table 6. Direct (diagonal) and indirect (off-diagonal) effects of yield-contributing traits on seed yield at the genotypic level.

Traits	DTFPF	DTM	PH	HFCBN	NPBPP	NCPP	CL	CW	NSPC	TSW	Genotypic correlation with yield
DTFPF	**-0.278**	-0.009	0.178	-0.617	0.312	1.202	0.001	-0.023	0.054	-0.372	0.449**
DTM	-0.058	**-0.041**	0.183	-0.084	-0.056	-0.722	-0.026	0.113	-0.118	0.292	-0.517**
PH	-0.131	-0.020	**0.379**	-0.352	0.090	-0.036	-0.018	0.124	0.068	-0.100	0.005^{ns}
HFCBN	-0.254	-0.005	0.198	**-0.674**	0.412	1.388	0.012	-0.159	-0.013	-0.255	0.647**
NPBPP	-0.176	0.005	0.069	-0.562	**0.493**	1.489	0.023	-0.344	-0.056	-0.150	0.791**
NCPP	-0.182	0.016	-0.007	-0.510	0.401	**1.833**	0.026	-0.347	-0.008	-0.478	0.744**
CL	0.002	-0.015	0.098	0.109	-0.156	-0.679	**-0.071**	0.163	-0.054	0.046	-0.557**
CW	0.012	-0.008	0.084	0.192	-0.304	-1.138	-0.021	**0.559**	0.244	-0.118	-0.498**
NSPC	-0.034	0.011	0.057	0.019	-0.061	-0.031	0.009	0.305	**0.448**	-0.384	0.339*
TSW	0.130	-0.015	-0.048	0.216	-0.093	-1.100	-0.004	-0.083	-0.216	**0.796**	-0.416**
Residual:	0.2031										

Note: * and ** = significant correlated at $p < 0.05$ and $p < 0.01$, respectively; ns = non-significant.
DTFPF = days to 50% flowering; DTM = days to maturity; PH = plant height; HFCBN = height of first capsule bearing node; NPBPP = number of primary branches per plant; NCPP = number of capsules per plant; CL = capsule length; CW = capsule width; NSPC = number of seeds per capsule; TSW = thousand seed weight; SYPP = seed yield per plant.



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DTFPF = days to 50% flowering; DTM = days to maturity; PH = plant height; HFCBN = height of first capsule bearing node; NPBPP = number of primary branches per plant; NCPP = number of capsules per plant; CL = capsule length; CW = capsule width; NSPC = number of seeds per capsule; TSW = thousand seed weight; SYPP = seed yield per plant.

Fig. 3. Genotypic path coefficient diagram of 10 observed agronomic traits in sesame.

4. Conclusion

The traits days to 50% flowering, days to maturity, height of first capsule bearing node, number of primary branches per plant, capsule length, capsule width, number of seeds per capsule and 1000 seed weight had high heritability, while plant height, number of capsules per plant and seed yield per plant reported moderate heritability. The results of correlation and path analysis described that number of primary branches per plant, number of capsules per plant and number of seeds per capsule may be considered as reliable selection criteria for sesame breeding programs to improve seed yield.

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Appendix

Table A. Mean comparison of yield and its components for 54 sesame genotypes.

No.	DTFPF	DTM	PH	HFCBN	NPBPP	NCPP	CL	CW	NSPC	TSW	SYPP
1	43.00^{b-h}	105.00^{ab}	134.20^{c-n}	37.87^{b-i}	4.80^{a-l}	201.40^{a-h}	3.60^{d-l}	0.82^{f-k}	65.13^{e-i}	3.24^{b-n}	23.46^{a-f}
2	43.00^{b-h}	100.67^{b-f}	131.80^{c-n}	37.20^{b-j}	4.53^{c-n}	171.02^{d-j}	3.36^{g-o}	0.78^{g-k}	68.73^{e-i}	3.03^{e-p}	22.16^{a-f}
3	41.33^{f-k}	97.33^{f}	123.67^{i-n}	21.53^{m-q}	3.53^{g-q}	162.73^{d-j}	3.48^{e-o}	0.79^{g-k}	75.13^{d-g}	3.18^{b-o}	22.65^{a-f}
4	41.33^{f-k}	97.67^{ef}	117.00^{mn}	22.00^{m-q}	3.20^{i-r}	180.60^{c-j}	3.30^{h-o}	0.84^{e-j}	60.80^{f-i}	3.61^{abc}	20.44^{a-f}
5	41.67^{f-j}	102.67^{a-f}	116.52^{n}	27.65^{h-o}	4.15^{c-o}	150.87^{d-j}	3.34^{g-o}	0.78^{g-k}	61.80^{f-i}	3.33^{b-k}	23.07^{a-f}
6	40.33^{h-k}	100.67^{b-f}	125.53^{g-n}	28.00^{h-o}	3.73^{f-p}	164.13^{d-j}	3.25^{i-o}	0.81^{f-k}	61.40^{f-i}	3.47^{a-g}	23.69^{a-f}
7	41.33^{f-k}	98.00^{ef}	133.60^{c-n}	30.93^{e-m}	5.07^{a-j}	192.20^{a-i}	3.49^{e-o}	0.79^{g-k}	69.00^{e-i}	3.25^{b-n}	26.94^{a-d}
8	43.00^{b-h}	102.67^{a-f}	131.60^{c-n}	23.53^{l-p}	3.33^{h-q}	139.80^{d-j}	3.55^{d-m}	0.81^{f-k}	61.33^{f-i}	3.32^{b-l}	20.13^{a-f}
9	43.33^{b-g}	100.67^{b-f}	128.60^{e-n}	38.67^{a-h}	6.67^{a}	213.33^{a-g}	3.22^{k-o}	0.74^{ijk}	59.40^{f-i}	2.96^{i-p}	20.31^{a-f}
10	42.00^{e-j}	100.67^{b-f}	136.47^{b-n}	29.67^{g-n}	4.67^{b-m}	196.20^{a-i}	3.50^{e-o}	0.77^{g-k}	72.27^{d-h}	3.12^{d-o}	25.40^{a-e}
11	44.67^{bcd}	97.67^{ef}	145.87^{a-j}	43.00^{abc}	6.73^{a}	270.07^{abc}	3.23^{j-o}	0.73^{jk}	60.47^{f-i}	2.73^{opq}	28.26^{abc}
12	45.33^{ab}	103.00^{a-e}	149.80^{a-f}	48.73^{a}	5.27^{a-h}	279.60^{ab}	3.17^{mno}	0.76^{g-k}	66.33^{e-i}	2.45^{q}	26.11^{a-d}
13	42.00^{e-j}	99.00^{c-f}	125.27^{h-n}	24.40^{l-p}	3.80^{e-p}	175.07^{c-j}	3.54^{d-n}	0.80^{g-k}	70.4^{d-i}	3.33^{b-k}	22.92^{a-f}
14	42.33^{d-i}	103.00^{a-e}	132.53^{c-n}	29.00^{g-n}	4.27^{c-o}	152.00^{d-j}	3.73^{c-g}	0.79^{g-k}	63.27^{f-i}	3.49^{a-f}	24.55^{a-f}
15	41.67^{f-j}	105.00^{ab}	131.40^{c-n}	24.13^{l-p}	2.67^{n-s}	134.07^{e-j}	3.73^{c-g}	0.82^{f-k}	68.13^{e-i}	3.39^{a-j}	15.60^{b-f}
16	47.33^{a}	97.33^{f}	130.33^{c-n}	48.53^{a}	5.67^{a-f}	285.80^{a}	3.78^{c-f}	0.97^{bcd}	114.73^{ab}	1.65^{r}	33.55^{a}
17	41.67^{f-j}	105.00^{ab}	121.27^{lmn}	17.40^{opq}	2.80^{m-s}	148.80^{d-j}	3.65^{c-i}	0.80^{g-k}	66.47^{e-i}	3.36^{a-j}	13.46^{c-f}
18	42.67^{c-h}	102.67^{a-f}	128.2^{f-n}	24.20^{l-p}	3.33^{h-q}	148.53^{d-j}	3.69^{c-h}	0.81^{f-k}	66.53^{e-i}	3.49^{a-e}	21.49^{a-f}
19	40.67^{g-k}	98.00^{ef}	138.93^{b-n}	23.73^{l-p}	3.53^{g-q}	159.53^{d-j}	4.26^{a}	0.74^{h-k}	66.60^{e-i}	3.52^{a-d}	23.11^{a-f}
20	39.67^{jk}	98.33^{def}	146.07^{a-j}	27.53^{i-o}	4.20^{c-o}	155.73^{d-j}	3.64^{c-j}	0.81^{f-k}	71.20^{d-i}	3.22^{b-n}	23.62^{a-f}
21	40.67^{g-k}	97.67^{ef}	130.87^{c-n}	15.93^{pq}	1.60^{q-t}	148.27^{d-j}	3.69^{c-h}	0.96^{bcd}	70.13^{d-i}	2.94^{j-p}	20.20^{a-f}
22	40.33^{h-k}	103.00^{a-e}	129.67^{d-n}	18.80^{n-q}	0.00^{t}	112.73^{g-j}	3.45^{e-o}	0.93^{b-f}	71.20^{d-i}	2.86^{l-q}	15.15^{b-f}
23	39.00^{k}	97.67^{ef}	125.67^{g-n}	21.27^{m-q}	3.80^{e-p}	156.6^{d-j}	3.31^{h-o}	0.78^{g-k}	59.07^{ghi}	3.13^{d-o}	20.24^{a-f}
24	40.00^{ijk}	98.00^{ef}	136.87^{b-n}	15.60^{pq}	0.00^{t}	106.20^{hij}	3.19^{l-o}	1.17^{a}	117.80^{a}	2.72^{opq}	18.74^{a-f}
25	42.67^{c-h}	105.00^{ab}	145.00^{a-k}	30.53^{e-m}	4.20^{c-o}	166.60^{d-j}	3.45^{e-o}	0.81^{f-k}	65.93^{e-i}	3.29^{b-m}	26.35^{a-d}
26	42.67^{c-h}	105.00^{ab}	136.33^{b-n}	30.93^{e-m}	4.93^{a-k}	219.00^{a-f}	3.57^{d-m}	0.80^{g-k}	57.93^{ghi}	2.89^{k-q}	23.39^{a-f}
27	42.67^{c-h}	97.67^{ef}	139.47^{b-n}	30.33^{f-m}	5.33^{a-g}	146.80^{d-j}	3.11^{o}	0.94^{b-e}	100.93^{bc}	3.03^{e-p}	26.30^{a-d}
28	43.67^{b-f}	105.00^{ab}	157.60^{ab}	45.67^{ab}	5.27^{a-h}	189.13^{a-i}	3.47^{e-o}	0.80^{g-k}	71.10^{d-i}	3.43^{a-h}	23.38^{a-f}
29	43.00^{b-h}	105.00^{ab}	133.13^{c-n}	33.93^{c-l}	4.27^{c-o}	237.87^{a-d}	3.60^{d-l}	0.82^{f-k}	53.93^{hi}	2.79^{n-q}	19.27^{a-f}
30	42.33^{d-i}	105.00^{ab}	130.75^{c-n}	26.37^{j-p}	3.10^{j-r}	147.53^{d-j}	3.65^{c-i}	0.83^{e-k}	59.97^{f-i}	2.83^{n-q}	12.37^{def}
31	43.33^{b-g}	106.67^{a}	152.80^{a-d}	39.13^{a-g}	6.00^{a-d}	176.87^{c-j}	3.62^{d-k}	0.77^{g-k}	66.33^{e-i}	3.12^{d-o}	27.03^{a-d}
32	44.00^{b-f}	106.00^{ab}	147.4^{a-h}	42.13^{a-d}	6.53^{ab}	178.93^{c-j}	4.20^{ab}	0.71^{k}	66.60^{e-i}	3.00^{h-p}	15.61^{b-f}
33	43.00^{b-h}	98.33^{def}	149.93^{a-f}	37.13^{b-j}	4.80^{a-l}	201.13^{a-h}	3.54^{d-n}	0.75^{h-k}	74.00^{d-g}	2.95^{j-p}	30.40^{ab}
34	44.33^{b-e}	99.00^{c-f}	146.27^{a-j}	46.20^{ab}	5.40^{a-g}	179.80^{c-j}	3.30^{h-o}	0.82^{f-k}	66.33^{e-i}	3.15^{c-o}	23.15^{a-f}
35	43.00^{b-h}	103.00^{a-e}	143.87^{a-l}	42.93^{abc}	5.80^{a-e}	187.40^{b-i}	3.47^{e-o}	0.78^{g-k}	77.87^{def}	2.93^{j-p}	24.77^{a-f}
36	43.00^{b-h}	99.00^{c-f}	147.00^{a-i}	42.33^{a-d}	5.60^{a-f}	190.68^{a-i}	3.21^{k-o}	0.74^{jk}	65.00^{e-i}	3.02^{f-p}	25.90^{a-e}
37	43.00^{b-h}	105.00^{ab}	148.80^{a-g}	37.20^{b-j}	5.07^{a-j}	193.33^{a-i}	3.42^{f-o}	0.81^{f-k}	71.10^{d-i}	3.15^{c-o}	27.05^{a-d}
38	40.67^{g-k}	97.67^{ef}	133.00^{c-n}	11.93^{q}	0.93st	154.00^{d-j}	3.32^{g-o}	0.86^{d-i}	77.80^{def}	2.58^{pq}	19.51^{a-f}
39	41.67^{f-j}	98.33^{def}	129.60^{d-n}	31.13^{e-m}	4.07^{d-o}	220.27^{a-e}	3.39^{f-o}	0.77^{g-k}	67.13^{e-i}	3.32^{b-l}	30.21^{ab}
40	43.33^{b-g}	99.00^{c-f}	138.95^{b-n}	31.82^{d-m}	1.32^{rst}	96.02^{ij}	4.23^{a}	0.98^{bc}	53.58^{i}	2.83^{m-q}	10.47^{ef}
41	41.33^{f-k}	103.67^{abc}	133.07^{c-n}	25.00^{k-p}	2.53^{o-s}	129.38^{e-j}	4.03^{abc}	1.03^{b}	60.70^{f-i}	3.43^{a-i}	9.45^{f}
42	42.33^{d-i}	107.00^{a}	146.27^{a-j}	29.40^{g-n}	2.07^{p-s}	116.20^{g-j}	3.64^{c-j}	0.87^{c-h}	64.33^{e-i}	3.47^{a-g}	15.63^{b-f}
43	40.67^{g-k}	106.00^{ab}	144.4^{a-l}	28.53^{g-n}	2.60^{n-s}	122.33^{e-j}	3.40^{f-o}	0.88^{c-g}	67.53^{e-i}	3.49^{a-f}	18.55^{a-f}
44	45.00^{bc}	106.67^{a}	151.87^{a-e}	41.07^{a-f}	5.53^{a-g}	149.33^{d-j}	3.47^{e-o}	1.15^{a}	87.33^{cd}	3.09^{d-o}	25.86^{a-e}
45	42.67^{c-h}	103.00^{a-e}	140.80^{b-l}	35.53^{b-k}	4.40^{c-o}	151.27^{d-j}	3.49^{e-o}	0.82^{e-k}	70.25^{d-i}	3.63^{ab}	22.68^{a-f}
46	43.00^{b-h}	98.00^{ef}	133.87^{c-n}	26.27^{j-p}	4.53^{c-n}	186.53^{b-i}	3.65^{c-i}	0.78^{g-k}	75.67^{d-g}	3.02^{f-p}	25.37^{a-e}
47	43.33^{b-g}	100.67^{b-f}	122.13^{k-n}	36.07^{b-j}	5.13^{a-i}	189.20^{a-i}	3.40^{f-o}	0.82^{f-k}	65.00^{e-i}	3.33^{b-k}	26.24^{a-d}
48	43.00^{b-h}	107.00^{a}	143.87^{a-l}	27.80^{h-o}	2.93^{l-r}	117.87^{f-j}	3.86^{b-e}	1.04^{b}	60.93^{f-i}	3.36^{a-j}	13.40^{c-f}
49	43.00^{b-h}	105.33^{ab}	153.20^{abc}	33.27^{c-l}	3.00^{k-r}	131.60^{e-j}	3.93^{a-d}	1.02^{b}	63.60^{f-i}	3.12^{d-o}	15.06^{b-f}
50	41.33^{f-k}	107.00^{a}	163.93^{a}	21.07^{m-q}	0.00^{t}	81.13^{j}	4.20^{ab}	1.03^{b}	82.47^{de}	3.39^{a-j}	14.96^{b-f}
51	43.33^{b-g}	103.33^{a-d}	137.60^{b-n}	27.33^{i-o}	2.53^{o-s}	152.53^{d-j}	3.65^{c-i}	1.01^{b}	70.87^{d-i}	3.19^{b-n}	17.21^{b-f}
52	41.67^{f-j}	99.00^{c-f}	129.67^{d-n}	28.27^{g-o}	5.53^{a-g}	219.80^{a-e}	3.51^{e-o}	0.76^{g-k}	69.00^{e-i}	2.97^{h-p}	28.33^{abc}
53	43.00^{b-h}	105.00^{ab}	123.49^{j-n}	27.80^{h-o}	3.02^{k-r}	108.31^{hij}	3.17^{mno}	0.77^{g-k}	62.53^{f-i}	3.79^{a}	12.35^{def}
54	43.67^{b-f}	97.67^{ef}	139.87^{b-m}	41.20^{a-e}	6.13^{abc}	223.80^{a-e}	3.14^{no}	0.76^{g-k}	59.53^{f-i}	3.01^{g-p}	24.63^{a-f}
Minimum	39.00	97.00	116.52	11.93	0.00	81.00	3.11	0.71	54.00	1.65	9.45
Maximum	47.00	107.00	163.93	48.73	7.00	286.00	4.26	1.17	118.00	3.79	33.55
Mean	42.44	101.76	136.96	30.88	3.96	169.81	3.54	0.84	69.30	3.14	21.68

Note: Mean with the same letters are not significantly different; DTFPF = days to 50% flowering; DTM = days to maturity; PH = plant height; HFCBN = height of first capsule bearing node; NPBPP = number of primary branches per plant; NCPP = number of capsules per plant; CL = capsule length; CW = capsule width; NSPC = number of seeds per capsule; TSW = thousand seed weight; SYPP = seed yield per plant.