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Phenotypic variation and relationships among sesame (*Sesamum indicum* L.) sub-core collections

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Abstract: A total of 70 accessions/ecotypes including 50 accessions from the sesame core collection of China and 7 collected in Benin (West Africa) were evaluated for 22 morphological traits, at Zhejiang University, Huajiachi campus, Hangzhou (China). Multivariate and principal component analyses revealed considerable genetic diversity in the material and led to their grouping into 8 clusters. The first two principal components explained 45.2% of the variation. There was no strong relationship between geographic origin and genetic diversity. Seed exchange over short distances and influence of microenvironments may have taken place. Nonetheless, using morphological markers it was possible to group 2 accessions (INRAB-S42 and INRAB-38-1-7) from Benin in cluster III, the 6 accessions from Hangzhou (Zhejiang) in cluster VIII; cluster V was formed by accessions from North-East and North-West of China.

Key words: sesame (*Sesamum indicum* L.); genetic diversity; cluster analysis; principal component analysis

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芝麻次级核心样品表型变异和相关性(英文). 浙江大学学报(农业与生命科学版), 2004, 30(1): 10-16
摘要: 在中国, 杭州, 浙江大学华家池校区农场, 对来自中国和西非贝宁不同生态型的 70 份芝麻核心样品的 22 个形态学性状进行评价. 应用多元和主成分分析揭示其遗传多样性并将其分为 8 个聚类组. 结果表明, 主成分可解释 45.2% 的变异. 尽管地理起源与遗传多样性没有密切相关, 但利用形态标记进行聚类分析, 可将非洲贝宁 2 个品种分为聚类 III, 杭州 6 个品种分为聚类 VIII, 中国东北和西北品种分为聚类 V.

关键词: 芝麻; 遗传多样性; 聚类分析; 主成分分析

Sesamum indicum L. is the most cultivated species in the genus *Sesamum* (Pedaliaceae family). From more than 4200 accessions of sesame germplasm resources in China, a

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core collection was constructed based on agronomic, morphological and ecological zones^[1,2].

The major objective of selecting a core collection is to use it effectively. For breeders and gene bank curators to understand the nature of these introduced core collections, it is necessary to estimate the genetic diversity and relationships between accessions under the same growing conditions.

Variability and relationships among accessions can be evaluated with morphological characteristics, seed proteins, isozymes, and DNA markers. However, morphological characterization is the first step in classification of the germplasm.

The main objective of this study was to e-

valuate the potential of morphological traits in characterizing and classifying germplasm accessions derived from sesame core collections, under Hangzhou growing conditions, using multivariate analysis.

1 Materials and methods

1.1 Plant material

Original seeds of most accessions (Table 1) were obtained from the Oil Crops Institute, China Academy of Agricultural Science, Wuhan (China). A total of 70 landraces and cultivars were used during the present investigations. These included 50 accessions taken from the China sesame core and 7 accessions from Benin (West Africa).

Table 1 List of the 67 accessions collected for the study

Accession	Origin	Code	Accession	Origin	Code
ZZM0611	—	1	ZZM 2953	Guangxi	35
ZZM1415	—	2	ZZM3287	Liaoning	36
ZZM1799	Xingjiang	3	ZZM3642	Xichuan	37
ZZM2773	Zhejiang	4	ZZM4036	Fujian	38
ZZM2876	Guizhou	5	Zhima-05	Zhejiang	39
ZZM3186	Jiling	6	ZZM1141	—	40
ZZM3348	Shaanxi	7	ZZM1719	Xingjiang	41
ZZM3705	Xichuan	8	ZZM2750	Zhejiang	42
ZZM4157	Hainang	9	ZZM2871	Guizhou	43
Sesame-01	Benin	10	ZZM2966	Guangdong	44
ZZM0795	—	11	ZZM3319	Shanxi	45
ZZM1561	Heilongjiang	12	ZZM3693	Xichuan	46
ZZM2304	Shangdong	13	ZZM4129	Guangxizizhi	47
ZZM2797	Jiangxi	14	INRAB38-1-7	Benin	48
ZZM2891	Yunnan	15	Zhima-06	Zhejiang	49
ZZM3213	Jiling	16	ZZM1317	—	50
ZZM3379	Shanxi	17	ZZM1749	XingJiang	51
ZZM4026	Fujian	18	ZZM2764	Zhejiang	52
ZZM4166	Hainang	19	ZZM2874	Guizhou	53
Zhima-03	Zhejiang	20	ZZM2974	Guangdong	54
ZZM0829	—	21	ZZM3342	Shanxi	55
ZZM1588	Heilongjiang	22	ZZM3696	Xichuan	56
ZZM2431	Anhui	23	ZZM4131	Guangxizizhi	57
ZZM2812	Jiangxi	24	Sesame-02	Benin	58
ZZM2918	Guangxi	25	Zhima-01	Zhejiang	59
ZZM3247	Liaoning	26	Zhima-02	Shanxi	60

Continuation of table 1 List of the 67 accessions collected for the study

Accession	Origin	Code	Accession	Origin	Code
ZZM3395	Shanxi	27	Zhongzhi-7	Zhejiang	61
ZZM4029	Fujian	28	Yiyangbai	Zhejiang	62
INRAB-S42	Benin	29	Laohongzhuanzhlian	Zhejiang	63
Zhima-04	Zhejiang	30	Jiaoganzhu	Zhejiang	64
ZZM0939	—	31	Balinzhima	Zhejiang	65
ZZM 1702	Xingjiang	32	Zhijiangwu	Zhejiang	66
ZZM 2737	Zhejiang	33	Changzhongzhi	Zhejiang	67
ZZM 2834	Jiangxi	34			

Note: —, unknown origin.

The names of the places of origin of the above mentioned 50 accessions were recorded according to Anonymous^[3-5].

1.2 Morphological characterization

The experiments were conducted at the Zhejiang University, Huajiachi Campus during 1999. The seeds were sown on 27th May in a randomized complete block design with two

replications. The experimental plot consisted of two rows, each 1.5 m in length and spaced 0.35 m apart with a plant to plant distance 0.15 m, resulting in 10 plants per row. All accessions were characterized for different morphological traits (Table 2). Traits selection and measurement techniques were based on IBPGR (1981), Mahajan, *et al*^[6].

Table 2 Morphological traits recorded in the *S. indicum* accessions for the study

Traits designation	Description of the traits
Days to flowering	Number of days to 50% plant having first flower from date of sowing
Days to maturity	Number of days to 75% plants reaching physiological maturity from date of seed sowing
Plant height/cm	Height of main stem from soil level to the tip inflorescence (mean of 5 random plants)
Flower colour	1=white; 2=white with light violet/purple shading; 3=white with deep violet/purple shading; 4=violet; 5=purple
Corolla hairiness	1=glabrous-light hairy; 2=hairy; 3=very hairy
Stem hairiness	1=glabrous; 2=sparse; 3=hairy; 4=very hairy
Density of capsule hair	1=glabrous; 2=sparse; 3=high
Branching habit	1=un-branched; 2=low (2-3 branches); 3=moderate (4-6 branches); 4=high (more than 6 branches)
Number of capsules/leaf axil	1=one; 2=two, three; 3=four, five or more than five
Capsule shape	1=small (≤ 3 cm); 2=medium (3.1-4 cm); 3=long (≥ 4.1 cm)
Number of locules/capsule	1=four; 2=four and six; 3=four, six, eight and more than eight; 4=six
Number of capsules/plant	Total number of capsules originated from main stem and branches (mean of 5 random plants)
Number of seeds/capsule	Mean number of seeds from 10 random capsules
100-seed weight/g	Weight of 100 dry seeds
Capsule length/mm	Mean length of 3 capsules each of 5 random plants
Capsule width/mm	Mean width of 3 capsules each of 5 random plants
Capsule length/width ratio	The ratio of capsules length to capsule width
Capsule thickness/mm	Mean thickness of 3 capsules each of 5 random plants
Seed colour	1=white; 2=yellow; 3=brown; 4=grey; 5=black
Seed length/mm	Mean length of 10 random seeds (10replications)
Seed width/mm	Mean width of 10 random seeds (10replications)
Seed length/width ratio	The ratio of seed length to seed width

1.3 Statistical analysis

Mean values, standard deviation and variation indices were computed for each accession. The means were standardized prior to cluster and principal component analyses. The recorded morphological characters were analysed to detect natural groupings in the sub-core collections. The Euclidian distance measurements computed from the variables were clustered by Ward's method. No formal statistical criteria were used. The statistical analysis was performed using the software Minitab (version 12.1 for Windows).

2 Results and discussion

2.1 Traits variation

The range of variation and standard of deviation for the 22 traits considered, for 67 accessions, are presented in Table 3. Wide variations were found for most quantitative characters. Plant height varied from 79.2 cm to 183 cm and capsules per plant from 11 to 309. Seeds per capsule ranged from 52 to 165, while 100-seed weight was between 0.18 and 0.37g, and ratio of seed length to seed width between 1.5 and 2.0.

Table 3 Mean values and ranges of the variables measured in analysis of 67 accessions

Traits	Mean	Standard deviation	Minimum	Maximum	Coefficient of variation
Days to flowering	57.2	13.11	26.0	93.0	22.9
Days to maturity	108.8	12.99	83.0	142.0	11.9
Plant height/cm	139.2	25.58	79.2	183.0	18.4
Flower colour	2.4	0.81	1.0	5.0	33.8
Corolla hairiness	1.8	0.80	1.0	3.0	44.4
Stem hairiness	2.4	1.11	1.0	4.0	46.3
Density of capsule hair	1.9	0.69	1.0	3.0	36.3
Branching habit	2.0	1.16	1.0	4.0	58.0
Number of capsules/axil	1.7	0.52	1.0	3.0	30.6
Capsule shape	1.3	0.47	1.0	3.0	36.2
Number of locules/capsule	1.9	1.00	1.0	4.0	52.6
Number of capsules/plant	90.2	47.82	11.0	309.0	53.0
Number of seeds/capsule	84.9	24.97	52.0	165.0	29.4
100-seed weight/g	0.25	0.04	0.18	0.37	16.0
Capsule length/mm	28.4	3.73	20.0	45.7	13.1
Capsule width/mm	9.1	1.53	6.7	14.2	16.8
Capsule length /width ratio	3.2	0.62	1.8	4.7	19.4
Capsule thickness/mm	8.4	2.01	5.0	14.2	23.9
Seed colour	2.3	1.72	1.0	5.0	74.8
Seed length/mm	3.0	0.20	2.6	3.6	6.7
Seed width/mm	1.7	0.11	1.6	2.1	6.5
Seed length/width ratio	1.7	0.09	1.5	2.0	5.3

Capsule length varied from 20 mm to 45.7 mm and capsule width from 6.7 to 14.2 mm. The ratio of capsule length to capsule width was between 1.8 and 4.7. Days to flowering varied from 26 for some accessions growing in Zhejiang province to 93 for 38-1-7

from Benin. Days to maturity ranged from 83 to 142 for the same accessions.

Seed colour was very variable, from white to various shades of yellow and brown, and from grey to black. Capsules were small in the majority of cases, with the number of

locules ranging from 4 to 8 and even up to 18 in a capsule.

2.2 Cluster analysis

Based on Ward's method, as suggested by Zhang Xiurong, *et al*^[1]. and Bisht *et al*^[6]. sesame accessions were grouped into clusters. The dendrogram of the 67 accessions is presented as Figure 1. The accessions were grouped in 8 clusters (Table 4). Cluster VI was the largest with 16 accessions, followed by clusters I and IV with 11 accessions each, cluster V with 9, cluster II with 8, cluster VIII with 7, cluster VII with 3 and cluster III with 2 accessions. All the accessions from Xingjiang, Heilongjiang and Jilin were grouped in cluster V, while those traditionally cultivated under

Hangzhou conditions were grouped in cluster VIII. Cluster IV contained the majority of the accessions from the South of China and 2 accessions from Benin (Sesame-01 and Sesame-02). Cluster III consisted of another 2 accessions from Benin (S42 and 38-1-7). Accessions from the remaining provinces or zones did not form distinct clusters. This lack of association between genetic diversity and geographical origin, observed in our experiment, could be due to the fact that accession diversity in different zones is getting broadened^[7]; and microclimatic differences within zones could explain the distinct sub-clusters found within the main cluster^[6].

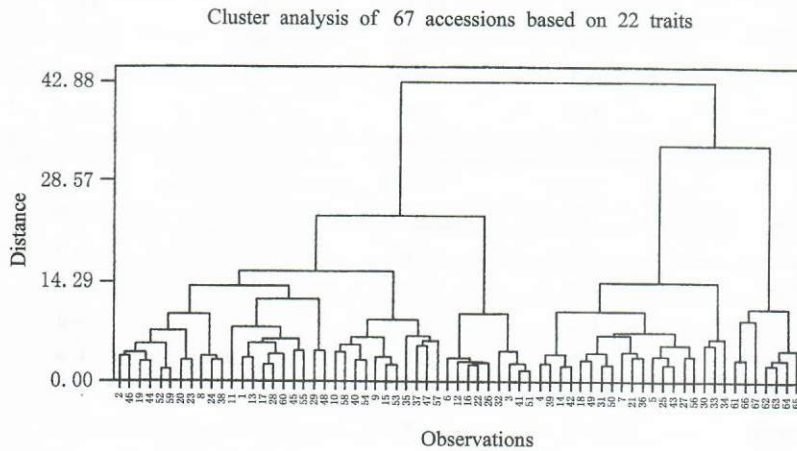


Fig. 1 Cluster analysis showing the relationships between 67 accessions of sesame based on morphological traits

Table 4 Distribution of 67 sesame accessions into different clusters based on 22 traits

Cluster	Number of accessions	Accessions No (code)	Origin
I	11	2,8,19,20,23,24,38,44,46,52,59.	Zhejiang, Xichuan and others
II	8	1,11,13,17,28,45,55,60.	Shanxi and others
III	2	29,48.	Benin
IV	11	9,10,15,35,37,40,47,53,54,57,58.	South-China and Benin
V	9	3,6,12,16,22,26,32,41,51.	North-East and North-West China
VI	16	4,5,7,14,18,21,25,27,31,36,39,42,43,49,50,56.	Zhejiang and others
VII	3	30,33,34.	Zhejiang and Jiangxi
VIII	7	61,62,63,64,65,66,67.	Zhejiang (Hangzhou)

2.3 Principal component analysis

The use of principal components analysis (PCA) revealed that the 7 principal components (PCs) had Eigenvalues of more than 1 and together accounted for 84% of the variability amongst the 67 accessions evaluated (Table 5). PC1 had 23.5% of the total variation in morphological traits. Corolla hairiness, stem hairiness, density of capsule hair and ratio of seed length to seed width contributed positively to PC1. In contrast, days to flowering contributed negatively. PC2 exhibited 21.7% of the total morphological variability and was positively associated with

ratio of capsule length to capsule width were negatively associated with PC2, PC3 had 9.5% of the total variation and was mostly connected with capsule length. PC4 had 9.3% of the total morphological variation and was mainly linked to days to maturity. The other traits were associated with the remaining eigenvectors. Plant height and capsules per plant were mostly connected with PC5. Flower colour and branching habit contributed negatively to PC6; in contrast, capsules per leaf axil contributed positively. PC7 was positively associated with flower colour and seed colour, and was negatively associated with capsule shape.

Table 5 Eigenvalues, proportions of variability and morphological traits that contributed to the first seven principal components of sesame germplasm

Traits	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	5.17	4.77	2.09	2.04	1.88	1.31	1.06
Proportion of variance%	23.5	21.7	9.5	9.3	8.6	6.0	4.8
Cumulative variance%	23.5	45.2	54.7	64.0	72.5	78.5	83.3
Eigen vectors							
Days to flowering	-0.30	-0.16	-0.23	0.23	-0.11	-0.07	-0.10
Days to maturity	-0.28	-0.16	-0.20	0.34	0.03	-0.04	-0.18
Plant height/cm	0.07	-0.06	-0.10	0.42	0.47	0.09	-0.02
Flower colour	0.09	0.14	-0.05	-0.13	-0.10	-0.59	0.40
Corolla hairiness	0.30	0.11	-0.21	-0.10	0.24	-0.05	-0.07
Stem hairiness	0.31	0.06	-0.24	-0.10	0.15	-0.24	-0.08
Density of capsule hair	0.29	0.21	-0.22	-0.13	0.11	-0.10	-0.08
Branching habit	-0.22	0.07	-0.28	0.21	0.08	-0.34	0.14
No of capsules/leaf axil	0.11	-0.06	0.23	-0.20	0.26	0.43	0.22
Capsule shape	0.23	0.13	0.32	0.26	-0.04	-0.12	-0.32
No of locules/capsule	0.13	-0.37	-0.01	0.05	0.02	-0.12	0.07
No of capsules/plant	-0.01	-0.05	0.27	0.11	0.49	-0.21	0.38
No of seeds/capsule	0.24	-0.29	0.13	0.16	-0.15	-0.09	0.03
100-seed weight	0.25	0.22	-0.19	0.23	0.09	0.22	0.03
Capsule length	0.22	0.15	0.34	0.29	-0.07	-0.18	-0.31
Capsule width	0.25	-0.34	-0.07	0.12	0.01	-0.01	-0.08
Capsule length/width ratio	-0.07	0.37	0.30	0.08	-0.10	-0.13	-0.11
Capsule thickness	0.24	-0.36	-0.02	0.06	-0.01	-0.05	-0.01
Seed colour	-0.02	0.03	0.26	0.37	-0.15	0.06	0.49
Seed length	0.26	0.12	-0.23	0.19	-0.36	0.20	0.25
Seed width	0.09	0.31	-0.25	0.27	-0.07	0.23	0.18
Seed length/width ratio	0.23	-0.21	-0.01	-0.07	-0.38	-0.01	0.12

In order to ensure the efficient and effective utilization of crop germplasms, its characterization is imperative. The characters contributing largely to the total variation should be given more emphasis for the purpose of further selection and choice of parents for hybridisation.

The first two principal components were plotted to observe the relationships between sesame accessions investigated in this work (Figure 2). In general, the PCA result confirmed those obtained by cluster; the accessions traditionally growing under the microenvironment of Huajiachi (Hangzhou) could be once again grouped together.

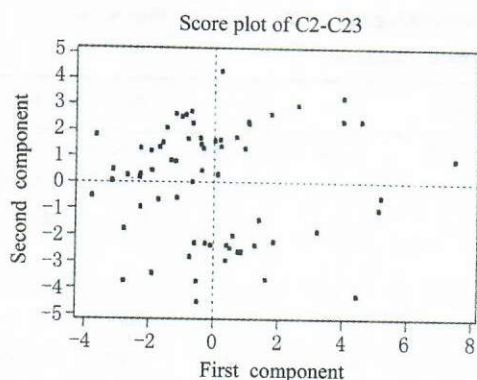


Fig. 2 Plot of the two first principal components

3 Conclusion

From the present study, it is concluded that the multivariate analysis of 22 morphological characteristics of the sesame sub-core collections allowed a clustering of 67 accessions in groups.

In a few cases the recorded passport classification did not agree with the data collected.

PCA for the interaction of the 22 traits used in characterizing the accessions showed that corolla hairiness, stem hairiness, density of capsule hair, 100-seed weight, ratio of seed

length to seed width, days to flowering, ratio of capsule length to capsule width, seed width, locules per capsule, seeds per capsule, capsule thickness and capsule width were the characteristics contributing most to the total variability and were determinant in the groups of accessions.

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