Australian Journal of Crop Science AJCS

AJCS 4(7):498-504 (2010) ISSN:1835-2707

Morphological evaluation of sesame (*Sesamum indicum* L.) varieties from different origins

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Abstract

Sesame (*Sesamum indicum* L.) is known as the king of oil seeds in Vietnam due to the high oil content (50 – 60%) of its seed. The purpose of this study was to evaluate morphology of sesame from different origins. Seventeen sesame varieties originating from El Salvador, Tanzania, Kenya, India, Cambodia and Vietnam were studied. The field experiment was carried out in the Mekong Delta region, Vietnam. Fifteen agronomic traits were analysed to select the best varieties for use as potential breeding sources. Varieties from Africa and Central America showed clear signs of being influenced by the climatic differences between Vietnam and from their place of origin. Large biomass growth, late onset of flowering and low yield was the most pronounced features. Sesame varieties from Vietnam and Cambodia gave high seed yields and developed well in the Mekong delta region. Based on the average, the order of the varieties from low to high in seed yield ranked as follows Tanzanian sesame < El Salvadoran sesame < Kenyan sesame < Indian sesame < Vietnamese sesame < Cambodian sesame. Several of the Cambodian and Vietnamese varieties were identified as high yielding and potential sources to be included in future breeding activities. The results achieved could be used for improvement of sesame varieties in various regions.

Keywords: Growth and development; growth behavior; plant height; seed yield; sesame breeding; vegetative phase; yield component

Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest crops in the world, and is under cultivation in Asia for over 5000 years (Bisht et al., 1998). The crop has early origins in East Africa and in India (Nayar and Mehra, 1970; Bedigian, 2003). Today, India and China are the world's largest producers of sesame, followed by Myanmar, Sudan, Uganda, Nigeria, Pakistan, Tanzania, Ethiopia, Guatemala and Turkey. World production fluctuates due to local economic, crop production disturbance and weather conditions. In Vietnam, sesame is known as the king of oil seeds due to the high oil content (50 – 60%) of its seed. The crop is highly drought tolerant, grows well in most kind of soils, regions and is well suited to different crop rotations. In reality, sesame is mostly grown under moisture stress with low management input by small holders (Cagrgan, 2006). However, the sesame production is below expectation and the potential could be considerably higher. The low production is due to a number of reasons such as low inputs and poor management (e.g low or non-fertilization, irrigation, pest control etc), occurrence of biotic and abiotic stresses and more importantly, a lack of an appropriate breeding program. Nowadays, many sesame varieties are ready in the world market. There are including local varieties and commercial varieties. However, the cultivation of improved varieties is limited due to insufficient variety information. The farmers continue to grow local varieties with low yields. Therefore, adequate knowledge of morphology as well as phylogenetic relationship among sesame varieties will help the breeder to improve high yielding of sesame, good quality cultivars that will increase sesame production in Vietnam. In 2008, Vietnam grew about 45000 ha of sesame with seed production was 22000 metric tons. The average seed yield of sesame in Vietnam was about 500 kg ha^{-1}, which is quite low in comparison with most other sesame producing countries. One important factor that affects the seed yield of sesame is a lack of good varieties for the farmers in Vietnam. This situation can be improved by selecting varieties of good quality and adjusted to the climatic conditions in Vietnam. Sesame process involves evaluation of the varieties with respect to growth, development and seed yield components. The seed yield component of the varieties is important since it directly translates into seed production in sesame cultivation. The purpose of this study was to evaluate morphology of sesame varieties from different origins, which could be used for breeding strategy. Sesame varieties were selected in this study could be used in sesame improvements.

Material and methods

Experiment design

Seventeen sesame varieties were used in this study, which consisted of four varieties each from Northern Vietnam (HD, ND, TH, VINH), Southern Vietnam (AG, DT, CT, TN), Cambodia (EKD, SKD, KPC, KPT) (Pham et al., 2009), and two from Kenya (McBlack, Lungalunga) as well as one variety each from Tanzania (MT2), El Salvador (Exel) and India (Indian) (Were et al., 2006). The field experiment was carried out in the Mekong delta region, on a research station at Tien Giang College of Agriculture (Tien Giang province, Vietnam) 100 km South of Nong Lam University, where the annual temperature fluctuates between 25°C and 35°C and mean annual rainfall measures up to 1500 mm. The experimental layout was a Randomized Complete Block Design with three replications. The soil was amended by adding earthworm compost (2 ton ha^{-1}) and fertilized three times during the growth period by application of 20N - 15P - 15K kg ha^{-1}. Seeds were sown manually with 70 cm spacing between rows and 50 cm between plants in a row. Plants were irrigated during the whole cultivation period and pesticides were applied when appropriated.

Measurement of traits

Morphology of all sesame varieties was characterized by 15 agronomic traits on ten randomly selected plants per variety. The traits measured were plant height, branching, number of leaves, days to first flowering, days to first capsule, number of capsules per plant, number of seeds per capsule, 100-seed weight, yield per plant, internode length, loculi per capsule, capsule length, capsule width, harvest day, capsules per axil.

Analysis of data

The differences in the means of each agronomic trait between varieties were compared using ANOVA (analysis of variance), while phylogenetic relationship between accessions were estimated using Multivariate cluster analysis. The Minitab 15.0 software package program was employed.

Results and Discussion

All varieties grew and developed well but with a clear difference in plant development between those varieties originating from El Salvador (Exel), Tanzania (MT2) and Kenya (McBlack, Lungalunga) and the others. Those varieties (Fig.1 A, B, C) developed a large biomass with big trifoliate leaves and robust stem and had a much-delayed switch into growing lanceolate leaves and a longer juvenile period before start of flowering in comparison with Vietnamese or Cambodian varieties. The Vietnamese and Cambodian varieties showed similar growth and development (Fig.1 D, E). The first developed leaves were trifoliate shaped and these were followed by lanceolate single leaves that coincided with the start of flowering that happened at a much earlier time-point in comparison with the other varieties. Some individual plants among the Cambodian varieties appeared with shoot and stem fasciation. This symptom was rare, but eye-catching to see a flat stemmed plant covered with many capsules in reproductive phase. The Indian variety (Indian) in much resembled the Cambodian and Vietnamese varieties in development but reached a lower plant height (Fig.1 F). Analysis by ANOVA was done on yield component characters. There were significant differences between the varieties for all characters ($P \leq 0.01 – P \leq 0.001$) (Table 1). Comparison of growth and development characters are shown in Table 2. The time of first flower opening among the Vietnamese, Cambodian and Indian varieties ranged from 24 to 31 days after sowing, with the earliest appearance of flowering recorded for variety CT. In contrast, the El Salvadoran and Kenyan varieties showed the first flowering 40 days or more, after sowing, and the extreme Tanzanian variety (MT2) started flowering 79 days after sowing. The first capsule among the varieties was observed two to three days after flower opening. The number of leaves at maturity in all varieties was highly variable and ranged from 138 (CT) to 261 (KPC). Similarly, the number of branches ranged from two (CT) to 56 (Exel) with the McBack, Lungalunga, Exel varieties having higher degree of branching than the others. Notably, most of the branches on the McBlack, Lungalunga, Exel varieties did not carry capsules. Moreover, the capsule length and capsule width showed mean values of 2.60 cm and 1.03 cm respectively. The highest number of capsules on an axil was recorded for variety CT with six capsules, followed by variety KPC with five. Theoretically, varieties carrying traits such as high density of capsule or multi-capsular per axils would produce more capsules per plant and potentially generate a higher seed yield. However, an example in this study shows that this is not always true since variety CT possessed all of the above important characters but yielded less than other varieties (Table 3). This could be explained as even though variety CT produced a high number of capsules, many of these did not produce a high number of seeds. These results were in agreement with Baydar (2005) that reported on sesame plants with more capsules per axil but with lower seed number per capsule and a resulting low seed yield. Although, the less or none branching varieties (CT, TH, KPT) possess several positive traits such as medium plant height, multi-capsular per axils and early flowering, they still under performed with a low seed yield. However, according to Baydar (2005) sesame varieties with non-branching character do have a production advantages for mechanized cultivation, because of their short stature and uniform maturity in a short growing period. None branching varieties could as well allow for higher plant density than bushy varieties and in such a way still reach a good yield per hectare. Comparisons of plant height and yield component characters showed highly significant differences ($P \leq 0.01 – P \leq 0.001$). The plant height of all sesame varieties ranged from 104 cm (TH) to 161 cm (Lungalunga). The highest capsules/plant and seeds/capsule were recorded for variety KPC (232) and TH (138) respectively (Table 3). With the exception of the McBlack, Lungalunga, MT2, Exel varieties that only developed a large biomass, this study showed a positive relationship between plant heights, numbers of branches and seed production. These results were in agreement with previous observations of Varisai and Stephen (1964), Gupta and Gupta (1977), Pathak and Dixit (1992) that reported a positive relationship between plant height, capsules per plant and seed yield. Seed production for each variety is given as yield per plant. The obtained results showed that a few sesame varieties from Vietnam and Cambodia gave higher seed yields than the varieties from El Salvadoran, Tanzanian, Kenya and India. Some varieties from Southern Vietnam (TN, DT, AG) and Cambodia (SKD, EKD, KPC) reached the highest yields (Table 3). Based on the average, the order of the varieties from low to high in seed yield ranked as follows Tanzanian sesame < El Salvadoran sesame < Kenyan sesame < Indian sesame < Vietnamese sesame < Cambodian sesame. This study found that the traits capsules per plant and seeds per capsule directly influenced the seed yield component of sesame. There was a positive relationship between number of seeds per capsule, capsule number per plant and seed yield per plant. For example, the varieties TN, SKD, KPC, EKD, DT and AG all displayed a high number of capsules per plant, high number of seeds per capsule and presented a high seed yield (Table 3). Studies by Majumdar et al. (1987), Reddy and Haripriya (1992) also reported a positive and highly significant relationship between seed number per capsule, capsule number per plant and seed yield per plant. The varieties listed above were found interesting enough to be selected for use in breeding strategy to improve high yielding sesame cultivars. In the present study, the Kenyan, Tanzanian and El Salvadoran varieties gave a lower seed yield than varieties from India, Vietnam and Cambodia. Several factors may contribute to this observation including climatic reasons such as temperature (day/night), day length, light intensity,

Table 1. Mean squares from analysis of variance of yield components

Source of variation	df	Mean squares								
		Plant height (cm)	Capsules/ plant	Seeds/capsule	100-seed weight (gram)	Yield/plant (gram)	Loculi/ capsule	Capsule length (cm)	Capsule width (cm)	Harvest day
Varieties	16	719.34(***)	9511(***)	2845(**)	0.020996(***)	490.67(***)	2.3652(***)	1.5829(***)	0.24059(***)	1497.5(***)
Block	2	1159.88	2165	1787.8	0.002359	828.35	0.6078	0.0241	0.00207	43.6
Error	32	99.23	1150	899.6	0.000758	54.82	0.2328	0.0435	0.00787	19.9

** Significant at $P \leq 0.01$; *** Significant at $P \leq 0.001$

Table 2. Agronomic traits related to growth and development in 17 sesame varieties

Varieties	Number of branching	Number of leaves	Days to the first flowering	Days to the first capsule	Internode length (cm)	Capsule length (cm)	Capsule width (cm)	Capsules/axil
AG	15	223	30	33	9.73	2.95	1.18	2
CT	2	138	24	27	6.10	3.24	0.95	6
DT	13	244	31	34	9.17	2.53	1.16	2
TN	15	238	29	33	9.20	2.57	1.20	2
HD	13	208	29	32	8.82	2.47	1.23	2
ND	11	250	29	32	8.23	2.74	1.16	2
TH	2	150	27	30	5.01	3.10	1.18	4
VINH	10	207	30	33	6.55	3.13	1.17	2
EKD	13	246	29	32	8.53	2.68	1.06	3
SKD	14	256	30	33	8.37	2.59	1.21	2
KPC	12	261	29	32	7.70	3.05	0.94	5
KPT	6	141	27	30	6.30	3.09	1.02	4
Lungalunga	51	259	45	47	9.97	2.26	1.00	2
McBlack	45	236	40	43	9.41	2.51	1.07	2
MT2	–	243	79	–	5.20	–	–	–
Exel	56	210	46	48	7.94	2.64	0.99	2
Indian	9	157	29	32	9.03	2.65	1.07	2
Max	56	261	79	48	9.97	3.24	1.23	6
Mean	17	216	34	37	7.96	2.60	1.03	3
Min	2	138	24	27	5.01	2.26	0.94	2
SE	4	26	1	1	0.80	0.12	0.05	1
F value	21.09 (***)	2.77 (**)	89.77 (***)	95.18 (***)	3.81 (***)	36.39 (***)	30.56 (***)	5.93 (***)

** Significant at $P \leq 0.01$; *** Significant at $P \leq 0.001$

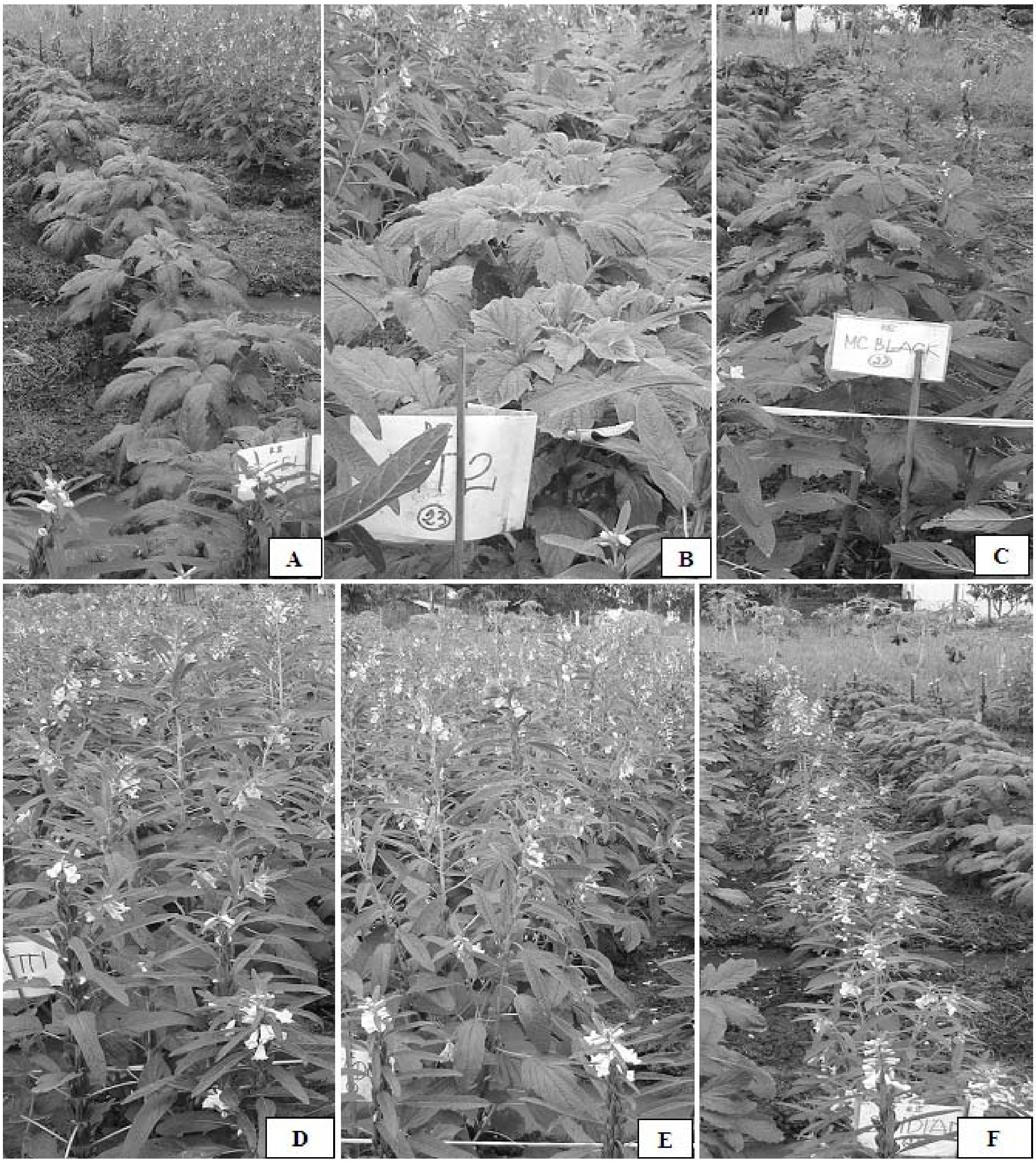

Fig 1. Diversity of phenotypes in sesame varieties from different origins, A: El Salvadoran sesame (Exel); B: Tanzanian sesame (MT2); C: Kenyan sesame (McBlack); D: Vietnamese sesame (TN); E: Cambodian sesame (SKD); F: Indian sesame (Indian)

precipitation, altitude and latitude. Photosynthesis is influenced by various biotic and abiotic stresses during grain-filling, therefore, that decreasing or increasing photosynthesis capacity is a major limiting factor for yield and all yield components (Beheshti and Fard, 2010). There are reasons to believe that the less performing varieties from Kenya, Tanzania and El Salvador were not adjusted to the field conditions and therefore gave a low yield in this study. Basu et al. (2009) also reported that seed yield is known to be a complex trait governed by polygene and therefore is influenced more by environmental factors. The results were in agreement with previous studies, which sesame were shown to be highly sensitive to day length since it is a short day plant (Narayanan and Reddy, 1982). Suddihiyam et al. (1992) also reported about the significant interactions temperature and day length had on the flowering rate. The yield depends on the interaction of different climatic parameters such as solar radiation, temperature, humidity relative to photosynthetically active radiation (PAR) (Beech, 1985; Nath et al., 2001). Yadav et al. (1988) also reported the close correlation between PAR absorption and yield in sesame. The different developmental pattern of the varieties from Africa and Central America indicates that in the climatic conditions of Southern Vietnam their switch from vegetative to reproductive phases happened much later than compared with the other varieties (Fig. 1) The varieties McBlack, Lungalunga and Exel showed by far a much later harvest day than the other varieties. In addition, the variety MT2 developed a large biomass and had a much-delayed induction of flowering but did not produce capsules. The earliest harvest day was found for varieties SKD, HD (75), followed by CT, TN, DT and VINH that were harvested 76 days after sowing. Based on harvest day, the order from early to late variety ranked as following Vietnamese < Cambodian < Indian < Kenyan sesame < El Salvadoran sesame < Tanzanian sesame. Cluster analysis for phylogenetic relationship between accessions showed that sesame accessions grouped into two main clusters (Fig. 2). The first group was composed of Kenyan, Tanzanian, El Salvadoran sesame. The second group consisted of Indian, Cambodian and Vietnamese sesame. There were defined groups according to geographic regions as Africa, Asia. Based on

Table 3. Agronomic traits related to yield contribution in 17 sesame varieties

Varieties	Plant height (cm)	Capsules/plant	Seeds/capsule	100-seed weight (gram)	Yield/plant (gram)	Loculi/capsule	Harvest day
AG	124.40	172	119	0.29	40.55	4	77
CT	109.70	198	77	0.31	20.83	2	76
DT	129.80	172	88	0.30	40.70	4	76
TN	132.50	164	108	0.26	51.65	4	76
HD	117.00	185	85	0.27	35.25	4	75
ND	119.30	205	108	0.28	38.50	4	78
TH	104.70	141	138	0.31	29.05	2	76
VINH	121.60	191	98	0.25	33.58	3	76
EKD	118.10	213	107	0.26	43.75	3	77
SKD	123.70	176	98	0.28	44.36	4	75
KPC	113.00	232	105	0.27	42.88	2	78
KPT	107.30	159	90	0.33	27.89	2	78
Lungalunga	161.60	121	50	0.42	26.51	2	106
McBlack	144.60	110	81	0.36	27.64	3	96
MT2	142.60	–	–	–	–	–	115[(1)]
Exel	145.60	78	62	0.29	12.18	2	106
Indian	133.90	137	88	0.29	33.69	3	78
Max	161.60	232	138	0.42	51.65	4	106
Mean	126.44	156	88	0.28	32.30	3	77
Min	104.70	78	50	0.25	12.18	2	75
SE	5.75	20	17	0.02	4.28	0.2	3
F value	7.25 (***)	8.27 (***)	3.16 (**)	27.69 (***)	8.95 (***)	10.16 (***)	75.33 (***)

** Significant at $P \leq 0.01$; *** Significant at $P \leq 0.001$; [(1)] The last day of variety MT2 observation; The symbol "–" in MT variety is no parameters

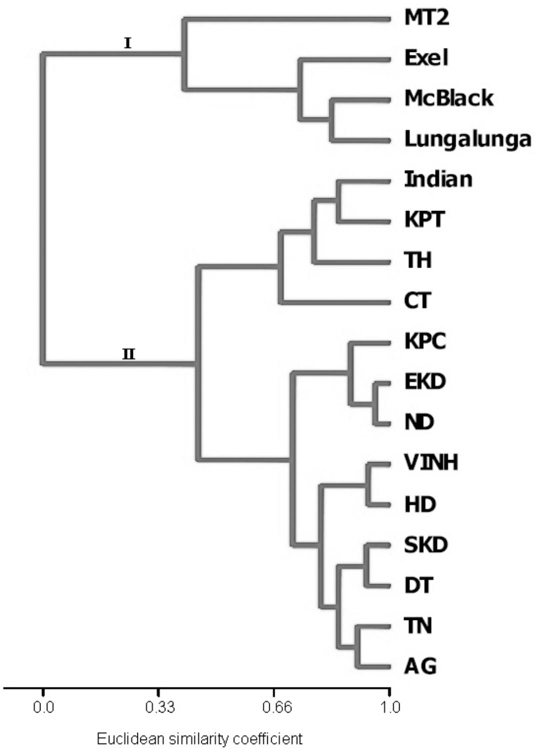

Fig 2. Dendrogram showed phylogenetic relationship among 17 sesame accessions based on morphological analysis

dendrogram of cluster analysis, sesame from Africa spread to the West (El Salvador) and sesame from India spread to the Orient including Vietnam and Cambodia. It is appropriate to consider Africa as the primary centre of origin while India may be considered as secondary centre of sesame in the world (Bedigian, 1981). Then it spread to the Orient and the West by trade exchange (Carlsson et al., 2008).

Conclusion

Three varieties each from Vietnam (TN, DT, and AG) and Cambodia (SKD, KPC, and EKD) were found interesting and could be candidates for potential breeding sources due to their high seed yield. Their high yield potential can subsequently be combined with improvements of other traits such as plant height, oil content, synchronous flowering, synchronous ripening, or resistance to pests. The results achieved could be used for improvement of sesame varieties in various regions.

Acknowledgements

This project was supported by the Swedish International Development Agency (SIDA/SAREC). The authors acknowledge Mr Duyet and his students at Tien Giang College of Agriculture for valuable advices, support, and for the managements of the experimental field, Dr. Bonaventure Aman for helpful correction on the manuscript.

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