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GENETIC VARIATION IN SESAME GENOTYPES (*Sesamum indicum* L.) GROWN IN THE SEMI-ARID ZONE OF THE SUDAN

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SUMMARY

Sesame is an important oilseed and cash crop production in Sudan. The objective of this study was to estimate the extent of genetic variability in genotypes of sesame (*Sesamum indicum* L.) under rainfed conditions in semi-arid zones. Twelve genotypes of sesame were grown at El Fasher Research Station Farm for 3 consecutive seasons (2006, 2007 and 2008). Genotypic and phenotypic variability, genetic advance and heritability in a broad sense were estimated in a randomized complete block design with 4 replications. The highest genotypic coefficient of variation was observed for seed yield kg/ha while days to flowering showed high heritability estimate (above 85%) during these seasons. Moreover, the high genetic advance was recorded in 1000-seed weight while all other traits showed low genetic advance. Highly significant differences among genotypes were observed in days to flowering, plant height and 1000-seed weight. Significant differences in seed yield (kg/ha) and biomass yield (kg/ha) and non-significant difference in days to maturity were observed. The high yielding genotypes were Ang5 (4 locules with black seeds) and Hirehri with seed yields of 365 and 347 kg/ha, respectively. Seed yield (kg/ha) was highly significant and positively correlated with biomass (yield kg/ha) (r = 0.81), 1000- seed weight (r = 0.57) and plant height (r = 0.50). However, it was highly significant and negatively correlated with days to flowering (r = -0.22). Therefore, the characters biomass yield kg/ha, 1000-seed weight and plant height were the most contributing characters on sesame seed yield. The promising genotype identified in this study could provide valuable sources of tolerance to climate-change-related stresses and for other consequent breeding activities in sesame crop improvement.

Key words: Broad sense heritability, correlation, genetic variability, Sesame (*Sesamum indicum* L.)

Key findings: Based on their positive association with seed yield, the character's biomass yield, 1000-seed weight and plant height would be useful selection criteria for sesame improvement program in the country.

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INTRODUCTION

Sesame (*Sesamum indicum* L.) belongs to the family Pedaliaceae, a diploid species with 2n = 26 (Daniel and Heiko, 2011). It is commonly known as sim-sim, til, gingelly, and beniseed (Ahmed and Ahmed, 2013; Ogbonna and Ukaa, 2012). Sesame is an important oilseed crop successfully grown in tropical and sub-tropical climates from 25°N to 25°S (Ahmed and Ahmed, 2012; Daniel and Heiko, 2011). It has a deep tap root system and ability to set seeds under high temperature that enable it to grow well in different agroecological zones, including the arid and semi-arid zones (Iman *et al*., 2011; Sandipan *et al*., 2010) and it is described as a drought-adapted crop (Boureima *et al*., 2011; Ogbonna and Ukaa, 2012). Sesame is widely used as a source of food, feed, and edible oil and besides, its industrial and medicinal properties, it is an important element in crop rotation and intercropping (Renuka *et al*., 2011; Sandipan *et al*., 2010). Sesame seeds contain (45-60%) oil with the highest antioxidant content as a high quality digestible oil and biofuel (Banerjee and Kole, 2009a; Boureima *et al*., 2011; Engin *et al*., 2010; Renuka *et al*., 2011; Revathi *et al*., 2012; Toan et al., 2010), protein 25% and carbohydrates 13.5% (Iman *et al*., 2011). The seed of sesame added as ingredients form highly nutritious components of the dessert in cakes and bread (Iman *et al*., 2011). It is rich in phosphorus, methionine, tryptophan and calcium (Ahmed *et al*., 2010).

Sudan is one of the most important sesame producers in the total world production (Banerjee and Kole, 2009b). Sesame is one of the most important oilseed and cash crops in Sudan. It has many domestic uses for local consumption, industry and for export (Ahmed and Ahmed, 2013). Sesame plays an important role in income generation and subsistence for commercial and small scale farmers. It is cultivated in wide areas under rainfed conditions, depending on rainfall amount and distributions, hence ranks third after sorghum and millet in Sudan (Ahmed, 2008). Rainfall amount and distribution during the growing season are considered the most serious environmental problem limiting crop production under rainfed conditions (Baydar, 2005). Total cultivated area and production of sesame in Sudan gradually increased during the last 10 years for local use and exports (Ahmed *et al*, 2012). However, its productivity remained very low compared to the other oilseed crops due to the traditional cultivation, yield losses through threshing/shattering, the poor yield potential of cultivated types, and limited use of agricultural inputs (Baydar, 2005; Iman *et al*., 2011; Ogbonna and Ukaa, 2012).

Genotypic diversity in sesame is very important in selecting the high yielding and desirable genotypes (Banerjee and Kole, 2009a). A successful breeding program and development of any crop improvement depends on the nature, magnitude of genetic variability, trait association, genetic advance, direct and indirect effects of traits on yield related character to yield and to select component maximizing yield (Sandipan *et al*., 2010; Seymus and Bulent, 2010). Several studies on sesame have been carried out, but, there is limited information regarding its genetics, breeding and production, particularly genetic improvement under rainfed conditions in the semi-arid zone (Banerjee and Kole, 2009b; Ogbonna and Ukaa, 2012). Moreover, to improve the yield of sesame, plant breeders should have a better understanding of the genetic variability of yield and its components (Ahmed, 2008). Hence, the objectives of this study were to estimate the genotypic and phenotypic variability, the broad sense heritability, morphological and yield associated traits of sesame genotypes under rainfed conditions in semi-arid zones of Sudan.

MATERIALS AND METHODS

Plant materials

Twelve sesame genotypes were used in this study, which consisted of 2 traditional cultivars Hirehri, Gabrowk, 1 mutant and 1 variety of recently improved Elobeid1. As well as, 8 genotypes Ang5 (6 locules-brown), Ang5 (4 locules-brown), Ang5 (6 locules-white), Ang5 (6 locules-white), Ang5 (6 locules-white), Elobeid1 with selected, Ang5 (4 locules-white) and Ang5 (4 locules-black). Which have been developed from a cross between Elobeid1 and Hirehri by breeders through hybridization and selection, National rainfed sesame breeding program, Elobeid Research Station, Agricultural Research Corporation (ARC), Sudan. The improved advanced breeding lines are developed for general cultivation to increase productivity in the Western Sudan in locations that receive low average and erratic annual rainfall, have poor sandy soil making the area vulnerable to terminal water stress.

Table 1. Monthly and seasonal rainfall during growing season of 2006, 2007 and 2008 at El Fasher Research Station in North Darfur State, Sudan.

Month	Season 2006	Season 2007	Season 2008
April	-	-	6.1
May	-	13.5	-
June	6.0	-	-
July	68	42.9	58.6
August	122.8	207.5	107.7
September	59.2	14.2	24.2
Total annual rainfall	256 mm	278.1 mm	196.6 mm

Study site and experimental design

The study was conducted under rainfed conditions at El Fasher Research Station Farm located on (13° 37′ N 25° 20′ E, 748 msl) North Darfur State, Sudan, on sandy soil without using fertilizers, pesticides or irrigation for 3 consecutive cropping seasons 2006, 2007 and2008. The total amount of rainfall received during the growing seasons was 256, 278.1 and 196.6 mm for 2006, 2007 and 2008, respectively (Table 1). The experiments were planted on 5th August in 2006, 11th August in 2007 and 19th July in 2008 in Randomized Complete Block Design (RCBD) with 4 replications. Each genotype was planted in 5 rows of 4 meters length, with spacing of 60 cm between rows and 20 cm between plant to plant. The total plot size was 12 m^2 and the net harvested plot size was 6.48 m^2 (3 middle rows of 3.6 meters length). Five to 6 seeds were planted in each hole, and 2 weeks after planting seedlings were thinned to 2 plants per hole. Weeding was eliminated by hand 2 times per season.

Data collection

Data were recorded for days to flowering (days from sowing to a time when 50% of the plants start to flower) and days to maturity (days from sowing to a time when 95% of the plants start to mature). In addition, plant height (cm), 1000- seed weight (g), biomass yield (kg/ha) and seed yield (kg/ha) were determined.

Statistical analysis

Analysis of variance (ANOVA) was carried out for each trait using SAS (1999-2000), to detect significant effects among the genotypes. Based on the analysis of variance, heritability in the broad sense, genotypic coefficient of variation, phenotypic coefficient of variation and genetic advance were estimated. Phenotypic correlation between seed yield, flowering, maturity, plant height, 1000-seed weight and biomass yield (kg/ha) traits were estimated. The means for each season and for the 3 seasons were used to compute simple linear correlation coefficients.

RESULTS AND DISCUSSION

The results showed highly significant differences among the genotypes for flowering time in 3 seasons. Significant differences maturity and plant height in seasons 2007 and 2008, seed yield kg/ha and biomass yield kg/ha in season 2006 and 1000-seed weight in seasons 2006 and 2008 were revealed. Seed yield kg/ha and biomass yield kg/ha in seasons 2007 and 2008 were observed non-significant (Table 2). This indicates the substance of a high degree of genetic variation in the materials to be exploited for the sesame improvement program in Sudan. Ahmed and Ahmed (2013), Ogbonna and Ukaa (2012) and Parameshwarappa *et al.* (2009) suggested that selection based on these characters will be meaningful in predicting seed yield in sesame.

Table 2. Estimates of heritability in the broad sense (h^2B), Genotypic coefficients of variation (GCV), Phenotypic coefficients of variation (PCV) and genetic advance (GA) as a percentage of the mean for 6 traits in 12 Sesame genotypes grown at the FRS, seasons 2006, 2007 and 2008.

Traits	Seasons	Range	G. mean	F value	h^2B	GCV	PCV	GA
SY	2006	195.0- 365.0	270.9	2.07*	67.38	21.5	25.89	0.02
	2007	140.0 - 245.0	178.7	1.24 ns	55.31	19.13	25.71	0.03
	2008	87.8- 208.3	132.1	1.48 ns	59.60	24.23	31.39	0.04
DF	2006	36.0- 50.0	46.0	22.41***	95.73	8.34	8.53	0.51
	2007	36.0 - 48.0	46.0	16.36***	94.24	7.17	7.4	0.58
	2008	37.0- 51.0	46.0	6.83 ***	87.22	9.34	10.00	0.42
DM	2006	80.0- 86.0	82.0	0.85 ns	47.6	2.88	4.18	0.43
	2007	88.0- 101	94.0	3.31**	76.8	3.84	4.38	0.44
	2008	73.0-77.0	75.0	2.83*	73.92	1.82	2.12	1.11
PH	2006	56.3- 76.3	68.3	1.32 ns	61.94	8.57	10.9	0.19
	2007	52.3- 72.5	61.2	3.08**	75.49	12.97	14.93	0.20
	2008	52.0 - 78.5	67.2	1.90*	65.49	12.38	15.30	0.16
SW	2006	2.7- 3.9	3.1	1.89 *	75.71	26.88	30.9	1.93
	2007	2.9- 3.7	3.2	1.04ns	51.05	8.12	11.37	4.08
	2008	2.7 - 3.6	3.1	2.79*	73.58	8.98	10.47	5.49
BY	2006	657.0- 1065.8	896.4	1.83*	64.65	16.87	20.98	0.01
	2007	515.5 - 678.0	594.5	0.85 ns	45.89	6.78	10.01	0.02
	2008	314.3 - 461.3	381.3	0.48 ns	32.44	13.00	22.81	0.01

*, **, *** Significant at 0.05, 0.01 and 0.001 probability level, respectively, SY: seed yield (kg/ha); DF: Days to flowering; DM: Days to maturity; PH: Plant height (cm); SW: 1000-seed weight; BY: Biomass yield (kg/ha).

The highest genotypic coefficient of variation was observed for seed yield (kg/ha) and high heritability estimate (above 85%) was for flowering in 3 seasons (Table 2). The same results have been indicated in previous studies made by Ahmed and Ahmed (2013), Banerjee and Kole (2009a) and Parameshwarappa *et al*. (2009) that flowering is highly and genetically controlled and less affected by environment. Moreover, the high genetic advance was recorded in 1000- seeds weight, while all others traits were observed to have low genetic advance in the 3 seasons (Table 2). Similar results were reported by Ahmed and Ahmed (2013), indicating the presence of additive gene action in their inheritance.

The combined analysis showed (Table 3) that the genotypes differed highly significant at $P = 0.01$ level for flowering, plant height, 1000-seed weight and significantly ($P = 0.05$) different for seed yields kg/ha and biomass yield kg/ha. Similar pattern of variability was also reported by Ogbonna and Ukaa, (2012) and Parameshwarappa *et al*. (2009). However, non-significant difference was observed for maturity. This may be due to the variations and distribution in the rainfall during the growing seasons. The early flowering genotype was Ang5 (4 locules-black), while the genotype Ang5 (4 locules-white) was late flowering genotype. The tallest genotype was Hirehri and the genotype Ang5 (4 locules-black) was the shortest.

Table 3. Mean performance of 12 Sesame genotypes grown at the FRS Farm (combined over 3 seasons; 2006, 2007 and 2008).

Varieties	SY	DF	DM	PH	SW	BY
Ang5 (6 locules-brown)	295.3 bc	45 d	77 a	82.5 abc	66.5 bcd	957.8 abc
Elobeid1	321 bc	45 d	75.8 a	78.5 abc	71.5 abc	1040 ab
Mutant	318.8 bc	45.75 cd	81.5 a	73 abc	65.5 cd	989.3 abc
Ang5 (4 locules-brown)	246.3 bc	49 a	81.5 a	80.3 abc	71.8 abc	832.8 abc
Ang5 (6 locules-white)	274.3 bc	46.25 bcd	80 a	76.5 abc	70.8 abcd	1002.5 abc
Ang5 (6 locules-white)	220.8 bc	47.5 bcd	80 a	69.3 bc	64.3 d	657 c
Ang5 (6 locules-white)	195 c	48 abc	78.5 a	70.8 abc	72.8 ab	710.3 abc
Elobeid1 with selected	212.5 bc	45.75 cd	75.8 a	75.5 abc	73.5 a	670.3 bc
Ang5 (4 locules-white)	240.8 bc	50 a	77.3 a	73.3 abc	70.5 abcd	926.8 abc
Ang5 (4 locules-black)	365 a	35 e	75.5 a	66.5 c	72.8 ab	1065.8 a
Hirehri	347 ab	45 d	75.8 a	87.8 a	70.8 abcd	1062.3 a
Gabrowk	214.3 bc	48.5 ab	78.5 a	85.8 ab	70.3 abcd	841.8 abc
CV%	28.93	6.05	6.45	17.61	10.51	24.21
SE	18.87	0.70	1.33	3.01	0.67	45.57
Pr > F	0.98^{*}	18.69^{***}	1.06^{ns}	2.35^{**}	1.66^{***}	1.02^{*}

*, **, *** Significant at 0.05, 0.01 and 0.001 probability level, respectively. Means followed by the same letter(s) within a column are not significantly different at 0.05 probability level according to LSD test. SY: seed yield (kg/ha); DF: Days to flowering; DM: Days to maturity; PH: Plant height (cm); SW: 1000-seed weight (g); BY: Biomass yield (kg/ha).

Table 4. Simple linear correlation coefficients between 6 sesame traits (combined over 3 seasons, 2006, 2007 and 2008).

Traits	SY	DF	DM	PH	SW	BY
SY	1.000					
DF	-0.217^{**}	1.000				
DM	-0.032^{ns}	0.118^{ns}	1.000			
PH	0.499^{***}	0.092^{ns}	-0.354^{***}	1.000		
SW	0.567^{***}	-0.026^{ns}	-0.301^{***}	0.416^{***}	1.000	
BY	0.806^{***}	-0.078^{ns}	-0.013^{ns}	0.470^{***}	0.682^{***}	1.000

** and *** Significant at 0.01 and 0.001 probability level, respectively. SY: seed yield (kg/ha); DF: Days to flowering; DM: Days to maturity; PH: Plant height (cm); SW: 1000-seed weight; BY: Biomass yield (kg/ha).

The high yielding genotypes were Ang5 (4 locules-black) and Hirehri with seed yields of 365 and 347 kg/ha, respectively. High variability among genotypes was revealed in seed yield indicating the possibility to increase seed production through selection. The promising genotypes identified in this study could provide valuable sources of tolerance to climate-change-related stresses and could be incorporated in future sesame breeding programs.

These results indicated that the seed yield was positively correlated with the biomass yield kg/ha (r = 0.81), 1000-seeds weight (r = 0.57), and plant height (r = 0.50), which confirmed those previously recorded by Ahmed and Ahmed (2012), Engin *et al*. (2010), Ogbonna and Ukaa, (2012), Renuka *et al*. (2011) and Sumathi *et al*. (2007). It was suggested that selection on the basis of the phenotypic characters will lead to high seed yield in sesame. However, negative and highly significant association for days to flowering (r = -0.22), while negative non-significant for days to maturity (r = -0.03) were exhibited (Table 4). These findings are in agreement with results reported by Engin *et al*. (2010), Gnanasekaran *et al*. (2008), Ogbonna and Ukaa (2012) and Sandipan *et al*. (2010). They indicated that onset of flowering and late maturity plants would tend to produce more seed yield and selection based on days to flowering alone will be depressing seed yield in sesame. However, selection for the early maturity is a desirable trait that may protect the crop from various biotic and abiotic stresses. The results from this study revealed that the biomass yield (kg/ha), 1000-seed weight, plant height and days to flowering traits should be considered during selection for seed yield in sesame. Therefore, these traits are suggested to be the most important selection criterion for the improvement of the seed yield in sesame.

CONCLUSION

Our results concluded that there is adequate genetic variability present in the material studied. According to the broad sense heritability, genetic advance and correlation among traits, selection for biomass yield (kg/ha), 1000-seed weight, plant height and days to flowering could be the most effective traits in boosting seed yield performance of sesame genotypes. Among the evaluated genotypes, higher yields were Ang5 (4 locules-black) and Hirehri with average seed yields of 365 and 347 (kg/ha) respectively. They have the greatest potentiality to adapt to semi-arid zone with adverse climatic conditions, enhance sesame production and breeding activities for sesame improvement under rainfed condition of the Western Sudan.

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