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GENOTYPIC VARIABILITY IN SESAME MUTANT LINES IN KENYA

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ABSTRACT

Sesame (*Sesamum indicum* L) is one of the major oil crops with potential for production by small- scale holders in the marginal agro-ecological zones of Kenya. Variability studies on yield and yield components of sesame mutant lines now in M7generation was carried out in two locations for two seasons in Kenya. The objective of the study was to assess performance of the mutant lines developed through induced mutational breeding. According to mean performance, the thirty selected mutant lines and four check cultivars showed a wide range of genotypic variability for all the studied traits. Seed yield per plant registered the highest coefficient of correlation (63.8%). In addition, seed yield had positive and significant (P<0.05) correlation with biomass yield, harvest index and 1000- seed weight. It showed a weak positive association with plant height, oil content, number of capsules per plant and number of days to flowering. Biomass yield, harvest index, 1000 seed weight and oil content had positive direct effect on seed yield. Line Mun 096/1/k5/2/4 was superior to the best check cultivar Spssik 116.

Key Words: Kenya, *Sesamum indicum,* sesame mutant lines, variability

RÉSUMÉ

Sésame (Sesamum indicum L) est l'une des plantes oléagineuses principales avec potentiel pour la production chez les petits producteurs dans les zones agro-écologiques marginales du Kenya. Des études de variabilité sur le rendement et les composantes de rendement des lignes de mutation de sésame maintenant dans la génération M7ont été effectuées dans deux endroits pendant deux saisons au Kenya. L'objectif de l'étude était d'évaluer l'exécution des lignes de mutant développées par l'élevage mutationnel induit. Selon la performance moyenne, les trente lignes de mutation choisies et quatre cultivars de contrôle ont montré une variabilité génotype multiple pour tous les traits étudiés. Le rendement de la semence par plante a enregistré le coefficient de corrélation le plus élevé (63.8%). En outre, le rendement de la semence a eu une corrélation positive et significative (P<0.05)avec le rendement de la biomasse, l'index de moisson et le poids de 1000 graines .C'a montré une faible positive association avec la taille, le contenu d'huile,le nombre de capsules par plante et le nombre de jours de Floraison. Le rendement de la biomasse, l'index de la moisson, le poids de 1000graines et l'huile ont un effet positif direct sur le rendement de la semence. La ligne Mun 096/1/k5/2/4 était supérieure au meilleur cultivar de contrôle Spssik 116.

Mots Clés: Kenya, *Sesamum indicum*, lignes de mutation de sésame, variabilité

INTRODUCTION

Sesame (*Sesamum indicum* L) is one of the major oil crops with potential for production by small-scale holders in the marginal agro-ecological zones of Kenya (Ayiecho and Nyabundi, 1997). Its production is currently restricted to lower midlands in Western Kenya(Western and Nyanza provinces) and coastal lowlands (Coast province).Available estimates reveal that approximately 1,182,000 hectares of land is under crop production with an average yield on farmers field being between 80- 400 kg ha^{-1} (Anon, 1995). However experimental plots can give yields up to 2230 kg ha^{-1} (W'opindi, 1981), whereas on farmers fields, sesame yields are in the range of 450 - 550 kg ha^{-1} (Infonet-Biovision, 2009). Low yield on farmers' field has been blamed on the use of landraces with limited genetic variability. In an effort to address this problem, it was decided that induced mutation techniques be applied to enhance genetic variability in the working collections. Induced mutation had earlier been recommended by an expert consultative meeting organised by FAO between 1981 and 1987 (Van Zanten, 2001). Substantial genetic variability of sesame following induced mutation has been reported (Rahman *et al*., 1996). Induced mutation resulted in the identification of a number of agronomic ally useful sesame mutant lines (Ayiecho and Nyabundi, 1997).

Since all desirable mutant lines cannot be released for production, selection is inevitable. This study was, therefore, conduced to assess genotypic variability and correlations among various traits and identify the mutant lines that can be advanced to further evaluations.

MATERIALS AND METHODS

The study was conducted in the short rains and long rains of 2000 and 2001, two locations (sites) in Western Kenya. The locations were Siaya Farmers Training Centre (FTC) and Maseno University Farm. Siaya FTC is located on latitude 0^o 16'N and longitude 34^{o}17' 43''E at 1200m above sea level. Maseno University Farm is located on latitude 0^o and longitude 34^o 30'E, at 1515 above sea level.

The thirty mutant lines along with four check cultivars (Table 1) used in this study were acquired from the sesame mutation projects of the University of Nairobi. The study was laid out in a randomised complete block design, replicated three times at each site.

Individual plots consisted of three rows 4 m long, with a spacing of 50 cm between the rows and10 cm within the rows. Plots were hand planted with more than one seed per hill to ensure proper stand. Plants were later thinned to one at 10- 15 cm height stage. During growth data on agronomic traits were measured on ten randomly selected plants from the centre row in each plot. The average for the ten plants gave the mean of each genotype in each replicate.

Traits studied were number of days to flowering determined when 50% of plants in each plot had flowers, first capsule height, plant height, number of capsules per plant and number of branches per plant at physiological maturity.

Biomass yield was determined from the above ground part of a single plant. Harvest index was calculated as the proportion of the seed yield in the plant biomass. Seed weight was determined from 1000 seeds for each plot. Seed yield per plant was determined and subsequently, seed yield per hectare. Oil content was determined by extracting the ground seed in a Soxhlet apparatus with petroleum ether (A.O.A.C., 1984).

Data for the quantitative traits obtained during the two seasons and two sites were combined and analysed using GENSTAT. The mean values of sesame genotypes were compared using least significant different test (LSD) values (Steel and Torrie, 1980). Correlation coefficients of all variables were established from mean values of the traits according to Millers *et al*. (1958). Path coefficient analysis was also performed as presented by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

The mean variability and analysis of variance for yield and yield components among the genotypes are summarised in Tables 1 and 2. Results revealed existence of significant differences ($P<0.05$) among the genotypes for all traits. The number of days to flowering varied from 42.8 days in Mun 50/1/14/2 to 50.6 days in Spssik 116 with coefficient of variation of 2.9%. Mutant lines are early flowering since they comparatively had a short period to flowering, hence, can be grown during short rains (Weiss, 1983). The first capsule height ranged from 29 cm im Mun 50/1/96/5 to 59 cm in Spssik 113, with coefficient of variation of 20% (Table 2). Plant height was variable among the genotypes. Tehran

TABLE 1. Performance of 34 sesame genotypes grown in western Kenya during 2000-2001

Genotypes	DF	FCH	PH	NCPP	NBWC	BPP	SYPP	SW	HI	SY/ha	%OIL
Mun 50/1/63/1	44	35.3	87.6	41	2	19.49	2.52	2.62	0.15	376.53	41.80
Mun 50/1/124	45	36.9	96.9	55	2	21.41	3.40	2.60	0.17	477.65	39.50
Mun 50/1/53/3/2	47	39.7	90.1	43	3	28.93	4.29	2.68	0.15	554.93	44.90
Mun096/k5/1/2/4	45	43.0	91.0	51	3	44.57	8.56	3.10	0.22	1188.70	49.60
Mun50/1/2/1	45	30.1	84.9	44	2	22.21	4.02	2.86	0.20	523.25	47.20
Mun 50/1 /164	47	39.0	90.3	50	3	38.11	2.47	2.75	0.07	440.23	42.30
Mun 006/k33/2	45	42.7	90.2	62	5	22.37	3.90	2.96	0.18	519.15	46.90
Mun 50/1/149	44	39.7	90.5	44	3	23.73	3.22	2.92	0.13	374.95	43.30
Mun 50/1/85/3	44	39.7	97.0	36	2	20.63	2.89	2.47	0.13	305.95	47.40
Mun 50/1/71/1	44	29.9	89.5	46	2	20.66	2.16	2.52	0.14	392.85	45.10
Mun 50/1/109/2/1	44	35.0	99.4	40	2	22.14	3.48	2.83	0.16	513.38	41.00
Mun 50/1/52/2	44	34.2	84.8	34	3	20.02	2.18	2.64	0.12	431.85	43.10
Mun 006/252/2	45	42.6	95.5	43	3	19.99	2.90	2.63	0.14	313.90	46.30
Mun 006/330/2	45	41.2	93.9	47	3	27.72	4.33	2.66	0.18	559.65	47.10
Mun 096/303/2/3	45	51.0	96.1	52	4	26.16	3.21	2.95	0.13	489.70	43.80
Mun 50/1/123/5	43	43.7	89.2	47	3	27.18	2.77	2.76	0.12	337.85	35.60
Mun 50/1/121	45	33.9	97.3	44	2	24.58	5.41	2.93	0.23	656.73	47.40
Mun 50/1/34	45	38.0	89.5	45	3	20.30	2.39	2.49	0.14	309.55	42.00
Mun 113/258/2/1	44	41.4	91.7	36	3	23.18	4.37	2.57	0.18	585.85	49.00
Mun 50/1/122/2	43	37.9	100	42	2	28.74	5.10	2.77	0.19	514.18	44.10
Mun 50/1/100/2	45	41.7	96.9	42	2	25.02	2.83	2.81	0.12	408.05	47.40
Mun 50/1/109/2/2	44	34.1	84.0	39	2	32.94	4.19	2.55	0.16	418.98	42.60
Mun 50/1/148/1	44	34.0	84.4	45	2	31.27	4.49	3.01	0.14	537.60	41.30
Mun 50/1/218/2	45	35.7	90.0	46	3	20.51	2.93	2.31	0.15	437.73	45.00
Mun 50/1/218/1	44	41.3	99.1	48	4	20.09	2.75	2.28	0.14	360.00	42.15
Mun 50/1/128/1	45	35.3	90.0	34	2	15.14	1.82	2.42	0.12	392.90	43.40
Mun 50/1/14/2	43	38.9	89.1	42	3	27.72	3.79	2.78	0.14	484.63	42.90
Mun 50/1/96/1	45	34.6	96.6	51	3	24.35	4.41	2.86	0.18	531.98	45.90
Mun 50/1/218/3	43	37.6	92.0	63	3	2718	3.50	2.77	0.14	518.18	44.30
Mun 50/1/96/2/5	46	29.0	94.1	56	2	24.26	2.85	2.45	0.12	381.48	44.50
Spssik 116	51	54.1	96.2	51	4	27.68	3.86	2.79	0.16	515.50	51.0
Spssik 16	49	53.5	97.0	52	4	41.83	3.64	2.48	0.09	464.18	40.0
Sik 004	50	32.6	81.7	31	3	34.96	3.21	2.60	0.11	410.83	39.60
Spssik 113	48	58.9	71.0	33	2	17.21	1.21	2.60	0.07	214.83	47.50
Mean	45	39.0	91.4	45	3	25.66	3.50	2.69	0.15	468.93	44.26
LSD($P \leq 0.05$)	1	6.4	9.8	27	1	9.91	1.79	0.41	0.06	190.30	-

Key: DF Number of days to flowering, HFCF= First capsule height, PH plant height, NCPP number of capsules per plant, NBWC= number of branches with capsules. BPP =Biomass yield per plant, SYPP = seed yield per plant, SW= 1000- seed weight, HI= harvest index, SY/ha = seed yield per hectare and percent oil content. Mun linens were the mutants, the rest were the landraces

et al. (1975) reported similar results. Mun 50/122/2 and the tallest plants (100.1 cm)< while Spssik had the shortest (71.0 cm). Coefficient of variation was 13.5%. Marked variation was exhibited in number of branches with capsules and number of capsules per plant.

This conforms with earlier findings of Gupta (1975). The number of capsules per plant varied from 31 in Sik 004 to 63 in Mun 50/1/218/3 with, coefficient of variation of 41.9 %. The high numbers of capsules per plant values for mutant lines suggest their superiority to the check

TABLE 2. Combined analysis of variance for yield and its components of sesame genotypes grown in western Kenya during two seasons of 2000 and 2001

Source	df	Days to 50% flowering	First capsules height (cm)	Plant height (cm)	Branches with capsules	Capsules per plant	Biomass yield per plant (g)	Seed yield per plant (g)	100-seed weight (g)	Harvest index	Seed yield per hectare
		M.S	M.S	M.S	M.S	M.S	M.S	M.S	M.S	M.S	M.S
Replication within environments	8	4.234	129.33	795.2	4.044	159.0	883.9	12.566	0.7668	0.040150	21786
Environments	3	558.242**	2736.79**	14415.3**	18.097**	14659.5**	5267.8**	96.05**	25.2169**	0.108189**	711331**
Genotypes	33	40.096**	485.82**	274.8**	8.623**	700**	532.8**	20.479**	0.4767**	0.015407**	299998**
Genotypes x environments	99	13.115**	91.58**	240.1**	2.157**	479.1*	240.4**	1.77**	0.3642*	0.010168**	103782**
Pooled error	270	1.674	62.63	149.0	1.085	356.2	152.1	4.941	0.2573	0.006262	56069
CV		2.9	20	13.3	38.4	41.9	48.1	63.8	18.9	54.5	50.5

** and * represent significance at P< 0.01 and P<0.05 respectively, df = Degrees of freedom, M.S = Mean squares, CV = Coefficient of variation

cultivars. However, these values were far below those registered in the literature (200- 1000 capsules per plant) (Pustovoit, 1973). The high range of biomass yield (17.21 in Spssik 113 to 44.57 in Mun 096/K5/1/2/4) with coefficient of variation of 48.1% and low range o seed yield per plant (2.31 in Mun 50/1/218/2 t0 8.56 in Mun 096/ k5/1/2/4) with coefficient of variation of 63.8% resulted in low harvest index. Harvest index varied from 0.07 in Spssik 113 to 0.23 in Mun 50/1/121. The low harvest index could be due to optimum environmental conditions during vegetative growth followed by low soil moisture and high temperature during grain filling period.

Weight of 1000 seeds ranged from 1.21 in Spssik 113 to 3.10 in Mun 096/k5/1/2/4 (Weiss, 1983; Purseglove, 1987). Inconsistency in seed yield per plant was observed among thirty four genotypes. Mutant line 096/k5/1/2/4 gave the highest seed yield per hectare (1188.7 kg ha^{-1}). It also had the highest oil content (49.60%) among the mutant lines. The superiority of mutant line 096/k5/1/2/4 may be attributed to its adaptation and high values of biomass yield, seed yield per plant, 1000–seed weight and plant height. This mutant is medium flowering, moderate ranching and has high oil content among mutants, thus could be adopted as a strain in these areas.

According to the correlation coefficients (Table 3) harvest index, biomass yield and 1000-seed weight were positively and significantly correlated with seed yield. These traits may be important yield predictors for sesame improvement. Among these traits, harvest index had the strongest association with seed yield, suggesting that it is probably the most important for yield improvement in sesame. Vanisri *et al.* (1994) obtained similar results in sesame. Ayiecho (1985) also reported that harvest index is an important yield predictor, and selection for harvest index led to a substantial response in grain amaranths. The strong direct contributions of harvest index to seed yield (Table 4) also suggest its importance for sesame yield improvement. Donald (1962) and Donald (1976) supported the use of harvest index as yield predictor in cereals. Both argued that if breeding for higher yield leads to a high harvest index, the corollary is true that breeding for higher harvest index is a useful approach to higher grain yield.

TABLE 3. Correlation coefficients among various traits in thirty four sesame genotypes grown over two sites i.e. (Siaya and Maseno) during two seasons of 2000- 2001

	Number of branches with capsules	Plant height (cm)	Days to flowering	Height to first capsules (cm)	100-seed weight (cm)	Number of capsules per plant	Biomas yield per plant	Harvest index	Oil content
Plant height (cm)	.130								
Days to lowering	.206	-.138							
Height to first capsules (cm)	.573**	-.018	.430*						
1000- Seed weight (cm)	.161	.025	-.136	.091					
Number of capsules per plant	.516**	.397*	-.015	.105	.275				
Biomass yield per plant (g)	.221	.041	.321	.159	.360*	.228			
Harvest index	-.039	.344	.344	-.302	.395*	.188	.013		
Oil content	.096	.074	.162	.209	.203	.029	-.101	.415*	
Seed yield per plant (g)	.105	.268	-.082	-.048	.576**	.244	.608**	.752**	.337

, and ** correlation is significant at 0,05 and 0.01 respectively

The correlation between biomass yield and seed yield was positive and significant, suggesting that high dry matter contributes to high yield in sesame. Biomass yield per plant had a high positive direct effect on yield (Table 4). Its indirect effects through number of branches with capsules, days to flowering, capsules per plant and oil content were negative and low. Its positive indirect effects were registered via plant height, first capsule height and harvest index. The net large positive effect (0.6079) on seed yield suggests that increased biomass yield will lead to a corresponding increase in seed were reported by Sharma (1984) and Ayiecho (1985). Increase in the vegetative parts of the plant results in higher seed yield because of an increased sink: source ratio. Biomass yield per plant had a positive and significant correlation with a 1000 seed weight also suggesting that the larger plants gave heavier seeds.

Other traits had weak correlations with biomass yield. For example biomass yield and harvest index had an extremely weak correlation. Harvest index had weak correlations with all trait except 1000- seed weight, oil content and seed yield.

The correlation between 1000-seed weight and seed yield per plant was positive and significant (Table 4). The direct effects of 1000-seed weight on seed yield were low and positive. This contradicted the findings of Yadava *et al.* (1980). However, its positive indirect effects on seed yield *via* harvest index and biomass yield counter-balance the negative direct and indirect effects, making the overall correlation between 1000-seed weight and seed yield positive.

The results, therefore, indicate that a 1000-seed weight an important yield component in sesame improvement. This confirm with the findings of Sharma *et al.* (1984) and Dharmalingam and Ramanathan (1993).1000-seed weight also had weak correlations with the rest of traits. The correlation between plant height with seed yield per plant was positive but not significant (Table 3). Generally, it had low path effects on seed yield. The only substantial path effects that it had were through harvest index (Table 4). Plant height had significant positive association with height to first capsule and the number of capsules per plant. Its correlations with other characters were weak. Most of the traits were weakly interrelated and weakly related to seed yield with the accompanying low path effects. The only characters that may be considered for improvement of seed yield of the genotypes are 1000 seed weight, biomass yield and harvest index. Since sesame is primarily grown for oil, yield of oil is also considered as important. Therefore selection for both seed yield and oil content simultaneously would be plausible if the two are positively correlated.

TABLE 4. Correlation coefficients among various traits in thirty four sesame genotypes grown over two sites i.e. (Siaya and Maseno) during two seasons of 2000- 2001

	Branches with capsules	Plant height (cm)	Days to flowering	Height to first capsules (cm)	100-seed weight (cm)	Capsules per plant	Biomass yield per plant (g)	Harvest index	Oil content (%)	Seed yield per plant (g)
Number of branches with capsules	-0.0489	0.0009	-0.0231	0.0628	0.0083	-0.0181	0.1389	-0.0264	0.0105	0.1049
Plant height (cm)	-0.0064	0.0069	0.0154	-0.0019	0.0013	-0.014	0.0259	0.233	0.0081	0.2684
Days to flowering	0.0101	-0.001	-0.1119	0.0471	-0.007	0.0005	0.2016	-0.2195	0.0177	-0.0825
Height to first capsules (cm)	-0.028	0.0001	-0.0481	0.1097	0.0047	-0.0037	0.0998	-0.2048	0.0227	-0.0479
1000- Seed weight (cm)	-0.0079	0.0002	0.0153	0.01	0.0517	-0.0097	0.2263	0.2682	0.0221	0.5762
Number of capsules per plant	-0.0252	0.0028	0.0017	0.0115	0.0142	-0.0352	0.1435	0.1278	0.0032	0.2443
Biomass yield per plant (g)	-0.0108	0.0003	-0.0359	0.0174	0.0186	-0.008	0.6287	0.0086	-0.0109	0.6079
Harvest index	0.0019	0.0024	0.0362	-0.0331	0.0204	-0.0066	0.0079	0.6782	0.0452	0.7524
Oil content	-0.0047	0.0005	-0.0181	0.0229	0.0105	-0.001	-0.0632	0.2812	0.1089	0.3369
Residual = 0.221										

The underlined values denote direct effects while the rest are indirect effects values

Oil content showed a moderate insignificant positive correlation with seed yield, suggesting that selection for oil content will have no adverse effects on seed yield. Its importance is strengthened by its significant positive association with harvest index, one of the strong seed yield predictors in the study. This suggests that selection for harvest index to improve seed yield leads to some improvement on oil content. Path coefficient also revealed strong indirect contribution of oil content on seed yield *via* harvest index. Mutant lines like Mun 096/k5/1/2/4, Mun 006/330/2, Mun 50/1/121 and Mun 113/258/2/1 having averagely high oil contents, also had high average seed yield. Therefore, the study suggests the possibility to improve seed yield and oil content concurrently. It is also suggested that these three mutant lines be subjected to further tests if possible in more than two sites to verify their potentials and stability for cultivation in western Kenya.

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REFERENCE

Anon., 1995. Ministry of Agriculture, Livestock Development and Marketing. ANNUAL Report- Oil crops (Nairobi: Government press).

A.O.A.C. 1984. Official methods of analysis 14th edition. Association of official analytical chemists, Washington D.C.

Ayiecho, P.O. 1985. Quantitative studies in two grain amaranth populations using two selection methods. Ph.D. Disserttion. University of California, Davis.

Ayiecho, P.O and J.O Nyabundi. 1997.Sesame (K) project ii. Final Technical Report. University of Nairobi. Report to IDRC Ottawa, Canada.

Dixit, R.K. 1975. Path analysis for some quantitative traits in sesame (*Sesamum oriental* L.). *Plant Science* 7:9-12

Dharmahngam, V and Ramanathan, T. 1993. Combining ability for yild and its componentsin sesame. (Oleagineux France). *Abstr. Of Trop. Agric.* 48: 421-424.

Donald, C.M. 1962. In search of yield. *J. Aust. Inst. Agric.* Sci. 28: 171-178.

Donald, C.M. and Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria,. *Agronomy* 28: 361-405.

Gupta, V.K. and Gupta, Y.K. 1977. Variability interrelationship and path coefficient analysis for some quantitative characters in sesame (*Sesamum indicum* L.) India j. *Hereditary* 9: 31-37.

Infonet-Biovision. 2009. Sesame: General information and agronomic aspects. http://www.infonet-biovision.org/default/ct/194/crops.

Miller, P.A., Williams, V.C., Robinson, H.P. and Comstock, R.C. 1958. Estimates of genotypic and environmental variances and covariances in upland cotton and their implication in selection. *Agronomy Journal* 50 :126-131.

Purseglove, J.W. 1987. *Tropical Crops*. pp. 430-435.

Pustovoit, V.S. 1973. Handbook for selecting seed. Growing of oil plants. Jerusalem: Isreal programme of scientific Translation.

Rahman, A. and Das, M.L.1996. Evaluation of improved varieties of sesame through induced mutation. 2nd FAO/ IAEA. Research co-ordination meeting on induced mutations for sesame improvement, 9-13th sept. 1996. Antaly. Turkey. IAEA. Vienna. pp. 2- 7.

Singh, R.K. and Chaudhary, B.D. 1985. Biometrics in quantitative genetics analysis. Kalayani publ. New Delhi. pp. 61 – 75.

Steel R.G.D. and Torrie, S.H. 1980. Principles and procedures of statistics. Mc Graw- Hill.

Tehran, K.B., Rao. A.V., Mehta, S.K., Chand, H., Sharma, H.N. and Baija, S.K 1975. Genetics divergence in sesame. *Indian Journal of Agricultural Science* 44: 208 – 213.

Van Zanten, L. 2001. Seame improvement by induced mutations. Results of the coordinated research projects and recommendation for future studies. Final reports of an FAO/ IAEA Coordinated research project organized by joint FAO/ IAEA Division of Nuclear Techniques in Food and Agriculture. pp. 1- 12.

Vanisiri, S., Raghunatham, G.., Ranganatha, A.R.G. and Sarma, P.S. 1994. Studies on character association and path analysis in sesame (*Sesamum indicum* .L.) *Journal of Research APAU* 22:92-96.

W' opindi, H.A.E. 1981. Sesame growing in Kenya. In sesame status and improvement.

Weis, E.A. 1983. Oil seed crops. Long man London and NY. pp. 282 – 340.

Yadava, T.P., Kumar, P. and Yadava, A.K. 1980. Association of yield and its components in sesame. *Indian Journal of Agricultural Science* 54 :1 – 5.