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Full Length Research Paper

Contributions of some growth characters to seed yield of sesame (*Sesamum indicum* L.)

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Field trials were conducted during the rainy seasons of 2005, 2006 and 2007 to study the contributions of some growth characters to the seed yield of sesame. The experiments consisted of four levels of poultry manure (0, 5.0, 10.0 and 15.0 t ha^{-1}), three levels of nitrogen in the form of urea (0, 60 and 120 kg N ha^{-1}) and three levels of phosphorus in the form of single super phosphate (0, 13.2 and 26.4 kg P ha^{-1}). The thirty-six treatment combinations were laid out in a split-plot design with three replications. The factorial combination of N and P were assigned to the main plot, while poultry manure was assigned to the sub-plot. All growth characters measured (plant height, leaf area index, number of branches per plant, and total dry matter per plant), correlated positively and significantly (p = 0.05) with the yield throughout the years of experimentation and the mean of the three years. The highest direct contribution among the growth parameters to seed yield when the three years data was combined was from total dry matter per plant (0.782a) followed by leaf area index (0.782a). Similarly, when the three years data was combined, Path coefficient analysis revealed that the combined contribution of two growth characters to seed yield was made by plant height and total dry matter (0.407). The highest percent contribution to seed yield was made by and via total dry matter per plant (61.171 and 11.659%) when the data was combined. Total dry matter should therefore be considered as the most important traits among growth characters of this crop in the determination of seed yield per unit area and selection of parents.

Key words: Total dry matter, leaf area index, number of branches, correlation, path analysis, percent contribution.

INTRODUCTION

Sesame (*Sesamum indicum* L.) also known as beniseed in West Africa and Sim-sim in East Africa is an oil crop belonging to the family Pedaliaceae grown in both tropical and sub-tropical regions of Africa, Asia and Latin America. It is the most important crop from which semi-drying vegetable oils are obtained and perhaps the oldest crop cultivated for its oil (Onwueme and Sinha, 1991). Asia and Africa are the major producers of sesame in the World, with Asia producing more than half of the global production. In 2007, Asia produced 2.4 million short tons of whole sesame seed, while Africa produced 1.2 million short tons of sesame (UN/FAO, 2008).

The importance of sesame lies in its high quality oil which is often referred to as the “queen” of vegetable oil. The outstanding characteristic of sesame oil is its stability and keeping quality as well as resistance to rancidity. Sesame oil is use in making paints, soaps, cosmetics, perfumes, insecticides canned sardine, canned beef, as well as for pharmaceutical and ethno botanical uses (FAO, 2002; RMRDC, 2004; Biabani and Pakniat, 2008). The leaves are used as vegetables and are rich sources of vitamins (Auwalu and Babatunde, 2007). As in cultivated crops, the main objective of growing sesame is for high yield and high quality. The performance of the crop is affected by factors such as climatic, nutrients, water availability, inter and intra-specific competitions, pest and diseases, as well as socio-cultural and socio-economic factors among other things. The relationship that exists between different parts of the crop has a

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Table 1. Physico-chemical properties of soils of the experimental site during the 2005, 2006 and 2007 wet seasons at Samaru.

Soil characteristics	Soil depth (cm)					
	2005		2006		2007	
	0 - 15	15 - 30	0 - 15	15 - 30	0 - 15	15 - 30
Particle size (%)						
Sand	18	34	58	48	38	28
Silt	56	40	32	26	40	30
Clay	26	26	10	26	22	42
Textural class	Silt Loam	Sandy loam	Sandy loam	Clay loam	Loam	Clay loam
Chemical composition						
pH in water	6.02	4.83	6.20	4.90	6.29	5.00
pH in 0.01ml $CaCl_2$	4.32	3.55	4.50	3.90	4.85	4.00
Organic carbon (%) g kg^{-1}	0.84	0.40	0.84	0.26	0.76	0.66
Total Nitrogen (%) g kg^{-1}	0.10	0.11	0.035	0.035	0.10	0.10
Available phosphorus (ppm)	2.67	1.78	10.50	5.25	12.60	14.07
Exchangeable bases (C mol (+) kg^{-1})						
Ca	7.70	11.70	4.17	8.33	3.74	2.21
Mg	0.55	1.17	1.42	2.64	0.77	0.55
K	0.15	0.17	0.14	0.18	0.20	0.30
Na	0.36	0.34	0.30	0.35	0.19	0.25
CEC	8.25	15.8	7.60	14.80	5.69	12.21

significant influence on the seed yield (Adeyemo and Ojo, 1991).

Correlation analysis is a useful technique, which provides information about the degree of relationship between important plant traits and is also a good index to predict the yield response in relation to the change of a particular character (Muhammad et al., 2007). In sesame, seed yield as in other crops, is a complex character that is dependent on a number of variables. To increase its yield, the study of direct and indirect effects of yield and its growth components provide the basis for its successful breeding program and thus increase of seed yield can be more effectively tackled on the basis of performance of growth characters and selection for closely associated traits. Path co-efficient analysis measures the direct and indirect effect of one variable upon another and permits the separation of the correlation co-efficient into components of direct and indirect effect (Dewey and Lu, 1959). For efficient breeding and crop improvement, it is of utmost importance in any crop plant to ascertain the contribution of each growth related trait to yield and to select components that help maximize yield (Sandipan et al., 2010). The present research work is one of such efforts to study the relationship between some growth characters and the seed yield per unit area of sesame.

MATERIALS AND METHODS

Field experiments were conducted during the rainy seasons of 2005 to 2007 at the Institute for Agricultural Research (IAR) Farm, Ahmadu Bello University, Samaru, (11° 11′ N; 07° 38′E, 686 m above sea level), located in the northern Guinea savanna agro-ecological zone of Nigeria. The experiment consisted of factorial combinations of three levels of nitrogen (0, 60 and 120 kg N ha^{-1}) in the form of urea, three levels of phosphorus (0, 13.2 and 26.4 kg P ha^{-1}) in the form single super phosphate and four levels of poultry manure (0, 5.0, 10.0 and 15.0 t ha^{-1}). The thirty six (36) treatment combinations were laid out in a split-plot design with nitrogen and phosphorus levels assigned to the main-plot, while poultry manure was assigned to the sub-plot. The gross plot size was 13.5 m^2 (4.5 m × 3 m), while the net plot size was 9 m^2 (3 m × 3 m). Soil samples were taken randomly at a depth of 15 to 30 cm prior to land preparation in each season and analyzed for physico-chemical properties. The result of the soil analysis is presented in Table 1. In each year, different experimental site was used to avoid build up of nutrients. A total annual rainfall of 790, 1,110 and 962.4 mm were recorded during the rainy seasons of 2005, 2006 and 2007, respectively. The amount of rainfall recorded was uniformly distributed throughout the growing seasons.

The experimental area was disc-ploughed and harrowed twice to a fine tilt. This was then followed by ridging at 75 cm apart (between rows) and the field marked into plots and replications. The plots were separated by 1.0 m unplanted boarder, while replications were separated by 2.0 m unplanted boarder. The three levels of phosphorus and the four levels of poultry manure were incorporated into the ridges according to field plan after land preparation and left for two weeks before sowing. Half of the nitrogen levels were applied at 3 weeks after sowing (WAS), while the remaining half was applied at 6 WAS. The planting material used was Ex-Sudan; it is white in colour, of medium height (100 cm) and medium maturity (85 to 90 days) (RMRDC, 2004). Sesame was planted on the 16^{th}, 19^{th} and 20^{th} day July in 2005, 2006 and 2007, respectively. Six to ten seeds of sesame were sown at 15 cm intra-row spacing on ridges spaced 75 cm apart and was later thinned to two plants per stand at 3 WAS. Manual hoe weeding was done at 3, 6 and 9 WAS to keep the experimental plots weed-free. There was no incidence

Table 2. Correlation matrix between some growth characters of sesame and seed yield in 2005.

Growth character	Plant height (cm)	Leaf area index	No. of branches Plant^{-1}	Total dry matter Plant^{-1} (g)	Seed yield ha^{-1} (kg)
Plant height	1.00				
Leaf area index	0.38**	1.00			
No. of branches plant^{-1}	0.24*	0.75**	1.00		
Total dry matter plant^{-1}	0.42**	0.48**	0.32**	1.00	
Seed yield ha^{-1}	-0.04	-0.19*	-0.09	0.44**	1.00

*Significant at 5% level of probability; **significant at 1% level of probability.

of pests and disease throughout the period of studies.

Experimental evaluations

The crop was harvested on the 23rd, 27th and 28th of October 2005, 2006 and 2007, respectively, when the leaves and the stems changed colour from green to yellow with a reddish tint on them. Harvesting was manually done with the aid of a sickle by cutting the plants at the base close to the ground. Plants from each plot were put in a sack to dry so as to minimize seed loss when capsules dehisce. When the harvested plants were adequately dry, the sacks were gently beaten with sticks in order to release all the seeds from the capsules. The seeds were separated from the chaff by winnowing manually. The entire plants in the net plot were used to obtain the seed yield per hectare while, five randomly selected tagged plant samples from each plot were used for the purpose of observing vegetative characters. The period of maximum vegetative development of the crop was at 10 weeks after planting. Only data taken at the peak of growth period (10 WAS) are presented here.
Height of each tagged plants was measured from ground level to the top of the terminal bud and the mean recorded. Numbers of branches and leaves from each of the tagged plants were counted, summed up and the mean recorded. Leaf area index was calculated as the ratio of the cumulative leaf area per plant to the ground area;

$$LAI = A/L$$

Where, A = Leaf area per plant and L = Ground area covered by the leaves.

The total dry matter per plant was determined by cutting five plants from each plot from the ground level (excluding the tagged plants and those in the net plots), oven-dried to a constant weight at 70°C and weighed using a Mettler balance. The average dry weight per plant was recorded.

Statistical analyses

The data collected were subjected to analysis of variance using the ‘F’ test to estimate the significance in the effects of the treatments as described by Snedecor and Cochran (1967). Comparisons of treatment means were done using the Duncan’s multiple range test (Duncan, 1955). The magnitude and type of association between the treatments measured were assessed through simple correlation analysis as described by Little and Hills (1978). The results of the correlation were used to develop simultaneous equations to work out the path coefficients as described by Dewey and Lu (1959) using MSTATC and SAS software. The direct and indirect effects of individual and combined (two factors) contributions of growth characters to total seed yield per hectare were determined using Path- coefficient analysis. The combined contribution was estimated as described by Ajala et al. (1996). More also, the residual factor (Rx) that is unaccounted for by the direct and combined contributions was estimated using the following formula:

$$Rx = 1 - \sqrt{(P_1 r_{15} + P_2 r_{25} + P_3 r_{35} + P_4 r_{45})}$$

RESULTS

In 2005, with the exception of total dry matter per plant, all the growth characters measured correlated negatively with the yield but positively and significantly with each other (Table 1). The strongest relationship between a growth parameter and the yield in 2005 was that recorded between total dry matter and the yield per unit area (r = 0.44**) while, the strongest relationship between two growth parameters recorded was that between leaf area index and number of branches per plant (r = 0.75**). Moreover, in 2006 all the growth characters measured correlated positively and significantly with the yield and with each other (Table 2). The strongest relationship between a growth parameter and the yield in 2006 was that recorded between total dry matter and the yield per unit area (r = 0.72**), while the strongest relationship between any two growth parameters recorded was that between leaf area index and number of branches per plant (r = 0.72**).

Similarly, in 2007 all the growth characters measured correlated positively and significantly with the yield and with each other (Table 3). The strongest relationship between a growth parameter and the yield in 2007 was that recorded between total dry matter and the yield per unit area (r = 0.82**), while the strongest relationship between any two growth parameters recorded was that between leaf area index and number of branches per plant (r = 0.81**). When the three years data were combined, similar trend was observed as in 2006 and 2007 – that is all the growth characters measured correlated positively and significantly with the yield (Table 4). The strongest relationship between a growth parameter and the yield when the three years data was combined was that recorded between total dry matter and the yield per unit area (r = 0.64**), while the strongest

Table 3. Correlation matrix between some growth characters of sesame and seed yield in 2006.

Growth character	Plant height (cm)	Leaf area index	No. of branches $Plant^{-1}$	Total dry matter $Plant^{-1}$ (g)	Seed yield ha^{-1} (kg)
Plant height	1.00				
Leaf area index	0.41**	1.00			
No. of branches $plant^{-1}$	0.42**	0.72**	1.00		
Total dry matter $plant^{-1}$	0.41**	0.26**	0.21*	1.00	
Seed yield ha^{-1}	0.18*	0.20*	0.27**	0.72**	1.00

*Significant at 5% level of probability; **significant at 1% level of probability.

Table 4. Correlation matrix between some growth characters of sesame and seed yield in 2007.

Growth character	Plant height (cm)	Leaf area index	No. of branches $Plant^{-1}$	Total dry matter $Plant^{-1}$ (g)	Seed yield ha^{-1} (kg)
Plant height	1.00				
Leaf area index	0.53**	1.00			
No. of branches $plant^{-1}$	0.43**	0.81**	1.00		
Total dry matter $plant^{-1}$	0.44**	0.26**	0.15	1.00	
Seed yield ha^{-1}	0.42**	0.37**	0.28**	0.82**	1.00

**Significant at 1% level of probability.

Table 5. Correlation matrix between some growth characters of sesame and seed yield (2005 to 2007) mean.

Growth character	Plant height (cm)	Leaf area index	No. of branches $Plant^{-1}$	Total dry matter $Plant^{-1}$ (g)	Seed yield ha^{-1} (kg)
Plant height	1.00				
Leaf area index	0.50**	1.00			
No. of branches $plant^{-1}$	0.40**	0.76**	1.00		
Total dry matter $plant^{-1}$	0.52**	0.45**	0.29**	1.00	
Seed yield ha^{-1}	0.24**	0.15*	0.18*	0.65**	1.00

*Significant at 5% level of probability; **significant at 1% level of probability.

relationship between any two growth parameters recorded was that between leaf area index and number of branches per plant (r = 0.76**). The weakest association recorded though positive and significant was that between leaf area index and the yield when the three years data were combined (r = 0.15*).

The direct and indirect contributions from plant height and number of branches per plant, and through them were negative in 2005, 2006 and the mean of the three years (Table 5). In 2007, with the exception of plant height through leaf area index and total dry matter which were negative, the direct and indirect contributions from plant height and number of branches per plant, and through them were positive. The direct and indirect contributions from total dry matter and leaf area index were positive in 2005, 2006, and the mean of the three years, but negative in 2007. Total dry matter made the greatest direct effect on the seed yield of sesame in 2005, 2006 and the mean of the three years (0.749^a, 0.777^a and 0.782^a) (Table 6). In 2007, number of branches per plant made the greatest direct contribution to seed yield of sesame (0.591a). The weakest direct effect was from plant height when the three years data were combined (-0.095^a), while the weakest indirect effect was via plant height. All the growth characters had their greatest effect on yield via total dry matter per plant in 2005, 2006, and the mean of the three years, but through number of branches in 2007.

Total dry matter contributed to the yield more than any other growth character in 2005, 2006, and the mean of the three years (56.10, 60.37 and 61.15%, respectively), while in 2007, it was leaf area index that made the highest percent contribution to yield (34.93%) (Table 7). This was followed by leaf area index (12.25%) and

Table 6. The direct and indirect contributions of some growth components to seed yield from 2005 to 2007 and the mean.

Growth character	Plant height	No. of branches plant^{-1}	Leaf area index	Total dry matter plant^{-1}
2005				
Plant height	**-0.161[a]**	-0.235	0.041	0.315
No. of branches plant^{-1}	-0.061	**-0.617[a]**	0.129	0.360
Leaf area index	-0.039	-0.463	**0.172[a]**	0.240
Total dry matter plant^{-1}	-0.068	-0.296	0.240	**0.749[a]**
Total	-0.329	-1.611	0.582	1.664
2006				
Plant height	**-0.207[a]**	-0.048	0.117	0.319
No. of branches plant^{-1}	-0.085	**-0.118[a]**	0.201	0.202
Leaf area index	-0.117	-0.085	**0.279[a]**	0.163
Total dry matter plant^{-1}	-0.319	-0.031	0.059	**0.777[a]**
Total	-0.78	-0.282	0.656	1.461
2007				
Plant height	**0.455[a]**	0.313	-0.079	-0.270
No. of branches plant^{-1}	0.241	**0.591[a]**	-0.149	-0.314
Leaf area index	-0.079	0.479	**-0.184[a]**	-0.211
Total dry matter Plant^{-1}	-0.270	0.378	-0.079	**-0.490[a]**
Total	0.347	1.761	-0.491	-1.285
Combined				
Plant height	**-0.095[a]**	-0.254	0.103	0.407
No. of branches plant^{-1}	-0.048	**-0.350a**	0.195	0.352
Leaf area index	-0.038	-0.266	**0.257[a]**	0.227
Total dry matter Plant^{-1}	-0.049	-0.158	0.075	**0.782[a]**
Total	-0.23	-1.028	0.63	1.768

[a]Direct contribution.

number of branches (6.61%) when the three years data were combined. There was an inconsistency in the data obtained for combined contribution of two parameters to seed yield throughout the sampling periods. However, when averaged over the years, the greatest and positive combined contribution of 11.66% was made by number of branches plus total dry matter, followed by plant height and leaf area index (3.31%).

DISCUSSION

The significant and positive correlation recorded between sesame seed yield per unit area and some growth characters particularly total dry matter, number of branches and leaf area index, indicated inter-dependency between these characters. It also indicated that these parameters are important yield determinants because the higher the numbers of branches, the more the number of leaves which increase the canopy cover and hence greater interception of light energy and higher rates of photosynthesis, which translates to increase yield. This finding corroborated with those of Delgado and Yermanos (1975), Selvi and Subramanian (1994), Yingzhong and Yishou (2002), Kumar and Vivekanandan (2009) and Sandipan et al. (2010) who reported positive and significant correlations between growth characters of sesame and the final yield. Dry matter production contributed more to seed yield, and this could probably mean that seed yield in sesame is greatly dependent on dry matter production. The strong relationship observed between LAI and number of branches per plant could be attributed to the fact that the higher the number of branches, the more the number of leaves and hence increased canopy cover and increased photosynthetic activity.

In addition, the individual or combined percent contributions of two parameters to seed yield showed that the highest contribution was made by or via total dry matter. This could be attributed to the fact that at flowering and fruit setting stages, most of the dry matter produced is being translocated to the sink (capsule) which bears the seed. Contributions from LAI and number of branches to sesame yield followed that of dry

Table 7. Percent contribution of some growth parameters to seed yield from 2005 to 2007 and the mean.

	Percent contribution			
Growth character	**2005**	**2006**	**2007**	**Combined**
Individual contribution				
Plant height	2.592	4.285	20.703	0.903
Leaf area index (LAI)	38.069	1.392	34.928	12.250
Number of branches plant^{-1}	2.958	7.784	3.386	6.605
Total dry matter (TDM)	56.100	60.373	24.010	61.152
Combined contribution				
Plant height vs. LAI	4.768	2.052	23.126	2.660
Plant height vs. no. of branches	-2.110	-4.736	-8.874	-2.442
Plant height vs. TDM	-10.130	-13.189	-19.620	-7.726
LAI vs. no. of branches	-15.919	-4.741	-17.617	-13.672
LAI vs. TDM	-29.577	-3.851	-8.688	-15.875
Number of branches plant^{-1} vs. TDM	12.368	11.273	4.688	18.088
Residual	40.881	39.358	43.957	38.057
Total	100	100	100	100

matter. This was expected because only a small quantity of the assimilate produced is being translocated to the leaf and the stem. This finding was also in harmony with those of Gnanasekaran et al. (2008).

Conclusion

From the results obtained, it can be concluded that although all the growth characters measured contributed significantly to the seed yield of sesame, however, that from total dry matter was the highest and should therefore be used in sesame breeding programs for increased yield.

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