Journal of Tropical Agriculture 43 (1-2):13-18, 2005

Influence of population density and season on seed yield and its components in Nigerian sesame genotypes

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Received 2 May 2005; received in revised form 14 July 2005; accepted 5 August 2005

Abstract

A field experiment was conducted to assess the impact of three population densities and two seasons on seed yield of 14 genetically diverse Nigerian sesame genotypes. Cultivars 530-6-1, Type A and Pbtil No 1 generally outperformed others. Population density of 166,667 plants ha^{-1} gave 40% more yield than that at 266,667 plants ha^{-1} and was the best for maximizing yield under rain-fed conditions. Regarding seasonal influences, yield was about 11% higher in the 2002 season than in 2001. Heritability results revealed that seed weight is highly heritable in sesame with a possibility for high selection gains, while the other yield components were greatly influenced by population densities and seasons signifying moderate-to-high gains. Significant positive relationship was found between seed yield and capsule weight, capsule number and seed production efficiency implying that yield is a function of these parameters and selection based on these could further improve the yield potential.

Keywords: Heritability, genetic advance, seed production efficiency

Introduction

Sesame (*Sesamum indicum* L.) is an important oil seed crop world-wide and it yields a high quality, edible and odourless oil that serve as a good source of protein and fat for humans and livestock. The crop is grown under a range of environments, which probably affects its performance. The environmental factors that influence sesame productivity include climatic factors such as temperature, rainfall and day length, soil types and management practices such as plant densities, time of sowing, irrigation, fertilizers, herbicides and fungicides, some of which may partially mitigate others (Geleta et al., 2002; Adebisi, 2004). In particular, population density plays a cardinal role in determining seed yield. Adeyemo et al. (1992) reported that optimal population of sesame is between 133,333 and 266,667 plants ha^{-1}. However, Olowe and Busari (1994) recommended 166,667 and 333,333 plants ha^{-1} for the semi-arid regions of Northern Nigeria. The influence of population density on the performance of high-yielding sesame genotypes in south-western Nigeria is, however, unknown. Moreover, seasonal variations abound in the productivity of many sesame genotypes especially under rain-fed situations. There is again little or no location-specific information available on such variations from south-western Nigeria. The objectives of this study, therefore, were to investigate the influence of three population densities and two seasons on seed yield, and yield components of 14 sesame genotypes and to evaluate the interrelationships among these parameters.

Materials and methods

The field trial was conducted at the Teaching and Research Farm and Seed Laboratory of the University of Agriculture, Abeokuta (7^o15^1 N; 3^o25'E), Ogun State, Nigeria, under rain-fed conditions during 2001 and 2002. The site was well-drained with sandy loam soil having a pH range from 6.8 to 7.8, N between 0.07 and

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0.14% and organic matter from 0.82% to 1.66%. The average annual rainfall for the two seasons was ~500 mm in 2001 and ~800 mm in 2002. Mean temperature ranged from 24.1°C in the 2001 experimental period to 27.9°C in 2002, while the relative humidity varied from 74.9% to 77.45%.

Fourteen sesame genotypes sourced from the National Cereal Research Institute, Badeggi, Niger State, Nigeria grown at three spacing/population densities, *viz.*, 50 x 15 cm (133,333 plants ha^{-1}), 60 x 10 cm (166,667 plants ha^{-1}) and 75x 5 cm (266,667 plants ha^{-1}) and over two seasons, constituted the experimental variables. The experiment was planned in a split-split plot design with three replications. Seasons, population densities and genotypes formed the main plot, sub-plot and sub-sub plot respectively. Each genotype was sown in four-row plots of 3 m length (plot size: 4.5 m^2, 5.4 m^2 and 6.75m^2 for low, medium and high population densities). Sowing was done by hand-drilling after mixing with sand. The seedlings were thinned to about 15, 10 and 5 cm plant-to-plant spacing at three weeks after planting. Following thinning, a top dressing of NPK was given by drilling at the rate of 60 kg N, 30 kg P_2O_5 and 50 kg K_2O ha^{-1}. Weeding was carried out twice: manually before and after fertilizer application.

Data on seed yield per plant, capsule weight per plant, seed number per capsule and 1000-seed weight were collected from 20 randomly selected plants in the two inner rows. Seed production efficiency (SPE) was estimated as the ratio of seed weight to weight of capsule per plant.

Data analysis

The data were subjected to combined analysis of variance using GENSTAT 10.0 statistical package for split-split plot design and genotype x environment effects tested according to Moot and McNeil (1995). Treatment means were compared using Duncan Multiple Range Test at 5% probability level. Broad-sense heritability (H^2_B) and genetic advance (GA) were calculated for each population density and season as follows (Allard, 1960).

$$H^2_B = [\delta^2 gx/(\delta^2 gx+\delta^2 ex)] \times 100$$

Where $\delta^2 gx$ is the genotypic variance of character '*x*' while $\delta^2 ex$ is the environmental variance for character '*x*'.

$$GA = (K)\ \delta A\ (H)$$

Where *K* is a selection differential (2.06) at 5%, while δA is the phenotypic standard deviation and *H* is broad-sense heritability. Correlation among the characters was computed across plant populations for each cropping season.

Results and discussion

Results of the combined analysis of variance for seed yield and yield components are presented in Table 1. Season exerted a profound effect on all parameters except the seed number/capsule. The effect of plant population density and genotypes were also significant. A significant genotype *x* season interaction implied that genotypes differ substantially in capsule weight/plant and seed yield/plant due to seasonal variations, and a significant genotype *x* population interaction denoted that genotypes responded differently to changes in plant population densities too. Similar findings were reported by Olowe and Busari (1994) for sesame from southern Guinea. Population x season interaction effects were also significant indicating changes in seed yield/plant as a function of season of cultivation and population density.

Genotypic performance

An examination of the data on seed yield and its components across three plant population densities (Table 2) reveals that genotype 'Yandev 55' gave the best performance in terms of capsule number/plant (84), while Type A had the highest seed number/capsule (91), Pbtil No 1 showed the highest 1000-seed weight (5.21 g) and 69B-88Z, E8, C-K-2 and 530-3 showed high seed production efficiencies (54 and 56 %). Based on overall performance, the genotypes 530-6-1, Type A and Pbtil No 1 were the three top yielders across the range of population densities and seasons evaluated (Table 3).

Table 1. Analysis of variance showing the mean squares of seed yield and yield components of 14 sesame genotypes evaluated under three population densities in two seasons at Abeokuta, Ogun State, Nigeria

Source of variation	Df	Mean squares					
		Capsule weight/plant (g)	Capsule number/plant	Seed number/ capsule	SPE (%)	1000-seed weight(g)	Seed yield per plant (g)
Replication	2	49.53	1496.10	1179	453.60	4.08	22.24
Season (S)	1	26169.14**	228362.70**	2063^{ns}	11040.60**	69.17*	11897.19**
Error (a)	2	877.05	769.20	480	369	6.39	496.10
Population(P)	2	2445.08**	3819.67**	3140*	411.6*	6.32*	954.68**
P x S	2	215.61^{ns}	689.81^{ns}	1888^{ns}	65.3^{ns}	4.91^{ns}	218.68**
Error (b)	8	715.12	290.40	349	13.06	4.28	28.18
Genotype (G)	13	33.22^{ns}	687.20*	1445**	125.6*	6.75*	49.17*
G x S	13	195.01**	605.11^{ns}	1137^{ns}	85.6^{ns}	4.67^{ns}	31.10*
G x P	26	105.1*	587.60^{ns}	1042^{ns}	74.1^{ns}	4.11^{ns}	16.62*
G x P x S	26	48.34^{ns}	588.10^{ns}	932^{ns}	65.8	4.24^{ns}	14.93^{ns}
Error (c)	156	45.80	371.78	1002	152.17	3.81	12.26
Total	251						
CV (%)		14.0	9.3	20.0	9.2	24.4	10.3

** Significant at 1% probability level; * significant at 5% probability level; SPE= seed production efficiency

Table 2. Yield components of 14 sesame genotypes grown under three population densities during two seasons at Abeokuta, Ogun State, Nigeria.

Genotypes	Capsule wt/plant	Capsule no/plant	Seed no/capsule	Seed production efficiency	1000-seed weight (g)
'Yandev 55'	27.50	84^{a}	55^{b}	45^{b}	2.62^{b}
93A-97	23.61	65^{bc}	63^{b}	52^{ab}	3.33^{b}
'Goza'	25.72	67^{bc}	63^{b}	51^{ab}	3.31^{b}
Type A	26.89	65^{bc}	91^{a}	51^{ab}	3.56^{b}
73A-11	24.33	76^{bc}	53^{b}	52^{ab}	3.18^{b}
530-6-1	26.44	70^{bc}	61^{b}	52^{ab}	3.31^{b}
73A-94	23.39	71^{bc}	62^{b}	52^{ab}	3.43^{b}
69B-88Z	25.00	67^{bc}	64^{b}	54^{a}	3.42^{b}
E8	24.83	71^{bc}	55^{b}	56^{a}	3.64^{b}
'Domu'	26.61	71^{bc}	57^{b}	49^{ab}	3.41^{b}
73A-97	24.72	80^{ab}	65^{b}	52^{ab}	3.11^{b}
C-K-2	23.82	68^{bc}	69^{b}	54^{a}	3.31^{b}
530-3	25.83	80^{ab}	63^{b}	55^{a}	3.29^{b}
Pbtil No 1	27.06	78^{ab}	65^{b}	51^{ab}	5.21^{a}
Mean	25.41	72	63	52	3.44

Values within a column having the same superscript do not differ significantly ($p<0.05$)

Population density and season

On the whole, the sesame cultivars performed better at the medium population density of 166, 667 plants ha^{-1} (Table 3). Seed yield/plant at 166,667 plants ha^{-1} was about 36.3% higher than that obtained at 133,333 plants ha^{-1}. Further increase in the density from 166,667 to 266,667 plants ha^{-1}, however, resulted in a reduction in yield (ca 40%). Higher seed yield/plant observed under 133,333 and 166,667 plants ha^{-1} relative to 266,667 plants

Table 3. Seed yield per plant of 14 sesame genotypes grown under three population densities during two seasons at Abeokuta, Ogun State, Nigeria.

Genotypes	Seed yield (g plant^{-1})					
	Mean	Population density (plants ha^{-1})			Season	
		133,333	166,667	266,667	2001	2002
'Yandev 55'	11.73^{c}	13.33^{e}	12.72^{c}	9.25^{a}	15.28^{b}	16.32^{c}
93A-97	12.01^{b}	10.47^{f}	16.12^{b}	9.43^{a}	16.20^{b}	16.83^{c}
'Goza'	13.36^{ab}	13.00^{e}	19.18^{a}	7.90^{a}	16.01^{b}	20.79^{ab}
Type A	14.93^{a}	17.83^{a}	16.42^{b}	10.53^{a}	20.30^{a}	23.68^{a}
73A-11	13.02^{ab}	15.88^{b}	13.45^{c}	9.73^{a}	17.16^{b}	19.39^{bc}
530-6-1	14.96^{a}	16.70^{a}	17.82^{ab}	10.37^{a}	19.90^{a}	22.92^{a}
73A-94	12.66^{ab}	15.47^{bc}	13.18^{c}	9.33^{a}	17.72^{b}	18.33^{c}
69B-88Z	14.19^{ab}	15.63^{bc}	15.78^{b}	11.15^{a}	19.57^{a}	22.81^{a}
E8	14.34^{ab}	16.02^{b}	17.02^{ab}	10.00^{a}	18.48^{ab}	22.09^{a}
'Domu'	13.42^{ab}	13.18^{e}	15.87^{b}	11.22^{a}	18.18^{ab}	20.10^{ab}
73A-97	12.78^{ab}	13.15^{e}	15.77^{b}	9.42^{a}	17.85^{b}	18.41^{bc}
C-K-2	13.20^{ab}	16.28^{a}	15.20^{b}	8.12^{a}	16.49^{b}	20.51^{ab}
530-3	13.84^{ab}	14.70^{d}	17.57^{a}	9.27^{a}	18.64^{ab}	21.04^{ab}
Pbtil No 1	14.70^{a}	14.95^{d}	19.13^{a}	10.02^{a}	20.69^{a}	22.21^{ab}
Mean	13.51	14.76	16.09	9.70	18.11	20.39

Values within a row (for a given parameter) having the same superscript are not significantly different at $p<0.05$

ha^{-1} is presumably because of a possible lower interplant competition. Implicit in this is that population density might bring about micro-environmental variations, which may affect the agronomic traits of sesame. Genotypic differences also may play an important role in this respect. For instance, 'Goza' and Pbtil No1 were the top yielding cultivars at 166,667 plants ha^{-1} with 19.18 and 19.13 g yield per plant respectively, while 'Yandev 55' was the lowest yielder (12.12 g per plant). Achieving higher agronomic performance, therefore, requires management practices such as seeding rate to be carefully adjusted considering varietal characteristics (Geleta et al., 2002).

Our results also revealed that increasing the population to 266,667 plants ha^{-1} resulted in a substantial reduction in capsule weight/plant, capsule number/plant, seed number/capsule, seed production efficiency and yield/plant (Table 4). This observation suggests that in sesame population effects on yield/plant are mainly controlled by changes in capsule weight/plant, capsule number/plant, seed number/capsule and seed production efficiency. The results are in conformity with that of Carpenter and Board (1997) for soybean.

The 2002 sowing season was comparatively better than the previous one with 11% higher mean seed yield/plant. Genotypes Pbtil No1, 69B-88Z, 530-6-1 and Type A were among high yielding genotypes producing more than 22 g seeds/plant. In the 2001 season, Type A, 530-6-1 and Pbtil No 1 were among the genotypes with higher seed yield/plant. Capsule weight/plant in 2002 season was about 9.6% higher than that obtained in the 2001 (Table 4).

Heritability and genetic advance

A comparison of the data presented in Table 5 indicate that seed yield/plant, SPE, capsule weight/plant and capsule number/plant had low heritability along with high genetic advance under most of the population densities and seasons. This, in turn, suggests that population densities and seasons greatly influence these traits and, therefore, considerable gains from selection are probable. Although seed yield and SPE recorded low heritability estimates in most population densities and seasons, seed yield/plant recorded high heritability (51%) at P4 (Table 5) and high genetic advance for P3 to P6. Furthermore,

Table 4. Mean yield and yield components of sesame grown under three population densities during two seasons at Abeokuta, Ogun State, Nigeria

Components	Population density (plants ha^{-1})			Season	
	133,333	166,667	266,667	2001	2002
Capsule weight (g plant^{-1})	27.27^a	29.63^a	19.33^b	15.22^b	35.6^a
Capsule number/plant	69^b	81^a	57^c	82^b	102^a
Seed number/capsule	69^a	63^a	57^b	60^a	66^a
Seed production efficiency (%)	52^a	54^a	50^b	45^b	59^a
1000-seed weight (g)	3.45^a	3.32^b	3.27^b	3.11^b	3.58^a
Seed yield (g plant^{-1})	14.75^b	16.09^a	9.70^c	14.64^b	20.38^a

Values within a row (for a given parameter) having the same superscripts do not differ significantly ($p<0.05$)

seed number/capsule had moderate to high heritability estimates and low to high genetic advance. Likewise, 1000-seed weight recorded high heritability estimates (77 and 94%) under most population densities and seasons suggesting that genotypic effects accounted for a major portion of the total phenotypic variation for this character.

Correlation among seed yield characters

Knowledge of the interrelationships between seed yield and other characters is important to be able to effect selection (Ariyo, 1995). Consistent with this, efforts were made to evaluate the nature of interrelationships between different yield components. Results presented in Table 6, clearly reveal strong positive correlations between seed yield/plant and capsule weight/plant (r =0.82 and 0.86), capsule number/plant (r =0.81 and 0.45) and SPE (r =0.35 and 0.36 for 2001 and 2002 seasons respectively). This further suggests that seed yield could be improved by selecting for capsule number, weight/plant and SPE. These findings are in agreement with those of the earlier workers who found a positive association between single plant yield and number of capsules for sesame (Backiyarami et al., 1998). In addition, significant association between capsule weight and capsule number/plant (r =0.72 and 0.46 in 2001 and 2002 seasons respectively), seed number/capsule with seed weight (r =0.37 in 2001) and SPE and capsule number/plant (r=0.37 in 2001 season) were also noted suggesting that capsule number/plant and seed number/capsule contributed substantially to seed weight and SPE.

In summary, top yielding genotypes (530-6-1, Type A and Pbtil No1) could be used as seed producing parents

Table 5. Heritability (H^2_B) and genetic advance (GA) for seed yield components of sesame grown under three population densities during two seasons at Abeokuta, Ogun State, Nigeria

Components	Heritability/genetic advance (GA) for different population densities/season of production					
	P1	P2	P3	P4	P5	P6
Seed yield/plant	10(0.05)	05(0.09)	07(0.53)	51(0.30)	15(0.50)	17(0.47)
Capsule weight/plant	09(0.23)	02(0.13)	20(1.24)	40(0.26)	30(6.60)	02(0.14)
Capsule number/plant	04(0.72)	14(0.83)	18(1.25)	16(0.75)	13(1.53)	29(1.13)
Seed number/capsule	10(1.49)	19(3.09)	02(1.56)	53(0.66)	57(1.47)	67(0.86)
1000-seed weight	38(0.10)	41(0.01)	81(0.03)	94(0.06)	77(0.03)	89(0.03)
SPE	34(3.62)	26(3.44)	39(2.55)	06(0.50)	19(1.28)	05(0.42)

Values in parentheses are GA as percentage of the mean; P1 = 133,333 plants ha^{-1} in 2001, P2 = 133,333 plants ha^{-1} in 2002, P3 = 166,667 plants ha^{-1} in 2001, P4 = 166,667 plants ha^{-1} in 2002, P5 = 266,667 plants ha^{-1} in 2001 and P6 = 266,667 plants ha^{-1} in 2002; SPE = Seed production efficiency

Table 6. Pearson correlation coefficients of seed yield and yield components in sesame grown under three population densities during two seasons at Abeokuta in Ogun State, Nigeria (n = 42)

Yield components		Capsule no/plant	Seed no/capsule	SPE	1000-seed weight	Seed yield/plant
Capsule weight/plant	S1	0.72*	0.02	0.04	0.06	0.82**
	S2	0.46**	-0.02	-0.09	0.21	0.86**
Capsule no/plant	S1		0.16	0.37**	0.18	0.81**
	S2		0.02	-0.01	0.16	0.45**
Seed no/capsule	S1			0.28	0.37**	0.13
	S2			0.27	0.01	-0.09
SPE	S1				0.26	0.35*
	S2				0.06	0.36**
1000-seed weight	S1					0.20
	S2					0.25

SPE = seed production efficiency, S1= 2001 season, S2=2002 season; *, ** significant at 5% and 1% level of probability respectively

in crop improvement programmes. Yet these genotypes responded differently to population densities implying that population density for the new sesame genotypes should be judiciously selected. In general, the recommended 166,667 plants ha^{-1} was best for good seed production under rain-fed conditions. Seed yield in sesame is a product of three components: the capsule weight, capsule number and seed production efficiency. Number of seeds per capsule also had significant positive association with yield besides having high heritability and genetic advance estimates. Implicit in this is that these parameters could be used as predictors of seed yield in selection programmes.

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