ASSET Series A (2008) 8 (2): 194-204

ASSET
An International Journal

RELATIONSHIPS BETWEEN SEED TESTING TRAITS, FIELD EMERGENCE AND SEED YIELD OF SESAME (*Sesamun indicum* L.) UNDER DIFFERENT PLANT POPULATION ENVIRONMENTS

M. A. ADEBISI

Department of Plant Breeding and Seed Technology,
University of Agriculture, P. M. B. 2240, Abeokuta, Ogun State, Nigeria.
Email: mayoadebisi@yahoo.com.uk

ABSTRACT

Relationships between variables of seed testing traits and field emergence as well as seed yield of 14 indigenous sesame genotypes were tested at three plant population densities. Seed samples were taken from different harvests to conducts seed quality tests in the laboratory and to determine field emergence and seed yield under the three plant population densities. The results indicated that significant differences existed among the genotypes for all traits examined except emergence rate index. Genotypes 530-6-1,69B-88Z, 530-3 and C-K-2 appeared to have good seed quality and high seed yield. Coefficients of correlation between field emergence or seed yield and seed testing traits differed for the three plant population densities. Seed germination, seedling vigour index, excess water stress germination (EWSG) and plumule length were positively correlated with field emergence at low plant density of 133,3333 plant ha[1] while at high population densities of 266,667 plant ha[1] seedling vigour index had high and positive correlation with field emergence. Results of regression coefficients showed that 1000-seed weight as the best contributor to the regression equation, accounting for 36% of variation in field emergence and 13% for seed yield per plant. However, the contributions of other seed testing traits to field emergence were significant but reduced the variations from 8 to 1%. From this, it appears that prediction of seed yield of sesame from seed testing traits in the laboratory is more difficult than field emergence and found to be inefficient for both traits.

INTRODUCTION

Sesame (*Sesamun indicum* L.**)** is the most ancient oil-seed crop, with edible and odourless oil, and with good source of protein for man and livestock. It sets seeds and yields relatively well under high temperature and can be grown on residual moisture without extra rainfall. In Nigeria, the production and utilization of sesame is mainly for exports and limited household use.

Seeds are complex and variable biological inputs. Seed can be considered as grain, but not all grains can be classified as seed. Seed testing is therefore a useful tool in assessing the quality of seed before they are sown. Seed viability is a major component of any assessment of quality and germination (Odiemah,1991). Similarly, seed vigour has become very important because it provides good estimation for field emergence under stress conditions (Tekrony and Egli, 1977; Odiemah,1991).

ISSN 1595—9694

Crop planting geometry is an important factor that should be borne in mind in quality seed production (Adebisi, 2004). Comparative laboratory and field experiments by Odiemah (1991, 1995) and Adebisi *et al.* (2003) have shown that under certain environmental conditions there are close relationships between seed testing results and field emergence. Comstock and Moll (1963) classified environments into two categories; macro and micro-environments. Macro environmental variation is caused by fluctuation arising from variations in year, location, fertility, plant density and planting date, whereas, micro-environmental variations arise from plant to plant variations. According to Heydecker (1972), there are two views regarding the response of seeds to limiting conditions. One school of thought claims that the response of seeds to any stress will be representative of their ability to cope with other stress, while the other school claims that response will differ from one condition to another.

Simple correlation is adequate as a rough guide to the magnitude and direction of the relationship between two traits. The step-wise regression analysis, however, gave better insight into the interrelationship among many variables and is remarkably accurate in predictive ability under controlled (laboratory) and defined field conditions (Hertfield and Egli, 1974). Carnago and Vaughan (1973) found a positive correlation between seed vigour and yield in maize. Similarly, Odiemah (1991) reported that correlation coefficients between six quality traits and field emergence and grain yield were highly significant and positive. He identified specific gravity, standard germination and vigour tests as an excellent predictor of field emergence and grain yield per plant in maize hybrids. Kim *et al*. (1994) found out that field emergence was significantly correlated with grain yield of malting barley. They found percent tetrazolium vigour index, plumule length and percent germination were useful for predicting grain yield of feed barley. Singh and Mehndiratta (1970) postulated that 100-grain weight was among characters found to account for most of the variation in cowpea yield.

It has been frequently noted that seed quality (seed germination and seed vigour) tends to overestimate field performance under most planting conditions (Delouche and Baskin, 1973; Yaklick *et al*., 1979). It is also important to understand the relationship between various measurements of seed traits and field performance in a wide range of crops. Although the relationships are reasonably well established for some cereals and legumes (Kim *et al.,* 1994, Yamauchi and Winn, 1996; Tiwari and Hariprasad, 1997; Fabrizius *et al.,* 1999). There has been relatively little or no work for others, more especially sesame. A careful study of seed yield, field emergence and seed quality traits relationships is necessary in order to ascertain the magnitude and direction of changes to be expected during selection in sesame. The study was designed to determine the relative importance of seed testing traits to field emergence and seed yield in Nigerian indigenous sesame grown under three different plant population environments in two cropping seasons.

MATERIALS AND METHODS

Seeds of fourteen genotypes of sesame supplied by National Cereals Research Institute (NCRI), Badeggi, Niger State, Nigeria

ISSN 1595—9694 © UNAAB 2003

from 2000 and 2001 harvests were used for the study. Seed samples from the 14 sesame genotypes were assessed for seed quality using different tests and evaluated in the field under three different plant populations (133,333, 166,667 and 266,667 plants ha^{-1}) in 2001 and 2002 cropping seasons at the Seed Laboratory and Teaching and Research Farm, University of Agriculture, Abeokuta (7^o15^1N, 3^o25^1E), Nigeria. After cleaning, the seeds were divided into two lots. One of the lots was used for the laboratory and the other the field experiments.

Seed samples of different genotypes for each population were investigated in the laboratory for the following seed quality traits:

Standard germination test: The test was performed according to International Seed Testing Association (ISTA), 1995). Three 100-seed replicates of each genotype were germinated in 11 cm diameter petri dishes inside a moistened paper towels with 5ml of distilled water. The petri dishes were arranged inside an incubator at 30^0C temperature in a completely randomized design (CRD). After seven days of germination, the proportion of germinated seed was expressed as normal germination percentage.

Excess water stress germination: The test differed from the 'Standard" one only in the supply of higher water level (10 ml of distilled water) as described by Lovato and Cagalli (1992).

Tetrazolium viability (Tz) test (%): This test was conducted according to the procedures of the 'Tetrazolium Testing Handbook for Agricultural. Seeds' Association Of Official Seed Analysts (AOSA), 1970). A 100% solution (i.e., 1g of tetrazolium powder (2,3,5-triphenyl tetrazolium chloride) into 100 ml of distilled water was first prepared, then 1% concentration this solution (i.e., 1ml of above solution into 99 ml distilled water) was prepared. One hundred seeds of each genotype under each treatment were soaked in 200 ml of the solution for 24 hrs at 30^0C. Viable seeds were determined as seeds that were completely stained, margin of scutellum unstained and seed with basal portion of scutellum and radicle unstained (AOSA, 1970).

***Plumule length (cm*):** The plumule lengths of ten randomly selected normal seedlings were measured (AOSA, 1983).

Seedling vigour index: Seedling vigour levels of each genotype was calculated by multiplying percent normal germination by the average of plumule length for each genotype after seven days of germination (Kim *et al*., 1994) and divided by 1000.
1000-seed weight: Three 1000-seed replicates were weighed for each genotype in gramme.

The second part of the seed samples was sown in 2002 season as field experiments under the three plant population environments. The experimental field was a well-drained sandy-loamy soil with a pH range of 6.81 to 7.80, nitrogen status of between 0.07% and 0.14%, organic matter between 1.42% and 2.86% and carbon status of between 0.82% and 1.66 %. The average rainfall for the two seasons ranged from 500 mm annum $^{-1}$ in 2001 to about 800 mm $annum^{-1}$ in 2002. For each plant population and season, the 14 entries were arranged in randomized complete blocks with three replications. Sowing was done by hand in four-row-plots of 3 m long and spaced 50 cm x 15 cm with 133,333 plants ha^{-1}, 60 cm x 10 cm with 166,667 plants ha^{-1} and 75 cm x 5 cm with 266,667 plants ha^{-1}. Seeds were mixed with sand and hand drilled while seedlings were thinned at 3 weeks after sowing to about 15 cm, 10 cm and 5 cm within rows. A post emergence fertilizer application of NPK 15:15:15 was applied by drilling at the rate of 60 kgN, 30 kg $P_2 0_5$ and 50 kg $K_2 0$ ha^{-1}. Weeding was carried out twice before and after fertilizer application.

The percentage of field emergence was determined after two weeks from planting. Emergence counts were used according to the formula reported by Fakorede and Ojo (1981) to compute the following:

$$\textit{Emergence Index (EI) (days)} = \frac{\sum\text{(Plants emerged in day) (days after planting)}}{\text{Plant emerged by 8 DAS}}$$

$$\textit{Emergence Percent (E\%)} = \frac{\text{Seedling emerged by 8 DAS}}{\text{Number of seed planted}} \times 100$$

$$\textit{Emergence Rate Index (ERI) (days)} = \frac{\text{Emergence Index (EI days)}}{\text{Emergence \% (E\%)}}$$

***Seed Yield Per Plant*:** This was determined by weighing clean seeds of 30-plants from the two inner rows in each plot and expressed it as seed per plant. In addition, three samples from the seed yield were tested in laboratory as previously mentioned.

Data Analysis

For the two experiments, data analyses were performed using the SPSS 11.0 for windows statistical software package. Data collected were subjected to combined analysis of variance with three factors (season, plant population and genotype) and means were separated using Duncan's multiple range test (DMRT) at 5% probability level. Data on standard germination, excess water stress germination, tetrazolium viability and emergence tests were analyzed after angular transformation (arcsine) of percentages.

Pearson correlation coefficients between laboratory seed traits and field emergence as well as seed yield per plant were determined at the three plant population environments. Step-wise multiple regression equation was performed in order to determine the relative importance of seed quality attributes to field emergence and seed yield.

RESULTS AND DISCUSSION

Seed quality and yield are naturally the first consideration of sesame production. From the results in Table1, significant differences were observed between some of these genotypes for all determined traits, except for emergence rate index (ERI). It was clear that genotypes 530-6-1, 69B-88Z, 530-3 and C-K-2 were among genotypes with superior standard germination and field emergence. Only five genotypes, 93A-97, Type-A, Goza, 530-6-1 and 73A-11, had 3 to 4 days emergence index indicating that it took the seeds of these genotypes three to four days to emerge. It would take the other genotypes above 5 days for their seeds to emerge. Significantly higher plumule length and seedling vigour index were shown by Yandev 55 and 69B-88Z due to their longer plumule lengths. Genotype 73A-94 had the highest 1000-seed weight while Yandev 55 and 73A-97 recorded the lowest 1000-seed weight of 2.5 g. In terms of seed yield, Type-A was among the best genotypes with 23.8 g per plant while 93A-97 and Yandev 55 recorded a relatively low yield of less than 17.0g per plant. But other genotypes had similar seed yield.

Table 1: Means of laboratory and field seed testing traits and seed yield of 14 sesame genotypes over two cropping seasons and three plant populations

Genotype	SG (%)	EWSG (%)	Tz test (%)	Field emergence (%)	EI (days)	ERI (days)	Plumule length (cm)	SVI	1000-seed weight (g)	Seed yield/ plant (g)
Yandev 55	74b	71ab	67a	66a	5.2a	6.5a	4.7a	4.3a	2.5f	16.3c
93A-97	71bc	62d	60c	59b	2.9e	8.4a	3.7bc	3.3c	3.2ce	16.8c
Goza	71bc	70ab	62c	58cd	4.0cd	6.2a	4.3ab	3.8b	3.1de	20.9abc
Type A	74b	67b	65ab	52d	3.1de	7.6a	4.2abc	3.9b	3.4bcd	23.8a
73A-11	77ab	69ab	68a	64abc	4.1cd	5.1a	4.1bc	3.8b	3.1de	19.4abc
530-6-1	79a	72a	67a	64abc	4.0cd	5.2a	3.9bc	3.7b	3.1de	22.9ab
73A-94	74b	63c	58d	59bc	5.6a	7.9a	4.0bc	3.7b	3.9a	18.2abc
69B-88Z	79a	71ab	65ab	65ab	5.5a	6.7a	4.7a	4.5a	3.1de	22.8ab
E8	77ab	67b	64abc	61abc	5.9a	8.2a	4.5ab	4.2a	3.5bc	22.1abc
Domu	76ab	70ab	65ab	60bc	5.1abc	7.6a	4.3ab	4.1a	3.4bcd	20.1abc
73A-97	78ab	71ab	63abc	65ab	5.3ab	6.6a	4.0bc	3.8b	2. 9e	18.6abc
C-K-2	79a	74a	65ab	67a	4.5bc	5.4a	3.9bc	3.7b	3.2ce	20.7abc
530-3	76ab	71ab	64abc	66a	4.7bc	5.7a	4.2ab	4.0a	3.2ce	22.0ab
Pbtil No1	72bc	67bc	66ab	58c	5.6a	7.8a	4.0bc	3.6c	3.1de	22.1ab
Mean	76	69	64	62	4.7	6.8	4.2	3.9	3.2	20.5
F-test	*	*	**	**	**	ns	**	*	**	**

Values within a column with a letter subscript in common are not significantly ($P \leq 0.05$) different.
*, ** = significant at 5% and 1% probability levels, ns = not significant
SG-Standard germination, EWSG- Excess water stress germination, EI- Emergence index
Tz test-tetrazolium viability test, ERI - Emergence rate index,, SVI- Seedling vgour index

From the results in Table 2, field emergence showed that different characters were differently associated with it under different population environments. Standard germination and seedling vigour index were found to be positively correlated with field emergence at low (133,333 plant ha-^{1}) and high (266,667 plantha-^{1}) plant population environments. Similarly, excess water stress germination (EWSG) and plumule length recorded positive correlations of r = 0.30 and 0.31, respectively, with field emergence under low plant populations (133, 333 plantsha-^{1}). Emergence rate index (ERI) was negatively correlated with field emergence under medium (166,667 plant ha-^{1}) and high (266,667plant ha-^{1}) population environments. It was obvious that selection for seeds of high germinability and seedling vigour would positively affect field emergence under any of these two plant densities evaluated. Perry (1978a,b); Kraak *et al*. (1984); Durrant *et al.* (1985) and Adebisi *et al*. (2003) had earlier reported strong correlations between standard germination and field emergence, seedling vigour index or excess water stress germination. This was probably due to the favourable environmental conditions encountered by seed during the period of field emergence and therefore standard germination can always be taken as a reliable predictor of sesame seed vigour and performance in the field. The result further revealed that most of the coefficients of correlation for most of the traits assessed were not significant under medium plant population (166,667 plant ha -^{1}).

Table 2: Correlation coefficient between seed testing traits and field emergence under three plant populations over two cropping seasons (N=82)

Traits	Field emergence		
	133,333 plants ha-^{1}	166,667 plants ha-^{1}	266,667 plants ha-^{1}
Seed germination (%)	0.35*	0.16	0.33*
EWSG (%)	0.30*	0.13	-0.29
Tz viability (%)	0.16	0.18	0.02
Emergence index (days)	0.04	0.16	-0.21
ERI (days)	0.20	-0.48*	-0.44*
Plumule length (cm)	0.31*	0.13	0.14
Seedling vigour index	0.37*	0.14	0.24*
1000-seed weight (g)	-0.37*	0.18	-0.30*

*Correlation is significant at the 0.05 level of probability
EWSG= Excess water stress germination, Tz =Tetrazolium, ERI= Emergence rate index

Table 3 shows correlation coefficients between seed testing traits and seed yield under three plant population environments. Seed yield revealed that different traits were positively associated with seed yield. Seed germination and field emergence were found positively correlated with seed yield only under low plant population (133,333 plant ha-^{1}). This may be probably due to the favourable environmental conditions of more nutrient, rainfall and sufficient space during growth and development. The results suggest that seeds that germinated and emerged well will ordinarily lead to good stand establishment count and eventually good yield. Seedling Vigour Index (SVI) (r =31) and plumule length (r =30) was positively associated with seed yield under high population (266,667 plant ha-[1]) only, suggesting that selection for high seedling vigour indices would lead to high seed yield in this environment. In similar vein, correlation between 1000-seed weight and seed yield was positive and highly significant (r = 0.47 and 0.32, respectively) under 133,333 and 266,667 plant ha-[1]) plant population environments. The results demonstrate that selection for high seed weight would positively lead to high seed yield of sesame under these two environments. Correlation coefficients in most cases were not significant under the three plant population environments.

Correlations between seed testing traits and field emergence, and seed yield across three plant population environments are presented in Table 4. Seed germination, EWSG, SVI and 1000-seed weight were found positively associated with field emergence. This was not in the case between ERI and field emergence where significant and negative correlation was found (r = -0.35). Based on this result, seed germination, EWSG, SVI and 1000-seed weight could be recommended as selection criteria for field emergence in sesame. The coefficients of correlation in most cases showed non significance between seed yield and seed testing traits except 1000-seed weight (r =0.36), suggesting that irrespective of plant population environment, selection for genotypes with good seed weight would positively affect seed yield of sesame. The result, therefore, indicates the possibility of producing high yielding sesame with good seed weight and superior seed quality. In general, the non-significant coefficients of correlation indicate that selection for the different traits could be done separately and independently.

Step-wise multiple regression analysis has been used by many authors to assess the relative contributions of many components of seed quality to field performance (Kim *et al.*, 1994; Tiwari and Hariprasad, 1997; Adebisi *et al*., 2006). From the result in Table 5, the nine seed testing traits ascribed 69% (cumulative percent) of the total variation. This analysis ranked 1000-seed weight as the major contributor to field emergence, accounting for 36% of total variation in field emergence as indicated by Partial R^2. Variation in field emergence was reduced when contributions of variables such as emergence index, emergence rate index, plumule length, seedling vigour index and standard germination were added to the equation, giving 8, 7, 5, 4 and 4%, respectively. Excess water stress germination and Tz viability contributed less than 3% of the observed variation in field emergence. Using regression analysis, Kim *et al*. (1994) postulated that vigour index, percent standard germination, plumule length and percent cold germination in this order of importance together accounted for about 77% of the variation in field emergence of seven barley cultivars evaluated. In contrast, none of these components were found to account for most of the variation in field emergence observed in the present study.

Table 3: Correlation coefficient between seed testing traits and seed yield under three plant populations over two cropping seasons (N=82)

Traits	Seed Yield per plant (g)		
	133,333 plants ha-1	166,667 plants ha-1	266,667 plants ha-1
Seed germination (%)	0.35*	0.20	0.19
EWSG9 (%)	0.18	-0.17	-0.12
Tz viability (%)	0.13	0.14	0.20
Field emergence (%)	0.37*	0.20	0.18
Emergence index (days)	0.15	0.12	-0.19
ERI (days)	0.13	0.17	0.15
Plumule length (cm)	0.31*	0.15	0.30*
Seedling vigour index	0.15	0.17	0.31*
1000-seed weight (g)	0.47*	0.21	0.32*

*Correlation is significant at the 0.05 level of probability
EWSG- Excess water stress germination ERI- Emergence rate index, Tz-Tetrazolium

Table 4: Correlation coefficients between seed testing traits and seed yield over three plant populations (N=82)

Traits	Field emergence (%)	Seed yield per plant (g)
Seed germination (%)	0.33**	0.15
EWSG (%)	0.25**	-0.11
Tz viability (%)	0.12	0.13
Field emergence (%)	1.0	-0.13
Emergence index (days)	-0.13	0.12
ERI (days)	-0.35**	-0.12
Plumule length (cm)	0.19	-0.18
Seedling vigour index	0.29**	-0.14
1000-seed weight (g)	0.31**	0.36**

* Correlation is significant at the 0.05 level of probability. EWSG- Excess water stress germination, ERI- Emergence rate index

Similarly, Adebisi *et al.* (2006) found seed germination as the highest predictor of seedling emergence of West African rice, accounting for 91% of the variation.

Using seed yield as dependent variable (Table 6), all the nine seed testing traits accounted for 34% (cumulative percent) of the total variation observed. The 1000-seed weight alone accounted for 17% of the observed variation as indicated by partial R^2, while seedling vigour contributed 12% of the variation observed.

ISSN 1595—9694 © UNAAB 2003

Table 5: Summary of a step-wise multiple regression analysis of seed testing traits on field emergence over 14 sesame genotypes.

Traits	MR	R^2	Partial R^2	b-value	F-test
1000-seed weight (g)	0.60	0.36	0.36 (36)	6.19	7.25**
Emergence index (days)	0.56	0.32	0.02 (38)	0.83	6.74**
Emergence rate index (days)	0.55	0.30	0.02 (40)	0.59	7.22**
Plumule length (cm)	0.46	0.21	0.09 (49)	17.37	5.26**
Seed yield per plant (g)	0.42	0.18	0.03 (52)	0.11	5.23**
Seedling vigour index	0.41	0.17	0.01 (53)	2.84	6.16**
Standard germination (%)	0.37	0.14	0.03 (56)	0.38	6.49**
Excess water stress germination (%)	0.27	0.07	0.07 (63)	0.30	4.78ns
TZ viability (%)	0.12	0.01	0.06 (69)	0.16	1.81ns

Field emergence used in the equation was the average of 14 genotypes
** significant at 0.01 probability level, ns = not significant
MR = Multiple regression coefficient
R^2 = Coefficient of determination (proportion of variation explained)
b-value = Unstandardized partial regression coefficients
F-test = Values from ANOVA of multiple regression
Values in parentheses are the cumulative percentages of Partial R^2

The contribution to variation in seed yield decreased when other three seed quality traits (seedling vigour index, Tz viability, field emergence and plumule length) were added to the equation, accounting for 3, 1 and 1%, respectively, of the total variation.

Results of regression analysis, therefore, indicate that only 1000- seed weight accounted for most of the variation in field emergence and seed yield observed in the present study, ascribing 36 and 17%, respectively to the variation in these two traits.

In conclusion, it appears from this investigation that environmental conditions on the relationships between seed testing traits and field emergence as well as seed yield is important for sesame production. However, sesame must be tested for seed vigour in different environments to determine the favourable conditions for its production.

ACKNOWLEDGEMENTS

The author appreciates the financial support provided by the Federal Government of Nigeria and University of Agriculture, Abeokuta, Nigeria for the Ph.D programme. The author is also grateful to Dr. M. O. Ajala, Prof. O. J. Ariyo and Prof. K. Okeleye for their technical assistance to the study.

Table 6: Summary of a step-wise multiple regression analysis of seed testing traits on seed yield over 14 sesame genotypes

Traits	MR	R^2	Partial R^2	b-value	F-test
1000-seed weight (g)	0.41	0.17	0.17 (17)	8.36	18.03**
Seedling vigour index	0.22	0.05	0.12 (29)	-1.79	2.37ns
TZ viability (%)	0.l3	0.02	0.03 (32)	0.16	2.22ns
Field emergence (%)	0.13	0.02	0.01 (33)	-0.12	2.16ns
Plumule length (cm)	0.12	0.01	0.01 (34)	-1.55	1.74ns
Excess water stress germ (%)	0.11	0.01	0.00 (34)	-0.12	1.56ns
Standard germination (%)	0.05	0.00	0.00 (34)	-5.95	0.30ns
Emergence rate index (days)	0.05	0.00	0.00 (34)	-7.59	0.28ns
Emergence index (days)	0.05	0.00	0.00 (34)	0.10	0.04ns

Seed yield used in the equation was the average of 14 sesame genotypes
** significant at 0.01 probability level, ns = not significant

MR = Multiple regression coefficient
R^2 = Coefficient of determination (proportion of variation explained)
b-value = Unstandardized partial regression coefficients
F-test = Values from ANOVA of multiple regression
Values in parentheses are the cumulative percentages of Partial R^2

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