SEED PRODUCTION IN OKRA
(ABELMOSCHUS ESCULENTUS (L.) MOENCH)

BY

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ABSTRACT

Fifteen genotypes of okra were evaluated in eight environments for stability of seed yield, and also to identify the most suitable environments for producing high quality seed at the University of Ibadan, Nigeria from 1984 to 1986. There was significant genotype x environment interactions for all characters examined except for percent seed germination. On the average, highest seed yield and best seed quality as measured by percent seed germination were associated with environments with low total precipitation (460.4 mm), low average relative humidity (50.1%) and high number of sunshine hours (1153.7 hrs).

Studies on agronomic requirements for okra seed production revealed that high plant population (111,110 plants/ha) produced about 39% higher seed yields/ha than low plant population of 55,555 plants/ha. Nitrogen levels of 65 kg/ha and 130 kg/ha raised seed yield by 35 and 39% over the control (no nitrogen) respectively.

Seeds harvested 35-49 DAF, stored in polythene bags at 4°C with 50% RH retained most of their viability after 16 months of storage.

Removing the first two to four edible pods on each plant raised okra seed yields by about three percent. Removal of the first 6 to 14 pods/plant reduced seed yields by 36-80%. Removal of up to four edible pods/ plant was compensated for by higher total pod dry matter yield reflected in a higher 1000-seed weight and larger size of seeds.

Seeds in categories of 4.0 and 4.5 mm size grades were more vigorous as indicated by 1000-seed weight, percent seed germination and seedling emergence.

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CERTIFICATION

We certify that the work presented in this thesis was carried out by Mr. I .A. Adetunji of the Department of Agronomy, University of Ibadan.

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DEDICATION

TO MY MOTHER

DORCAS OLALONPE ATOBATELE

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CHAPTER ONE

INTRODUCTION

Okra (Abelmoschus esculentus (L.) Moench) is one of the most popularly grown tropical fruit vegetables. It is a predominantly self-pollinated annual of the family Malvaceae.

The exact origin of okra is not certain. Its ancient use as a crop and its widespread distribution at an early date make its origin difficult to trace. De Candolle (1886) reported that okra was mentioned in ancient sacred books of India. Bates (1968) suggested an Asian origin due to presence of its wild relatives in southeast Asia. However, the presence of wild varieties in Ethiopia and the presence of primitive perennial varieties in West Africa also imply an African origin (Purewal and Randhawa, 1947; Harlan, 1972; Martin and Ruberte, 1978).

In Nigeria, okra cultivation has largely been at the subsistence level, often intercropped with yam and maize. It is grown mainly for its green tender pods which are used in soup preparations. Apart from the primary

role of the seed as planting material, oil expressed from it is useful as a cooking oil and for production of margarine (Edwards and Miller, 1947). The potential of okra seeds as a new source of protein, calcium and iron has been stressed. Karakoltsides and Constantinides (1975) reported that a sample of mature okra seed which they analyzed contained 20.58% protein, 282.26 mg calcium and 10.26 mg iron. Compared to soya seeds, the okra seed is lower in protein but high in iron and calcium. Whether okra seed will become a major source of oil and protein in the tropics depends largely on breeding, selection, agronomic research, post-harvest handling and processing of the seed.

A major limiting factor in the production of okra and other vegetables in Nigeria is that of obtaining good quality and viable seeds for sowing at the appropriate time (Ajayi, 1975); Joshua, 1975). This poor seed supply situation may be attributed to poor techniques for seed production, inadequate seed storage and sale facilities, and low yields of the existing land varieties.

Breeding and agronomic studies which were initiated in the early seventies at the University of Ibadan in southwest Nigeria have resulted in new superior varieties of okra (Fatokun et al. 1979). The dissemination of new varieties to growers depends to a large extent on an increased availability of good quality seeds. It is essential to gather information on the fruit and seed yields of new varieties under different agro-ecological conditions prior to their release. Trials conducted over a number of different locations during varietal evaluation, permit better evaluation of genotype x environment interactions which in turn make recommendations more reliable.

The effect of different plant population densities and fertilizer rates on seed yield and quality of okra has not been well documented for Nigeria. In India, okra seed yields increased with higher population density (Mangual and Martin, 1980; Pandey and Singh, 1982). Several researchers have recorded significant increases in seed yield of okra under nitrogen (N) fertilization

(Singh and Pandita, 1981; Pandey et al., 1980). However these authors did not observe any significant effect of N on seed quality as measured by germination percentage and seedling vigour.

For most farmers, it is difficult to combine production of edible pod and plantable seed from the same okra fields. For maximum profit, the farmers harvest all marketable pods and reserve remnant pods for seed production. There is however the need for agronomic management particularly harvesting regimes for optimum seed yield.

Uniformity of establishment among crop stands is often influenced by the size of seed planted. Large seeds produce seedlings which show more vigour, attain greater weight and size and produce larger yields than plants grown from small seeds. Because of the relationship between seed size and seedling vigour, commercial seed agencies usually screen seeds to remove under-sized seeds before sale. However, there is need to relate seed size and seedling vigour in okra.

Given the above constraints and dearth of information regarding okra seed production in Nigeria, a number of studies were conducted with a view to:

(a) investigate seed yield and quality of okra in different environments,

(b) determine the effects of plant population and nitrogen fertilizer on seed yield and quality of okra, and

(c) gather information on the effects of harvesting time, storage methods and seed size on okra seed viability and seedling vigour.

CHAPTER TWO

LITERATURE REVIEW

2.1 Genotype x environment interactions

When varieties are compared over a series of environments, the relative rankings usually differ i.e genotype x environment (GE) interactions occur. This causes difficulty in the evaluation and selection of superior varieties in plant improvement programmes. Comstock and Moll (1963) showed that a large (GE)interaction reduces selection progress in plant breeding programmes.

Various statistical models have been proposed for the evaluation of GE interactions. Lin et al (1986), in their review of these models classified the most frequently cited ones into four groups according to their similarity and the concepts of stability they represent (Table 1).

The frequent linearity of relationship between performance of different genotypes in various environment on one hand, and some measures of these environments on the other has made the regression methods of stability analysis popular among plant breeders (Yates and Cochran, 1938; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Perkins and Jinks, 1968; Breese, 1969;

Table 1: [illegible] measures of stability (Lin et al., 1986)

Group	Measure of stability	Authors	Concepts of stability
A	Variance of a genotype over environments (S_i^2)		A genotype is considered to be stable if its among environment variance is small
	Conventional coefficient of variation of a genotype over environments (CV_i)	Francis and Kannenberg (1978)	
B	Mean variance component for pairwise GE interactions (θ_i).	Plaisted and Peterson (1959)	A genotype is considered to be stable if its response to environments is parallel to the mean response of all genotypes in the trial
	Variance components for GE interaction ($\theta_{(i)}$).	Plaisted (1960)	
	Ecovalence (W_i^2)	Wricke (1962)	
	Stability variance (σi^2)	Shukla (1972)	
C	Regression coefficient (bi)	Finlay and Wilkinson (1963)	Concept (B) is implied if stable genotype is defined as having $b_i = 1$ or $B_i = 0$. Concept (A) is implied if $b_i = 0$ ($B_i = -1$)
	Regression coefficient (b_i') (similar to (bi) except that the observed values are adjusted for location effects before the regression)	Perkins and Jinks (1968)	
D	Deviation from regression (σ_i^2)	Eberhart and Russell (1966)	A genotype is considered stable if residual MS from the regression model on the environmental index is small
	Regression coefficient (Bi)	Perkins and Jinks (1968)	

Baker, 1969). Although this linearity does not always account for all observed variation, it is very important in breeding, since it can be used to provide crop performance data free from GE interactions. This, in turn, enables the plant breeders to obtain more reliable estimates of heritability and hence predict with greater accuracy the rate of genetic progress under selection for a given character.

In the regression method of stability analysis, various parameters have been used to characterise individual varieties for performance in different environments. A regression coefficient obtained by regressing the means of a cultivar from several environments on the environmental means averaged over genotypes has been widely used as stability index. It was first proposed by Yates and Cochran (1938). Finlay and Wilkinson (1963) working on adaptation of 277 varieties of barley in south Australia reported that the regression coefficient and mean yield could be used to select cultivars adapted to environments with differing productivities. They concluded that a cultivar with yield and regression coefficient greater than average is one that is adapted to high yielding environment

while a cultivar with a lower than average yield and greater than average regression coefficient would be one that is adapted only to the best environment. But, when the variation for GE interaction is due to heterogeneity among regression coefficients, characterization of cultivars by regression coefficient become ineffective (Baker, 1969; Shukla, 1972; Freeman, 1973).

However, Eberhart and Russell (1966) claimed that the regression coefficient was a cultivar response parameter and that the stability of performance could be measured by the magnitude of deviation from performance as predicted by regression. Perkins and Jinks (1968), also proposed another form of analysis of variance known as joint regression analysis. This method was effectively used by Freeman (1973) to measure the proportion of GE interaction that is due to heterogeneity among regression coefficients. The total GE interaction variance is partitioned to components due to regression and deviation from regression (Eberhart and Russel, 1966; Perkins and Jinks, 1968). Jopper et al. (1971), demonstrated the importance of regression analysis in decisions regarding the release of hard red spring wheat cultivars. Stroike and Johnson (1972) also used regression analysis to characterize cultivars in international winter wheat performance. Ariyo (1985) reported the usefulness of joint regression analysis

in measuring pod yield stability in 30 genotypes of okra in the south western Nigeria.

However, the success of regression methods for studying GE interactions are based on the assumption that the relationship between the performance of different genotypes in various environments is linear (Freeman, 1973). Thus regression methods can be highly informative where GE interaction have a linear assoication with environmental index. Where a low degree of linearity exists, the regression techniques may be at least uninformative and at worst misinformative regarding genotypic performance (Byth et al., 1976).

Environmental factors per se, acting on seeds before harvest or indirectly on them through the parent plant affect the seed quality (germination and viability) of a seed crop. Austin (1972) reported that regions of the world having hot dry weather at the time when seeds ripen are the most favourable for production of high quality seeds. Poor quality okra seed (2-5% germination) were produced under hot humid derived savanna zone of Nigeria (Ewete 1976).

2.2 Plant population density and fertility responses

The beneficial influence of fertilizers on edible pod yield and improved quality of okra is well known (Sharma and Shukla, 1973; Hooda et al 1980; Fatokun and Chheda, 1983). Nitrogen at rates of 134 kg/ha was recommended by Asif and Greg (1972) for maximum edible pod yields of okra, while Fatokun and Chheda (1983) obtained maximum green pod yields of okra with 60-120 kg N/ha. However, Khalil and Hamid (1964) found that N applied as ammonium sulphate did not significantly increase okra pod yields. This poor response was attributed to the high alkalinity of the soil used. Reports differ on the response of okra to other elements such as phosphorus (P). Sutton (1963) reported increased green pod yields under P application especially during the first five pickings of fresh pods. Sutton (1966) also observed that with further increase in P, yields correspondingly increased. But Fatokun and Chheda (1983)

observed that P application did not significantly increase fresh pod yields; this result agrees with reports from India (Mani and Ramanathan 1980). Of two-nutrient combinations, application of P with N have been reported to improve pod yield (Ahmad and Tulloch-Reid, 1968; Singh, 1979).

There is no information on the nutrient requirements of okra plants for high quality seed production in Nigeria. Workers in other tropical and sub-tropical parts of the world report the response of okra to fertilization in terms of seed yield and quality. Pandey et al (1980) observed a significant increase in seed yield of okra with increasing N rates. They also reported a non-significant effect of P fertilization on seed yield. On the effect of two-nutrient combinations, Singh and Pandita (1981) reported that the highest seed yield was obtained

from okra plants receiving N and P at rates of 120 and 25 kg/ha, respectively. Some authors claim that N or P application does not affect okra seed viability and seedling vigour (Pandey et al., 1980; Pandey and Singh, 1982; Singh and Pandita, 1981).

In Nigeria, most farmers interplant okra with such major field crops as maize, yam and cassava. When okra is grown sole, spacing is often irregular and the number of plant per stand varies from one to five (Fatokun and Chheda, 1983). Consequently, efficient use of available so nutrients by the crop is hampered. Similarly, field operations are difficult. Sutton and Albregts (1970), investigated the response of okra to plant population density in the U.S.A and obtained maximum fresh fruit yield per hectare. Later, Albregts and Howard (1976) also observed a comparable response and concluded that okra pod yield per hectare increases in an asymptotic manner. In Nigeria, maximum pod yield was obtained at the highest plant population density (108,000 plant/ha) tested (Fatokun and Chheda, 1983). The response of individual plants to increase in plant population density indicates that pod yield per plant decreases with increase in plant population (Kamalanathan et al., 1970).

The effects of plant population density on okra seed yields and quality have not been reported in Nigeria. However, in Puerto Rico, okra seed yields increase with plant population density (Mangual and Martin, 1980) but Pandey and Singh (1982) in India reported that seed quality (seed viability and seedling vigour) and seed yield per plant decreased with increasing plant densities.

Researchers have shown that the optimum population density of field crops vary with soil nutrient status. Shrestha (1983) did not find any interactive effect between N and plant spacing on the fresh fruit yield of okra.

2.3 Seed maturity and storage

Reviews on the storage and longevity of seed show that relative humidity (RH) and temperature of the storage environment are the most important factors affecting maintenance of seed quality in storage (Barton, 1961; Christensen and Kaufmann, 1969; Robert, 1972; Bass, 1973).

The effects of RH and temperature are highly inter-dependent (Robert, 1972). Most crop seeds lose viability rapidly at RH approaching 80% and temperatures of 25-30°C, but can be kept for 10 years or more at RH of 50% or less with temperatures of 5°C or less (Toole, 1950). According to Harrington (1960), the sum of the percentage RH and the

temperature in degree Fahrenheit should not exceed 100 for safe storage. In another report safe storage for 1-3 years requires that, this sum could reach 120 provided the temperature contributes no more than half the total (Bass, 1967). It has been suggested that the RH should not be higher than 60% for seeds at 21°C and no higher than 70% for seeds at 4 to 10°C; however at 5°C and 45-50% RH, seeds of many crops can be safely stored for 10 or more years (Toole, 1957). Seeds of different kinds have their own specific requirements of RH and temperature for safe storage. Bean seeds stored at 12°C and 30% RH did not change in viability after 4 years (Fonseca et al., 1980). Lettuce, onion, cauliflower, tomato, carrot and eggplant seeds can be stored safely at 50% RH and 20°C or less (Barton, 1939). RH of 15-45% provided excellent storage condition for soyabeans and alfalfa seeds at air temperatures of 21-27°C (Akamine, 1943).

Seed packaging prior to storage is another important factor to be considered for safe storage. An efficient packaging material must be completely impervious to moisture vapour and gases (Robert, 1972). 10-mil polyethylene and other plastic materials were reported to be better than friction top tin cans, bottles, glass jars and vials with screw top Lids as moisture - barrier containers of seed

(Barton, 1949; Isely and Bass, 1960; Miyagi, 1966 and Delouche et al., 1973). Periods of safe storage for wheat, corn, cucumber, Kentucky bluegrass, hemp and kenaf seeds were increased significantly under storage in thick 10-mil polyethylene packages (Bass, 1959). Seeds in packages that are not completely impervious to moisture vapour may gain or lose moisture with time during storage. The direction, rate and amount of change of the moisture are controlled by the temperature and RH of the storage area (Bass, 1973). Hence, in most studies, sealed containers were investigated in conjuction with temperature control and predrying. High viability of low-moisture content vegetable, flower and tree seeds was maintained during 20 years of sealed storage at -4°C (Barton, 1953). Perhaps, the most interesting study of long term storage of okra seed is that of Martin et al (196 In the study, okra seed with 12% moisture content germinated 90% after 11 years storage in sealed glass jars at 2 to 4°C. In cotton, another Malvaceous crop, Pate and Duncan (1964) also reported that good quality seed can be stored in sealed containers for up to 38 years without complete loss of viability, if the temperature is held at 0-6°C and the seed moisture does not exceed 11%.

The pre-storage history of seed also has a decisive influence on its subsequent storability. Seeds harvested before maturity do not store well (Thomson, 1979). Ewete (1980) obtained the highest seed germination from okra pods harvested at 35 days after flowering. Bass (1965) also found that mature seed of Kentucky bluegrass remained viable longer than immature seeds under similar conditions of storage. Shands et al., (1967) also showed that harvesting barley prematurely was deleterious to viability in storage. In addition, these workers showed that delay of harvest by about three weeks was equally adverse to subsequent viability of grain stored at high moisture content.

2.4 Pod removal and seed yields

Little information is available on the effects of fresh pod removal on yield and quality of plantable okra seeds. Regular picking of green okra pods prolongs the fruiting duration and increases green pod yield (Martin and Ruberte, 1978). This compensatory responses of plants to the removal of portions of their reproductive structures, has also been shown in cowpea (Nangju, 1979), wheat (Thorne, 1981), sorghum (Hamilton et al., 1982)

and soyabean (McAlister and Krober, 1958). This phenomenon assumes ever greater importance when such compensations enhance the economic product of crops.

It has been shown that the effect of fruit removal on seed yield in seed crops depends on the number of fruits removed and the developmental stage of the crop at the time of fruit removal. Smith and Bass (1972) reported that soyabean plants tolerated removal of up to 80% of pods without significant reduction on seed yield if carried out before the initiation of pod filling. As pods mature, removal of even fewer pods reduced yields. This was further confirmed by Tayo (1977).

Although regular green pod removal in okra increased the total number of fruits produced per plant, such increases were not accompanied by appreciable changes in the amount of dry matter produced (Kolhe and Chavan, 1967). However, in other crops such as soyabean, removal of flowers and pods significantly reduced the amount of dry matter accumulated in the stem, root and pods (Tayo, 1977).

2.5 Seed size and seedling vigour

Uniformity of establishment among crop stands is essential for fully exploiting the yield potential of most crop plants. Seed quality in terms of germination and seedling vigour influence field establishment (Harper and Obeid, 1967). The effect of seed size as a measure of quality upon seed germination, and seedling growth have been investigated in a number of crop species such as sorghum (Abdullahi and Vanderlip, 1972), cotton (Gelmond, 1972), soyabean (Johnson and Leudders, 1974) and onion (Hewston, 1964). These studies revealed that the larger and heavier seeds produce seedlings which showed more vigour, attained greater weight and size and produce larger yields than did plants grown from small light seeds.

Although seedlings from the large seeds had obvious initial advantage, it was subsequently inappreciable at plant maturity. Oexemann (1942) found that the superiority of seedlings from heavier seeds of soyabean, tomato, and cucumber disappeared completely at plant maturity. Hewston (1964) also observed a similar diminishing advantage of large seededness in sweet corn, radish and cauliflower.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Okra seed yield stability under different environments

Fifteen varieties of okra (Appendix I) were grown under eight environments which were derived from locations with two contrasting agro-ecologies viz:

(a) Ibadan at latitude 7° 18'N and longitude 3°54'E, situated in the humid derived savanna zone of Nigeria and

(b) Maiduguri, located in the semi-arid sudan savanna zone of Nigeria at latitude 11°51'N and longitude 13° 05'E.

The eight environments were obtained from combinations of site, sowing date and plant population as follows:

Environment:

I: Maiduguri, sowing date 17/6/86 , 55,555 plants per hectare (pph).

II: Maiduguri, sowing date 17/6/86 , 111,110 pph

III: Maiduguri, sowing date 1/7/85 , 55,555 pph

VI: Maiduguri, sowing date 1/7/85 , 111,110 pph

V : Ibadan, sowing date 10/3/86 ,55,555 pph

VI: Ibadan, sowing date 20/3/86 111,110 pph

VII: Ibadan, sowing date 28/8/86 , 55,555 pph

VIII: Ibadan, sowing date 28/8/86 , 111,110 pph

At Maiduguri, the experimental site had been under fallow for three consecutive years while the Ibadan site had been fallowed for two years.

Experimental design and cultural practices

After land preparation at each location the experimental site was divided into four blocks in a randomized complete block layout with 15 plots per block and one okra variety in a plot. The plot size was 3x3 m surrounded by 1 m path. Each plot had four rows of 2.5 m long spaced 0.6 m apart and hills within the rows were spaced 0.3 m apart. Each hill was planted with 3 to 4 seeds and was thinned to either one plant/stand (55,555 plants/ha) or two plants/stand (111,110 plants/ha) at about two weeks after planting. Due to prevalence of pod and leaf-eating insects in all the environments, the plants were sprayed twice weekly, beginning about 3 weeks after sowing, with 0.12% Monocrotophos at 1.2 kg a.i/ha. Urea was banded (65 kg N/ha) in two equal doses i.e. at seedling emergence and at commencement of flowering in all environments. Plots were weeded manually as necessary through out the experiment. Dry pods were picked by hand as soon as they began to split. Weather data were collected for the experimental period.

The following data were collected for each variety in all environments based on 10 competitive plants from the two middle rows in each replicate.

Plant height. The height of the main stem of each plant was measured from the soil surface to the tip at the cessation of flowering. The average of the ten competitive plants was expressed as plant height.

Number of field dried pods/plant. Dry pods on ten competititve plants on each plot were counted at harvest and the average number of field dried pods/plant determined for each variety.

Flowering dates. These are (i) the number of days from sowing to first flower opening and (ii) number of days from sowing to when 50% of the plants in a plot attained flowering.

Number of seeds/fruit. Field dried fruits harvested from each plot were thoroughly mixed in a large jute bag. Ten fruits randomly selected from the jute bag were threshed and the seed counted. The average was taken as number of seeds per fruit in each variety.

Seed yield/plant. Mature pods were harvested, threshed and the seed weighed. The average weight in gram was recorded as seed yield per plant.

Seed yield/ha. Field dried weight of seed obtained from 10 competitive plants which occupied an area of 1.8 m^2 in the center of each plot was substituted into the following formula to obtain seed yield/ha.

$$\text{Seed yield (kg/ha)} = \frac{10\ X}{A}$$

where:
X = weight of seed(g)
A = area sampled (m^2)

1000-seed weight. Eight replicate samples of one thousand (8x1000) sun-dried seeds were weighed per variety and the mean expressed in grams to the nearest tenth for each variety according to (International Seed Testing Association, ISTA 1976) procedures.

Percent seed germination. Four replicate samples of 100 seeds were counted per variety, and placed on moistened 9 cm, Whatman No 1 filter paper inside covered petri dishes. This was held under ambient laboratory condition for 7 days (ISTA 1976). For germination only normal seedlings were counted.

Percent moisture content of seed at harvest. Samples of 500 seeds per replicate were weighed packed in envelopes and oven-dried at 133°C for one hour (ISTA, 1976). The values obtained were substituted into the following formula (ISTA, 1976), to obtain moisture content at harvest.

$$M_2 - M_3 \times \frac{100}{M_2 - M_1}$$

where: M_1 - is the weight in grams of the container before drying

M_2 - is the weight in grams of the container and contents before drying

M_3 - is the weight in grams of the container, and contents after drying.

Statistical analysis

The joint regression method of stability analysis of Perkins and Jinks (1968) was used to assess the stability of performance of fifteen okra varieties under eight different environments in respect of the following characteristics: Number of days to flowering, number of days to 50% flowering, plant height, number of pods per

plant, seeds per pod, seed yield/plant, 1000-seed weight, percent seed germination and seed moisture content.

The joint regression analysis is based on the following model:

$$Yij = \mu + di + Ej + gij + eij$$

where:

Yij = i^{th} observation in j^{th} environment;

μ = grand mean over all varieties and environments;

di = additive genetic contribution of a given variety;

Ej = additive environmental contribution of a given environment;

gij = genotype x environmental interaction of a given variety in a given environment;

eij = experimental error;

i = a given variety;

j = a given environment

The form of joint regression analysis of variance for this model is presented in Table 2.

Table 2: Form of the analysis of variance for stability of performance (Perkins and Jinks 1968).

Sources of variation	df	Ms
Genotypes	g - 1	$S\Sigma(di)^2/g-1$
Environment (joint regression)	s - 1	$t\Sigma(Ej)^2/s-1$
Genotype x Environment (GE):	(g-1) (s-1)	
Heterogeneity among regressions	(g-1)	$\Sigma(bi)^2$ $(\Sigma EJ)^2/g-1$
Remainder	(g-1) (s-2)	$\Sigma\delta^2 ij$ (g-1) (s-2)
Error	sg (r-1)	

where:

di = additive genetic contribution of a given variety, i

Ej = additive environmental contribution of a given environment, j

bi = Linear regression coefficient for i^{th} variety;

δij = deviation from linear regession line of the i^{th} line in the j^{th} environment.

g = number of genotypes;

s = number of environments

r = number of replications

In this analysis the GE interactions sum of squares was partitioned into components due to heterogeneity for regression coefficients and a component due to remainder (residual). The heterogeneity item in the analysis of variance tests the linearity of the environmental values while the remainder tests non-linearity of variation in the model. In this analysis, a stable variety according to Perkins and Jinks (1968) is one with a regression coefficient (1 + Bi) value of 1.0 and a Bi value of zero, while Breese (1969) defined stable variety as one with a very small standard error (S.E.) attached to its regression coefficient.

3.2. Influence of stand density and nitrogen fertilizer on seed yield and quality

As a preliminary study, this experiment was intended to determine (i) the effect of high or low population density on okra seed yield and quality, (ii) the effect of interaction between, high or low population density and soil nitrogen level on okra seed yield and quality.

The studies were conducted during the rainy seasons (7th June and 21st August) of 1985 and (25th June and 30th August) of 1986, at the Teaching and Research Farm, University of Maiduguri. The experimental plots had been fallowed for 2-3 years. The okra cultivar used, TAe 38, was obtained from the National Horticultural Research Institute (NIHORT), Ibadan.

After land preparation, planting was done in a split plot layout with four replications. Main plots had one or two plants per stand at a spacing of 60x30 cm, corresponding to population densities of 55,555 plants/ha and 111,110 plant/ha respectively. The subplots comprised three levels of N viz. 0, 65 and 130 kg/ha as urea. There were four rows per sub-plot and seven plant stands per row. The plot size was 3x3 m for all the treatments. Fertilizer N was applied in two equal split doses at seedling emergence and at flowering.

Before planting, soils were randomly sampled at 15 cm depth, bulked, air-dried, sieved through 2 mm mesh and analyzed. The result (Table 3) of this soil analysis was used to determine the levels of N applied in this study.

The outer rows on all four sides of each sub-plot were harvested from the inner ten plants of the 2 middle rows of each sub-plot from all treatments. These were counted, shelled and the resulting seeds measured to determine: seed yield/plant, seed yield/ha, number of seeds/fruit and 1000-seed weight as described in experiment 3.1. Seeds were also assessed for quality in terms of

germination percentage, germination rate and percentage seedling emergence as follows:

Seed germination percentage. This was obtained as described in section 3.1

Germination rate/percent seedling emergence. Four replicate samples of 100 seeds were germinated in sand. A seed was considered germinated when the plumule emerged. Seedling counts were made daily from the fourth to seventh day. The percentage emergence on each day was recorded and the total was expressed as percentage seedling emergence. The rate of germination expressed as a number was calculated using the formula proposed by Maguire (1982).

$$R.G = \frac{X_1}{Y_1} \times \frac{(X_2 - X_1)}{Y_2} \times \text{--------} \times \frac{(X_n - X_{n-1})}{Y_n}$$

Where:

R.G = rate of germination;

Xn = percentage seedling emergence at nth count;

Yn = number of counts from planting to nth count.

Table 3. Analysis of soil samples prior to planting (0-15 cm depth) at Maiduguri

	Planting seasons	
	1985	1986
Mechanical Analysis:		
Sand (%)	84	85
Silt (%)	15	14
Clay (%)	1	1
Texture	Loamy sand	Loamy sand
Chemical Analysis:		
PH (H_2O)	6.80	6.76
Organic carbon (%)	1.12	1.10
Total Nitrogen (%)	0.056	0.054
Available - P Bray-1 (ppm)	27.7	21.8
Calcium (me/100g)	3.83	3.93
Potassium (me/100g)	0.66	0.58
Magnesium (me/100g)	1.10	1.12

3.3 Effect of seed maturity and storage conditions on longevity of okra seed

Okra cultivar U.I 117 was sown at the Teaching and Research Farm, University of Ibadan during the late rainy season on 12th September, 1985. The area chosen was ploughed, harrowed and marked out into four blocks each consisting of five plots. The plot size was 3.6 x 3.6 m and each plot separated by guard row of 0.6 m. Planting was done on the flat at a rate of 4 seeds/hill at a spacing of 60 x 30 cm. There were five rows per plot and seven plants per row. Seedlings were thinned to one plant per hill about two weeks after planting.

Treatments consisted of five harvesting regimes which included harvesting of okra pods at 28, 35, 42, 49 and 56 days after flowering (DAF). These were randomized according to a randomized complete block layout. For the purpose of harvesting at different periods, plants from the three middle rows were used. Okra plants in these three rows had their flowers tagged as they opened daily. Pods were harvested as they reached the required age of maturity. The pods from

each harvesting regime were threshed separately and the moisture content of the seeds was determined immediately after threshing (Table 13) by a high constant temperature oven method recommended by ISTA (1976), as described in section 3.1.

The seeds from each harvesting regime were later spread out on a flat top table in the sun, and were stirred several times a day to facilitate drying. During drying, samples were taken daily from each seedlot for moisture content determination. This was done for five days when the moisture content of each seedlot had become constant.

The initial germination percentages of seedlot (Table 14) from each harvesting regime were measured as described in section 3.1.

Three packaging materials were used as seed containers for storage. These were bottles (15 x 7 cm) with screw - top lids; 10-mil polythylene bags and friction - lid tin cans (8x5 cm). Four batches of 5000 seeds from each seedlot of each harvesting regime were placed in four of each type of seed containers. All containers were sealed. Polyethlene bags were sealed with adhesive

tape. Bottles were screw-capped while the friction lids of tin cans were properly fixed. Each container with 5000 seeds was stored in each of the following four storage conditions:

(1) a desiccator with self-indicating silica gel placed on shelf in a laboratory with temperature of 26-30°C and RH of 20-23% inside the desiccator.

(2) a desk drawer in the laboratory with temperature of 26-30°C and RH of 70-75%.

(3) refrigerator located in the laboratory with temperature of 4°C and RH of 50%.

(4) freezer located in the laboratory with temperature of - 3°C and RH of 85%.

Every two months seed germination tests were conducted on each stored seedlot. On each test day, the container from each storage condition was opened and 100 seed samples in four replicates removed for germination tests. The containers were then re-sealed and stored again. The experiment was terminated at the end of 16 months storage period.

3.4 Effect of edible pod removal on seed yield and quality in okra

The studies were conducted at the Teaching and Research Farm, University of Maiduguri during the rainy seasons (18th June to 23 September 1985 and (29th June and 30th September) of 1986.

Okra cultivar TAe 38, an early high yielding cultivar obtained from NIHORT, Ibadan was utilized in this experiment. Fields were ploughed, harrowed and divided into four blocks each with eight 4x4 m plots in a randomized complete block design. Seeds were hand planted at the rate of three to four per hill at a spacing of 60 x 30 cm on flats. There were four rows per plot and seven plants per row. Seedlings emerged within three to seven days and were then thinned to one plant per stand at about two weeks after planting.

There were eight pod removal treatments, which included the removal of the first 2, 4, 6, 8, 10, 12 and 14 edible (one week old) pods per plant plus the control (no pod removal). These treatments were randomized as in a randomized complete block design. For the purpose of pod removals 10 competitive plants

from the two middle rows per plot were used. The following data were gathered on the edible pods removed per plant:

Edible pod Yields

(i) Edible pod yield/plant - The specified number of edible pods removed per plant from 10 middle row plants per treatment were weighed and the average weight recorded as the edible pod yield/plant (g/plant).

(ii) Edible pod yield/ha - The weight of edible pods removed from the 10 plants on an area of 1.8 m^2 in the center of each plot was substituted into the following formula to obtain pod yield/ha:

$$\text{Edible pod yield/ha (kg/ha)} = \frac{10}{A} X$$

where:
X = weight of seed (g)
A = area sampled (m^2)

Fresh weight of edible pods removed/plant. This was estimated as the average fresh weight of edible pods removed from 10 plants in the two middle rows per plot in each treatment.

Dry weight of edible pods removed/plant. This was determined as the average dry weight of edible pods removed from 10 plant in the two middle rows per plant in each treatment. Dry weight was obtained by oven-drying the sample at 100°C to a constant weight.

After the specified number of pickings, all other pods were left on the plant to mature and dry in the field. Dry fruits per treatment were harvested, counted, weighed, shelled and the cleaned seeds weighed. Five pods per treatment in four replicates were oven-dried at 100°C to determine dry matter content.

Seed yield/ha, seed yield/plant, number of seeds/fruit, 1000-seed weight and seed germination percentage were estimated as described in section 3.1. Seed size was determined as the percentage by weight of 100 g of seed per treatment, that passed through a 4.5 mm sieve.

3.5 The relationship of seed viability and seedling vigour with seed size in okra

This study was conducted in the green house of the Department of Agronomy, University of Ibadan during August and September, 1986. Seeds of 20 genotypes of

okra were obtained from NIHORT and the Department of Agronomy and Agricultural Biology, University of Ibadan. The seeds of these genotypes were screened through round perforated screens with a hole diameters of 3.5, 4.0 and 4.5 mm. Each of the respective screened seed-lot was cleaned and used to estimate the following parameters per seed size grade per genotype:

1000-seed weight. This is the weight of 1000 seeds per size grade per genotype. It was estimated as the average of 8 x 1000 seeds from each of seed size grades in each genotype.

Seed germination. Four replicate samples of 100 seeds per seed size grade per genotype were planted on water moistened Whatman No 1 filter paper inside 9 cm petri dishes. The petri-dishes were kept under laboratory conditions for seven days (ISTA, 1976). To estimate percent seed germination only normal seedlings were counted.

Seedling emergence. One hundred seeds in four replicates per seed size grade per genotype were sown in four rows (100 seed/row) inside 50x25 cm plastic trays filled with

sterilized sand. This was kept in a glasshouse condition for seven days. A seed was considered germinated when the plumule emerged. Average number of seedlings that emerged in the four replicates by the seventh day was recorded as percentage of the total number of seeds planted.

Seedling growth. Fifty seeds in four replicates per seed size grade per genotype were sown inside 50x25 cm plastic trays filled with sterilized sand. There were four rows per tray. The trays were kept in a glasshouse for 12 days. On the twelfth day, 24 competitive seedlings were selected from the two middle rows. The seedlings were carefully up rooted, washed and measurement taken of root length, shoot length and fresh weight. Dry weights of seedlings were also recorded after drying in an oven at 80°C to constant weight.

Distribution of seed sizes in seedlots of 20 genotypes of okra.

A composite of 2 kg of seed was obtained from combinations of 100 g seed from each of 20 genotypes. This composite seed was separated into three size grades

of 3.5, 4.0 and 4.5 mm. Seedlots of each size grade were weighed and the weight expressed as percentage of 2 kg seed composite.

The relationships of seed size with seed viability and seedling vigour were determined by the chi-square (X^2) test of association (Steel and Torrie, 1960).

CHAPTER 4

RESULTS

4.1 Okra seed yield stability under different environments

The joint regression analysis of variance for stability of performance, showed significant mean differences among environments, the genotypes and their interactions (Table 4) for most of the characters investigated.

Environmental means for seed yield/plant (Table 8) showed that seed yield ranged from 2.7 g/plant in environment VIII to 38 g/plant in environment I. Environments I to IV located at Maiduguri were the most favourable, while environments V to VIII at Ibadan were the least favourable for seed yield. Generally, for seed yield, yield components and seed quality parameters, mean squares due to environments were larger than the respective genotypic variances, which in turn, were larger than those obtained from the corresponding GxE interaction effects (Table 4).

Table 4 Mean squares from the stability analysis of 15 okra lines computed after Perkins and Jinks (1968)

Sources of variation	DF	Days to first flowering	Days to 50% flowering	Final plant height (cm)	Seed yield plant (g)	No of dry pods/ plant	No of seed/ fruit	1000-seed weight (g)	Seed germination (%)	Seed moisture content at harvest (%)
Genotype	14	266.4**	450.5**	2577.7**	170.9**	3.3**	985.4**	302.6**	739.4**	5.2**
Environment (Joint regression)	7	794.7**	1112.1**	38710.5**	2725.2**	70.5**	9481.1**	529.1**	442.3**	46.4**
Genotype x environment	98	20.8**	30.1**	216.7**	37.7**	1.0**	83.5**	7.8*	48.6NS	1.4**
Heterogenity between regression	14	34.1**	102.8**	906.5**	185.8**	7.0**	268.9**	36.7**	13.4NS	5.7**
Remainder	84	18.6**	18.0**	101.8NS	13.0NS	0.9**	52.6**	3.0NS	54.4NS	0.6NS
Error	360	3.0	1.9	54.9	25.6	0.4	37.8	4.7	45.2	0.6

* Significant at P = 0.05

**Significant at P = 0.01; and N.S. = Not significant

Table 5. Mean seed yield/plant and regression coefficients $(1+B_i)$, for 15 okra genotypes

Genotypes	Seed yield/ plant (g)	Regression coefficients (1 + B_i) and SE
U.I 79-5	16.8	1.17 ± 0.25*
U.I 81-33	13.8	0.98 ± 0.10
U.I 22-77	18.2	1.37 ± 0.18*
U.I C-6-2	10.4	0.56 ± 0.19*
U.I 81-28	8.5	0.68 ± 0.10
U.I 53-139	20.4	1.75 ± 0.47*
TAe 38	15.5	1.24 ± 0.21*
NHAe 47-4	13.7	0.98 ± 0.11
NHAe 15	11.8	0.71 ± 0.40
NHAe 394	11.9	0.82 ± 0.10
Puso	4.2	0.36 ± 0.11*
U.I 104	11.1	0.90 ± 0.10
U.I 117	11.2	0.85 ± 0.16
U.I 211	13.1	0.94 ± 0.30
U.I 10	22.1	1.64 ± 0.32*
Mean	13.5	1.00

* Regression coefficients (1+Bi), significantly greater or less than 1.0. Remaining genotypes have regression coefficients not significantly different from 1.0.

The highly significant genotypic variances also implies that there were real genetic diversities among the fifteen experimental genotypes for most of the characters examined.

Significant heterogeneity for regression mean squares were obtained for number of days to flowering, plant height, number of days to 50% flowering, seed yield/ plant, pods/plant, seeds/fruit and 1000-seed weight. The significant remainder indicated that a significant portion of the variation due to GxE interaction was non-linear.

The average pod yield per plant and regression coefficient of each line are presented in Table 5. Since regression coefficients measure responses of genotypes to changes in the environment, varieties U.I 79-5, U.I 22-77, U.I 53-139, TAe 38 and U.I 10 with regression coefficients greater than unity reflecting above average responses and were consistently high yielders in all better environments such as environments I-IV at Maiduguri. Varieties U.I 81-33 and NHAe 47-4 had an average response of 1+Bi = 0.98, and were adapted to all environments

In this study $(1+ B_i) = 1$ is a measure of stability but the standard errors attached to regression coefficients

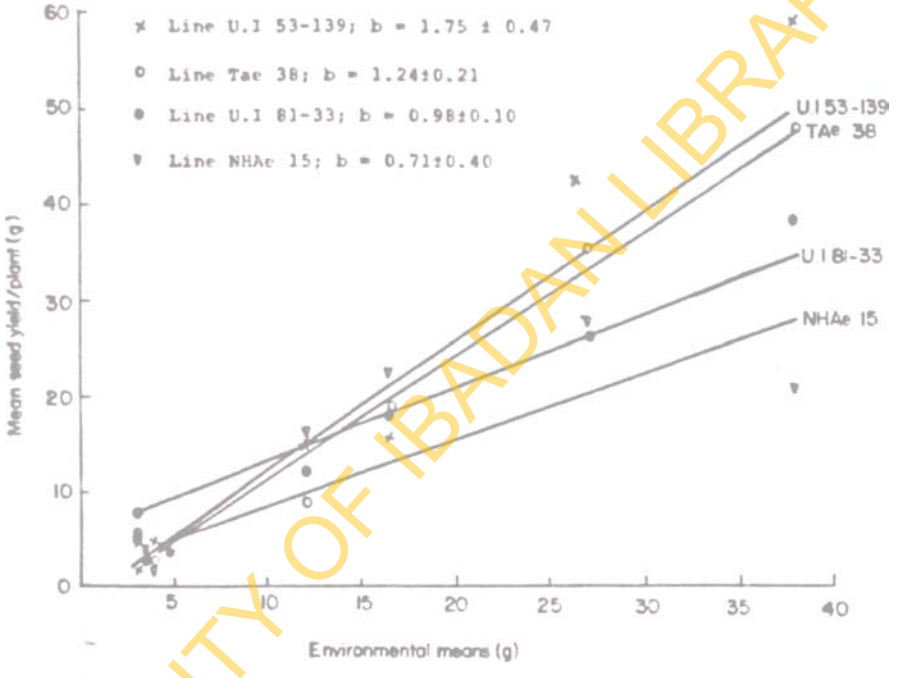

Fig. 1. Regression of the mean seed yields of four okra genotypes on environmental means.

Table 5 Mean values of eight characters in 15 okra lines averaged over eight environments

Genotypes	Days to first flowering	Days to 50% flowering	Final plant height (cm)	No of pods/ plant	No of seed fruit	1000-seed weight (g)	Seed moisture content (%)	Seed germination (%)
U.I 79-5	48.3	56.8	93.6	3.8	77.6	50.6	9.9	61.2
U.I 81-33	61.2	72.7	94.8	3.8	83.2	42.0	10.6	61.5
U.I 22-77	54.6	54.1	74.1	5.1	74.5	47.6	10.2	51.2
U.I c-6-2	46.6	56.6	81.7	4.1	64.8	49.7	9.9	47.8
U.I 81-28	62.2	77.7	86.9	3.6	62.2	38.2	11.0	58.7
U.I 53-139	59.1	66.3	65.5	4.6	77.7	48.6	10.7	55.8
TAe 38	49.3	57.3	90.3	3.8	79.8	51.7	9.3	74.2
NHAe 47-4	60.2	71.5	71.9	3.1	72.2	50.6	9.5	66.8
NHAe 15	56.5	70.2	112.4	4.6	82.8	44.6	11.1	55.0
NHAe 394	60.6	74.3	99.9	3.6	77.4	40.4	11.0	53.6
Pusa	51.6	63.2	63.5	4.6	42.1	29.0	12.4	32.2
U.I 104	63.7	73.7	70.1	3.0	80.5	46.3	10.8	54.0
U.I 117	58.8	71.6	76.7	4.6	78.1	41.6	10.6	48.7
U.I 211	52.3	64.1	68.6	4.1	68.6	41.6	9.5	58.1
U.I 10	56.6	66.1	125.4	4.7	85.8	49.7	9.6	47.7
LSD (0.05)	4.3	3.8	17.0	1.5	15.4	5.5	2.3	17.8

Table 7. Regression coefficient (1+Bi) of mean values of seven characters in 15 okra genotypes across eight environments

Genotypes	Days to first flowering	Days to 50% flowering	Final plant height (cm)	No of pod/ plant	No of seeds/ fruits	1000-seed weight (g)	Seed moisture content (%)	Seed germination (%)
U.I 79-5	0.63±0.16	0.64±0.33	1.15±0.09*	0.74±0.07	1.47±0.01*	1.20±0.20	0.76±0.09*	1.02±0.06
U.I 81-33	0.97±0.28	1.15±0.22	1.35±0.06*	0.82±0.12	1.04±0.09	1.20±0.06*	1.31±0.17	0.81±0.18
U.I 22-27	0.52±0.12*	0.62±0.23	0.82±0.05*	1.44±0.09*	0.84±0.00*	1.08±0.08	0.80±0.11	1.14±0.07
U.I c-6-2	0.61±0.11*	0.80±0.06*	0.75±0.06	0.97±0.08	0.57±0.11*	0.80±0.23	1.11±0.05	0.59±0.17
U.I 81-28	1.07±0.19	1.14±0.22	1.08±0.06	1.01±0.08	0.92±0.16	0.92±0.18	1.45±0.06*	1.11±0.15
U.I 53-139	1.45±0.17*	1.16±0.03*	0.72±0.03	1.54±0.25	1.18±0.09	0.84±0.05*	1.11±0.08	1.24±0.11*
TAc 38	0.56±0.19	0.53±0.12	0.96±0.05	0.71±0.12	1.08±0.15	1.09±0.04	0.84±0.04*	0.98±0.09
NHAe 47-4	1.38±0.22	1.40±0.18	0.87±0.05	0.63±0.11*	1.06±0.09	1.07±0.10	0.46±0.14*	1.01±0.05
NHAe 15	0.80±0.24	0.69±0.08*	1.32±0.08*	1.00±0.22	1.10±0.16	1.52±0.08*	1.50±0.34	1.21±0.12
NHAe 394	1.34±0.19	1.08±0.27	1.21±0.07	0.67±0.08*	0.82±0.11	1.07±0.05	1.23±0.26	1.16±0.13
Pusa	0.73±0.27	0.26±0.20*	0.76±0.07*	1.63±0.27*	0.59±0.08*	0.13±0.16	1.71±0.16	0.71±0.18
U.I 104	1.59±0.28	1.52±0.09*	0.88±0.07	0.69±0.07	1.21±0.05*	1.11±0.05	1.27±0.08*	1.36±0.11*
U.I 117	1.37±0.15*	1.46±0.15*	1.15±0.09	1.11±0.21	0.91±0.06	0.75±0.11	0.48±0.25	0.78±0.13
U.I 211	0.80±0.22	1.11±0.09	0.71±0.07*	0.86±0.17	1.14±0.10	1.55±0.09*	0.23±0.16*	1.25±0.09*
U.I 10	1.14±0.16	1.04±0.04	1.27±0.09*	0.95±0.08	1.06±0.08	1.17±0.13	0.74±0.22	0.58±0.12*

* Regression coefficients, (1+Bi), significantly greater or less than 1.0. Remaining genotypes have regression coefficient not significantly different from 1.0.

may also regarded as another stability parameter (Breese, 1969). Since varieties with the smallest standard error are regarded as being stable, the varieties U.I 81-33 and NHAe 47-4 possess stability of seed yields across all environments under investigation (Table 5).

Figure 1 shows the relative performances of two newly developed lines viz. U.I 53-139, U.I 81-33 and two established varieties: TAe 38 and NHAe 15 with respect to seed yield/plant. U.I 81-33 had fairly constant performance under contrasting environmental conditions, while U.I 53-139 and TAe 38 were better performers in improved conditions.

The regression coefficient of other characters and their corresponding mean values are presented in Tables 6 and 7, respectively. Seed germination being a good measure of seed quality was used to evaluate the quality of seed produced in each environment. The GxE interaction for germination was not significant. However, on average, highest percent germination was obtained from seed produced under environments I to IV located at Maiduguri, followed by environments VII and VIII at Ibadan during

Table 8. Average seed yield (g/plant) of 15 okra genotypes in eight environments

Genotypes	[a] Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	41.5	39.5	18.4	20.5	3.7	3.0	3.5	4.0	16.8
U.I 81-33	38.4	26.1	18.3	12.3	3.0	7.8	2.6	3.0	13.4
U.I 22-77	54.5	34.2	23.8	18.4	5.1	3.1	3.8	3.0	18.2
U.I C-6-2	28.1	14.5	9.5	11.0	6.4	4.0	5.4	4.0	10.4
U.I 81-28	25.1	20.7	9.4	5.2	2.5	1.2	2.1	1.6	8.5
U.I 53-139	59.2	59.3	15.8	15.3	4.5	3.3	4.2	2.6	20.5
TAe 38	48.4	35.1	15.0	9.4	3.2	4.3	5.0	3.6	15.5
NHAe 47-4	35.6	30.2	16.4	14.6	2.2	3.0	3.0	3.0	13.5
NHAe 15	21.3	28.0	22.5	15.5	1.6	2.4	2.9	1.7	11.9
NHAe 394	30.6	26.3	15.1	10.1	5.9	3.0	2.3	2.2	11.9
Puso	13.4	11.8	2.4	2.2	1.0	1.0	1.5	1.1	4.3
U.I 104	34.6	24.4	11.1	11.2	3.5	1.5	2.4	1.3	11.1
U.I 117	35.3	19.9	15.3	8.3	3.2	2.6	3.1	2.3	11.2
U.I 211	36.6	22.3	25.3	11.6	2.5	2.0	2.6	2.3	13.1
U.I 10	67.5	39.8	31.7	15.6	6.0	5.9	6.4	5.8	22.3
LSD (0.05)	8.5	5.6	14.1	8.2	2.2	1.2	1.4	1.5	2.4
Mean	38	28.8	16.6	12.1	3.6	2.9	3.4	2.7	

[a] Environments

I-IV: Maiduguri; V-VIII: Ibadan

Table 9. Average seed germination (%) of 15 okra genotypes in eight environments

Genotypes	[a]Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	73	72	83	83	27	31	65	56	61.2
U.I 81-33	83	72	86	53	33	35	70	60	61.5
U.I 22-77	67	62	82	72	23	12	50	42	51.2
U.I c-6-2	57	34	64	65	32	25	53	53	47.8
U.I 81-28	72	62	94	85	24	29	50	54	58.7
U.I 53-139	74	74	89	77	27	13	48	45	55.8
TAe 38	81	89	96	95	40	46	76	71	74.2
NHAe 47-4	83	76	87	90	39	34	67	59	66.8
NHAe 15	85	77	68	74	21	13	54	48	55.0
NHAe 394	72	60	93	66	26	13	51	48	53.6
Puso	55	51	33	33	5	9	38	34	32.2
U.I 104	72	75	79	86	14	11	49	46	54.0
U.I 117	67	65	57	51	24	19	56	51	48.7
U.I 211	85	67	76	85	20	17	60	55	58.1
U.I 10	63	55	60	43	31	24	52	54	47.7
LSD (0.05)	13.1	11.7	22.9	27.0	19.7	20.3	15.4	12.7	
Mean	72.6	66.1	76.4	70.5	25.7	22.1	55.9	51.9	

[a]Environments

I - IV: Maiduguri; V-VIII: Ibadan

late planting season. Environments V and VI, early season planting at Ibadan were the least favourable for high quality seed production (Table 9).

4.2 Influence of plant population and N on seed yield and quality

(a) Effect of plant population on seed yield and quality

Seed yield/ha was significantly increased at the higher plant population density (111, 110 plants/ha) tested (Tables 10 and 11), when compared to seed yield from the treatment with low plant density (55,555 plants/ha). However, low plant density significantly increased seed yield/plant by 43% than high plant density. High plant population density significantly reduced the number of fruits/plant in both 1985 and 1986 by about 60% below that of low population density (Table 10 and 11). Number of seeds/fruit was not affected by plant population.

Seed quality (measured as percent seed germination, germination rate, percent seedling emergence and 1000-seed weight), was not significantly affected by plant population density. However, seed germination, germination rate and 1000-seed weight were relatively higher in treatment with 55,555 plant/ha than that of 111,110 plant/ha (Table 12).

Table 10: Effects of plant population and N on okra seed yield

Treatments	Seed yields kg/ha 1985	Seed yields kg/ha 1986	Seed yields g/plant 1985	Seed yields g/plant 1986	fruits/plant (no) 1985	fruits/plant (no) 1986	seeds/fruit (no) 1985	seeds/fruit (no) 1986
(A) Plant population/ha:								
55,555	647.5	767.8	27.6	23.1	12	6	104	96
111,110	952.6	1020.3	20.2	15.3	8	3	107	94
LSD (P = 0.05)	45.6	10.1	1.6	1.8	1.9	1.7	NS	NS
(B) N (kg/ha):								
0	617.3	738.9	20.1	15.8	8	3	99	89
65	882.3	947.2	25.7	21.1	10	6	109	103
130	900.4	996.2	26.0	20.7	10	5	110	95
LSD (P = 0.05)	107.7	5.6	2.3	1.9	1.2	1.4	NS	NS

NS = not significant 0.05

Table 11 : Annual okra seed yield (kg/ha) averaged over 1985 and 1986

Plant pop/ha	N levels 0	65	130	Mean
55,555	563.6	831.6	727.8	707.6
111,110	792.6	998.0	1168.8	986.4
Mean	678.1	914.8	948.3	

5% LSD = 21.7

(b) Effect of nitrogen on seed yield and quality

The average seed yield of okra in treatment with 130 kg of N per hectare was 1168.8 kg/ha. This, was the average over a 2-year period and was obtained from plots having a population of 111,110 plants per hectare. The yield from plots with 55,555 plants/ha was significantly less than this, being 727.8 kg/ha (Table 11).

In treatment with 65 kg of N per hectare, the highest average seed yield was 998 kg/ha produced by a population of 111,110 plants/ha as compared to that of 831.6 kg/ha from population of 55,555 plants/ha.

Nitrogen level had a highly significant effect on okra seed yield at different populations. This interaction of population rate x nitrogen level is graphically presented in Figure 2. Seed yields averaged over 1985 and 1986 (Table 11) show that the first level of N (65 kg N/ha) significantly raised seed yield by 35% above the control, a further addition of 65 kg N/ha also produced a significant additional yield of 3.5% above the first 65 kg of N per hectare. There was a significant increase in the number of fruits/plant as the level of N was increased. Seed germination percentage and seedling

Table 12: Effects of plant population and N on okra seed quality

Treatments	Seed germination (%)		Seed germination rate (%)		Seedling emergence (%)		1000-seed weight (g)	
	1985	1986	1985	1986	1985	1986	1985	1986
(A) Plant population/ha:								
55,555	63.4	90.3	19.7	21.6	60.4	82.2	50.9	55.8
111,110	64.0	87.4	18.7	21.2	58.4	82.3	49.0	54.3
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
(B) N (kg/ha):								
0	67.0	91.0	19.4	22.0	61.6	85.3	49.3	55.3
65	64.5	89.5	19.6	21.4	60.6	82.5	50.7	55.2
130	59.6	86.1	18.5	20.8	55.3	79.0	49.8	54.6
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = not significant at P = 0.05

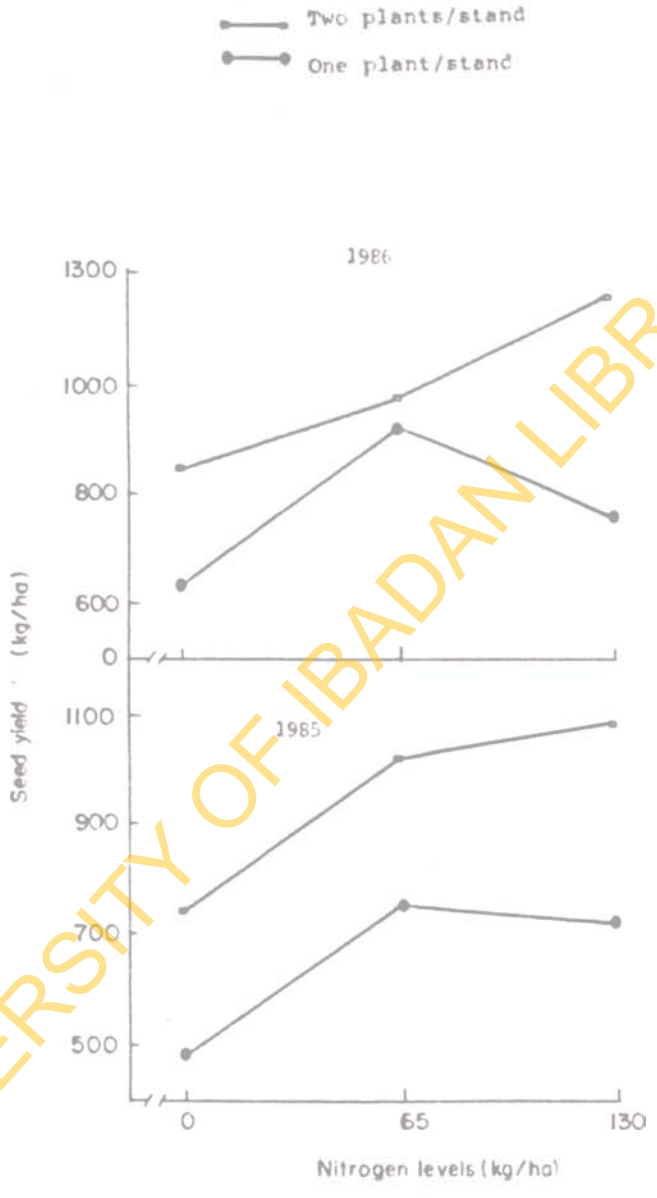

Fig. 2: Effects of N levels on seed yields/ha at different plant population/ha in 1985 and 1986

emergence responded significantly to N levels in 1986 (Table 12). In 1985, none of the seed quality components was significantly affected by N level.

4.3 Effect of seed maturity and storage condition on longevity of okra seed

The moisture content of seeds immediately after harvesting and after drying in the sun is shown in Table 13. Seeds from fruits harvested 28-35 days after flowering had the highest initial moisture content of 21.8 and 16.4%, respectively. Initial seed moisture content decreased with increase in the number of days before harvesting. The highest initial percent seed germination (95%) was obtained from the seeds of fruits harvested at 35 WAP (Table 14).

(a) Effects of maturity on seed viability in storage

Effects of different harvesting regimes, seed containers and storage conditions on viability of okra seeds were presented in Tables 15 and 16. Deterioration was more marked in seed harvested at 28 DAF than seeds harvested at 35, 42, 49 and 56 DAF. Compared to

Table 13: Seed moisture content before drying

Harvesting regimes (DAF)	Percentage moisture content of seed (%)
Initial moisture content	
28	21.8
35	16.4
42	9.9
49	9.5
56	9.1
Moisture content after drying	
28	9.4
35	9.2
42	9.2
49	9.1
56	9.0

Table 14: Initial percent seed germination after drying

Harvesting regime (DAF)	Initial germination (%)
28	69
35	95
42	89
49	86
56	87

initial germination percentage in Table 14, seeds harvested at 28, 35, 42, 49 and 56 DAF deteriorated by 50.7, 36.8, 31.4, 32.5 and 35.6%, respectively after 16 months in storage (Table 16). Thus seeds harvested earlier after flowering deteriorated at a faster rate.

(b) Effect of seed containers and storage conditions on seed viability

Seeds packed in polythene bags, tin cans and glass bottles deteriorated at a similar rate throughout the 16 months of storage (Table 16). Compared to seed germination after two months of storage, viability declined by 31.5, 30 and 25% for seeds packed in glass bottles, tin cans and polythene bags, respectively after 16 months of storage.

Table 15 Effect of harvesting regimes and storage conditions on the germination of okra seed

Harvesting regime	Storage container	Storage conditions	Months of storage								Mean
			2	4	6	8	10	12	14	16	
28 DAF	Glass bottle	Desiccator (30°C & 23% RH)	46	52	22	28	36	36	24	22	32.5
		Drawer (30°C & 75% RH)	59	68	38	28	20	14	10	10	32.1
		Refrigerator (4°C & 50% RH)	76	70	58	60	56	50	44	60	59.7
		Freezer (-3°C &85% RH)	47	52	60	64	68	72	50	48	57.6
	Polythylene bag	Desiccator (30°C & 23% RH)	50	50	36	24	28	16	32	24	32.5
		Drawer (30°C & 75% RH)	51	70	46	42	46	38	26	16	41.8
		Refrigerator (°C & 50% RH)	57	66	58	50	57	46	56	50	54.3
		Freezer (-3°C & 85% RH)	50	60	54	54	68	66	54	62	56.0
	Tin cans	Desiccator (30°C & 23% RH)	35	44	20	38	22	22	14	14	26.1
		Drawer (30°C & 75% RH)	58	58	40	30	34	32	12	11	34.3
		Refrigerator (4°C & 50% RH)	65	76	60	52	80	80	64	54	66.3
		Freezer (-3°C & 85% RH)	52	52	44	42	44	46	34	44	44.7
35 DAF	Glass bottle	Desiccator (30°C & 23% RH)	74	58	50	36	30	30	36	22	42.7
		Drawer (30°C & 75% RH)	90	96	84	74	62	50	44	30	66.7
		Lower (4°C & 50% RH)	78	86	72	72	78	84	96	94	87.2
		Freezer (-3°C & 85% RH)	81	90	74	80	80	88	80	62	79.3
	Polyethylene bag	Desiccator (30°C & 23% RH)	73	70	32	34	42	38	40	38	46.6
		Drawer (30°C & 75% RH)	78	78	70	76	74	72	66	70	72.2
		Lower (4°C & 50% RH)	81	98	74	72	88	74	94	80	82.6
		Freezer (-3°C & 85% RH)	74	86	84	74	82	82	92	84	82.5
	Tin cans	Desiccator (30°C & 23% RH)	67	64	36	24	46	44	44	21	43.2
		Drawer (30°C & 75% RH)	93	92	82	78	70	54	26	36	67.1
		Lower (4°C & 50% RH)	81	88	84	88	86	78	86	88	82.6
		Freezer (-3°C & 85% RH)	75	86	80	78	82	86	90	98	69.4
42 DAF	Glass bottle	Desiccator (30°C & 23% RH)	58	40	42	47	46	44	52	36	45.6
		Drawer (30°C & 75% RH)	89	76	86	68	62	56	36	34	63.6
		Lower (4°C & 50% RH	84	82	78	79	84	74	78	62	78.5
		Freezer (-3°C & 85% RH)	96	82	82	84	82	71	72	80	81.6
	Polyethylene bag	Desiccator (30°C & 23% RH)	72	66	46	26	54	46	46	32	48.7
		Drawer (30°C & 75% RH)	93	88	72	76	78	78	68	48	75.1
		Lower (4°C & 50% RH)	90	92	86	74	78	76	78	63	79.8
		Freezer (-3°C & 95% RH)	90	82	84	80	86	81	78	74	81.8
	Tin cans	Desiccator (30°C & 23% RH)	52	48	46	30	48	28	40	30	40.2
		Drawer (30°C & 75% RH)	86	82	84	72	82	68	56	38	71.2
		Lower (4°C & 50% RH)	89	92	90	86	88	70	84	78	84.6
		Freezer (-3°C & 85% RH)	94	84	82	82	84	80	78	81	83.1
49 DAF	Glass bottle	Desiccator (30°C & 23% RH)	53	68	28	24	46	44	52	36	43.8
		Drawer (30°C & 75% RH)	77	82	82	64	64	44	40	64	64.6
		Lower (4°C & 50% RH)	86	88	84	78	78	84	80	82	79.5
		Freezer (-3°C & 85% RH)	80	82	84	86	80	86	72	76	80.7
	Polyethylene bag	Desiccator (30°C & 23% RH)	61	54	46	54	56	52	46	40	51.3
		Drawer (30°C & 75% RH)	84	84	82	72	68	64	68	48	71.2
		Lower (4°C & 50% RH)	78	85	70	76	72	78	86	68	76.75
		Freezer (-3°C & 85% RH	79	74	76	76	82	88	74	76	78.1
	Tin cans	Desiccator (30°C & 23% RH)	57	50	42	52	46	44	44	28	46.3
		Drawer (30°C & 75% RH)	87	80	68	64	56	52	48	34	81.1
		Lower (4°C & 50% RH)	71	74	72	78	76	80	64	66	72.6
		Freezer (-3°C & 85% RH)	75	74	82	76	86	86	74	82	79.6
56 DAF	Glass bottle	Desiccator (30°C & 23% RH)	77	74	50	43	50	56	44	40	56.3
		Drawer (30°C & 75% RH)	87	88	78	70	65	60	32	30	63.7
		Lower (4°C & 50% RH)	83	84	72	84	88	84	80	76	81.3
		Freezer (-3°C & 85% RH)	90	86	84	86	86	84	78	76	83.2
	Polyethylene bag	Desiccator (30°C & 23% RH)	74	72	50	54	68	70	58	48	61.7
		Drawer (30°C & 75% RH)	85	84	80	60	64	50	72	36	66.3
		Lower (4°C & 50% RH)	88	82	80	88	85	80	82	82	83.3
		Freezer (-3°C & 85% RH)	84	84	82	82	88	80	86	86	84.0
	Tin cans	Desiccator (30°C & 23% RH)	69	62	42	52	48	64	60	34	53.8
		Drawer (30°C & 75% RH	87	86	78	70	72	62	40	14	63.6
		Lower (4°C & 50% RH)	75	86	78	80	88	86	84	68	30.3
		Freezer (-3°C & 85% RH)	78	84	80	84	84	92	82	80	83.1

Table 16 Percent germination of stored okra seed averaged over harvesting regime, storage containers and storage conditions.

Storage treatments	Months of storage								Mean
	2	4	6	8	10	12	14	16	
	% germination								
Harvesting Regimes:									
28 DAF	54	58	45	43	46	44	35	34	44.8
35 DAF	79	73	68	65	66	65	66	60	67.7
42 DAF	83	76	73	67	68	64	64	61	69.5
49 DAF	74	75	66	67	68	67	62	58	67.1
56 DAF	82	81	71	71	73	72	67	56	71.6
Storage containers:									
Bottles	76	75	64	63	63	61	55	52	63.6
Polyethylene bags	75	75	66	62	68	64	65	56	66.3
Tin cans	72	72	64	63	66	63	56	50	63.2
Storage conditions:									
Desiccator (30°C & 23% RH)	61	58	39	38	42	42	40	31	43.8
Desk drawer (30°C & 75% RH)	70	71	72	63	61	54	43	34	58.5
Refrigerator (4°C & 50% RH)	79	83	71	74	76	75	74	71	75.3
Freezer (-3°C & 85% RH)	76	76	75	75	76	74	73	74	74.8

* This table was computed from Table 15.

Harvesting regimes: Percent seed germination averaged over seed containers and storage condition for each harvesting regime.

Storage containers: Percent seed germination averaged over harvesting regimes and storage condition for each seed container.

Storage condition: Percent seed germination averaged over seed container and harvesting regimes for each storage condition.

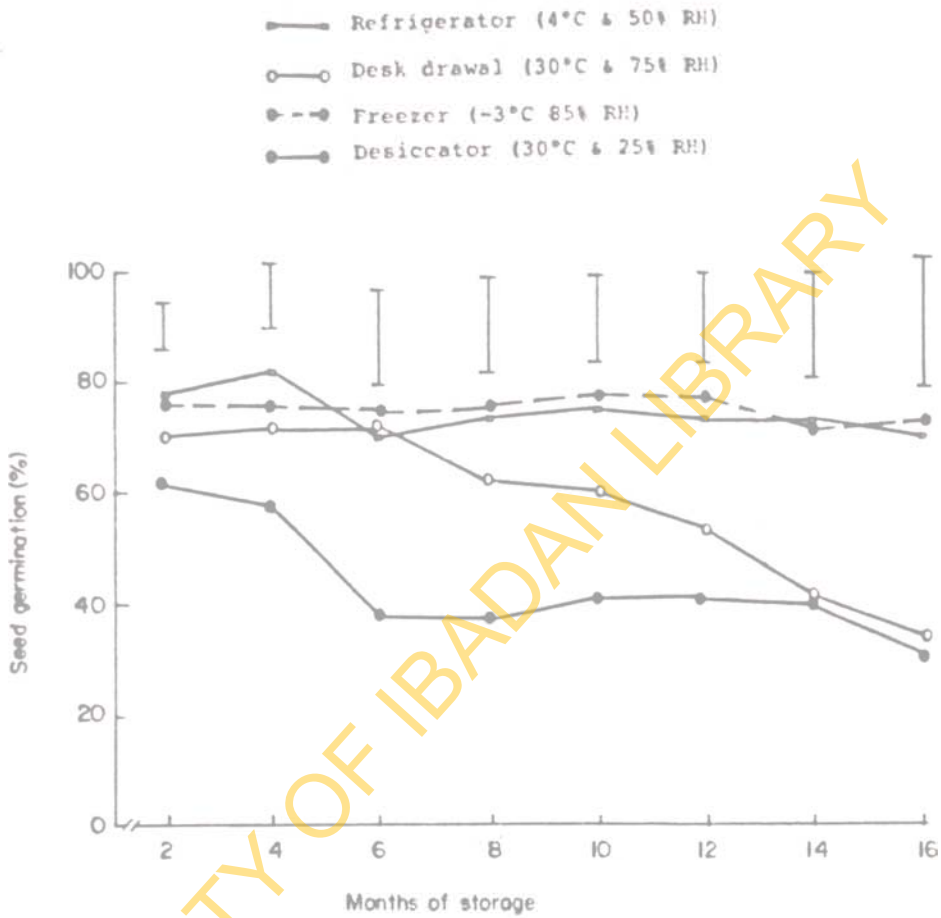

Fig. 3. Percent germination of okra seed stored under storage conditions of refrigerator, desk drawer, freezer and desiccator. Vertical lines represent standard errors.

The effect of storage temperature and RH was evident throughout the 16 months of storage (Figure 3). The most rapid decline in viability was observed in seeds stored inside desiccator at 30°C and 25% RH and desk drawer at 30°C and 75% RH. There was no significant difference between the viability of seed stored in the freezer (-3°C & 85% RH) and refrigerator (4°C & 50% RH) throughout the storage period (Figure 3). The reduction in viability of seeds stored under four storage conditions were 51, 49, 10 and 3% for desk drawer (30°C & 75% RH), desiccator (30°C & 23% RH), refrigerator (4°C & 50% RH) and freezer (-3°C & 85% RH) respectively, at the end of 16 months of storage (Table 16). Seeds sealed in polyethlene bags and stored inside refrigerator at 4°C and 50% RH gave the highest percent germination at the end of 16 months of storage.

4.4 Effect of edible pod removal on seed yield and quality in okra

(a) Effect of edible pod removal on pod yield

The effect of different number of pod removal on total number of pods/plant were similar for both years (Figure 4 and Table 17). The total number of pods/plant

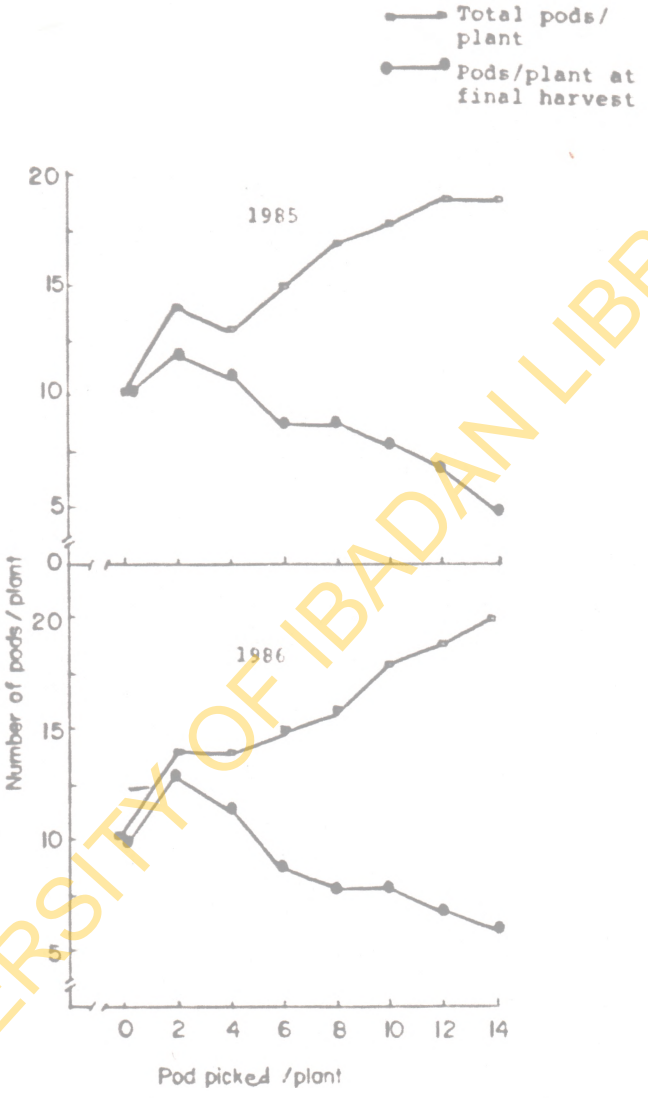

Fig. 4 Effect of pods picked on pod number/plant in 1985 and 1986.

Table 17. Response of seed yield parameters to pod removal in okra (average of 1985-1986)

Number of pods removed	Field dried wt of pods/plant (g)	Pods/plant at harvest (no)	Seed yield per plant (g)	1000-seed weight (g)	Plant height (cm)	Total pods/ plant (no)
Control	109.3	10	65.6	60.5	130.5	10
	Effect of treatment expressed as percent increase (+) or decrease (-) from control					
2	+16.4	+20	+ 2.6	+4.6	+ 17.6	+45
4	+ 6.6	+10	+ 1.6	+2.5	+ 19.3	+35
6	- 6.5	-10	-36.6	-1.6	+ 39.1	+50
8	-19.7	-10	-51.4	-2.3	+ 45.2	+65
10	-29.2	-20	-66.7	-4.2	+ 52.1	+80
12	-42.4	-30	-74.3	-4.0	+ 65.9	+90
14	-55.4	-50	-80.8	-4.8	+102.7	+95
LSD (0.05)	14	3	13	7	32	3

increased significantly as more edible pods were removed per plant. Total dry matter of harvested edible pods/ plant also increased with increased number of pods removed (Figure 5).

The number of sun-dried pods/plant were significantly reduced by about 10-50% when 6-14 edible pods were removed per plant (Figure 4, Table 17'). A significantly high number of sun-dried pods were obtained from the plants with two and four pods picked/plant (figure 4 and Table 17), and increases of 20% and 10% above the control resulted from picking two to four pods per plant, respectively (Table 17). Sun-dried weight (pods/plant) of pods remaining on the plants after each pod removal treatments was significantly reduced by treatments with 6, 8, 10, 12 and 14 pods picked/plant (Table 18). However, the removal of two and four pods/ plant increased field dried weight of pods/plant by 16 and 7%, respectively in both years (Table 17). Different intensities of pod removals per plant had no appreciable effect on the total pod dry matter yield per plant (Figure 5).

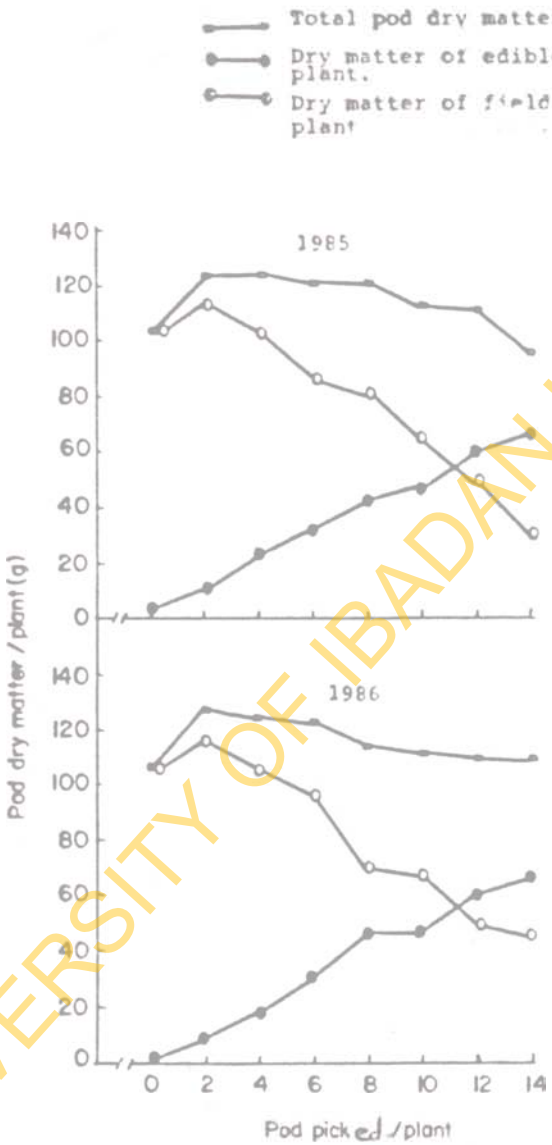

Fig. 5. Effect of pods picked on dry matter/plant in 1985 and 1986

Table 18 Effect of pod removal on pod and seed yields of okra

Characters	Number of pods picked/plant								
	Control	2	4	6	8	10	12	14	LSD (0.05)
				1985					
Edible pod yield (t/ha)	-	1.8	3.9	6.6	10.3	11.2	14.1	15.3	2.4
Edible pod yield (g/plant)	-	59.8	128.8	219.1	342.2	372.6	469.2	509.8	81.9
Field dried wt. of harvested pods (g/plant)	110.1	125.8	115.6	90.7	92.3	74.8	61.3	42.7	13.6
Seed yield (kg/ha)	2068.4	2149.2	1688.4	1365.5	938.6	530.9	435.8	327.4	249.7
Seed yield (kg/plant)	68.9	71.6	63.3	45.5	31.3	17.7	14.5	10.9	8.3
Seeds/pod (no)	107	106	103	101	95	90	90	82	30.5
				1986					
Edible pod yield (t/ha)	-	1.9	4.0	6.6	9.6	10.9	12.5	16.7	1.3
Edible pod yield (g/plant)	-	63.3	132.6	218.8	320.8	364.3	416.6	558.1	43.9
Field dried wt. of harvested pods (g/plant)	114.5	128.7	117.5	107.6	83.1	80	64.7	54.9	14.7
Seed yield (kg/ha)	1870.4	1968.7	1602.7	1129.7	974.4	772.9	575.9	426.1	533.7
Seed yield (g/plant)	62.4	63.3	64.4	37.6	32.5	25.8	19.2	14.4	17.1
Seeds/pod (no)	144	150	148	132	124	88	68	64	30.0

Table 19 Change in seed quality with varying number of pods picked per plant

Character	Number of pods removed per plant								
	Control	2	4	6	8	10	12	14	LSD (0.05)
				1985					
Seed germination (%)	96	97	95	94	92	88	85	72	7.2
1000-seed weight (g)	60.0	65.2	62.5	59	59.5	59.5	58.0	59.0	5.6
Seed size, (as percentage (g) of 100g of seed that passed through 4.5 mm sieve)	70	73	72	69	67	66	67	65	5.7
				1986					
Seed germination (%)	91	76	94	94	91	86	85	76	16.9
1000-seed weight (g)	61.0	64.0	62.5	59.5	59.5	58.2	57.5	57.7	8.0
Seed size (as percentage (g) of 100 g of seed that passed through 4.5 mm sieve)	72	71	70	68	66	66	65	64	4.8

(b) Effect of pod removal on seed yield

Seed yields of control plants, from which no pods were picked, were significantly higher than for treatments with more than four pods picked/plant (Table 18). Compared to the control, seed yield/plant declined by 36, 51, 66, 74 and 80% for treatments with 6, 8, 10 12 and 14 pods picked/plant, respectively whereas removal of up to 4 pods/plant increased seed yield by about 2-3% (Table 17).

(c) Effect of edible pod removal on seed quality

Seed quality as measured by seed germination, seed weight and size declined significantly with increased pod removal per plant (Table 19). General reductions in seed germination 1000-seed weight, and seed size were observed with treatments beyond six pods picked per plant.

4.5 The relationship of seed viability and seedling vigour with seed size in okra

The means and standard errors of seed and seedling vigour characteristics as well as their association with seed size in 10 genotypes of okra are presented in Table 20. In the 10 genotypes of okra, 3.5, 4.0 and

Table 20: Mean values, standard errors and association of seven seed and seedling vigour characters with seed size in ten varieties of okra

Characters	Seed size (mm)			Association with seed size
	3.5	4.0	4.5	χ^2
1000-seed weight (g)	25.1± 2.84	39.2± 4.60	51.1± 5.51	37.88**
Seed germination (%)	45.1±15.91	79.0±12.62	89.6± 9.96	33.32*
Seedling emergence (%)	32.9±16.38	60.7±10.43	72.2±12.73	51.72**
Seedling root length (cm)	3.0± 0.85	4.6± 1.02	7.5± 1.17	4.48
Seedling shoot length (cm)	7.7± 1.12	9.4± 1.01	10.9± 1.77	0.89
Seedling fresh weight (g)	0.2± 0.07	0.3± 0.06	0.4± 0.08	0.06
Seedling dry weight (g)	0.03±0.005	0.05±0.007	0.06±0.008	0.002

* = significant at the 5% level; ** = significant at the 1% level

values are averages of 10 varieties

4.5 mm seed size grades were significantly different with regard to seed germination, seedling emergence and 1000-seed weight. There was no significant association between seed size and seedling root length, shoot length, fresh and dry weights.

Seeds in categories of 4.0 and 4.5 mm size grades were more vigorous as indicated by their high 1000-seed weight, percent seed germination and seedling emergence. The performance of seeds in the three size categories were not significantly different in terms of seedling root length, shoot length, fresh and dry weights as shown in Table 20. Low standard errors attached to mean values of seed and seedling vigour components also indicate uniform seed germination and seedling emergence in the seed size categories of 4.0 and 4.5 mm as compared to germination and seedling emergence in 3.5 mm size grade.

The composite seedlot comprising equal quantities of seeds from each of 20 genotypes gave 56% of 4.5 mm seeds, 36% of 4.0 mm seeds and 7% of 3.5 mm seeds (Figure 6).

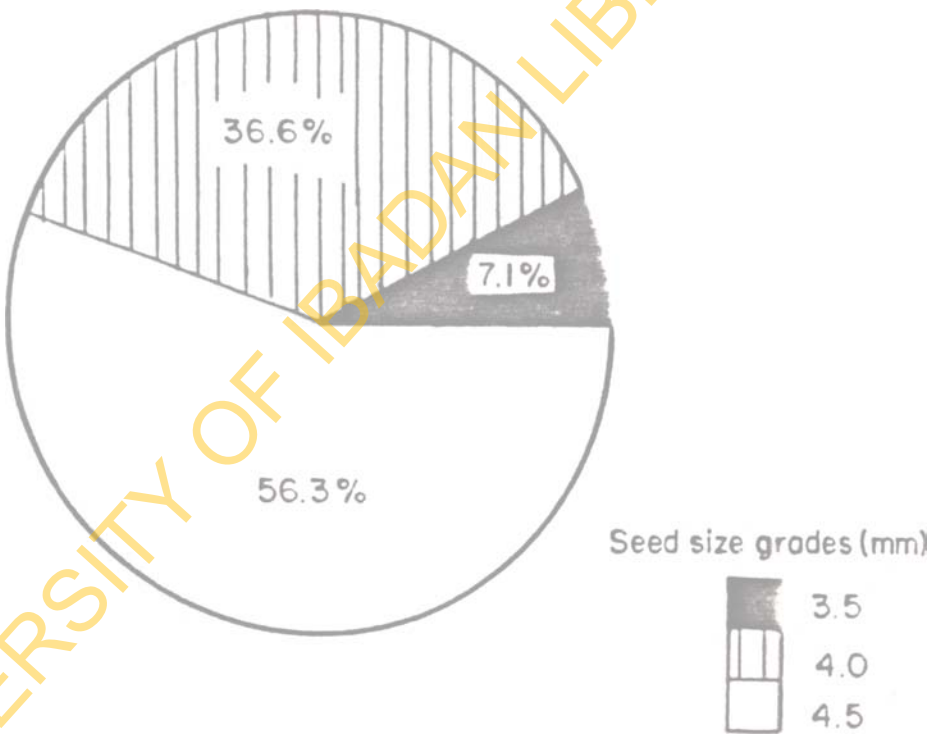

Figure 6. Distribution of seed sizes in a composite of 100g of seed from 20 cultivars

CHAPTER 5

DISCUSSION

Seed yield and quality in okra were significantly influenced by ecological regions of production varieties of okra, methods of cultivation and post-harvest handling and processing of seeds.

Although it is difficult to breed varieties individually adapted to all ecological conditions, breeding methods can be directed towards producing varieties with wide adaptation and high yield under different ecological zones. The two sites used in this study, provided contrasting ecological conditions. Seed yields varied between sites and there were differences in the relative performance of the varieties between sites. This was reflected in the significant GxE interaction for most of the characters examined in the present investigation.

The parameters commonly used in selecting varieties for high yield and stability of performance are mean yield, regression coefficient and minimum deviation from linear regression (Eberhart and Russell, 1966; Breese,

1969). Breese (1969) defined a stable variety as one having unit regression and sufficiently small standard error attached to the regression coefficient, while Perkins and Jinks (1968) define stable genotype as one with a unit regression coefficient ($1 + Bi = 1$). Thus, a variety that does not meet these requirements would be regarded as unstable.

In this investigation the regression of mean yields on environment means indicated that a significant portion of the total variation among genotypes was accounted for by linear regression although a portion of this variation was non-linear as indicated by significant remainder mean squares. The significantly large environmental differences further demonstrated the significant variation between the environments even when the trials were carried out at the same location.

Genotypes with above average performance were those that had regression coefficients greater than unity (Perkins and Jinks, 1968; Breese, 1969). Such genotypes will show an above average response to an improvement in the environment and hence may be useful if its growth

is confined to the better environments. While regression coefficients measure the responses of genotypes to environmental conditions, its standard error measures the stability of responses. In the present investigation, genotypes U.I 81-33 and NHAe 47-4 are stable and most desirable interms of seed yield/plant, because their mean seed yields were high, had regression coefficient closer to unity (0.98) with low standard error indicating yield stability. Genotypes U.I 79-5, U.I 22-77, U.I 53-139, TAe 38 and U.I 10 all of which had regression coefficients greater than unity together with large standard errors performed well only in the above average environments. Although other genotypes possess regression coefficients not significantly different from 1.0, their large standard errors indicate that they are unstable, according to Breese's (1969) definition of stability.

The lack of significance among the linear responses of the genotypes to environments in terms of percent seed germination, indicates that all genotypes responded the same way to environments in terms of the quality of seed produced. However, the large and significant environment mean square for percent seed germination shows that the

influence of environmental effects on percent seed germination of the genotypes as a whole is more important than the mean differences in percent seed germination between the genotypes and by far greater in importance than the interactions of the genotypes with the environment. This indicates that climatic variation from one site to another may be the main factor that determines most of the percent seed germination differences of the genotypes in the different environments. Thus the highest percent seed germination of different genotypes were obtained from among seeds produced at environments I, II, III and IV at Maiduguri and environments VII and VIII at Ibadan. These environments which are favourable for high quality seed production are characterized by relatively low precipitation, low relative humidity and high number of sunshine hours with hot dry weather at the time when seeds were ripening. These conditions are favourable for seed production generally (Austin, 1972) as they guarantee quick drying of the fruits and largely eliminate the detrimental effects of climatic and biodeteriorating agents on the seed.

This study further indicated that the higher population density of okra plants (111,110 plants/ha) enhanced seed production over the lower plant population (55,555 plants/ha), with 39% more seed yield at the higher plant population even though there were no differences in the viability of seeds produced. Similar results on seed yield and viability from increasing plant population have been observed in South America (Zanim and Kimoto, 1980). Applied N raised okra seed yield, but did not have any significant effect on seed viability. This agrees with observations of Singh and Pandita (1981) that high N levels increased okra seed yield but does not significantly affect seed quality and vigour.

Mature okra seed remained viable in storage for longer periods than seeds at various levels of immaturity. This finding supports earlier reports of Bass (1965) for Kentucky bluegrass seed. Orthodox seeds such as

okra often require drying and packaging in moisture barrier containers to prevent loss of viability in storage. In the present study, the viability of seeds packed in tin cans, polythene bags and glass bottles after 16 months of storage were comparable. This indicates that the resistance of the three packaging materials to moisture transmission were similar. However, since temperature and RH have been identified as the two most important factors determining longevity of stored seed (Bass, 1973), it is necessary to view the effects of packaging materials in conjunction with temperature and RH of the storage environments. In this study, the decline in okra seed viability was directly related to storage temperature and RH, packaging materials not withstanding. The effects of these two factors of the storage environment on seed germination after 16 months of storage suggests that temperature of

the storage area may be more important than RH in determining the duration of safe storage of okra seeds. Thus seed stored at high temperature (30°C) lost viability more rapidly at either low RH (23%) or high RH (75%) than when stored at low temperature (-3 to 4°C) with low RH (50%) or high RH (85%). Martin et al (1960) stored okra seed at 2-4°C for 11 years without appreciable loss in viability.

The adverse effect of storage at high temperature (30°C) and low RH (23%) on okra seed longevity was also evident. This effect is not special to okra seed. Seeds of cotton, another member of the malvaceae, also lost viability quite rapidly at room temperature of 30°C and 25% RH (McComb and Lovestead, 1954), but peanuts stored best at room temeprature (30°C) and 85-90 RH (Mathur et al, 1956).

According to Harrington (1960) a rule of thumb for safe storage is that "the sum of temperature in degree Fahrenheit plus the percent RH should not exceed 100". In this study the sum for the best storage condition (4°C (39°F) & 50% RH) and (-3°C (28°F) & 85%) ranged from 89 to 113. This suggests that a reasonably safe storage

of okra seed can be achieved by use of temperature and RH combinations which only slighly exceed the Harrington's (1960) sum of 100. This implies that the safe storage period probably would be shorter for seed stored in the freezer (-3°C & 50% RH) with combinations of less than 100. However, Bass (1967) recommendation for a sum not exceeding 120 with temperature contributing less than half was satisfied.

The combined yields of plantable seeds and edible pod per plant indicate that there is significant advantage in a limited harvest of edible pods from the same okra plants which are to be utilized for seed production. The increase in total pod yield per plant with increasing number of pods picked may be attributed to new buds added to those present at each harvest. Removal of edible pods, reduced competition for assimilates among (i) developing fruits and (ii) flowers that are yet to form fruit. Both of these, therefore receive more assimilates with removal of edible pods resulting in a higher percentage fruit set in treatments with higher number of pods picked. The reduced total pod (edible and

field-dry pods) number per plant in control and treatments with 2-4 pod pickings per plant was due to accumulation of pods that are not removed, such that competition for assimilates among developing fruits increases with each additional fruit set. This resulted to lesser share of assimilates to new fruits, causing a majority of the later fertilized flowers to abort. This result agree with the reports of Kolhe and Chavan (1967) and Akoroda (1986) that pod yield in okra increased with increase in the number of edible pods picked per plant.

Removal of more than four edible pods per plant significantly reduced the number of field dried pods per plant at final harvest. Since seeds constitute 57% of dry pod weight (Akoroda 1986), fewer field-dried pods per plant would also be associated with lower seed yield per plant as shown in this study. Velumani and Ramaswamy (1980) found that okra plant tolerates only the removal of the first two pods per plant without significant reduction in seed yield and pod number per plant at final harvest. However, in the present study

okra plants not only tolerated the removal of the first 2-4 pods per plant but also produced more pods (15%) and seed (3%) above the control (unpicked plant).

It is noteworthy that where up to four pods were removed per plant, there was a relative compensatory increment in the total pod dry matter yield per plant. This explains the high 1000-seed weight and large size of seeds obtained from such treatments. This results agrees with the report of Velumani and Ramaswamy (1980), that the removal of the first two pods per plant does not have adverse effects on seed quality. However, in pickings beyond four pods per plant, the total pod dry matter yields per plant declines. This may be due to the increased competition for assimilates between the stem and the remaining pods on the plant. With few number of pods on the plant, the stem act as a major sink where most of the assimilates are deposited. This was reflected by a sudden increase in plant height when over 4 pods were picked per plant as Velumani and Ramaswamy (1980) also reported.

The results of this investigation also indicate that seed size is a good measure of okra seedling establishment in the field. Large seeds (4.0-4.5 mm) produced seedlings which showed more vigour and attained greater fresh and dry weights than did seedlings grown

from smaller seeds (3.5 mm). Similar effects of seed size on seed and seedling vigour have been observed in cotton (Gelmond, 1972) and onion (Hewston, 1964).

The association of 1000-seed weight, seed germination and seedling emergence with seed size indicate that the rapidity of seed germination and plumule emergence depends on the size of seed planted. But, lack of association between seed size and seedling root length, shoot length, fresh and dry weights showed that subsequent seedling growth and development after the initial seed germination and seedling emergence does not bear any relationship with seed size. This agrees with the findings of Oexemann (1942) that the superiority of seedlings from larger seeds of soyabean, tomato and cucumber disappeared completely at plant maturity.

Considering the greater vigour of large okra seeds (4.0 - 4.5 mm) compared to small seeds (3.5 mm), it appears that large seed should be preferred. Thus, it may be recommended that 3.5 mm seeds be removed before planting, but their low proportion (7%) may render such an operation unnecessary.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Investigations were conducted at Ibadan and Maiduguri between 1984 and 1986 on the problems associated with production of high quality okra seeds needed for the improvement of edible okra fruit production in Nigeria. The results, summarized below, provide a reliable basis for developing appropriate techniques for the production of high quality okra seed:

(1) The variety trials under different environmental conditions indicate that variation in seed yield from one environment to another could be attributed to variation in precipitation, relative humidity and sunshine hours. Locations or sites with relatively low precipitation, low relative humidity and high sunshine hours which provide hot dry weather at pod ripening supported the highest seed yields and quality.

(2) Evaluation of stability of seed yields performance using regression method revealed that the varieties exhibited differential responses to varying conditions. Some varieties also performed better in some environments than in others, suggesting the possibility of producing seeds of certa varieties in specific environments.

(3) Improved soil fertility status is necessary for high seed yields in okra. In the present study, 130 kg N/ha significantly raised yields of okra seed above no N and 65 kg N/ha. The higher plant population density of 111,110 plants/ha resulted in the higher seed yields of 986.5 kg/ha compared to 707.7 kg/ha with 55,555 plants/ha.

(4) Mature okra seed harvested 35-49 DAF remained viable longer than immature seed harvested 28 DAF. Mature seed stored in polyethylene bags at 4°C with 50% RH retained most of their viability after 16 months of storage.

(5) Investigations on the effects of edible pod removal on seed yield and quality, showed that the removal of the first 2-4 edible pods/plant enhanced more pod formation leading to higher seed yields/plant. Edible pod pickings above 6 pods/plant reduced seed yield/plant by 36-80% below the control, with corresponding adverse effect on seed quality measured by percent seed germination and 1000-seed weight.

(6) The Chi-square (X^2) tests of association between seed vigour and seed size indicate significant association between seed germination and seedling emergence on one hand and seed size on the other. Seeds within the size grade of 4.0-4.5 mm are more vigorous than seed within 3.5 mm size grade.

Based on the results of the present study, hot dry weather during seed ripening, good soil fertility status, proper grading of seed and timely harvesting of pods are necessary for high seed yields and quality in okra seed production.

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APPENDICES

Appendix I: Sources of okra genotypes used in this study

	Genotypes	Sources
1.	U.I 79-5	Ibadan, Oyo State
2.	U.I 81-33	Ibadan, Oyo State
3.	U.I 22-77	Ibadan, Oyo State
4.	U.I C-6-2	University of Ibadan, Oyo State
5.	U.I 81-28	University of Ibadan, Oyo State
6.	U.I. 53-139	University of Ibadan, Oyo State
7.	TAe 38	NIHORT, Ibadan
8.	NHAe 47-4	Zaria, Nigeria
9.	NHAe 15	NIHORT, Ibadan
10.	NHAe 394	NIHORT, IBADAN
11.	Puso	University of Ibadan Oyo State
12.	U.I 104	Iseke-origbo, Bendel State
13.	U.I. 117	Igbeagu near Abakaliki, Anambra State
14.	U.I 211	Ibadan, Oyo State
15.	U.I. 10	Oghun village, near Ibadan, Oyo State

Appendix II: Characteristics of okra genotypes utilized in okra seed production studies

Genotypes	Characteristics
U.I 79-5	Early flowering, heavy, plump and long pods, fairly large number of branches and pods.
U.I 81-33	Late flowering, heavy, plump and short pods; few branches and pods.
U.I 22-77	Early flowering, heavy, plump and short pods; large number of branches and pods.
U.I C-6-2	Early flowering, heavy plump and medium size pods; few branches and pods.
U.I 81-28	Late flowering, heavy, plump and short pods; fairly large number of branches and pods.
U.I 53-139	Fairly late flowering, heavy, plump and medium size pods; fairly large number of branches and pods.
TAe 38	Early flowering, heavy, plump and long pods; very few branches and fairly large number of pods.
NHAe 47-4	Late flowering, heavy, plump and medium size pods; fairly large number of branches and pods.
NHAe 15	Fairly late flowering, heavy slender pods; few branches and pods.
NHAe 394	Late flowering, light and short pods; few branches and pods.

Genotypes	Characteristics
Puso	Fairly late flowering, light slender long pods; fairly large number of branches and pods.
U.I 104	Late flowering, heavy, plump and short pods; fairly large number of branches and pods.
U.I 117	Very late flowering, heavy, plump and short pods; very large number of branches and pods.
U.I 211	Fairly late flowering, heavy, plump and medium size pods; large number of branches and pods.
U.I 10	Fairly late flowering, relatively light, plump and short pods; very few branches and pods.

APPENDICE III: Average 1000 - seed weight (g) of okra genotypes in eight environments

Genotypes	Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	60.0	58.0	56.2	56.5	43.7	41.7	45.7	43.7	50.6
U.I 81-22	49.7	41.5	51.2	49.5	34.2	35.0	38.5	36.7	42.0
U.I 22-77	49.0	47.7	56.7	57.2	43.2	39.7	45.2	42.7	47.6
U.I. c-6-2	46.0	57.7	57.7	53.7	44.5	43.	48.7	46.5	49.7
U.I 81-28	43.2	40.0	46.7	39.7	28.0	31.5	37.5	39.5	38.2
U.I 53-139	50.7	53.0	52.2	54.5	41.0	42.7	48.7	46.2	48.6
TAe 38	55.5	51.2	58.0	61.7	42.2	46.2	50.7	48.5	51.7
NHAe 47-4	54.7	52.0	56.7	59.5	43.5	43.5	48.7	46.2	50.6
NHAe 15	51.0	46.0	55.7	56.0	36.7	33.2	40.7	38.2	44.6
NHAe 394	44.5	43.2	49.7	46.0	33.2	33.7	36.5	36.5	40.4
Puso	31.7	29.2	27.7	28.2	25.7	26.5	32.5	30.7	29.0
U.I 104	46.5	50.2	54	54.7	38.5	37.2	46.2	43.2	46.3
U.I 117	47.2	39	45.5	47.5	35.7	36.5	42.5	39.2	41.6
U.I 211	49.2	44.2	51.7	51.0	30.5	30.0	41.5	34.7	41.6
U.I 10	50.7	48.2	61.7	59.0	43.5	42.7	47.0	45.0	49.7
LSD (0.05)	3.6	4.3	8.9	8.6	4.1	1.9	4.9	7.7	
Means	48.6	46.7	52.1	51.6	37.6	37.5	43.3	41.2	

Appendix IV: Average seed moisture content (%) of 15 okra genotypes in eight environments

Genotypes	Environments								Genotype Means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	9.0	9.5	9.2	9.0	13.2	10.5	9.5	9.5	9.9
U.I 81-33	9.1	9.6	8.7	9.7	16.2	11.7	10.0	10.5	10.6
U.I 22-77	9.3	9.4	8.9	8.7	11.5	13.0	10.5	11.0	10.2
U.I c-6-2	9.2	8.5	7.7	8.2	12.5	13.0	10.5	9.7	9.9
81-28	9.5	10.4	9.1	9.2	16.2	13.7	10.2	9.7	11.0
U.I 53-139	9.4	9.4	8.7	10.0	14.5	12.5	10.5	10.7	10.7
TAe 38	8.7	8.2	8.2	8.0	12.5	10.2	9.5	9.2	9.3
NHAe 47-4	9.4	9.7	9.2	7.7	11.5	9.5	10.0	9.5	9.5
NHAe 15	9.0	9.9	8.7	8.0	18.2	14.0	10.2	10.2	11.1
NHAe 394	9.2	10.1	8.2	10.2	12.7	16.0	10.2	11.5	11.0
Puso	12.2	10.7	9.2	10.2	18.2	16.7	11.5	10.7	12.4
U.I 104	9.3	9.6	8.5	9.5	14.7	13.2	10.0	12.0	10.8
U.I 117	8.3	10.1	10.7	9.2	11.2	11.7	11.2	12.5	10.6
U.I 211	9.1	9.5	8.2	9.7	9.0	11.0	10.0	10.0	9.5
U.I 10	8.0	9.5	8.2	8.2	10.0	13.0	10.0	10.2	9.6
Mean	9.2	9.6	8.7	9.0	13.5	12.6	10.2	10.5	
LSD (0.05)	0.2	0.3	1.7	2.8	7.3	4.3	1.7	0.7	

Appendix V: Average number of fruit/plant in 15 genotypes of okra in eight environments

Genotypes	Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	7	5	5	4	3	2	3	2	3.8
U.I 81-33	7	5	6	4	2	2	3	2	3.8
U.I 22-7	11	8	7	5	3	2	3	2	5.1
U.I 6-6-2	8	7	4	4	3	2	3	2	4.1
U.I 81-28	8	5	5	4	2	1	2	2	3.6
U.I 53-139	11	10	4	4	2	2	2	2	4.6
TAe 38	7	6	4	3	3	2	3	3	3.8
NHAe 47-4	5	5	4	4	2	1	2	2	3.1
NHAe 15	8	5	8	7	2	2	3	2	4.6
NHAe 394	6	5	5	4	3	2	2	2	3.6
Puso	13	1.0	4	4	3	2	1	1	4.7
U.I 104	6	4	4	3	2	1	2	2	3.0
U.I 117	10	4	6	3	3	2	2	2	4.0
U.I 211	7	5	7	5	3	2	2	2	4.1
U.I 10	9	6	6	5	3	3	3	3	4.7
Mean	8.2	6	5.2	4.2	2.6	2	2.4	2.1	
LSD (0.05)	1.8	1.1	3.2	1.9	0.7	0.7	1.1	1.6	

Appendix VI: Average number of seed/fruit of 15 okra genotypes in eight environments

Genotypes	Environments								Gen typ mea
	I	II	III	IV	V	VI	VII	VIII	
U.I	119	113	107	109	39	43	46	45	77.6
U.I 81-33	113	108	95	114	51	65	61	59	83.2
U.I 22-77	76	94	90	97	55	56	56	52	74.5
U.I c-6-2	84	81	65	83	61	48	51	46	64.8
U.I 81-28	93	96	85	60	53	35	40	36	62.2
U.I 53-139	95	118	104	104	56	48	51	46	77.7
TAe 38	109	108	101	102	32	60	64	63	79.8
NHAe 47-4	106	103	95	84	41	51	48	50	72.3
NHAe 15	99	96	121	120	52	60	57	58	82.8
NHAe 394	96	91	97	103	69	57	48	58	77.4
Puso	61	59	54	49	18	32	35	29	42.1
U.I 104	106	107	109	114	56	49	53	50	80.5
U.I 117	93	101	96	108	59	59	56	53	78.1
U.I 211	87	110	96	88	35	44	42	47	68.(
U.I 10	109	116	118	102	69	59	59	55	85.8
LSD (0.05)	9.3	9.4	20.5	31.4	14.4	15.9	13.6	9.4	
Means	97.7	100	95.5	95.8	49.7	51.1	51.1	49.8	

Appendix VII: Average plant height (cm) of 15 okra genotypes in eight environments

Genotypes	Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	165.5	163.7	114.7	144.0	52.7	52.0	24.5	31.7	93.6
U.I 81-33	193.2	193.0	112.5	110.0	44.2	55.0	23.0	27.7	94.8
U.I 22-77	125	133.0	77.0	105.7	44.7	49.2	34.5	23.7	74.1
U.I c-6-2	122.7	137.7	92.2	108.7	63.0	59.0	35.2	35.7	81.7
U.I 81-28	170.2	157.5	89.2	118.7	45.2	44.2	40.0	30.7	86.9
U.I 53-139	117.0	115.7	69.0	86.0	35.0	38.2	34.5	28.8	65.5
TAe 38	168.2	154.5	100.7	100.5	54.0	57.5	39.7	47.5	90.3
NHAe 47-4	132.5	134.0	86.0	91.2	35.5	29.7	34.2	32.5	71.9
NHAe 15	197.7	192.7	143.0	160.2	62.5	64.5	51.7	27.5	112.4
NHAe 394	186.0	173.7	116.5	110.7	73.5	64.7	31.5	43.0	99.9
Puso	125.0	122.0	54.7	72.0	45.0	42.2	23.7	24.0	63.5
U.I 104	119.2	147.5	76.5	90.0	35.5	36.0	34.2	21.6	70.1
U.I 117	168.5	159.7	95.0	77.2	33.2	34.2	25.7	20.2	76.7
U.I 211	110.0	110.7	93.0	98.5	39.0	44.0	32.0	22.0	68.6
U.I 10	220.5	199.7	161.2	146.2	73.7	95.0	55.0	52.0	125.4
LSD (0.05)	15.5	15.0	36.9	35.2	9.7	8.3	5.1	10.6	
Means	154.7	153.0	98.7	100	49.1	51.1	34.6	31.2	

APPENDIX VIII: Average number of days to 50% flowering in 15 genotypes of okra in eight enviornments

Genotypes	Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	53	53	62	58	48	44	70	67	56.8
U.I 81-33	89	77	80	79	59	57	68	73	72.7
U.I 22-77	49	54	59	58	44	45	62	62	54.1
U.I c-6-2	61	60	61	59	45	46	63	58	56.6
U.I 81-28	86	87	85	91	64	63	74	72	77.7
U.I 53-139	76	80	71	71	49	41	71	72	66.3
TAe 38	55	59	61	62	52	48	63	59	57.3
NHAe 15	72	76	70	73	60	62	72	77	70.2
NHAe 394	88	91	73	77	60	63	72	71	74.3
Puso	58	59	67	69	58	60	67	68	63.2
U.I 104	87	90	77	81	54	52	75	74	73.7
U.I 117	84	87	79	80	54	50	69	70	71.6
U.I 211	68	70	65	72	52	46	69	71	64.1
U.I 10	69	74	69	71	52	52	70	72	66.1
Mean	71.9	73.7	70.3	71.6	53.7	52.1	69.0	69.1	
LSD (0.05)	2.7	6.4	4.8	1.8	3.4	3.7	3.6	4.1	

Appendix IX : Average number of days to first flowering of 15 okra genotypes in eight environments

Genotypes	Environments								Genotype means
	I	II	III	IV	V	VI	VII	VIII	
U.I 79-5	47	47	55	51	42	40	55	50	48.3
U.I 81-33	71	72	62	62	52	46	62	63	61.2
U.I 22-77	44	45	51	49	40	39	50	46	45.6
U.I c-6-2	50	48	51	48	38	40	51	47	46.6
U.I 81-28	57	68	66	71	50	48	62	66	62.2
U.I 53-139	67	67	67	63	42	41	65	61	59.1
TAe 38	47	47	58	53	44	42	54	50	49.5
NHAe 47-4	69	68	69	67	44	43	60	62	60.2
NHAe 15	50	53	61	59	50	46	64	69	56.5
NHAe 394	70	68	67	63	47	44	64	62	60.6
Puso	46	51	61	60	44	43	58	50	51.6
U.I 104	75	76	69	67	45	43	68	67	63.7
U.I 117	66	62	66	65	46	41	62	63	68.8
U.I 211	50	54	55	58	46	40	63	53	52.3
U.I 10	61	58	61	63	43	42	61	64	56.6
LSD (0.05)	2.4	4.1	4.6	4.0	6.2	0.6	6.3	6.7	
Means	58.6	59	61.2	59.9	44.8	42.5	59.9	58.2	

Appendix X Climatic data during 1985 and 1986 rainy seasons crop growth at Maiduguri

Crop growth period (months)	Total rainfall (mm)	Solar radiation (gm cal/ cm^2/day)	Monthly total sunshine (hrs)	Average relative humidity (%)	Mean monthly temperature (°C)
		1985 rainy season			
June	83.1	576.4	198.8	39.2	36
July	58.7	536.5	187.5	56.7	32
August	96.0	548.7	217.4	61.0	34
September	141.0	559.3	228.4	65.4	33
October	0.1	697.0	264.5	23.5	37
		1986 rainy season			
June	23	684.1	268	35.6	38
July	165.3	648.9	208.3	57.1	33
August	105.5	655.7	212.7	65.6	31
September	166.5	742.2	192.1	70.5	32
October	0.1	834.3	272.4	21.5	39

Appendix XI Climatic data at Ibadan in 1986

Months	Total rainfall (mm)	Solar radiation (gm cal/ cm^2/day)	Monthly total sunshine (hr)	Average relative humidity (%)	Mean monthly temperature (°C)
January	33.2	417.0	177.3	62	26.8
February	62.5	462.2	223.6	65	28.7
March	102.0	286.7	208.7	78	27.6
April	56.4	333.5	198.7	78	28.2
May	124.4	359.3	196.0	82	24.5
June	272.5	376.1	194.7	81	23.7
July	152.4	339.3	80.7	83	24.0
August	32.6	317.9	108.3	78	24.1
September	215.3	378.3	120.5	80	24.5
October	179.0	414.4	175.7	83	25.6
November	0.4	422.3	195.3	76	26.0
December	0.0	418.0	143.1	63	25.5

Appendix XIJ: Percentage of seeds in various seed grade sizes based on 100g of seed/cultivar

	Cultivar	Sieve size (mm)		
		4.5	4.0	3.5
1.	U.I 104	56	39	5
2.	U.I 38	53	40	7
3.	TAe 38	56	38	6
4.	U.I 117	55	36	9
5.	U.I 212	58	35	8
6.	NHAe 47-4	60	34	6
7.	V2	54	39	7
8.	U.I 81-33	59	32	9
9.	U.I 210	59	36	5
10.	U.I 211	54	40	6
11.	NHAe 394	59	36	5
12.	U.I 22-77	60	35	5
13.	NHAe 15	61	33	6
14.	U.I 45	62	30	8
15.	U.I 9	54	38	9
16.	U.I 92	55	39	6
17.	U.I 10	50	40	10
18.	U.I 81-28	55	38	7
19.	U.I 53-139	57	35	8
20	OP - 80	52	38	10
	Percent mean	56.3	36.5	7.1
	S.E ±	3.2	2.8	1.6
	cv (%)	5.5	2.8	23.1