GENOTYPE - ENVIRONMENT INTERACTION AND STABILITY ANALYSIS IN OKRA [*Abelmoschus esculentus* (L.) Moench] IN CAMEROON.

Abstract

A study was conducted to assess genotype-environment interaction and to determine stable okra (*Abelmoschus esculentus*) genotypes for nine traits in Cameroon. Eight okra genotypes (including 5 parents from Cameroon and 3 exotics) were evaluated across 3 locations (Dibang, Yagoua and Yaounde) using a randomized complete block design with 3 replications. Each plot consisted of three rows of six plants each. Genotypes-environment interaction has been evaluated using SAS Software. There was considerable variation for all traits studied among both genotypes and environments. Five methods of analysis of the stability have been used for the comparison of the genotypes and to determine the most suitable stability parameter at okra *Abelmoschus esculentus*. The stability in relation to the characters is independent of the genotypes. A total correspondence (r=1) exist between the general mean and the Pi performance for characters such as 50 % flowering day and the fruit length peduncle. For, the procedure of Lin and Binns appeared to be more of a genotype performance measure, rather than a stability measure. The Wricke's and Shukla's procedures of stability statistic showed the highest significant positive correlation (P<0.01) with the majority of the studied character. That makes these procedures equivalent for ranking purposes.

Key Words: Genotype - environment interaction, okra, stability.

Introduction

Okra, *Abelmoschus esculentus,* is a most important crop grown for its edible pods. Its young leaves and mature seeds may be also consumed in many countries in the world [1]. Okra has a relatively good nutritional value and is a good complement in developing countries where there is often a great alimentary imbalance [2]. The importance played by such a plant deserves that it is taken in charge the programs of varietals improvement. So therefore, all experimental techniques that succeed to the selection of superior value material and give evaluations of the genetic parameters seem the most valid for the future. Farmers in developing countries which use no or limited inputs or grow okra under harsh and unpredictable environments will need stable varieties. Many works were led in the breeding of varieties and hybrids of interesting natures [3, 4]. Selection of genotypes is based on the assessment of their phenotypic value in varying environments. But, the phenotypic performance of a genotype is not necessarily the same under diverse agro-ecological conditions [5]. As soon as it is about quantitative characters, the experiences should be made in order to distinguish the genetic influences of those due to the environment and to estimate in what measures a given phenotype is determined by the heredity and also by what means it is determined by the environment [6]. The development of cultivars or varieties, which can be adapted to a wide range of diversified environments is the ultimate goal of plant breeders in crop improvement programs. Furthermore, the adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted [7]. It is also known that for quantitative characters, the relative performances of the genotypes often vary from one environment to another giving place to the existence of a genotype-environment interaction [8]. Genotype-environment interactions (GEI) are extremely important in the development and evaluation of plant varieties because they reduce the genotypic-stability values under diverse environments [9]. If GEI is significant, we can further proceed and calculate the phenotypic stability of varieties [10]. Measuring GEI also helps to determine an optimum breeding strategy to breed for a specific or general adaptation which depends on the expression of stability under a limited or wide range environment [11, 12].

Evaluation of genotypic performance in some locations provides useful information to determine their adaptation and stability [11]. Then, it is imperative to study the performance of a crop in more than one environment to identify genotypes, which give high productivity over a wide range of environments [13]. In assessing the performance of okra genotypes, it is essential that yield stability of such genotypes, in addition to their yield performance, be determined in order to make specific selections and recommendations to okra producers. A few numbers of studies of genotype by environment interactions have been reported on okra in Cameroon. In addition, there are not enough studies on the stability of okra to part the few studies including description of fruits cultivated in Cameroon [14]. A few numbers of studies of genotype by environment interactions have been reported on okra in Cameroon. In addition, there are not enough studies on the stability of okra to part the few studies including description of fruits cultivated in Cameroon (Temple, 1999) or on heterosis and heritabjlity [15, 16]. In short, there is not real stability studies performed for okra developed by farmers and breeding programs and tested together in a multi-environment yield trial. Different concepts and definitions of stability have been described by many authors [17, 18]. Some of these methods can be used to test our genotypes through these different environments. The main objective of this study was to evaluate the stability of okra varieties through its interaction with different environments in Cameroon.

2. Materials and methods

2.1. Study site

Experiments were initiated in the year 2004 in the University of Yaounde I and were also conducted at localities of Dibang and Yagoua. The two first localities (Yaounde and Dibang), apart from different rainfall, had different maximum and minimum temperatures and soil constitution from Yagoua (Table 1).

Table 1. Main characteristics of study sites

Characteristics of study areas	Organic matter (N g/kg)	Soil type (pH)	Annual rainfall (mm)	Average temperature (°C)	Previous crop	Surrounding vegetation
Dibang	1.30	Sandy loamy (5.19)	2230.1	28	Fallow	Primary forest
Yagoua	0.67	Sandy (5.97)	844.2	39	Millet	Wasteland
Yaounde	1.10	Clayey-loamy-sandy (5.23)	1863	25	Fallow	Wasteland

2.2. Plant material and experimental design

Eight okra genotypes (including 5 parents from Cameroon and 3 exotics) were evaluated across 3 locations in Cameroon (Table 2). The experimental design was always a randomised complete block design with three replications. Each plot consisted of three rows and each row of six plants. The plants were supplemented with a daily artificial watering in the dry season and hoe weeding was carried out at two week intervals until crop maturity.

Table 2. Parental line performance of studied characters.

C: Clemson Spineless ; I : Indiana ; T : Rouge de Thiès ; L1 : local variety 1 ; L2 : local variety 2 ; L3 : local variety 3 ; L4 : local variety 4 ; L5 : local variety 5 ;
TP : plant height ; MCG : weight of 100 seeds; LPF : length of the peduncle of the fruit; LF : fruit length; NGF : seeds number per fruit ; DF : fruit diameter ; NFP : fruit number per plant ; JCF : 50 % flowering day ; DC : stem diameter.

Genotypes	TP	MCG	LPF	LF	NGF	DF	NFP	JCF	DC
C	57.93^{b}	6.33^{b}	3.26^{b}	12.98^{b}	58.96^{b}	2.75^{b}	4.63^{c}	52.44^{b}	1.09^{b}
I	40.19^{a}	4,.75^{a}	2.48^{b}	17.45^{b}	43.37^{a}	2.23^{b}	4.07^{c}	48.33^{c}	0.86^{a}
T	59.33^{b}	6,01^{b}	3.45^{c}	17.88^{b}	56.26^{b}	2.00^{a}	3.22^{b}	56.56^{b}	0.97^{b}
L1	92.21^{b}	5.27^{b}	2.82^{b}	10.47^{a}	67.07^{b}	4.58^{c}	2.44^{b}	57.11^{b}	1.30^{b}
L2	126.74^{c}	5.92^{b}	2.27^{a}	14.20^{b}	73.56^{b}	3.45^{b}	3.26^{b}	60.11^{a}	1.47^{c}
L3	69.15^{b}	7.24^{c}	2.80^{b}	21.22^{b}	77.26^{b}	2.62^{b}	2.00^{a}	50.11^{c}	1.21^{b}
L4	84.89^{b}	5.03^{b}	2.40^{b}	14.50^{b}	75.33^{b}	3.42^{b}	2.41^{b}	55.78^{b}	1.19^{b}
L5	76.48^{b}	5.45^{b}	3.35^{c}	25.03^{c}	70.59^{b}	2.63^{b}	2.44^{b}	53.56^{b}	1.24^{b}
Mean	75.87	5.75	2.85	16.72	65.30	2.96	3.06	54.25	1.17
Standard deviation	27.33	0.83	0.46	4.82	12.25	0.89	0.71	4.13	0.20

Means with the same letters are not significantly different at 5 % average probability

2.3. Data collection

At maturity, the data have been collected separately for the three sites. Three plants per plot, either nine plants are chosen at random for the assessment of the following characters: number of fruits per plant, height of the plants, basal diameter of the stem. The number of seeds, the length of the peduncle of the fruit, the diameter of the fruit, and the length of the fruit are counted randomly on a number of 9 fruits retained on the plants of the three repetitions on account of three per plot. The basal stem diameter is determined for every treatment. For the weight of 100 seeds, three shares of 100 seeds are randomly appropriated in the total of the seeds of the nine retained fruits on the studied genotypes and weighed for the circumstance. The length of the peduncle of the fruit and the length of the fruit were measured and the 50 % flowering day is considered as the day when half of the eighteen plants (nine of them) flowered in the three plots.

2.4. Genotype x environment interaction and yield stability methods

Genotypes environment interaction (GEI) have been evaluated using SAS Software. Five methods of analysis of the stability have been used for the comparison of the genotypes and to determine the most suitable stability parameter at okra *Abelmoschus esculentus*.

Environmental variance (S^2)

The environmental variance (S^2) is one of the major stability measures for the static stability concept (type 1 stability), i.e. the variance of genotype yields recorded across test or selection environments (i.e. individual trials).

For the genotype i:

$$Si^{2} = \Sigma (R_{ij} - mi)^2/(e - 1),$$

where R_{ij} = observed genotype yield response in the environment j,

m_i = genotype mean yield across environments,

and e = number of environments.

Performance of lin and binns (Pi)

According to this method, the value P_i is estimated by the square of differences between a genotype and the squares of the differences between the average of the maximum genotype mean at a location, summed and divided by twice the number of locations. This performance is given below by the formula [19] :

$$P_i = (n (Y_i – M..)^2 + \sum(Y_{ij} - Y_{i.} - M_j + M..)^2) / 2n,$$

where:

Y_{ij} is the mean answer of the i^{th} genotype in the j^{th} environment;

Y_i is the deviation of the average of the i^{th} genotype (average of the genotype less the general average of the j^{th} environment);

$Y_{i.}$ is the average of the i^{th} genotype in the n environments;

M_j is the genotype having the maximal answer among all genotypes in the j^{th} locality;

M.. is the average of the maximal answers in the different environments;

n is the number of localities.

Ecovalence of wricke (W_i)

The ecovalence (W_i) or the stability of the i^{th} genotype is its interaction with environments, squared and summed across environments. It describes the stability of a genotype, as the contribution of each genotype to the genotype x environment interaction sum of squares. The W_i ecovalence or stability of the i^{th} genotype is gotten with the help of the following formula [20] :

$$W_i = \sum_i (Y_{ij} - Y_i - Y_j + Y..)^2,$$

where:

Y_{ij} is the mean performance of the i^{th} genotype in the j environment;

Y_i is the average of the i^{th} genotype;

Y_j is the deviation of the average;

Y.. is the general mean.

Variance of stability of shukla (S_i^2)

The procedure of the variance of stability of Shukla (S_i^2) of an i genotype is gotten with the help of the following formula [21] :

$$\sigma^2{}_i = (p / (p\text{-}2)(q\text{-}1))\sum_i (Y_{ij} - Y_i - Y_j + Y..)^2 - \sum_i \sum_j (Y_{ij} - Y_i - Y_j + Y..)^2 / (p\text{-}1)(p\text{-}2)(q\text{-}1),$$

with:

Y_{ij} is the mean performance of the i^{th} genotype in the j^{th} environment;

Y_i is the average of the i^{th} genotype;

Y_j is the deviation of the average;

p is the number of genotypes;

q is the number of localities.

Parameter of huhn (S_i^3)

This non-parametric test is based on the ranks of the genotypes across locations. This gives equal weight to each location or environment. Genotypes with less change in rank are expected to be more stable. It is given by the following formula:

$$S_i^3 = \sum (r_{ij} - r_i)^2 / r_i$$

with:

r_{ij} = rank of the i^{th} genotype in the j^{th} environment;

r_i = mean of the ranks of the i^{th} genotype for all environments.

3. Results

The results of combined analysis show that highly significant differences ($P< 0.001$) exist between all the studied traits (Table 3). According to these results, the genotypes x environment interactions were highly significant for all traits studied ($P< 0.001$) except for the 50 % flowering day which is yet significant ($P< 0.01$).

Table 3. Combined analysis mean squares for okra characteristics for three different areas

		Stem diameter			Seeds number per pod			Pod girth		
Source of variation	DF	Sum square	Mean square	F	Sum square	Mean square	F	Sum square	Mean square	F
Model	191	151.51	0.79***	17.93	507058.99	2654.76***	13.96	631.46	3.31***	49.13
Error	384	67.96	0.04		292107.55	190.17		103.36	0.07	
Corrected Total	575	219.48			799166.55			734.82		
Rep	2	15.25	7.62***	172.27	22322.54	11161.27***	58.69	68.59	34.30***	509.66
Geno	63	81.22	1.29***	29.14	401695.37	6376.12 ***	33.53	428.06	6.79***	100.97
rep*geno	126	55.05	0.44***	9.87	83041.09	659.06***	3.47	134.81	1.07***	15.90

Table 3 (continued):

		Fruit number per plant			Pod length			Pod peduncle length		
Source of variation	DF	Sum square	Mean square	F	Sum square	Mean square	F	Sum square	Mean square	F
Model	191	1661.12	8.70***	10.67	31338.23	164.07***	33.09	220.56	1.15***	13.21
Error	384	1252.00	0.82		7615.50	4.96		134.25	0.09	
Corrected Total	575	2913.20			38953.73			354.81		
Rep	2	626.10	313.05***	384.06	3608.14	1804.07***	363.87	5.60	2.80***	32.05
Geno	63	461.79	7.33***	8.99	22047.96	349.97***	70.59	134.10	2.13***	24.35
rep*geno	126	573.24	4.55***	5.58	5682.12	45.10***	9.10	80.86	0.64***	7.34

Table 3 (continued):		Plant height			100 seeds weight			50 % flowering day		
Source of variation	DF	Sum square	Mean square	F	Sum square	Mean square	F	Sum square	Mean square	F
Model	191	1166872.85	6109.28***	36.44	492.95	2.58***	1790.20	63101.75	330.38***	23.68
Error	384	257496.22	167.64		0.55	0.001		5358.00	13.95	
Corrected Total	575	1424369.07			493.50			68459.75		
Rep	2	259630.81	129815.40***	774.37	150.91	75.46***	52339.1	54280.95	27140.47***	1945.12
Geno	63	547446.11	8689.62***	51.83	164.08	2.60***	1806.57	4080.19	64.76***	4.64
rep*geno	126	359795.93	2855.52***	17.03	177.95	1.41***	979.65	4740.61	37.62**	2.70

The values and ranking orders for stability of the 8 okra genotypes, according the assigned values from each procedure's analysis and definition (Tables 4, 5, 6, 7, 8, 9, 10, 11 and 12).

Table 4: Stability measure, rank and mean for stem diameter for 8 genotypes tested at three areas
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR
3	1.2111	4	0.0060	3	0.00513	2	0.0026	2	1.0374	4	0.4000	1	1
5	1.2407	3	0.0031	1	0.00779	4	0.0040	4	1.0524	6	1.7647	2	2
T	0.9667	7	0.0046	2	0.00540	3	0.0028	3	0.9837	1	1.7714	3	3
I	0.8593	8	0.0116	4	0.00070	1	0.0004	1	0.9979	3	3.8947	5	4
C	1.0926	6	0.0278	5	0.01151	5	0.0059	5	0.9957	2	9.8182	6	5
2	1.4741	1	0.0684	6	0.15163	6	0.0782	6	1.2722	8	1.9146	4	6
1	1.2963	2	0.1203	7	0.27591	8	0.1424	8	1.1611	7	31.1262	7	7
4	1.1926	5	0.2166	8	0.24671	7	0.1273	7	1.0413	5	48.3059	8	8

Table 5: Stability measure, rank and mean for fruit diameter for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR
T	2.0037	1	0.0462	1	0.0475	2	0.0245	2	5.9716	5	1.0769	2	1
C	2.7481	5	0.0610	2	0.0170	1	0.0088	1	5.9039	4	1.2000	3	2
3	2.6167	3	0.1519	5	0.0553	3	0.0285	3	5.8089	2	3.3103	4	3
5	2.6259	4	0.1267	4	0.0998	4	0.0515	4	5.7894	1	10.1446	6	4
I	2.2333	2	0.0933	3	0.1399	5	0.0722	5	5.8992	3	16.5455	8	5
1	4.5778	8	1.1633	8	1.4284	8	0.7371	8	10.5012	8	0.0426	1	6
2	3.4481	7	0.4644	6	1.3687	7	0.7063	7	7.2726	7	4.6076	5	7
4	3.4222	6	0.7231	7	0.8602	6	0.4439	6	6.9288	6	12.6842	7	8

Table 6: Stability measure, rank and mean for 50 % flowering day for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR
I	48.3333	1	85.44	2	21.8556	7	11.2775	7	1270.9259	1	5.0588	3	1

5	53.5556	4	128.26	3	5.1901	2	2.6781	2	1469.4691	4	10.8941	5	2
3	50.1111	2	150.26	6	8.1693	3	4.2154	3	1322.6173	2	30.1667	8	3
2	60.1111	8	157.37	7	2.5165	1	1.2985	1	1809.8025	8	0.2674	1	4
C	52.4444	3	83.59	1	34.4575	8	17.7801	8	1436.6173	3	22.3571	7	5
T	56.5556	6	167.70	8	10.1901	4	5.2581	4	1612.5432	6	2.2128	2	6
1	57.1111	7	142.70	4	15.3533	5	7.9223	5	1642.7284	7	10.2857	4	7
4	55.7778	5	144.15	5	19.8915	6	10.2640	6	1586.4321	5	12.1333	6	8

Table 7: Stability measure, rank and mean for fruit length for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	**M**	**R**	**S_i^2**	**R**	**W_i^2**	**R**	**σ_i^2**	**R**	**P_i**	**R**	**S_i^3**	**R**	**GR**
C	12.9815	2	4.5226	3	0.3156	1	0.1628	1	183.77	2	1.0000	1	1
1	10.4667	1	1.2342	1	0.8727	2	0.4503	2	194.47	4	2.6667	4	2
2	14.2037	3	8.2294	4	2.4446	4	1.2614	4	183.31	1	2.0000	3	3
I	17.4519	5	4.3853	2	1.9785	3	1.0209	3	199.16	5	3.2571	6	4
4	14.4963	4	10.0766	5	5.3041	5	2.7369	5	185.57	3	7.3478	7	5
T	17.8778	6	12.3164	6	11.7438	6	6.0598	6	206.80	6	11.7944	8	6
3	21.2222	7	18.1698	7	16.7901	7	8.6637	7	241.66	7	2.6800	5	7
5	25.0296	8	34.6218	8	46.3652	8	23.9245	8	317.06	8	1.3220	2	8

Table 8: Stability measure, rank and mean for fruit peduncle length for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	**M**	**R**	**S_i^2**	**R**	**W_i^2**	**R**	**σ_i^2**	**R**	**P_i**	**R**	**S_i^3**	**R**	**GR**
4	2.4000	2	0.0009	1	0.0195	3	0.0101	3	3.7508	2	6.6154	5	1
2	2.2741	1	0.0250	3	0.0157	2	0.0081	2	3.6586	1	37.0000	7	2
C	3.2593	6	0.0160	2	0.0079	1	0.0041	1	5.4436	6	0.0455	1	3
3	2.7963	4	0.0277	4	0.0313	4	0.0161	4	4.3624	4	3.6500	4	4
5	3.3481	7	0.0420	5	0.0526	5	0.0272	5	5.7134	7	0.4066	2	5
I	2.4778	3	0.1359	6	0.1867	6	0.0963	6	3.9258	3	31.8846	6	6
T	3.4481	8	0.1428	7	0.2910	7	0.1501	7	6.0352	8	0.7403	3	7
1	2.8222	5	0.7190	8	1.5601	8	0.8050	8	4.5926	5	80.8354	8	8

Table 9 : Stability measure, rank and mean for 100 seeds weight for 8 genotypes tested at three areas
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR
4	5.0310	2	0.1526	2	0.1297	1	0.0669	1	16.0063	1	10.9032	3	1
1	5.2672	3	0.0444	1	0.7166	4	0.3698	4	16.6625	3	24.7308	5	2
T	6.0144	6	0.5690	3	0.1353	2	0.0698	2	19.4779	6	3.3565	2	3
3	7.2404	8	0.9276	5	0.2396	3	0.1236	3	26.4341	8	0.3407	1	4
I	4.7502	1	3.2801	8	2.7536	8	1.4209	8	16.0811	2	25.2727	6	5
C	6.3342	7	0.6598	4	0.8101	5	0.4180	5	21.1251	7	12.1045	4	6
2	5.9246	5	1.8490	6	1.0548	6	0.5443	6	19.3330	5	27.5413	7	7
5	5.4500	4	2.5069	7	1.9518	7	1.0071	7	17.7744	4	69.1642	8	8

Table 10 : Stability measure, rank and mean for fruit number for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR
3	2.0000	1	0.9383	3	0.1502	1	0.0775	1	7.8230	4	43.5500	6	1
2	3.2593	6	0.7202	2	0.2472	2	0.1276	2	8.1180	5	0.4643	1	2
4	2.4074	2	1.4362	4	0.4648	3	0.2398	3	7.3032	3	35.1538	4	3
5	2.4444	3	1.8272	5	1.0268	4	0.5298	4	7.2469	1	42.9286	5	4
1	2.4444	4	0.2346	1	1.3856	5	0.7150	5	8.4691	6	47.5604	8	5
T	3.2222	5	5.4444	6	5.1680	6	2.6667	6	7.2716	2	43.6970	7	6
C	4.6296	8	7.4362	7	8.2063	7	4.2345	7	11.0398	8	0.5714	2	7
I	4.0741	7	8.5226	8	9.8352	8	5.0750	8	9.2085	7	5.7070	3	8

Table 11 : Stability measure, rank and mean for seed number per fruit for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR

4	75.3333	7	33.0494	3	3.9002	1	2.0125	1	3673.57	7	0.0000	1	1
T	56.2593	2	22.8683	2	75.1397	2	38.7722	2	3395.72	1	6.2286	3	2
C	58.9630	3	21.5597	1	126.1353	4	65.0859	4	3403.70	2	9.2692	5	3
I	43.3704	1	57.2387	4	185.6267	5	95.7836	5	3629.54	5	2.6667	2	4
1	67.0741	4	75.2140	5	90.6718	3	46.7868	3	3472.20	3	8.9091	4	5
5	70.5926	5	97.5967	6	193.5919	6	99.8936	6	3567.27	4	15.1209	6	6
2	73.5556	6	277.6420	7	301.3545	7	155.4992	7	3657.37	6	19.3400	7	7
3	77.2593	8	281.4979	8	711.6790	8	367.2271	8	3869.28	8	25.8000	8	8

Table 12 : Stability measure, rank and mean for plant height for 8 genotypes tested at three areas.
M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype, σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

Génotypes	M	R	S_i^2	R	W_i^2	R	σ_i^2	R	P_i	R	S_i^3	R	GR
5	76.4815	5	1634.522	7	1773.5003	8	915.1280	8	5564.5974	5	37.6632	8	1
1	92.2148	7	109.0224	2	78.2040	2	40.3534	2	5909.4079	6	0.8171	2	2
I	40.1852	1	99.8683	1	227.7044	5	117.4957	5	6528.8361	7	2.0000	3	3
3	69.1481	4	475.8313	4	216.8209	4	111.8798	4	5372.6756	1	6.8791	4	4
T	59.3333	3	423.1235	3	71.8402	1	37.0696	1	5417.5782	3	8.8214	5	5
C	57.9259	2	497.4609	5	108.2952	3	55.8805	3	5415.2394	2	21.8750	6	6
2	126.7407	8	1541.349	6	1310.2846	6	676.1082	6	8376.1036	8	0.1390	1	7
4	84.8889	6	1857.716	8	1750.7856	7	903.4071	7	5514.9362	4	24.0513	7	8

Genotypes with low rank are considered most stables. The analysis of these results showed that the local variety 1 which is stable for the fruit diameter under the Huhn's parameter (Table 4) is unstable under the others procedure of stability. The local variety 1 is the most stable for fruit length (Table 7) and the most unstable for the fruit peduncle length under the environmental variance (Table 8). It is also the case of Clemson Spineless which is stable for the fruit length (Table 7) and unstable for the 50 % flowering day (Table 6) under the same stability test of Wricke's ecovalence and Shukla's stability. Some genotypes prove to be very stable both for different characters and tests of stability. It is the case of Clemson Spineless (according to the ecovalence of Wricke, the stability of Shukla and the parameter of Huhn) for the length of the fruit (Table 7) and the length of the peduncle of the fruit (Table 8). It is also the case of the local variety 2 with regard to the ecovalence of Wricke, the stability of Shukla and the parameter of Huhn for the 50 % flowering day (Table 6).

A comparison of the stability parameters for these okra genotypes traits was done for the different stability measures applied using their rank levels. The overall ranking of genotypes for all stability parameters showed that the most stable genotype was the local variety 3 for the stem diameter, Rouge de Thiès for the fruit diameter, Indiana for the 50 % flowering day, Clemson Spineless for the fruit length, the local variety 4 for the fruit peduncle length, the 100 seeds weight and the seeds number per fruit, the local variety 3 for the fruit number per pod and the local variety 5 for the plant height.

The genotypic mean is different from the performance P_i of the cultivar for only fruit number and stem diameter. For the majority of the studied traits, Sperman's coefficient of rank correlation [22] was then determined for each of the possible pair wise comparisons of the ranks of the different procedures of stability for all the studied traits. The results of these correlations reveal that for the five procedures of stability and the general mean of the genotypes, positive and negative as well as meaningful and non-meaningful correlations exist. The general mean was significantly positively correlated ($P< 0.05$) with P_i (for fruit length and seeds number per fruit), S_i^2 (for fruit diameter), W_i^2 and σ_i^2 (for fruit number per plant), highly positively correlated ($P< 0.01$) with P_i (for stem diameter), S_i^2 (for the fruit length), W_i^2 and σ_i^2 (for the fruit length). A total correspondence (r=1) exist between the general mean and the Pi performance for characters such are 50 % flowering day and the fruit length peduncle.

The Wricke's and Shukla's procedures of stability statistic showed the highest significant positive correlation ($P<0.01$) with the majority of the studied character. A rank correlation coefficient of 1.0 was found between Shukla's and Wricke's procedures (r=1) (Table 13). According to this Spearman's correlation coefficient, the procedure of Huhn showed the greatest deviation from the other procedures, showing negative or not significantly correlation with these stability statistics.

4. Discussion

Highly significant differences among genotypes and locations revealed that greater variability was present among genotypes and locations for the traits studied. Similar results have been reported on okra for the days of flowering, final height, number of pods per plant and number of seeds per pod [23]. Similar results, indicating large amount of variability in selected genotypes of okra has also been reported [24, 25, 26].

Highly significant interaction of genotypes with environments indicate the need to develop cultivars that are adapted to specific environmental conditions and identify cultivars that are exceptional in their stability across environments [27]. Similar significant genotype-environment interaction has been found with respect to number of days to flowering [28], plant height, intermodal length, number of fruits per plant, early yield per plant, total yield per plant and yield per plot [29]. Such statistical interaction resulted from the changes in the relative ranking of the genotypes or changes in the magnitudes of differences between genotypes from one environment to another [30]. The analysis of the values and ranking orders for stability of the 8 okra genotypes, according the assigned values from each procedure's analysis showed that for one trait considered, a genotype may be stable under a procedure of stability and unstable under another. It is the case of the local variety 1 which is stable for the fruit diameter under the Huhn's parameter (Table 3) and unstable under the others procedure of stability. A genotype may also be stable for one character and unstable for another trait under the same procedure of stability. However, some genotypes prove to be very stable both for different characters and tests of stability.

Table 13: Spearman's correlation coefficient of the nine studied traits

M : genotype mean yield across environments S_i^2 : Variance of Stability of Shukla, R : rank of the genotype,
σ_i^2 : environmental variance, Pi : Performance of Lin and Binns, Wi^2 : Ecovalence of Wricke, S_i^3 : parameter of Huhn, GR : general rank

	S_i^2- M	S_i^2- W_i^2	S_i^2 -σ_i^2	S_i^2 - P_i	S_i^2 - S_i^3	W_i^2 - M	W_i^2 - σ_i^2	W_i^2 - P_i	W_i^2 - S_i^3	σ_i^2 - M	σ_i^2 - P_i	σ_i^2 - S_i^3	P_i - M	P_i - S_i^3	S_i^3 M
Stem diameter	0.26	0.738*	0.738*	0.405	0.857**	0.619	1.000**	0.595	0.667	0.619	0.595	0.667	0.905**	0.119	-0.071
Seeds number per pod	0.619	0.786*	0.786*	0.667	0.690	0.333	1.000**	0.452	0.857**	0.333	0.452	0.857**	0.762*	0.238	0.476
Pod girth	0.810*	0.857**	0.857**	0.524	0.024	0.690	1.000**	0.619	0.143	0.690	0.619	0.143	0.667	-0.405	-0.190
Fruit number per plant	0.575	0.738*	0.738*	0.167	-0.310	0.731*	1.000**	0.452	-0.048	0.731*	0.452	-0.048	0.611	-0.405	-0.587
Pod length	0.857**	0.929**	0.929**	0.619	0.071	0.905**	1.000**	0.738*	0.262	0.905**	0.738*	0.262	0.833*	0.214	0.238
Pod peduncle length	0.476	0.929**	0.929**	0.476	0.310	0.405	1.000**	0.405	0.357	0.405	0.405	0.357	1.000**	-0.643	-0.643
Plant height	0.452	0.690	0.690	-0.119	0.571	0.286	1.000**	0.333	0.357	0.286	0.333	0.357	0.405	-0.524	-0.286
100 seeds weight	-0.071	0.810*	0.810*	0.071	0.524	-0.262	1.000**	-0.095	0.810*	-0.262	-0.095	0.810*	0.976**	-0.405	-0.476
50 % flowering day	0.571	-0.643	-0.643	0.571	-0.405	-0.476	1.000**	-0.476	0.333	-0.476	-0.476	0.333	1.000**	-0.571	-0.571

**The correlation is highly significant (P< 0.01) ; *The correlation is significant (P< 0.05).

According to the comparison of the stability parameters for these okra genotypes traits, there is not particular stability bound at the origin of the genetic material: the exotic varieties are as stable as the locals. Once besides, the stability in relation to the characters is independent of the genotypes. From this analysis, the most stable cultivar ranked first for a procedure of stability is not necessary the same genotype first ranking neither for another procedure nor for another character. Thus, the ranks of the genotypes vary according to the characters and the procedures of stability. It brings back the problem of the stability tests raised indeed by Hohls. According to this author, the main problem with stability statistics is that they don't provide an accurate picture of the complete response pattern [31] because a genotype's response to varying environments is multivariate [17] whereas the stability indices are usually univariate. Then there is less accord on the most appropriate definition of "stability" and the methods to measure and to improve yield stability [18]. It is known that changes in ranking make it difficult for the plant breeder to decide which genotype should be selected [32]. It is why; methods of comparison must be finalized in order to allow a reasonable choice of the stability procedure to use.

The rank of the Pi measure and genotypic mean are in agreement. Furthermore, a total correspondence (r=1) exist between the general mean and the Pi performance according to the Sperman's coefficient of rank correlation. This indicates that the P_i measure is more an indication of performance and not really an indication of stability. These results are conformed to those on maize [33], and *Gossypium hirsutum* [34].

A rank correlation coefficient of 1.0 found between Shukla's and Wricke's procedures (r=1) indicates that these two stability tests were equivalent for ranking purposes. These results corroborate previous findings [35, 33]. According to these authors, Shukla's stability variance is a linear combination of deviation mean squares, in other words the ecovalence of Wricke. The Ecovalence of Wricke (W_i) and the variance of stability of Shukla (S_i^2), so-called two concepts of stability of type 2, give the same result with regard to the rank of the genotypes [18].

The magnitude of correlation coefficient between the Wricke's and Shukla's procedures of stability statistic and the others procedure of stability in this study placed these two procedures as the most preferred technique when selection for characters in okra crop. These results corroborate those on maize [33] in which these two procedures were cited among the best ones to select the most stable hybrids, on the basis on their high correlation and ranking of genotypes, which corresponded with the performance of the hybrids in practise.

5. Conclusion

Genotypes-environment interactions exist for all traits studied. Based on the different stability analyses, there is not particular stability bound at the origin of the genetic material: the exotic varieties are as stable as the locals. The stability in relation to the characters is independent of the genotypes. The total correspondence (r=1) between the general mean and the performance Pi showed that the procedure of Lin and Binns appeared to be more of a genotype performance measure, rather than a stability measure. The same total correspondence for the procedures of Wricke and Shukla make these procedures equivalent for ranking purposes. Nevertheless, the ranks of the genotypes vary according to the characters and the procedures of stability. It is why methods of comparison must be finalized in order to allow a reasonable choice of the stability procedure to use.

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