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Genetics Studies on the Agromorphological Parameters of Some Ecotypes of Okra

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Abstract:

The nutrient-rich okra, *Abelmoschus esculentus*, plays an essential role in the nutritional balance of rural populations in Chad, whose diet is based on cereals. Okra is also of considerable economic importance to women. However, Doba growers use traditional varieties which do not meet their acceptance criteria, making it essential to create new cultivars. For this reason, it was necessary to identify local population varieties with important characteristics. To this end, 9 ecotypes with varied agromorphological characteristics were sown in the field using a Fisher block design with 3 replications. Analysis of variance showed that there was considerable variability between the ecotypes used for all the agromorphological parameters studied ($p<0.05$). The results of the principal component analysis showed that ecotypes 2 and 4, the number of leaves per plant and the number of fruits per plant were positively and significantly correlated with the F1 axis (34.49%). Ecotype 6 and the number of seeds per fruit were strongly correlated with the F2 axis (27.90%). The correlation coefficient showed that number of seeds per fruit and plant height ($r = 0.61$); number of fruits per plant and number of leaves per plant ($r = 0.77$); number of fruits per plant and fruit width ($r = 0.57$); can be improved simultaneously. The integration of these agromorphological characteristics into the genetic improvement program could combat food insecurity and promote financial autonomy for women in Doba.

Keywords: *okra, ecotypes, Doba, variability, correlations.*

Introduction

Okra, *Abelmoschus esculentus*, is a predominantly self-pollinating, diploid plant grown mainly in Africa, Asia, the West Indies and South America (Cruden, 1976; Charrier, 1984; Hamon and Koechlin, 1991). Its origin remains highly controversial: the first theory proposes an Indian origin based on its range (Joshi *et al.*, 1974). However, from a linguistic point of view, there is no vernacular Sanskrit name for this species, which was not even described by the first Indian botanists. The second thesis suggests an East African origin - southern Egypt or Ethiopia - for the antiquity of its culture (Vavilov, 1935; Murdock, 1959). From this region, primitive forms migrated to West Africa and then to South America. Okra is cultivated for its fruits and leaves consumed as a vegetable, its stems used as firewood and for its roots used in traditional medicine (Marius *et al.*, 1997; Sawadogo *et al.*, 2009; Haoua *et al.*, 2011). Okra is characterized by diversity in fruit and stem shape and color (Seck, 1991; Nwangburuka *et al.,* 2011; Nsimi *et al.*, 2013; Osawaru *et al.*, 2014, Marwa *et al.*, 2023). It is a vegetable found fresh in all Doba markets during the rainy season and dries (slices, dried slices or powder) during the dry season. This is due to its richness in mucilage, its high market value and its high nutritional value. It's vital importance in the diet of both urban and rural populations (Kumar *et al.*, 2009; Ndogonoudji, 2014). Okra is of considerable economic importance to women and plays an essential role in the nutritional balance of rural populations (Ndogonoudji, 2016). A daily consumption of 100g of fresh okra would provide around 20% of calcium requirements, 15% of iron requirements and 50% of vitamin C requirements (Hamon, 1988; Nzikou *et al.*, 2002; Ndangui *et al.*, 2010; Kouassi *et al.*, 2013a; Singh and Nigam, 2023). Okra is very rich in magnesium, potassium, manganese and sodium (Kouassi *et al.*, 2013b; Singh and Nigam, 2023). Despite its many uses, its proven nutritional contribution and its financial value, okra is grown in Doba on very small areas, on the outskirts of huts, around termite mounds and often on dumps. Growers and market gardeners use traditional varieties. These cultivated varieties do not meet their criteria of acceptability, which makes it essential to improve them according to the preferred criteria of these producers and consumers. The aim of this study was to identify local population varieties with interesting characteristics for breeding purposes.

Materials and Methods

The experiments were carried out in Doba, a locality in the Sudanian zone of southern Chad (latitude 8°39' N, longitude 16°51' E, altitude 379m). The climate is tropical. Vegetation is typical of the tropical zone. Rainfall ranges from 1,000mm to 1,350mm per year. Temperatures vary between 10°C and 45°C (Semi-urban drinking water supply and sanitation program, phase I (2018).

Plant Material

The planting material consists of nine (09) local cultivars. These ecotypes were characterized according to farmers' selection criteria, and their essential characteristics are presented in Table 1 (Appendix 1).

Cultivation Operations

Cultivation of the various ecotypes took place in the field during the rainy season in Doba (June to October 2020). Crops were grown on ridges, and the previous crop was sorghum (*Sorghum bicolor*). After demarcation, ploughing of the plots using a hoe and shovel, and creation of the ridges, hand sowing was carried out at a rate of 3 seeds per piquet, with 7 to 10kg of okra seeds to cover 1 hectare. Spacing between seed pots was 1m along the row and 0.50m between seed pots (Fondio *et al.*, 2003). Emergence occurred 7 to 10 days after sowing. After emergence, weeding was carried out at a density of 20,000 plants per hectare, with 1 plant per cluster. The first weeding took place twelve days after emergence, followed by regular weeding at two-week intervals to keep the plots clean. The experimental design adopted for growing these ecotypes in the field was a Fisher block with 3 replicates. A basic fertilizer application of 250kg/ha of mineral fertilizer (NPK10-18-18) was made 15 days after sowing, followed 30 days after sowing by another application of 200 to 250kg/ha of urea by weeding (Fondio *et al.*, 2003). During flowering and fruiting, two treatments with cypermetrhine (Cypercal 50EC: 1l/ha) at two-week intervals kept insect pests under control.

Measurement of Agromorphological Parameters

Fruit length and width were measured with a caliper to an accuracy of ±0.1mm. Length was measured from the point where the fruit was attached to the branch to the tip. Width was measured at the largest diameter. Plant height, leaf length and leaf width were measured using a tape measure. The number of leaves per plant, the number of fruits per plant and the number of seeds per fruit were assessed by hand-counting.

Statistical Analysis

Analysis of variance (ANOVA) was performed using STATGRAPHICS PLUS version 5.0 software (Statgraphics, 1997). Inter-variable relationships and total correlations were provided by XLSTAT Version 2007.8.04. Principal component analysis (PCA) (Cherisey, 1983; Philipeau, 1986) was performed on the data to establish correlation matrices. The relative contributions of the axes and the explanatory variables were used to select the axes to be retained (Bonifas et al., 1984; Escofier and Pages, 1998).

Results

Analysis of Variance

Plant height, number of fruits per plant, number of seeds per fruit, number of leaves per plant, leaf area, fruit length and fruit width for the 9 ecotypes tested are presented in Table 2 (Appendix 1). Analysis of variance showed a significant genotype effect ($p < 0.05$). In terms of plant height, ecotypes 5 (55.08cm), 6 (52.20cm) and 7 (50.27cm) were taller, while ecotype 4 (39.67cm) was shorter. Average plant height is 45.78cm, with a coefficient of variation of 12.40%. The number of fruits per plant varies from 7.55 to 13.37. Ecotype 4 has a high number of fruits per plant (13.37). Ecotypes 3 and 1, on the other hand, have a low number of fruits per plant. The average number of fruits per plant is 9.51, with a coefficient of variation of 20.19%. The number of seeds per fruit varies from 43.32 (ecotype 2) to 50.14 (ecotype 1). Ecotypes 1 and 7 contain more seeds. Ecotype 2, on the other hand, has a low number of seeds per fruit. The average number of seeds per fruit was 46.69, with a coefficient of variation of 8.58%. Ecotype 4 (15.03) has a high number of leaves per plant. Ecotypes 2 and 3, on the other hand, have a low number of leaves per plant. The average number of leaves per plant was 11.84, with a coefficient of variation of 18.66%. In terms of leaf area, ecotype 2 (352.49cm²) has large leaves. In contrast, ecotypes 1 (292.74cm²), 8 (295.80cm²) and 2 (298.97cm²) have thin leaves. Average leaf area is 312.47cm², with a coefficient of variation of 6.40%. Fruit length ranged from 11.28cm (ecotype 2) to 13.13cm (ecotypes 4 and 6), with an average of 12.23cm and a coefficient of variation of 5.81%. Ecotypes 4 and 6 have long fruit (13.13cm), while ecotypes 2 (11.28cm), 8 (11.37cm) and 7 (11.62cm) have short fruit. In terms of fruit width, ecotypes 5 (5.01cm) and 4 (5.08) have wide fruit. In contrast, ecotypes 7 (4.17cm) and 6 (4.20cm) have narrower fruit. The average width is 4.63cm, with a coefficient of variation of 3.85%. The analysis of variance showed that there is considerable genetic variability between the genotypes used for the agronomic parameters.

Principal Component Analysis

Principal component analysis (PCA) was carried out to present an overview of the similarities, dissimilarities and correlations between the different agro-morphological parameters of the okra ecotypes studied. Figure 1 shows the mapping of the different ecotypes and agro-morphological traits on an F1 and F2 axis plane, and explains 62.39% of the results. Ecotypes 2, 4, number of leaves per plant and number of fruits per plant are correlated with the F1 axis, explaining 34.49% of the results. Ecotype 6 and the number of seeds per fruit are strongly correlated with the F2 axis, explaining 27.90% of the results.

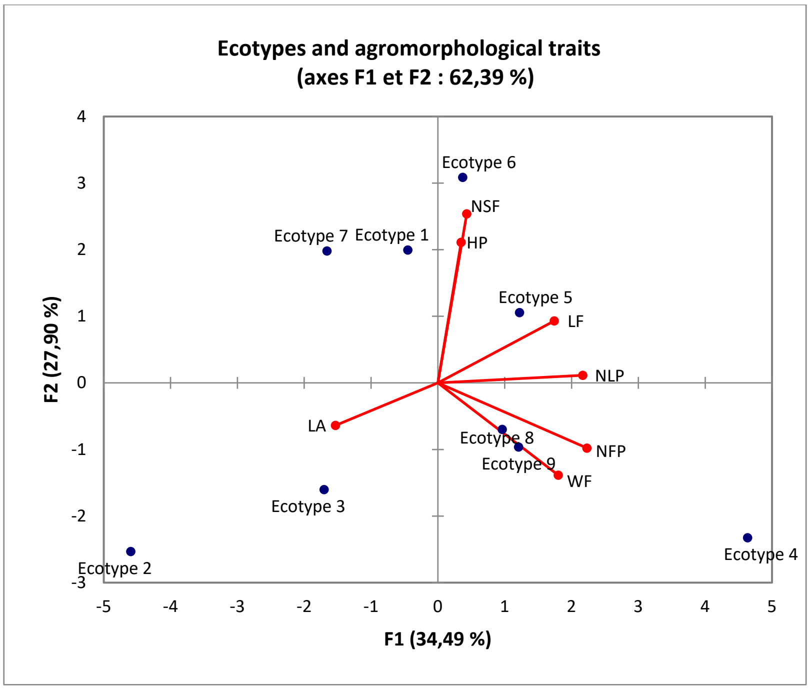

Figure 1. Mapping of Different Ecotypes and Agromorphological Traits on an F1 and F2 Axis Plane

Note: NFP: Number of fruits per plant, NSF: Number of seeds per fruits, NLP: Number of leaves per plant, LF: Length of fruit, HP: Height of plant, WF: Width of the fruit and LA: Leaf area.

Table 3. Contributions of the Different Ecotypes on the Main Axes (%)

	F1	F2	F3	F4	F5	F6	F7
Ecotype 1	0.38	11.60	27.88	1.49	0.08	38.73	0.02
Ecotype 2	40.24	18.66	4.10	2.83	4.52	0.25	5.44
Ecotype 3	5.51	7.46	35.10	0.82	1.63	8.28	2.77
Ecotype 4	40.95	15.75	0.00	0.46	17.42	3.40	8.39
Ecotype 5	2.85	3.25	4.03	52.27	25.98	0.43	0.04
Ecotype 6	0.27	27.73	0.50	0.19	15.24	38.58	2.46
Ecotype 7	5.24	11.43	22.70	5.77	1.31	6.24	0.05
Ecotype 8	1.77	1.42	0.63	33.99	33.55	3.54	11.37
Ecotype 9	2.79	2.70	4.16	2.19	0.28	0.56	69.46

On the map of different ecotypes and agro-morphological traits on an F1 and F2 axis plane, ecotypes and agro-morphological traits with a low but significant contribution on both axes appear unclear and non-conclusive. For this reason, it would be interesting to highlight the different contributions of each ecotype and agro-morphological trait on the different axes (Tables 3 and 4). Only ecotypes and agro-morphological traits with at least 5% are considered significant. Thus, ecotypes 2 (40.24%), 3 (5.51%), 4 (40.95%) and 7 (5.24%) and agro-morphological traits such as number of fruits per plant (26.72), number of leaves per plant (25.29%), leaf area (15.59%), fruit length (16.32%) and fruit width (17.43%) have a strong contribution to the construction of the F1 axis. Ecotypes 1 (18.66%), 3 (7.46%), 4 (15.75%), 6

(27.73%), 7 (11.43%), plant height (29.59%), number of fruits per plant (6.36%), number of seeds per plant (42.76%), fruit length (5.75%) and fruit width (17.43) are significant on the F2 axis.

Table 4. Contribution of Agromorphological Features to the Main Axes (%)

	F1	F2	F3	F4	F5	F6	F7
HP	0.65	29.59	15.30	10.65	20.29	21.25	2.28
NFP	26.72	6.36	14.47	0.96	5.16	3.17	43.17
NSF	1.00	42.76	0.01	1.63	0.20	54.39	0.02
NLF	25.29	0.09	17.18	23.90	1.19	2.47	29.89
LA	12.59	2.71	36.90	22.86	3.39	9.15	12.42
LF	16.32	5.75	12.93	30.66	26.59	2.01	5.75

Note: NFP: Number of fruits per plant, NSF: Number of seeds per fruits, NLP: Number of leaves per plant, LF: Length of fruit, HP: Height of plant, WF: Width of the fruit and LA: Leaf area.

The map of the different ecotypes and agro-morphological traits, together with the contribution tables for the different ecotypes and agro-morphological traits, enable us to assess their correlation with the F1 and F2 axes. It is therefore important to look for links between the different agro-morphological parameters in order to detect positive associations. The Pearson correlation matrix (Table 5) shows the links between the various parameters studied. Values close to 1 and shown in bold are significant ($p<0.05$). Thus, a positive and significant correlation exists between the number of seeds per fruit and plant height ($r = 0.61$), the number of leaves per plant and the number of fruits per plant ($r = 0.77$) and fruit width and the number of fruits per plant ($r = 0.57$).

Table 5. Correlation Matrix (Pearson (n))

Variables	HP	NFP	NSF	NLF	LA	LF	WF
HP	**1**						
NFP	-0.03	**1**					
NSF	**0.61**	-0.18	**1**				
NLF	0.21	**0.77**	0.16	**1**			
LA	0.07	-0.02	-0.30	-0.28	**1**		
LF	0.18	0.30	0.33	0.18	-0.48	**1**	
WF	-0.21	**0.57**	-0.32	0.26	-0.32	0.26	**1**

Note: Values in bold are significantly different from 0 at a level of significance $p < 0.05$

Discussions

The study of variability showed a significant difference between the 9 okra ecotypes. Ecotype 5 obtained above-average values for all parameters except the number of leaves per plant. Nsimi *et al.,* (2021) working on Genetic improvement of okra [*Abelmoschus esculentus* (L) Moench] based on agromorphological, biochemical and ethnobotanical studies in three Regions of Cameroon concluded that varieties with the above characteristics could be recommended to the populations. The good performance of ecotype 5 is explained by the fact that this ecotype is better adapted to Doba's pedoclimatic conditions. In a study on the expression of different okra (*Abelmoschus esculentus* L.) ecotypes to water deficit during budding and flowering, Sawadogo *et al.*, (2006) came to the same conclusion. Similarly, Kouayet *et al.*, (2021) on the study l'Effets des amendements sur les caractéristiques agromorphologiques et sur l'entomofaune d'*Abelmoschus esculentus* (L) Moench. (Malvaceae) in Ngaoundéré (Cameroon) and Kouame *et al.*, (2021) on the study of the Response to organic and mineral fertilization of two okra varieties (*Abelmoschus esculentus* (L) Moench, Malvacea) in Daloa, Côte d'Ivoire have shown that good yield also depends on fertilization. Sadak *et al.,* (2013) also showed that okra grown in the presence of compost substrates has a positive impact on A. esculentus fruit yield. In a study evaluating the yield of six varieties of okra (*Abelmoschus esculentus* (L.) Moench) under the agro-climatic conditions of Sédhiou in Senegal, Thiaw *et al.,* (2019) classified the Clemson spineless and Rouge de Thiess okra varieties as very low-yielding. This difference could also be due to the genetic characteristics of this ecotype. Similar results were obtained by Nsimi *et al.*, (2021).

Principal component analysis showed the existence of a significant and positive correlation between some traits. Positive and significant correlations suggest a close genetic association between these traits. Associated traits can be improved simultaneously. These results are in line with those of Mishra *et al.*, (2015), who reported a significant correlation between plant height and the number of sheaths per pod. On the other hand, for the correlation between number of leaves per plant and number of fruits per plant and between fruit width and number of fruits per plant, Mishra *et al.*, (2013) did not report a correlation. Nsimi *et al.*, (2013) and Haoua *et al.,* (2011) also reported non-significant correlations between plant height and pod length and between plant height and pod diameter. In short, the taller the plant, the more seeds it produces per fruit. Similarly, the more fruit the plant produces the larger the fruit and the more leaves.

Conclusion

Analysis of variance showed a significant genotype effect for all agro-morphological parameters. Principal component analysis showed positive and significant correlations between some parameters. However, these traits are scattered across different ecotypes.

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Appendix 1

Table 1. Name, Origin and Traits of Okra Ecotypes

Ecotypes	Local Names	Ethnic Groups	Meaning	Cycle to Maturity	Characteristics in the Farming Environment
Ecotype 1	Hima taa bee	Mango	Okra from the outskirts of huts	50 days	Branched plant, medium-sized green fruits
Ecotype 2	Madjinganeum	Ngambay	Fast-growing okra	45 days	Very early, very small green fruits
Ecotype 3	Lougolé	Mundang	Spiny-fruited okra	60 days	Ramified plant, medium-sized black fruits
Ecotype 4	Hima ndoh	Mango	Field okra	60 days	Large plant, long, green fruits
Ecotype 5	Hima ndah	Ngambay	Whitish-fruited okra	50 days	Precocious, medium-sized, whitish fruits
Ecotype 6	Hima Ngal	Ngambay	Long-fruited okra	60-70 days	Late, interesting reddish fruits
Ecotype 7	Hima kass	Ngambay	Reddish-fruited okra	50 days	Early, small reddish fruits
Ecotype 8	Godjé	Ngambay	Small-fruited okra	45-50 days	Early, small green fruits
Ecotype 9	Loukagné	Mundang	Chicken okra	60 days	Branched plant, medium reddish fruits

Table 2. Variability of the 9 Ecotypes Tested for Plant Height, Number of Fruits per Plant, Number of Seeds per Fruit, Number of Leaves per Plant, Leaf Area, Fruit Length and Fruit Width

Ecotypes	HP	NFP	NSF	NLP	LA	LF	WF
Ecotype 1	43.25 ± 1.80^{b}	7.65 ± 0.17^{b}	50.14 ± 0.14^{i}	10.12 ± 0.13^{c}	292.74 ± 0.06^{a}	12.63 ± 0.13^{f}	4.57 ± 0.16^{c}
Ecotype 2	40.15 ± 0.05^{a}	8.20 ± 0.13^{c}	43.32 ± 0.21^{a}	9.08 ± 0.13^{b}	352.49 ± 0.04^{i}	11.28 ± 0.26^{a}	4.37 ± 0.13^{b}
Ecotype 3	40.00 ± 0.25^{a}	7.55 ± 0.18^{a}	44.07 ± 0.66^{b}	8.67 ± 0.23^{a}	298.97 ± 0.03^{c}	12.24 ± 0.28^{e}	4.76 ± 0.06^{e}
Ecotype 4	39.67 ± 1.11^{a}	13.37 ± 0.34^{i}	45.18 ± 0.08^{c}	15.03 ± 0.08^{i}	305.10 ± 0.05^{e}	13.13 ± 0.10^{h}	5.08 ± 0.05^{h}
Ecotype 5	55.08 ± 0.20^{g}	10.25 ± 0.13^{g}	47.60 ± 0.17^{f}	11.25 ± 0.10^{d}	325.08 ± 0.20^{g}	12.68 ± 0.15^{g}	5.01 ± 0.04^{g}
Ecotype 6	52.20 ± 0.08^{f}	8.52 ± 0.21^{d}	48.23 ± 0.07^{g}	12.51 ± 0.10^{e}	300.63 ± 0.13^{d}	13.13 ± 0.10^{h}	4.20 ± 0.05^{a}
Ecotype 7	50.27 ± 0.15^{e}	9.08 ± 0.10^{e}	49.07 ± 0.10^{h}	12.70 ± 0.11^{f}	330.75 ± 0.08^{h}	11.62 ± 0.15^{c}	4.17 ± 0.06^{a}
Ecotype 8	46.13 ± 0.13^{d}	9.44 ± 0.25^{f}	46.08 ± 0.08^{e}	14.17 ± 0.14^{h}	295.80 ± 0.13^{b}	11.37 ± 0.13^{b}	4.86 ± 0.09^{f}
Ecotype 9	45.28 ± 0.17^{c}	11.52 ± 0.16^{h}	45.70 ± 0.15^{d}	13.11 ± 0.04^{g}	310.63 ± 0.11^{f}	12.01 ± 0.04^{d}	4.67 ± 0.08^{d}
Mean	**45.78±0.19**	**9.51±0.02**	**46.69±0.14**	**11.84±0.05**	**312.47±0.07**	**12.23±0.01**	**4.63±0.02**
LDS (0.05)	**0.640**	**0.002**	**0.028**	**0.004**	**0.001**	**0.007**	**0.026**
CV (%)	**12.40**	**20.19**	**8.58**	**18.66**	**6.40**	**5.81**	**3.85**

Note: Means with the same subscript within the same column do not differ ($p > 0.05$); LSD (0.05): least significant difference at 5% level; CV: Coefficient of variation; NFP: Number of fruits per plant, NSF: Number of seeds per fruits, NLP: Number of leaves per plant, LF: Length of fruit, HP: Height of plant, WF: Width of the fruit and LA: Leaf area.