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Plant Biology

Genetic Improvement of Okra [*Abelmoschus Esculentus* (L) Moench] Based on Agromorphological, Biochemical and Ethnobotanical Studies in Three Regions of Cameroon

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Abstract		**Original Research Article**

The study has been carried out to contribute to the development of new improved varieties of okra nearest in characterization with those lovely by Cameroonian population, from 4 Local and 2 exotic varieties. An ethnobotanical survey of populations was made to highlight a variety of okra ideotype. The agromorphological, biochemical and organoleptical characteristics of created hybrids have been evaluated to identify hybrids with the best strengths. The result shown that, the ideotype of okra proposed by ethnobotanical survey is the one with a short development (early), a medium-sized cycle, an average density of seedlings in field, an average number of fruits per plant, fruits of medium size, dark green color and smooth aspect. These varieties must have medium-sized seeds, a small number of seeds per fruit, a bland taste and high viscosity. The manifestation of the hybrid vigor appears on seven of the eight created hybrids specifically, L3xL1 for the diameter of edible fruits (5.61%) and weight of 100 seeds (16.78%), CxL1 for the number of fruits per plant (38,54%), L3xL2P for the number of branches (65,86%) and the edible fruit diameter (7.40%), IxL1 for the mass of edible fruits (24.33%), L5xL2P for the number of branches (39.62%) and diameter of edible fruits (4,30%). Regarding the biochemical parameters, some hybrids namely L5xL2P, L5xL1, CxL1, L3x L1, L3xL2P and IxL2P for the rate of dry matter, L5xL1 for the rate of carbohydrate hybrid, L3xL2P, IxL2P, CxL1 and IxL1 for the rate of fiber showed a positive useful heterosis. The study therefore permits to the conclusion that L3xL2P and L5xL2P both with the maximum number of the character are near to the ideotype needed by Cameroonian population.

Keywords: *Abelmoschus esculentus*, agromorphological parameter, okra ideotype, heterosis, hybrids.

INTRODUCTION

The okra plant (*Abelmoschus esculentus* L. Moench) is one of the most important traditional vegetables. It is found on almost every African market. Formerly attached to the genus Hibiscus, okra today constitutes the genus Abelmoschus, within the family Malvaceae [1]. Among the ten currently recognized species, two are cultivated for their fruit, which is a very popular vegetable in most tropical, subtropical and Mediterranean countries: *A. esculentus* and *A. caillei* [2], [3]. Okra is the subject of an intensive production system in urban and periurban agriculture [4], [5]. Its nutritional value is honorable, far behind the carrot, but before the tomato [6]. It is grown in the whole of Africa for its fruit (consumed boiled or fried, like spinach) 6.

World production of two species of okra cultivated in the form of vegetable-fruit fresh is estimated at 6 million tons per year, of which 95% of common okra (*A. esculentus*) 6, which represent approximately 1.5% of vegetable production. In West Africa, okra occupy second place in the vegetable productions behind tomatoes 6. The major producers are India (67.1%), Nigeria (15.4%) and Sudan (9.3%) 6. In Cameroon, all regions provide climatic conditions for the cultivation of okra 6. Despite its multiple uses, its nutrient proven, its financial value 6 and the revival of interest in gardening in general and the culture of okra in particular in Cameroon 6, the quantities of okra offered are still very low. The major causes of this insufficient supply are the limited availability on the market of the varieties improved and adapted to the agro-ecological zone conditions (hot and humid), the culture of old

Citation: Nsimi Mva Armand *et al*. Genetic Improvement of Okra [Abelmoschus Esculentus (L) Moench] Based on Agromorphological, Biochemical and Ethnobotanical Studies in Three Regions of Cameroon. Sch Acad J Biosci, 2021 Jan 9(1): 10-21

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varieties and the massive importation of seed poorly adapted to local conditions [13]. Furthermore, in general, okra has been considered as a minor crop and until recently no attention was paid to its improvement in the international research program [14]. It is known that identification of ideal parents, development and promotion of hybrids would not only increase yields, but also serve as sustainable sources of useful genetic variability for continuous improvement program 15.

The development of this crop still stays in a traditional stage in a lot of country without any implication of breeding program. Farmers actively select varieties on the basis of phenotypic characteristics (easily to observe visually) rather than the associated genotypes characteristics used in scientific plant breeding [16]. That is why the contribution of scientists is needed to help farmers in the realization of their choice.

In Cameroon, although it is shown that the heterosis effect exists between the hybrids of okra [17] and the heritability of the characters is effective on varieties of okra in Cameroon [18], it remains nonetheless that very few or no work on varietal improvement of this crop has been led to nowadays in Cameroon in the best of our knowledge. This study aimed to contribute to the development of new improved varieties of okra nearest in characterization with those lovely by Cameroon population.

MATERIAL AND METHODS
Identification okra ideotype by populations
Okra characterization was determined by a structured interview aimed to involve people in the proposal of okra ideotype from an ethnobotanical analysis. This structured interview schedule used for data collection included men and women for a total of 921 respondents. Three Regions in Cameroon was concerned namely the Center Region (263 respondents), the Far North Region (448 respondents) and the West Region (210 respondents) according to the importance of okra in these localities. Each interview was composed of open-ended and closed-ended questions based on agromorphological, agronomic, biochemical and organoleptic parameters. Data were collected using the International Plant Genetic Resources Institute (IPGRI) Descriptor List for okra [19].

For morphological parameters, the investigation has focused on the plant size characters, the fruit size, the fruit appearance, the fruit size and color, while agronomic parameters survey covered the print density of plants per hectare, the fruit number per plant, the development cycle, and the seed number per fruit. With regards to biochemical parameters, the respondents commented on the taste and the viscosity of the fruit.

Plant material used to improve the okro ideotype

Plant material used in this study were chosen as parents for the creation of hybrids guided by the results of the principal analysis component (PCA) of previous studies on the agromorphological and phytopathological characterizations of some local okra (*A. esculentus* L. Moench) and exotic varieties for one hands and ethnobotanical surveys among the population of the Far North, Center and West regions of Cameroon on the other hand [20], [21]. The varieties involved were: Local 1 (L1), Local 2 (L2P), and Local 5 (L5) for local varieties and Clemson (C), Indiana (I) for exotics. Eight hybrids were made: CxL1, IxL1, L3xL1, L5xL1, CxL2P, IxL2P, L3xL2P, and L5xL2P.

Creation of a few hybrids of okra close ideotype
Experimental fields work took place in a field located at the University of Yaoundé I. Controlled pollination was done to obtain F1 hybrids. The seeds of these hybrids were then sown and plants obtained were compared to the parents used as controls.

For the assessment of hybrids performance, morphological parameters measured were: the plant height, the internode length, the edible fruit length, the edible fruit diameter, the stem collar diameter, the lobe number and the first flowering date.

Agronomic parameters studied include the number of fruits per plant (NFP), the seeds number per fruit (SNF), the number of branches (NB), the number of nodes per plant (NNP), the germination rate, the latency, the 50% flowering date, the 100 seed mass and the edible fruit mass.

For biochemical parameters, each genotype of edible fresh fruit of okra was harvested and prepared for the measurement of the viscosity. The method described by [22] has been therefore used to estimate the total fat content. The extraction was based on differential solubility that lipids have in some organic solvents such as hexane or petroleum ether. After evaporation of the solvent from a soxhlet, extracted lipids were recovered and weighed. The method of determination of crude fiber used was that of [23]. Total sugar content was extracted according to the method of [24]. Total ash was also obtained according to [22] methods.

Finally, for each hybrid, thirty (30) plants and 30 fruits were used to evaluate characters below : edible fruit diameter (EFD), earliness (E), edible fruit mass (EFM), edible fruit length EFL), plant height (PH), fruit number (FN), viscosity (Vis), seed number (SN), 100 seed mass (HSM) branches number (BN), stem collar diameter (SCD), node number (NN), internode length (IL), germination rate (GR), latency time (LT), number of locules (NL); first flowering date (FFD), lipids (Lip), proteins (Pro), crude fiber (CF), carbohydrate (Glu), dry matter (DM). However only parameters with

significance difference have been presented among the [22] studied.

STATISTICAL ANALYSIS

The experimental design used was a randomized complete block design, with 3 replicates. Each block was divided into fourteen patches corresponding to fourteen combinations of hybrids and their parents. The data collected were analyzed by SPSS software and subjected to ANOVA to evaluate the effect of different genotypes. Significant differences were separated by the smallest significant difference (SDPP) at 5% threshold. The principal analysis component (PAC) was also made through XL STAT 2007 software. The relative contributions of the axes and the explanatory variables were used in the choice of our axes.

Identification of the best hybrids (ideotype)

Vigorous hybrids have been identified on the basis of heterosis according to the formulas below:
Mid - parent heterosis (Average heterosis): Avg % = (F1 - MP)/ MP x 100, where:

MP: mid-parent = (P1+P2)/2;   F1: hybrid; P1: parent 1 and P2: parent
Useful heterosis: UH % = (F1 - BP)/ BP x 100; where: F1: hybrid; BP: best parental value.

The significant differences between hybrid performance and the average of the parents, the hybrid performance and the best parent were assessed according to [25]. However, a descriptor has been also used for the hybrids characterization.

RESULTS AND DISCUSSION

Definition of the okra ideotype

On 921 respondents, 916 ideotype gave their perspective on the size of the plant, 874 on the plants density, 900 on the development cycle, 910 on the fruit number per plant, 906 on the fruit length, 898 on the fruit size, 889 on the fruit color, 884 on the fruit appearance, 892 on the seed size, 900 on the seeds number per fruit, 898 on taste and 914 on the viscosity. These characters were compared in the three sites of study (Table 1).

Table-1: Summary of the okra ideotypes provided by surveyed populations

Plant Characters	Far North Region	Centre Region	West Region
Plant lenght	medium	medium	medium
Sowing Thickness	medium	medium	medium
Development Cycle	short (precocious)	short (precocious)	long (late)
Fruit number per plant	6 – 10	6 - 10	6 - 10
Fruit size	medium	medium	medium
Fruit lenght	long	long	short
Fruit color	dark green	dark green	dark green
Fruit aspect	smooth	smooth	rough
Seed diameter	medium	medium	small
Seed number	Mean or few	Few	few
Fruit taste	Bland	Bland	bland
Fruit viscosity	Viscous	Viscous	Not very viscous

Evaluation of created okra hybrids performances
Fruit parameters of hybrids

Hybrids CxL1, IxL1, L3xL1 respectively obtained high values of viscosity, edible fruits mass, edible fruit diameter and seeds mass (Fig. 1). Other high

values were found by L3xL2P hybrid for the edible fruit mass, the seed mass and the edible fruit diameter. The hybrid L5xL2P was distinguished by its long edible fruits (Fig. 2).
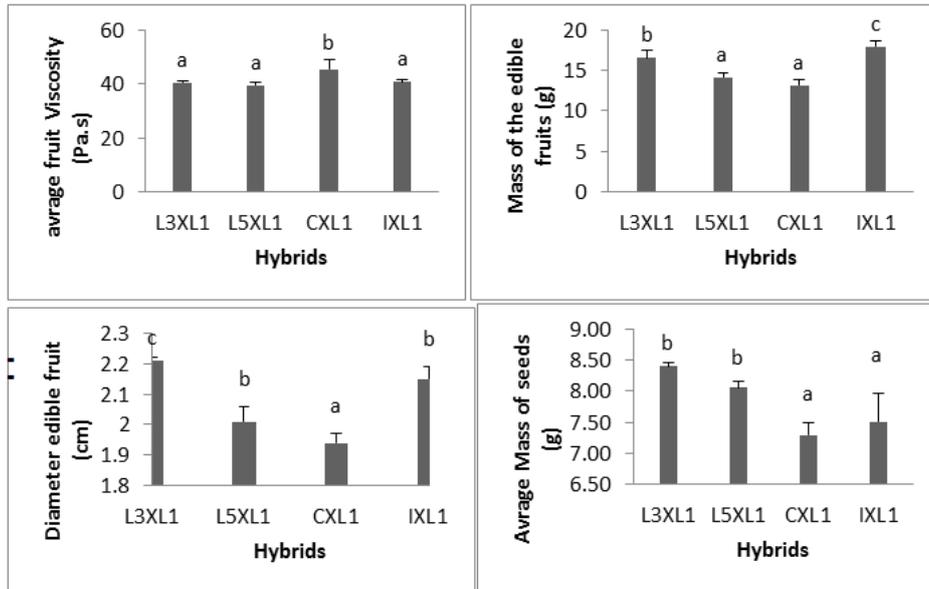
Fig-1: Agro morphological performances of hybrids with L1 as male parent
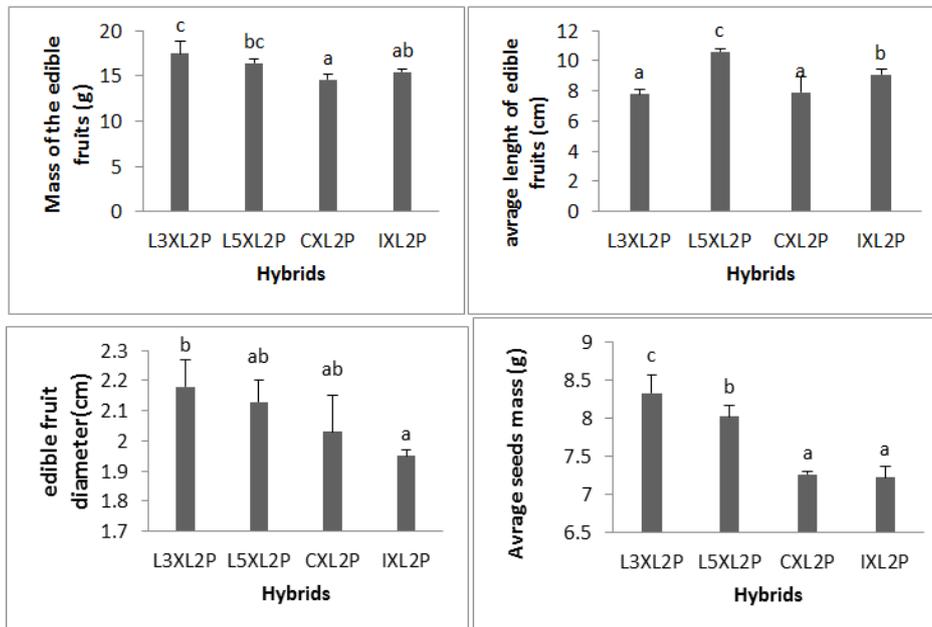
Fig-2: Agro morphological performances of hybrids with L2 (P) as male parent

Principal analysis component (PAC) enabled to better visualize the distinctions of evaluated parameters and the varieties studied which can be organized into major F1 and F2 components. The cumulative value of couples of components (F1, F2) is 60.52%. The circle of correlation at this probability separates four (04) groups of perfectly bound parameters. The first group is formed by characters (DCF), (SN); the second by (LN), (SV), and (LT); the third by (PH), (PD), (NN), (FN), (GR) and

the fourth by (HSM), (EFD), (E), (EFM), (RN), (EFL) and (IL).

Concerning hybrids, the circle of correlation at 60.52% threshold probability also allows distinguishing four groups. The first group is constituted of L3xL1, L5xL1 hybrids; the second group of CxL1, CxL2P hybrids, while the third group is formed by IxL1, IxL2P and the fourth group contains L3xL2P, L5xL2P hybrids (Fig. 3).
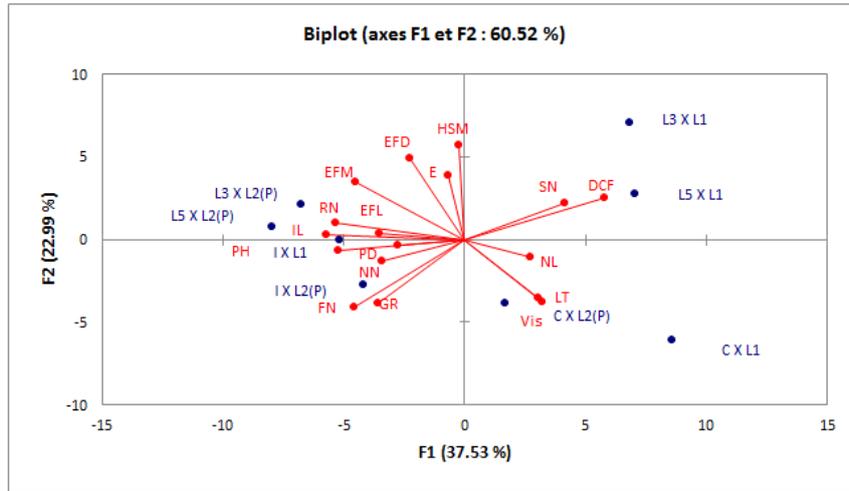
Fig-3: PAC of the different characters and okra hybrids on axes F1 x F2.

EFD: edible fruit diameter; E: earliness; EFM: edible fruit mass; EFL: edible fruit length; PH: plant height; FN: fruit number; Vis: viscosity; SN: seed number; HSM: 100 seed mass; RN: ramification number; PD: plant diameter; NN: number of nodes; IL: internode length; GR: germination rate; LT: latency time; NL: number of locules; DCF: distance between the cotyledonary node and the first floral node.

Biochemical performance

Hybrids whose male parent was L1 like L5xL1, L3xL1and IxL1 have high rate (%) values of carbohydrate (Glu), lipid (Lip) and protein (Pro) (Table 2).

For those hybrids that the male parent was L2 (P), high values were only observed by hybrid L5xL2P for the rate of carbohydrate (Glu) and the rate of dry matter (DM); hybrid CxL2P for the rate of lipid (Lip) and the hybrid L3xL2P for the rate of protein (Pro) (Table 3).

Table-2: Biochemical performance of hybrids with L1 as male parent

Hybrides	Glu (%)	Lip (%)	Pro (%)	CF (%)	DM (%)
CxL1	18.83^c	14.31^a	4.66^a	12.43^c	86.68^b
IxL1	17.78^a	15.18^a	18.51^d	$11.45b^c$	85.81^a
L3xL1	18.47^b	22.65^c	5.35^b	7.5^a	86.47^b
L5xL1	20.01^d	17.9^b	6.99^c	11.13^b	86.81^b

Pro: proteins; Lip: lipids; Glu: carbohydrate; DM: dry matter; CF: crude fiber.

Table-3: Biochemical performance of hybrids with L2 (P) as male parent

Hybrides	Glu (%)	Lip (%)	Pro (%)	CF (%)	DM (%)
CxL2P	16.97^c	24.04^c	5.87^a	6.53^a	84.64^a
IxL2P	15.95^b	19.94^a	16.2^b	11.25^{bc}	85.38^{ab}
L3xL2P	15.11^a	22.65^b	17.51^c	11.8^{4c}	85.54^b
L5xL2P	18.85^d	21.05^a	6.16^a	9.83^b	87.54^c

Pro: proteins; Lip: lipids; Glu: carbohydrate; DM: dry matter; CF: crude fiber.

Principal analysis component (PAC) enabled once more to better visualize the biochemical parameters of hybrids fruits at 86.68% probability into major F1 and F2 components. The circle of correlation at this probability also separate parameters on four (04) groups constituted by CF and DM for group 1, Glu for group 2, Lip for group 3 and Pro for group 4. When combining the evaluated parameters to hybrids, result shows that:

- Highest values of the rate of dry matter and rate of crude fibers are found by the L5xL1 hybrid, while L3xL1 and L5xL2P are those with the highest carbohydrate rates;
- Rate of the higher lipid is found by the hybrid CxL2P and the highest levels of protein were observed in L3xL2P, IxL1 and IxL2P hybrids (Fig. 4).
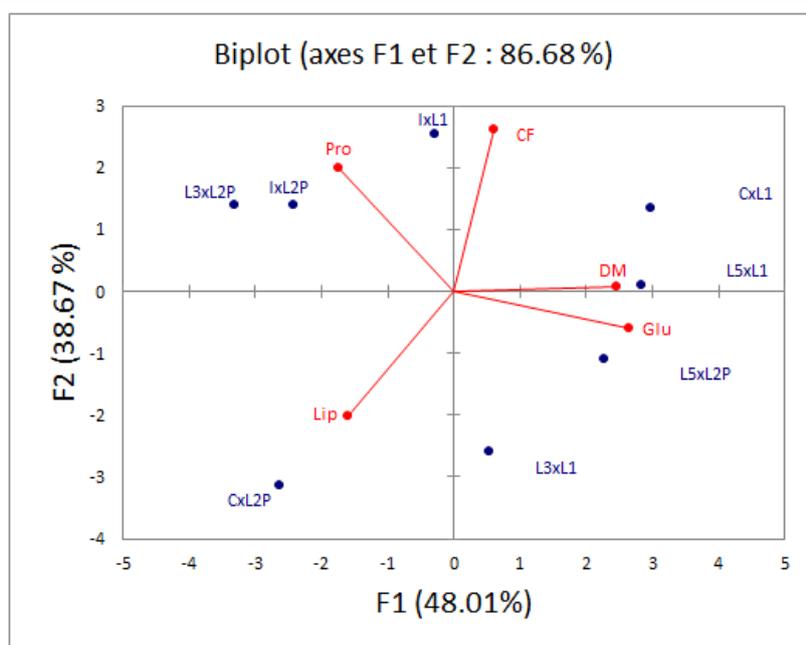
Fig-4: PAC of biochemical parameters and okra hybrids on axes F1 x F2 axes

Pro: proteins; Lip: lipids; Glu: carbohydrate; DM: dry matter; CF: crude fiber.

Identification of the best hybrids
Identification based on agromorphological parameters
Mid-parent heterosis

The value of the mid-parent heterosis differs from one character to another. However, only L5xL1 hybrid showed non-significant mid-parent heterosis (Table 4).

As regards to the time limit for 50% of flowering (earliness), hybrids L5xL1, CxL1, IxL1, L5xL2 (P), CxL2P and IxL2P presented an inbreeding depression while hybrids L3xL1 (1.1%) L3xL2P exhibited non-significant positive heterosis values.

Concerning the viscosity of edible fruits, the majority of hybrids showed negative heterosis except the hybrid CxL1.

Positive and significant values were however obtained by hybrids below:

- L3xL1 for the first flowering date, the edible fruit diameter and the 100 seed mass; CxL1 for the branches number, the fruit number per plant, the seed number per fruit, the plant height, the internode length, the node number, the edible fruit length and the first flowering date;
- IxL1 for the edible fruit mass, the lobe number per fruit, the ramification number, the seed number per fruit, the plant height, the 100 seed mass, the internode length, the latency time, the edible fruit length and the edible fruit diameter;
- L3xL2P for the plant height, the number of branches, the edible fruit diameter and the germination rate;
- L5xL2P for the number of branches, the edible fruit length, the edible fruits diameter, the plant diameter and the germination rate;
- CxL2P for the number of branches and the first flowering date;
- IxL2P for the germination rate and the number of locules.

Table-4: **Values of mid-parent heterosis based on the agro-morphological parameters (%).**

Characters	L3xL1	L5xL1	CxL1	IxL1	L3xL2P	L5xL2P	CxL2P	IxL2P
LN	-0.24	3.80	5.58***	20.30	-1.77	3.25	5.06	16.62**
NN	0.79	-7.39	12.69	-2.59	10.73	7.08	11.00	-7.62
GR	9.01	19.84	8.21	25.27*	14.98*	23.27*	18.31	23.23*
EFL	-2.42	5.06	9.30*	6.92	-8.95	13.11*	4.01	1.51
IL	1.65	-10.88	25.41**	7.56	5.48	1.71	17.06	2.62
SN	10.19	7.47	32.30**	12.33	-0.77	9.34	13.92	4.49
LT	4.76	6.35	4.76	6.35	2.78	1.59	-8.33	2.78
PH	5.01	-12.71	33.10**	10.26	13.70***	7.00	19.56	-0.75
FFD	7.02**	3.43	5.03*	1.17	1.59	-1.09	3.54*	1.19
BN	8.75	-2.98	51.06***	17.67	65.86*	39.62*	117.14**	27.81
Vis	-9.24	-6.77	1.95	-6.26	-3.98	-0.44	-3.31	-3.47
PD	-2.71	-7.36	18.83	3.97	10.71	13.03*	5.58	-10.36
FN	-2.50	-10.07	38.54*	-0.53	22.83	21.87	21.66	-2.69
E	1.11	-1.68	-0.33	-2.76	1.46	-2.05	-0.69	-1.73
EFM	9.48	-3.30	-5.14	24.33*	11.89	9.24	2.69	3.64
HSM	16.78***	9.68	6.00	10.15	7.11***	1.20	-2.82	-2.53
EFD	5.61*	-4.43	-6.03	6.34	7.40**	4.30*	1.10	-0.21

*significant at the 5% threshold, **significant at the 1% threshold, ***significant at the threshold 1‰

PH: plant height; BN: branches number; FN: fruit number; NN: number of nodes; EFL: edible fruit length; E: earliness; FFD: first flowering date; IL: internode length; EFD: edible fruit diameter; HSM: 100 seed mass; EFM: edible fruit mass; PD: plant diameter; SN: seed number; GR: germination rate; LT: latency time; Vis: viscosity; NL: number of locules.

Useful Heterosis

On the eight hybrids evaluated, three (L5xL1, CxL2 (P), IxL2P) showed non-significant useful heterosis. With regard to the time of 50% flowering date, all the hybrids presented an inbreeding depression effect. Concerning the viscosity of the edible fruits, all hybrids showed insignificant values of useful heterosis. L5xL1, CxL2 (P) and IxL2P combinations showed insignificant values of heterosis compared to the best parent for all characters studied.

Significant values were obtained by the following hybrids: L3xL1 for the edible fruits diameter and 100 seeds weight; CxL1 for the fruits number per plant; L3xL2P for the plant height, the ramifications number, the edible fruit diameter and the 100 seeds mass; IxL1 for the edible fruits mass; L5xL2P for the number of branches and the edible fruits diameter (Table 5).

Table-5: Values of useful heterosis based on the agronomic parameters (%)

Characters	L3xL1	L5xL1	CxL1	IxL1	L3xL2P	L5xL2P	CxL2P	IxL2P
LN	-2.33	2.02	4.86	-2.43	-2.33	0.00	2.75	-6.67
NN	0.86	-14.49	8.82	-7.30	3.97	5.37	0.89	-8.95
GR	5.80	8.70	5.80	14.49	13.24	13.24	15.00	13.24
EFL	-23.65	-22.36	-7.33	-18.59	-21.84	-8.63	-2.14	-15.66
IL	-2.61	-11.45	-6.78	6.92	-4.64	-4.79	-17.12	-2.72
SN	6.87	-1.28	5.72	-5.84	-1.89	4.78	-4.41	-8.86
LT	0	0	-8.33	0	0	0	-16.66	0
PH	-1.79	-19.32	14.07	-0.32	7.72**	1.77	-7.33	-3.59
FFD	3.76*	3.01	1.50	-1.50	-1.50	-1.50	0.00	-1.50
BN	-17.88	-15.45	-18.52	3.70	47.83*	30.73*	19.26	20.45
Vis	-18.18	-20.20	-8.08	-17.68	-9.50	-11.17	-8.94	-11.73
PD	-9.18	-15.58	16.10	-0.60	7.72	7.93	-2.25	-11.32
FN	-8.19	-27.00	35.91*	-22.80	13.77	18.95	10.18	-15.59
E	-5.37	-4.70	-6.71	-7.38	-5.33	-5.33	-7.33	-6.67
EFM	0.63	-7.41	-6.85	19.36*	6.18	7.40	-1.75	2.28
HSW	6.46***	-1.56	0.41	5.07	5.61***	-1.90	-5.44	-5.87
EFD	1.85	-7.23	-10.31	-0.92	6.70*	4.25*	-0.65	-4.25

*Significant at the 5% threshold, **significant at the 1% threshold, ***significant at the threshold 1 ‰.

PH: plant height; BN: branches number; FN: fruit number; NN: number of nodes; EFL: edible fruit length; E: earliness; FFD: first flowering date; IL: internode length; EFD: edible fruit diameter; HSM: 100 seed mass; EFM: edible fruit mass; PD: plant diameter; SN: seeds number; GR: germination rate; LT: latency time; Vis: viscosity; NL: number of locules.

Identification based on biochemical parameters
Mid-parent heterosis
Hybrids L3xL2P and IxL2P showed a positive heterosis effect for dry matter (DM), protein levels (Pro), lipid rate (Lip) and crude fiber (CF).

For the dry matter character, significant heterosis is presented by the combinations L3xL1, L5xL1, CxL1, IxL1, L3xL2P, L5xL2P and IxL2P.

With respect to the protein character, significant heterosis is effective among hybrids IxL1, L3xL2P and IxL2P.

Concerning the lipid rate, a positive and significant heterosis is presented by hybrids L3xL2P, L5xL2 (P), CxL2P and IxL2P.

Hybrids CxL1, IxL1, L3xL2P and IxL2P showed a positive and significant heterosis for the rate of raw while a heterosis effect is observed in the combinations L5xL1 and CxL1 for the carbohydrate rate (Table 6).

Table-6: Mid-parent heterosis values of biochemical parameters (%)

Characters	L3xL1	L5xL1	CxL1	IxL1	L3xL2P	L5xL2P	CxL2P	IxL2P
DM	1.80***	2.17***	1.77***	1.93***	0.93**	3.27***	-0.39	1.66***
Pro	-3.82	13.63	-15.48	245.62***	213.67***	1.12	7.16	204.15***
Lip	4.19*	-23.15	-35.29	-31.66	24.16***	6.43**	29.28***	6.79*
CF	-15.58	-2.52	32.92***	29.13***	59.04***	-1.38	-17.70	51.28***
Glu	-0.32	6.16***	0.26**	-12.26	-23.51	-6.09	-15.18	-25.77

*Significant at the 5% threshold, ** significant at the 1% threshold, *** significant at the threshold 1 ‰.Lip: lipids; Pro: proteins; CF: crude fiber; Glu: carbohydrate; DM: dry matter

Useful heterosis
Hybrid L3xL2P (P) showed positive and significant heterosis for the dry matter, the level of protein, the rates of lipid and the rate of raw fibers. The combinations IxL1 and IxL2P showed a positive and statistically significant heterosis for the dry matter (DM), levels of protein (Pro), crude fiber (CF). Hybrids L5xL1 and CxL1 hybrids showed a positive and significant effect for both characters dry matter and carbohydrate rates (Table 7).

Table-7: Values of useful heterosis based on the biochemical parameters (%).

Characters	L3xL1	L5xL1	CxL1	IxL1	L3xL2P	L5xL2P	CxL2P	IxL2P
DM	1.52***	1.91***	1.76***	0.74**	0.88**	3.25***	-0.61	0.70*
Pro	-6.57	3.66	-16.45	232.06***	205.64***	-8.75	6.67	194.55***
Lip	-3.30	-23.56	-38.90	-35.17	12.82***	-9.11	15.58***	-4.88
CF	-28.48	-9.73	18.53***	9.19**	55.42***	-20.23	-20.58	47.59***
Glu	-1.14	5.24***	-0.26	-18.60	-28.49	-10.79	-19.69	-26.98

* Significant at the 5% threshold, ** significant at the 1% threshold, *** significant at the threshold 1 ‰.

Lip: lipids; Pro: proteins; CF: crude fiber; Glu: carbohydrate; DM: dry matter.

Identification of the hybrids with the characterization needed by population
Evaluated parameters and the varieties studied on axes systems can be organized into major F1 and F2 components by Principal Analysis Component. The cumulative value of the components (F1x F2) couples is 54.08%. The correlation circle of 54.08% probability distinguishes four groups of perfectly bound parameters. The first group is constituted of the parameters EFD, E, EFM, PH, EFL, IL, BN, NN, PD, Lip; the second group by SM, SN, FFD, NL, DM, Glu; the third group is made up of the parameters FN, GR, Pro, CF and the fourth group includes Vis and LT.

Concerning the varieties, the correlation circle of the probability (54.08%) also allows four groups separation with two hybrids each order namely L3xL2P and L5xL2P for the first group; L3xL1 and L5xL1 for the second group; IxL1 and IxL2P for the third group and CxL2P and CxL1 for the fourth group.

When combining both the evaluated parameters and the varieties studied, L3xL2P and L5xL2P hybrids shows the highest values of the EFD, E, EFM, PH, EFL, IL, BN, NN, PD and Lip parameters, while L3xL1 and L5xL1 hybrids present the highest values of HSM, SN, FFD, LN, DM, Glu. IxL1 and IxL2P hybrids show the highest values of FN, GR, Pro and CF while viscosity and LT are shown by hybrids CxL1 and CxL2P. (Fig. 5).
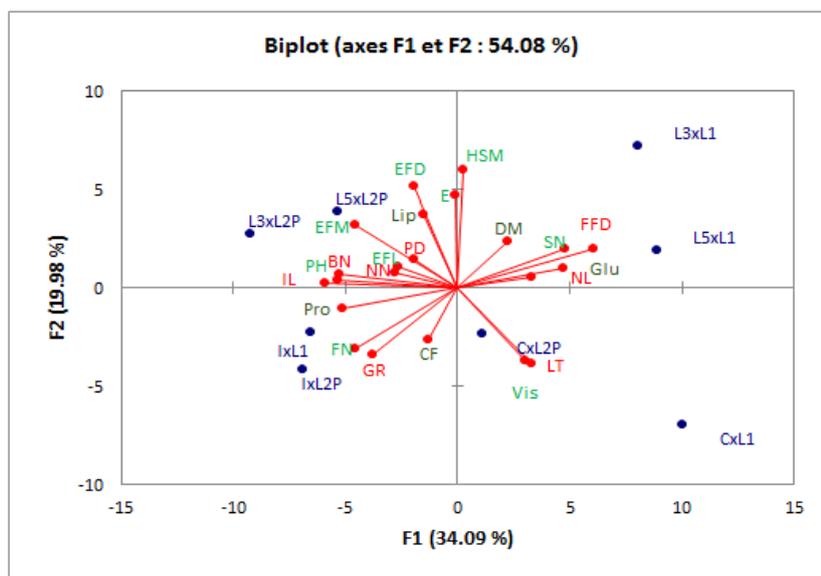
Fig-5: Mapping of representation of agromorphological and biochemical parameters of hybrids of okra on the F1xF2 axes

EFD: edible fruit diameter; E: earliness; EFM: edible fruit mass; EFL: edible fruit length; PH: plant height; FN: fruit number; Vis: viscosity; SN: seeds number; HSM: 100 seeds mass. BN: branches number; PD: plant diameter; NN: number of nodes; IL: internodes length; GR: germination rate; LT: latency time; NL: number of locules; FFD: first flowering date. Lip: lipids;

Pro: proteins; CF: crude fiber; Glu: carbohydrate; DM: dry matter.

In summary, the created ideotype of Okra was constituted by characters found in each hybrid from the six (6) parents (Table 8). These hybrids are constituted with good characters compared to these six (6) parents.

Table-8: Characters number of the hybrids

Hybrids	Numbers of characters shown	Good characters obtained (%)
L3xL2P and L5xL2P	10	47.62
L3xL1 and L5xL1	5	23.81
IxL1 and IxL2P	4	19.05
CxL1 and CxL2P	2	9.52
Total	**21**	**100**

DISCUSSION

The results of the ethnobotanical survey conducted locally on the interesting features of the okra and the results of the international genetic improvement work match those on characteristics like the high mucilage content, the low content in seeds, the bland flavor, the early development cycle and the high efficiency [26].

Heterosis observed in hybrids of *A. esculentus* varies according to the crosses and characters. Furthermore, heterosis values vary widely depending on genotype and characters ranging from negative to positive values. Regarding the plant height character, hybrids that presented a positive mid-parent heterosis are those which presented a positive but not significant heterosis value. On the other hand, the value of heterosis is negative for L5xL1 and IxL2P hybrids. The latter would have a smaller size than that of the average parent. These findings corroborate those works in which hybrids Daftari x Arka Abhay and Daftari x Parbhanti Kranti respectively obtained an insignificant heterosis

compared with the average of -5.3% and 3.2% parent [25].

In terms of the internode length, only the hybrid CxL1 presented a positive and significant mid-parent heterosis. These results match those observed on an increase of internode length in the hybrid Mothol-AE5 x Gerio-AE1 [27].

Regarding the precocity character, only L3xL1 and L3xL2P hybrids have positive but not significant heterosis values. Hybrids such as L5xL1, CxL1, IxL1, L5xL2P, CxL2P and IxL2P showed negative heterosis. They would therefore be earlier than average parents. These results are in line with those in which, on 36 crosses, 27 hybrids recorded an inbreeding depression and 9 hybrids expressed positive heterosis for its earliness [28]. Precocity in the okra is linked not only to the mean of flowering date, but also to the internode size and the distance between the cotyledonary node and the first floral node [29][30]. It appears that L3xL1, L5xL1 and CxL2P hybrids are considered as early hybrids.

Similar results have been reported [17] and are in agreement with the main objective in improvement programs on *A. esculentus* which is to get small plants [1]. These values of heterosis remain insignificant because the height of the plant is controlled by genes with additive effects [31] which form 'big size' dominates on the form "small size". This result is similar to that obtained by [32].

However, it should be noted that, in terms of earliness, the choice of the varieties depends on the agricultural practice type and the length of the seasons. Indeed, early varieties are recommended for those who practice intensive agriculture, while for farmers who practice subsistence farming, it is wise to cultivate the late varieties as flowering at those - this is spread over time. In the second case, L3xL2P and L5xL2P hybrids would be appropriate. This result is similar to that which shows that the distance between the cotyledonary node and the first floral node is high; more the variety is late [32].

Concerning the number of branches, it is known that degree of branching of okra germplasms is highly variable [33]. However, significant mid-parent heterosis was obtained by CxL1, L3xL2P, L5xL2P and CxL2P hybrids. These results are consistent with those of a significant heterosis value of branches number with P1xP5, P1xP8, P2xP5, P2xP6, P3xP4, P3xP6, P3xP9, P5xP9, P6xP8 and P6xP9 hybrids [27].

With regards to the viscosity of the edible fruit, almost all hybrids had inbreeding depression. This depression should be due to the effect of the parents used as female in crossings. Indeed, it has been proven that maternal effect exists in okra hybridization [29].

For the agronomic parameters, the results of the analysis revealed in terms of the fruits number that setting varies from one variety to another. High level of variability in the quantitative characters was also observed in a characterization of three okra accessions [34].These indicate that phenotypic and genetic variability are pertinent among okra collections [33]. These results are in agreement with those in a similar study [35], [36].

The L3xL1 hybrid presented positive and significant best-parent heterosis for the 100 seeds mass; the hybrid CxL1 for the fruits number per plant; the hybrid IxL1 for the edible fruit mass; the hybrid L3xL2P for the edible fruit diameter and the 100 seeds mass; the hybrid L5xL2P for the edible fruits diameter. These findings corroborate those whereby the positive best-parent heterosis was observed in the hybrid 2xBH-BH-10 for the 100 seeds mass, the fruit mass, the fruit diameter and the branches number 37 and those in which on 30 combinations achieved between a few varieties of okra, a positive heterosis had been obtained

for the following variables: average fruit weight, first flowering date, fruit diameter and fruits number per plant [38].

With regards to the seeds number per fruit, apart the CxL1 hybrid that presented a positive and significant mid-parent heterosis values, other hybrids showed positive but not significant values of heterosis, or negative values which involved that the fruit could not have enough seeds.

However, it should be noted that the seed-rich fruit would be a significant nutritional contribution, because okra seeds are rich in proteins, lipids, carbohydrates and mineral salts [39].

For the biochemical parameters, most of the hybrids showed a positive useful heterosis. So the hybrids L5xL2P, L5xL1, CxL1, L3xL1, L3xL2P and IxL2P have a total ash rate higher than the best parents. Therefore, these hybrids would be rich in minerals content.

The highest carbohydrate rate presented by the hybrid L5xL1 could foreshadow hybrid mucilage high in fruits of such rate.

Hybrids such as L3xL2P, IxL2P, CxL1 and IxL1 with a higher crude fiber could play the role of foods in ballast. Hybrids L3xL2P and L5xL2P are those which contain the maximum of good characters. Similar results were obtained on the MDU1 x Hissar Unnath hybrid which, apart the branches number and the edible fruit mass had the highest values of heterosis for the 50% flowering day, the plant height, the fruit number, the fruit length and of the fruit diameter [40]. Negative and significant heterosis for crude fiber observed in present study is in confirmation with many findings on similar works on heterosis in okra [41], [42].

The output of the PCA revealed that different characters contributed differently to the total variation [43]. Results of this study confirm well those of this author because the mean contributions of almost studied characters were relatively high in the principal axes.

CONCLUSION
Finally, the potential improvement of Okra varieties with nearest characterization as those need by the population of three region in Cameroon, have been study from an ethnobotanic and controlled pollinisation based on agromorphological, biochemical and organoleptical characteristics of local and exotic varieties. An ethnobotanical survey of populations highlight a okra ideotype variety with a short development (early), a medium-sized cycle, an average density of seedlings in field, an average number of fruits per plant, fruits of medium size, dark green color and smooth aspect. This variety must have medium-sized

seeds, a few seeds number per fruit, a bland taste and high viscosity. Heterosis hybrids of *A. esculentus* values vary widely depending on genotype and characters and range from negative to positive values. Regarding the biochemical parameters, some hybrids namely L5xL2P, L5xL1, CxL1, L3xL1, L3xL2P and IxL2P for the rate of dry matter, the L5xL1 for the rate of carbohydrate hybrid, hybrid L3xL2P, IxL2, CxL1, IxL1 for the fiber rate showed a positive best-parent heterosis. The study therefore concludes that hybrids L3xL2P and L5xL2P by having the maximum number of the characters are near to the ideotype needed by Cameroonian population.

REFERENCES

1. Aladele SE, Ariyo OJ, De Lapena R. Genetic relationships among West African okra (Abelmoschus caillei) and Asian genotypes (Abelmoschus esculentus) using RAPD. African Journal of Biotechnology. 2008;7(10).

2. Hamon P, Dumont R, Zoundjihekpon J, Ahoussou N, Tio-Toure B. Les ignames. l'amélioration des plantes tropicales.(Eds. A. Charrier, M. Jacquot S, Hamon D, Nicolas) Cirad/Orstom. 1997:385-400.

3. Saifullah M, Rabbani MG. Evaluation and characterization of okra (Abelmoschus esculentus L. Moench.) genotypes. SAARC J. Agric. 2009;7(1):92-9.

4. Anonymous 1. Activité de renforcement de la commercialisation agricole en Guinee: USAID. La filière gombo (okra) en Guinee. 2006; 32.

5. Ngeugang AP. L'agriculture urbaine et périurbaine à Yaoundé: analyse multifonctionnelle d'une activité montante en économie de survie. Thèse présentée en vue de l'obtention du grade de Docteur en Sciences Agronomiques et Ingénierie Biologique. FASA, Université de Dschang. 2008; 200.

6. Sawadogo M, Zombre G, Balma D. Expression de différents écotypes de gombo (Abelmoschus esculentus L.) au déficit hydrique intervenant pendant la boutonnisation et la floraison. BASE. 2006 Jan 1.

7. Akintoye HA, Adebayo AG, Aina OO. Growth and yield response of okra intercropped with live mulches. Asian Journal of Agricultural Research. 2011;5(2):146-53.

8. Siemonsma JS, Kouamé C. Abelmoschus esculentus (L.) Moench. Fiche de Protabase. Grubben GJH and Denton OA PROTA. Plant Resources of Tropical Africa). Wageningen, Pays Bas. 2004;14.

9. VarmuDy V. Need to boost okra exports. Facts For You. 2011;31(5):21-3.

10. Zonkeng C, Mbouapouognigni V, Mbog J. et Gandébé M. Collecte et caractérisation des variétés de gombo au Cameroun. *In* : Caractérisation des principaux nuisibles des gombos des zones Camerounaises de cultures et mise au point de la méthode de protection intégrée. Rapport trimestriel IRAD 2004. 2004; 166.

11. Medagam TR, Kadiyala H, Mutyala G, Konda CR., Hameedunnisa B, Reddivenkatagari SKR. and Jampala DB. Genetic analysis for yield and its components in okra [Abelmoschus esculentus (L) Moench]. *Songklanakarim J. Sci. Technol*. 2012; 34(2): 133-141.

12. Ngeulieu CR. Caractérisation morphologique et évaluation préliminaire du germoplasme de gombo (*Abelmoschus* spp) en zone tropicale humide: localité de Yaoundé (Nkolbisson), Cameroun. Mémoire de Diplôme d'Ingénieur Agronome. Université de Dschang. 2010; 80.

13. Anonymous 2, Proceedings of the APSA-AVRDC Workshop, AVRDC–The World Vegetable Center. Shanhua, Taiwan. AVRDC Publication 08-703. 2008; 44.

14. Duzyaman E. Okra: botany and horticulture. Horti. Rev. 1997; 21:42-68.

15. Olayiwola MO, Olaniran DD, Nassir AL and Ariyo OJ. Genetic analysis of some agronomic traits in okra [*Abelmoschus esculentus* (L.) Moench]. *Acta Horticulturae et Regiotecturae.* 2020; 1: 56-59.

16. FAO. The State of the World's Plant Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, 1997.

17. Dabandata C, Bell JM, Amougou A and Ngalle BH. Heterosis and combining ability in a diallel cross of okra (*Abelmoschus esculentus* (L.) Moench). *Agro. Afr.* 2010; 1: 45-53.

18. Dabandata C, Bell JM, Nsimi MA, Amougou A, Ngalle HB. et Ndoumbe NM. Etude de l'héritabilité et des corrélations chez le gombo [*Abelmoschus esculentus* (L.). *Continental J. Agronomy.* 2012; 6(1): 24 – 29.

19. IPGRI, Okra Descriptor List. International Crop Network Series 5. International Board for Plant Genetic Resources (IBPGR), Rome, Italy. 1991.

20. Nsimi MA, Bell JM, Dabandata C, Mba JE, Ngalle HB, Godswill NN and Amougou A. Assessment of some agro-morphological parameters of some local and exotic varieties of okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Biotechnology and Food Science.* 2013a;1(1): Pp. 6-12.

21. Nsimi MA. Bell JM, Dabandata C, Mba JE, Tiwa FM and Ngalle HB. Assessment of the sensitivity of some varieties of okra [*Abelmoschus esculentus* (L.) Moench] to cercosporiose of leaves caused by *Cercospora malayensis* and *Pseudocercospora abelmoschii*. *World Journal of Bioscience and Biotechnology Research.* 2013b; 1(1): 01-11.

22. AFNOR. Association Française de Normalisation. Recueil des Normes Françaises. *Acides gras et composés lipidiques*. Paris, France. 1981; 250.

23. Wolff JP. Manuuel d'analyse des corps gras. Paris-. Azoulay. 1968; 115.

24. Cerning J and Guilbot A. A specific method for the determination of pentosans in cereals and cereal products. Cereal Chem; 1973; 50: 176-184

25. Wynne JC, Emery DA and Rice PM. Combining ability analysis over environments in sprint weat. *Wheat Infor. Serv.*, Japan. 1970; 67: 21 - 24.

26. Sawadogo M, Balma D, Nana R et Livius Sumda RMK. Diversité agro morphologique et commercialisation du gombo (*Abelmoschus esculentus* L.) à Ouagadougou et ses environs. *International Journal of Biological and Chemical Sciences*. 2009;3(2) : 326 – 336.

27. Mahta N, Asati BS, Mamidwar SR. heterosis and gene action in Okra. Bangladesh J. Agril. Res. 2007; 32(3): 421-432.

28. Wammanda DT., Kadams AM and Jonah PM. Combining ability analysis and heterosis in a diallel cross of okra [*Abelmoschus esculentus* (L.) Moench]. *African Journal of Agricultural Research* 2010; 5(16): 2108-2115.

29. Khan FA, Din JU, Ghaffor A and Khan KW. Evaluation of different cultivars of okra (*Abelmoschus esculentus* L.) under the agro-economic conditions of Dera Ismail Khan. *Asian Journal of Plant Sciences*. 2002; 1(6): 663 – 664.

30. Saed A. Inheritance of some characters in okra (*Abelmoschus esculentus* Moench) under drough conditions. Ph. D Thesis. Sindh Agriculture University, Tandojam. 2002; 200.

31. Arora SK and Tripathi V. Detection of epistasis and estimation of components genetic variation in okra [*Abelmoschus esculentus* (L.) Moench]. *Vegetable Science*. 2001;28 (2): 109 – 112.

32. Parry G. le cotonier et ses produits. Manoeuvre et Larouse, Paris, France. 1982; 502.

33. Tesfa B and Yosef A. Characterization of okra (*Abelmoschus esculentus* (L.) Moench) Germplasms Collected from Western Ethiopia. *International Journal of Research in Agriculture and Forestry*. 2016; 3(2):11-17.

34. Osawaru ME, Ogwu MC and Omologbe J. Characterization of three Okra [*Abelmoschus esculentus* (L.) Moench] accassions using morphology and SDS-PAGE for the basis of conservation. Egyptian Academic Journal of Biological Sciences. 2014; 5(1): 55-65.

35. Dabandata C. Hétérosis, héritabilité et stabilité des hybrides contrôlés de *Abelmoschus esculentus* (L.) Moench. Thèse, Ph. D, Département de Biologie et Physiologie Végétales, Faculté des Sciences de l'Université de Yaoundé I, Yaoundé, Cameroun. 2014; 170.

36. Bello D, Sajo AA, Chubado D and Jellason JJ. Variability and correlation studies in okra [*Abelmoschus esculentus* (L). Moench]. *Journal of Sustainable development in Agriculture and Environment*. 2006; 2(1): 102 – 126.

37. Qhureshi Z. Breeding investigation in Bhendi [*Abelmoschus esculentus* (L.) Moench]. *Plant and Genetics Breeding*. 2007; 83.

38. Singh KP. Effect of spacing on okra. *Indian J. Agron.*, 1990;35: 439 – 441.

39. Ndangui CB, Kimbonguila A, Nzikou JM, Matos L, Pambou-Tobi NPG, Abena AA, Silou Th, Scher J and Desobry S. Nutritive composition and properties physico-chemical of gumbo (*Abelmoschus esculentus* L.) seed and oil. *Research Journal of Environmental and Earth Sciences.* 2010; 2(1): 49 – 54.

40. Kumar PS. and Sreeparvathy S. Studies on heterosis in okra [*Abelmoschus esculentus* (L). Moench]. Electronic Journal of Plant Breeding. 2010; 1(6): 1431-1433.

41. Sanket JM, Chaudhari KN, Vaidya GB and Chawla SL. Estimation of Hybrid Vigour for Fruit Yield and Quality Traits of Okra [*Abelmoschus esculentus* (L.) Moench] Through Line x Tester Analysis carried over Environments. International Journal of Current Microbiology and Applied Sciences. 2017; 6(7): 4101-4111.

42. Kumar S, Singh AK, Das R, Datta S and Arya K. Combining ability and its relationship with gene action in okra [*Abelmoschus esculentus* (L). Moench]. *J. Crop Weed*. 2014; 10(1): 82-92.

43. Nwangburuka CC, Kehinde OB, Ojo DK, Denton OA and Popoola AR. Morphological classification of genetic diversity in cultivated okra, *Abelmoschus esculentus* (L.) Moench) using principal component analysis (PCA) and single linkage cluster analysis (SLCA). African Journal of Biotechnology. 2011; 10(54): 11165-11172.