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RESEARCH ARTICLE

ASSESSMENT OF AGROMORPHOLOGICAL PERFORMANCES AND GENETIC PARAMETERS OF OKRA VARIETIES RESULTING FROM PARTICIPATIVE SELECTION

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Abstract

In Burkina Faso, *Abelmoschus esculentus* is especially appreciated for its fruits, which are requested throughout the year by consumers. However, its production is based on local varieties which are little productive. In order to identify the characters of interest, to increase production and enhance the value of local genetic resources of the okra, investigations and a participative selection on accessions collected in three (03) agricultural areas have been realized.

Agro-morphological evaluation on 16 favorite accessions of producers has been conducted in rain season following the block design of Fisher with three replications. Investigations have revealed that the preferences of producers are based essentially on the fruit and the precocity of the cycle. Thus, the green fruit, elongated and rich in mucilages are the most appreciated. Although the heritability within the meaning of all the characters is high, the yield components such as the height of the plant and the number of ramifications are the most inheritable. The analysis of the performance of the varieties has shown that eight varieties (G298, O2, G175, G289, KKO5, L2, X59, G263) are close to the producers' ideotypes and only two varieties (UAE 22 and G264) bring together the maximum characters of the interests of the producers.

The efficient varieties thus identified could be exploited in okra's breeding programs in Burkina Faso.

Introduction:-

Burkina Faso is an essentially agricultural country where nearly a million people have suffered from food insecurity and five hundred thousand children from acute malnutrition in 2015 (European Commission, 2015). Greater production and valorization of neglected plants such as okra could contribute to a significant reduction of malnutrition.

The okra (*Abelmoschus esculentus*) is a vegetable fruit whose consumption provides proteins, vitamins and mineral salts which are essential to any diet based on cereals (Nana *et al.*, 2009). In rural areas, the okra is the main food to bridge the gap and its sale provides substantial monetary incomes for producers (Sawadogo *et al.*, 2009). Referred to as the "Perfect villagers's vegetable" according to Kumar *et al.*, 2010, Okra can be a resilience agro economic culture for rural farmers. Indeed, in 2010 the world trade of okra has generated approximately $4.4 billion US (FAO, 2012). The potentialities of exploitation of all the parts of the plant in the production of biodiesel, of gold nanoparticles and even its immuno-modulator effect have been reported by several authors (Mugnier, 2008, Sheu *et al.*, 2009; Anwar *et al.*, 2010; Jayaseelan *et al.*, 2012).

In spite of favorable agro-climatic conditions (Balma *et al.*, 2003, Sawadogo *et al.*, 2006), Burkina Faso has produced only 23 000 tonnes in 2013 (FAOSTAT, 2015). This weak production of okra is related to the unavailability of adapted improved varieties (Sawadogo *et al.*, 2009). This is caused by the failure to transfer new varieties without taking into account the needs of African producers who are mostly rural and poor (Niangado, 2002).

Thus, to determine the characters of interest of the okra from producers and to assess their genetics performances, a participative selection on accessions collected and an agro-morphological characterization on accessions selected were carried out.

Material and methods:-

Participative selection:-

A semi-structured investigation and interviews were conducted in August 2014 in three of the major agricultural areas of Burkina which supply the capital with the Okra (Figure 1). Fifty five (55) producers of okra were interviewed individually and in group to identify the characters of interest in the okra. The participative approach has been inspired by those used by Vom Brocke (2013). A collection of 16 accessions including a local improved variety (UAE 22) obtained during a previous participative selection has been incorporated.

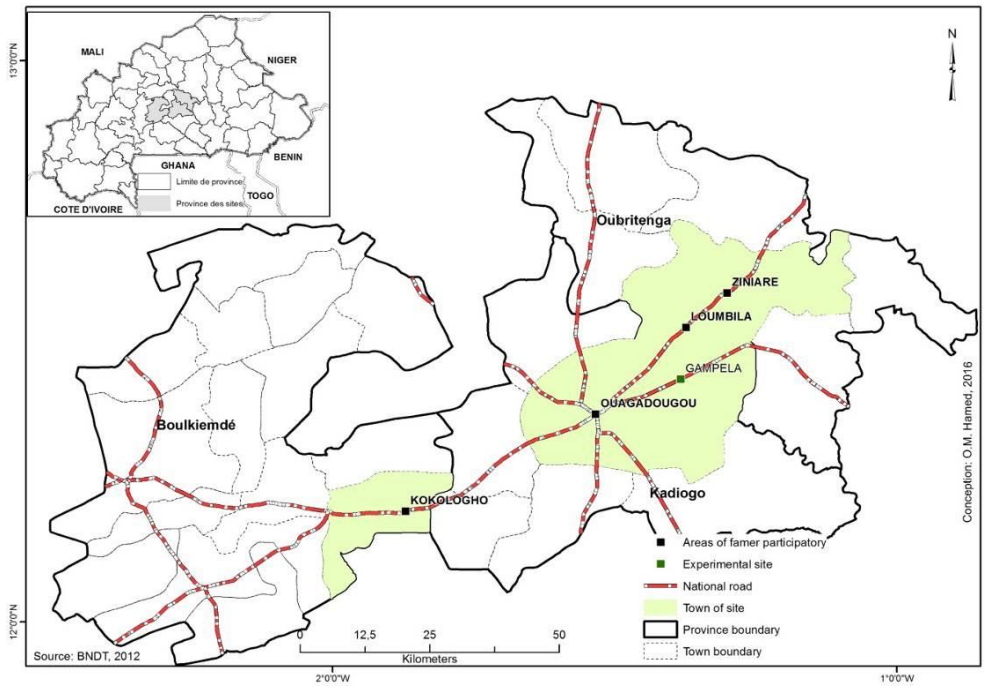


Figure 1: Areas of collection of favorite accessions and participative selection sites

Agromorphological characterization:-

Plant material:-

A total of sixteen (16) accessions selected during the participative selection were considered in this study.

- **Experimental site description**

The study was conducted at Gampela, experimental station of the Institute of Rural Development located in North-Sudanian at 18 kilometers from Ouagadougou. A geographical location of the site is 1 ° 21'W longitude and 12 ° 24'N latitude. The total rainfall amount during the test is 725 mm.

- **Experimental design and treatments:-**

The test was conducted in July 2015 according to a randomized complete block design (RCBD) in three replications. Each accession was planted on three successive lines in each block. Each input line of 4.2 m long included 8 bunches with inter-planting holes of 0.6 m and 0.8 m line spacing distances.

The experiment was conducted in the rainy season on a sandy loam. The seeds were previously treated with permethrin at 25 g/Kg. Sowing with three seeds per hill were carried out on moist soil plowed with a tractor. A thinning to one (1) seedling per hole was made in the 18th day after sowing (JAS). NPK fertilizer (10-20-20) at the rate of 165 kg/ha and weeding were done in 20th JAS. Provision of urea at the rate of 200 kg/ha with an earthing up of plants were done on 45thJAS.

- **Agro-morphological parameters measurements:-**

The evaluation concerned seven (7) qualitative characters and nine (9) quantitative characters linked to the okra's descriptors and the producers' characters of interest.Qualitative characters were observed on every plant starting from the 8th leaf. The observations focused on the shape of the leaf (FFE), the form of immature fruit (FFI), the color of the leaf (CFE), the color of the stem (CTI), the color of immature fruit (CFI), the pubescence of immature fruit (pFI) and pubescence of the stem (pTI)

Quantitative characters were evaluated on 4 plants randomly selected except the days to 50% flowering (50% FL) evaluated in all the line. The characters such as number of seeds per fruit (NGF), weight of mature fruits (PFI), and number of fruits per plant (NFP) were measured to evaluate the production. The length of immature fruit (LFI), the diameter of the immature fruit (DFI), the width of the leaf (lFE) were used to estimate the size of the fruit and leaf. The characters of yield evaluated at 60 JAS were the plant height (HPL), the diameter of stem (DTI), the number of nodes (NNO) and the number of branches (NRA).

- **Statistical analysis:-**

EXCEL (2013) software was used to pretreat data, to calculate the frequency and realize histograms. Data analysis was done with GENSTAT 10.3 software. It was used for the analysis of variance test with Newman-Keuls (SNK) separation average test in order to compare the performance of sixteen accessions of okra. Components of analysis of variance of each trait were used to estimate genetics parameters. The broad-sense heritability (H^2) has been determined using the genotypic (VG) and phenotypic (VP) variances according to REX formula (2002):

$$H^2(\%) = \frac{VG}{VP} X100$$

Results:-

Participative selection:-

The exchanges between targeted actors of the participative selection were used to determine their knowledge of the culture and characters of interest in the okra by the producers.

Producers' local knowledge on okra:-

The investigation revealed that producers use a dichotomous key based on the cycle to identify accessions of okra. Thus, the accessions of okra early cycle have very short sticky fruits with small seeds while those of late cycle have long and less sticky fruits with large seeds.

Identification of farmers' preferences of okra:-

The main characters of interest in the okra (Figure 2) were, in order of importance, short cycle and color of the capsules (23%), the mucilage content of the fruit (18%), the elongated shape fruit (13%) and the number of fruit per plant (10%). Over 75% of respondents, the characters of interest are linked to the fruit. In addition, green fruits (71.43%) and elongated shape (77%) are the most popular. The analysis of varietal preferences of producers recorded in Figure 3 shows that the improved local variety UAE 22 and G264 accession record the highest frequencies (12%).

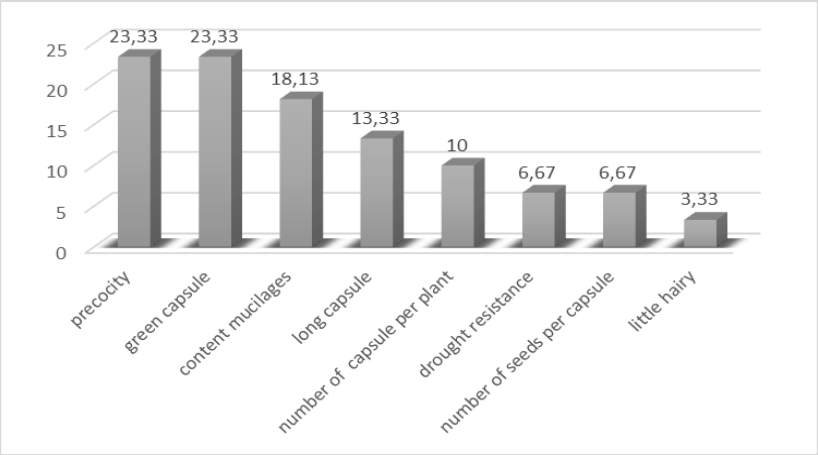


Figure 2: Distribution of characters of interest in the okra

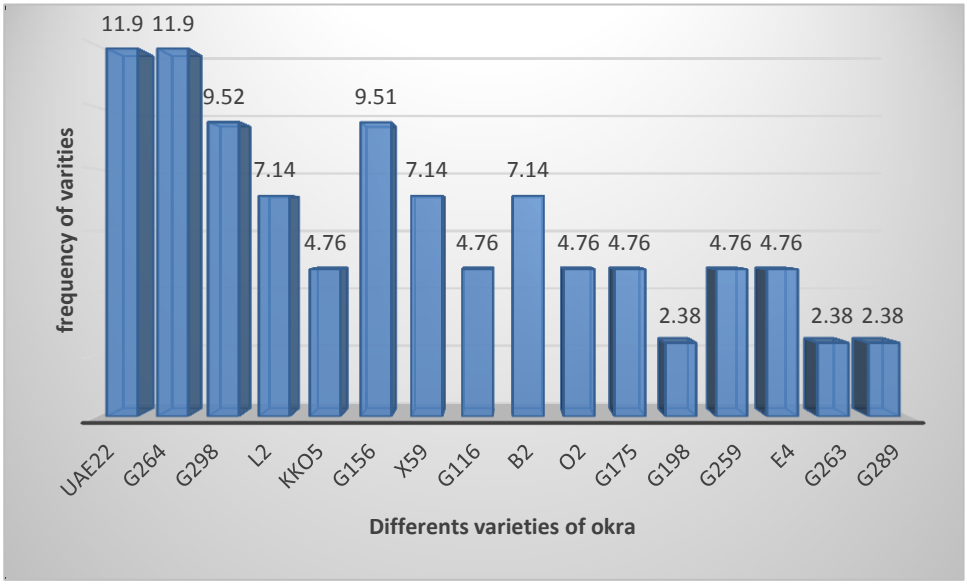


Figure 3: Distribution of the evaluation frequencies of assessment of okra accessions by producers by variety

Agro-Morphological Characterization:-

Description of accessions using qualitative traits:-

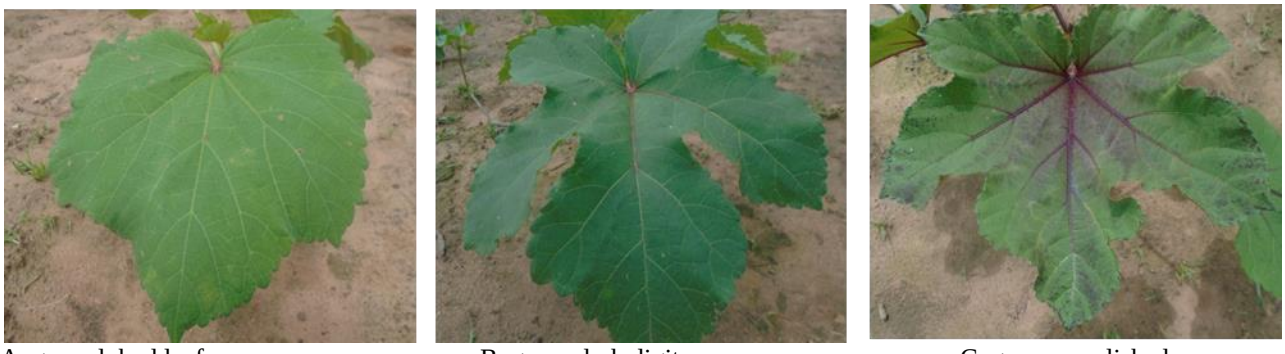
Stem and leaf characteristics: The study revealed variability among accessions related to character shape, color and pubescence of the stems and leaves (Table 1). Three main colors of the stem (purple, green, purple) were observed (Photos 1.A, 1.C, 1.D) with a high percentage of purple stems (55.9%). The majority of accessions have little hairy stems (81%). A diversity of colors of leaves (2) was observed. The leaves are uniformly green (47%), dark green (46%) and green variegated purple (7%). An important proportion of accessions (Photo 2) have pubescent leaves (90%) that are lobed shape (94%) or fingered (6%). The leaves of most of the accessions (90%) are hairy.

Table 1: Modalities of qualitative characteristics of the stem and leaf

Characters	Modalities	Percentages (%)
Stem color	Purple	55.9
	Green striped	5.1
	Green	18.86
	Violet (red-blue color)	20.14
Stem Pubescent	Glabrous	9
	Pubescent	91
Leaf color	Green	47.47
	Dark green	45.75
	Green-purple	6.78
Leaf shape	Lobed	93.9
	Fingered	6.1
Leaf pubescence	Pubescent	89.83
	Glabrous	10.17

A. purple B. Purple-dark C. green D. crimsom E. green striped of red

Photo 1: Variability of the stem color of varieties of Okra



A. green lobed leaf B. green dark digity C. green purplished

Photo 2: Variability of colors and shapes of okra leaves

Fruit characteristics: An important variability was observed on the color and shape of the fruits (Photo 3). Evaluation of the color of fruits of accessions (Figure 3) shows that fruits are mostly green (53%). As to the form of fruits, 92% of the capsules are elongated against 8% short. Short capsules are all green. Most of the accessions (87%) have pubescent fruits (Figure 4). Local improved variety UAE 22 and G264 accession have capsules lengthened which are green and white respectively.

Photo 3: variability of fruit color of the varieties of okra selected

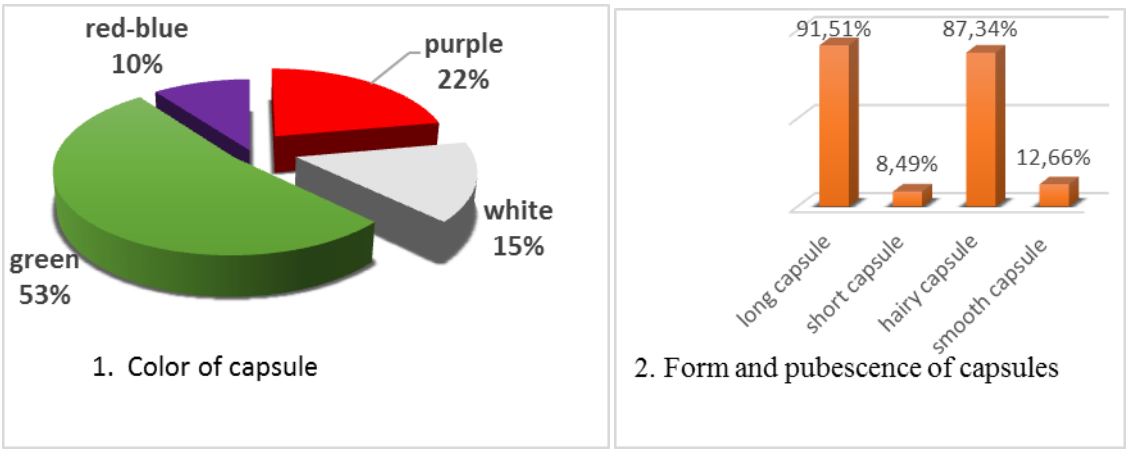


Figure 4: Distribution of accessions according to (1) the color, (2) the form and pubescence of capsules

Performance of accessions: Except the fruit diameter, the other quantitative traits discriminate significantly accessions studied at the level of 1% (Table 3). The coefficient of variation (CV) ranged from 3% to 38.69%. Only the number of branching character has a CV greater than 30%. Determination coefficients (R^2) of characters ranged from 54% to 91%.

Parameters related to production: average separation test revealed a distribution of accessions into several groups for all discriminating traits. Thus, the character related to the number of fruits per plant discriminated the accessions into three different groups and four intermediates. The most productive accessions are G116, (30 fruits per plant), B2 (20 fruits per plant) while the least productive (9 fruits per plant) are L2, UAE 22, G289, X59 and O2.

Depending on the number of seeds per fruit, three groups were identified including six accessions (G259, KKO5, G264, E4, G116, O2) which are the most productive group with an average of 106 seeds. The least productive group only consists of the improved local variety UAE22 with an average of 10 seeds per fruit. Concerning the weight of the immature fruit, the results showed a distribution of accessions into five distinct groups. An accession X59 with 40 g as a weight of the fruit is the most efficient while the accession G156 has the lightest fruit (8 g).

Flowering cycle: With a days to 50% flowering from 42 to 55 JAS, the accessions of okra studied are divided into three groups (Table 2): a group of 42 to 50 JAS with five accessions (G298, O2, G263, X59, L2 and UAE 22) and a group 51 to 55 JAS consisting of ten accessions (KKO5, G156, E4, G116, G259, G289, G264, G198, B2, G175).

Parameters related to fruit dimensions: the length of the fruit discriminated the accessions into three groups. Accession G116 has longer fruits (16 cm) while the accessions O2 and G298 have the shortest fruits (5 cm).

Plant dimensions: the height of the plant, number of nodes and branches have significantly discriminated accessions (Table 3). The high value of plant height (104 cm) and number of branches (6) were found in the B2 accession which also contains a large number of nodes.

Estimation of genetics parameters:-

Genetics parameters (Table 3) show that the phenotypic variance is greater than the genotypic variance for all traits. The highest values of the phenotypic variance were observed in the characters plant height (337.94) and number of seeds per fruit (281.4). However the lowest values of the phenotypic variance are recorded at the traits fruit diameter (0.18), days to 50% flowering (11.90) and length of immature fruit (12.49). The phenotypic and genotypic coefficients of variation are high (> 20%) for all parameters except days to 50% flowering , thousand seed weight, number of seeds per fruit, length of immature fruit (19.13%) which have moderated coefficients (Sumathi *et al.*. 2010). The broad sense heritability ranged from 72.82 to 97.78% is high for all the traits (Johnson, 1955; Stanfield, 1975). The expected genetic advance was raised for plant height (35.43%) and number of seeds per fruit (32.4%).

Table 2:Average performance of accessions and the results of the analysis of variance

	50% CFL	DTI	HPL	NRA	lFe	LFE	NNO	PFI	LFI	DFI	NGF	NF/P	PMG
G259	53.33abc	23.50 ab	93.750 abc	2.50b	32.25 ab	26.62 bc	12.00 a	25.92 b	13.02 bc	2.02ab	107.00a	18.75 bc	56.66 a
G156	54.33ab	25.92 a	99.000 ab	2.75 b	32.50 ab	23.45bcde	11.50 a	12.35 e	10.37 bcd	1.97 ab	78.00 c	14.25 cde	57.33 a
KK05	54.66 a	17.72 c	93.500 abc	2.25bc	34.75 ab	25.12 bcd	11.50 a	23.10 bc	12.30bc	2.17 ab	96.75 ab	10.50 de	36.66 c
L2	49.00de	18.87 c	86.25 bcd	1.75 bc	31.85 ab	25.90 bcd	11.50 a	17.72 d	14.30b	2.02ab	107.00 a	9.25e	58.00 a
G289	52.00abcd	12.95 d	94.00abc	2.75 b	31.75 ab	25.67 bcd	11.75 a	19.15 cd	14.17b	1.97 ab	86.50 bc	9.00 e	54.66 a
B2	51.00bcd	25.155 a	104.00 a	5.50 a	36.77 a	27.67 ab	6.75 b	11.10 ef	10.37 bcd	1.60 ab	82.25 c	20.00b	47.66 b
G264	52.00abcd	11.725 d	86.75 bcd	2.00 bc	30.62 b	20.12 efg	10.50a	23.57bc	12.37 bc	2.35a	106.75 a	11.25 de	61.33 a
E4	53.66ab	20.975 bc	73.00d	3.75 b	26.00 c	22.62cde	11.50 a	18.17 d	9.32 cd	1.32b	105.25 a	13.00 de	57.66 a
X59	49.00de	18.250 c	58.75 e	2.00bc	23.85 cd	28.25 ab	12.75 a	40.22 a	11.90 bc	1.95ab	85.25 bc	9.25 e	59.00 a
UAE22	47.33ef	24.750 a	80.50cd	0.25 c	33.05 ab	31.37 a	9.75 ab	21.50 bcd	12.97 bc	2.52 a	63.50 d	9.50 e	37.66 c
G175	51.33 abcd	18.100 c	53.50^{e}	2.75 b	23.42 cd	22.45 cde	10.50 a	23.05bc	13.57 bc	2.10 ab	88.50 bc	10.50 de	45.00 b
G116	54.00ab	10.150 d	61.25^{e}	1.75bc	21.90 cd	16.95 g	6.75 b	12.87 e	18.52 a	1.70 ab	109.50a	30.25 a	56.00 a
G298	42.33g	18.400 c	82.00bcd	3.50b	24.45 cd	21.47 def	9.75 ab	12.77 e	5.35 e	2.20ab	77.25 c	16.00 bcd	34.33 c
O2	45.333 f	12.625 d	74.50 d	1.50 bc	23.75 cd	24.52 bcde	9.25 ab	17.02d	7.35de	2.52a	105.50 a	8.50 e	58.00 a
G198	52.333 abcd	13.475 d	55.00^{e}	2.75 b	19.90d	17.62fg	12.75 a	7.97 f	9.50cd	1.30 b	80.50 c	12.75de	47.66 b
G263	50.000 cde	11.550 d	79.25 cd	3.50b	21.80 cd	21.25def	9.50 ab	12.25 e	11.35 bc	1.72 ab	74.75c	12.25de	48.66 b
M	50.73	17.76	79.67	2.58	28.04	23.82	10.50	18.67	11.67	1.97	90.89	13.44	51.02
CV (%)	3	19.41	10.47	10.14	9.36	15.77	8.32	19.81	7.92	15.97	38.69	12.46	6.39
R^2	0.88	0.91	0.83	0.63	0.88	0.80	0.60	0.93	0.776	0.54	0.84	0.85	0.91
F	15.44	32.08	15.53	5.49	21.38	12.04	4.72	45.01	11.05	3.68	16.33	18.07	21.79
Pr> F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001

The averages followed by the same letter are not significantly different with the threshold from P= 0.01, M : mean ; CV : Coefficient of Variation, R^2: coefficient of determination, 50%CFL : days 50% flowering, DTI : Diameter of stem, HPL : Height plant, NRA : Number of ramifications, lFE : width of leaf,: LOF : Length of leaf , NNO: Number of nodes, PFI: weight of the immature capsule, LFI: Length of immature capsule , NGF : Number of seed per capsule , NF/P : Number of capsules per plant, PMG : Thousand-seeds weight F: F of Fisher

Table 3: Estimates of genetic parameters of 11 characters of the okra

Variable	VG=(SMG- SME)/r	VP=VG+(SME/r)	H2=VG/VP*100	GCV=(√VG/X)*100	PCV=(√VP/X)*100	GA=H2*√VP*K
50% CFL	11.13	11.90	93.52	6.58	6.80	6.64
DFI	0.13	0.18	72.82	18.34	21.49	0.63
DTI	35.85	37.00	96.88	33.71	34.25	12.14
HPL	316.19	337.94	93.56	22.31	23.07	35.43
LFE	18.27	19.93	91.69	17.94	18.74	8.43
NFP	40.3	42.67	94.46	47.23	48.60	12.71
NRA	15.01	17.36	86.47	124.79	134.20	7.42
NGF	264.13	281.4	93.86	17.88	18.46	32.4
PFI	79.38	81.19	97.78	47.72	48.26	18.15
LFI	11.36	12.49	90.96	28.89	30.29	6.62
PMG	73.06	76.57	95.41	16.75	17.15	17.20

Discussion:-

Participative selection:-

The Dichotomous key used by the okra producers identifies early varieties by their short fruits and large seeds that are rich in mucilage. These findings are confirmed by agro-morphological assessment showing that accessions at short cycle (G298 and O2) have shorter fruits compared to accessions at long cycle (G116 and G156) which have the longest fruits. Participative selection that takes into account producers' knowledge is an essential tool for ensuring the introduction and success of new varieties in rural areas. Ouedraogo *et al.* (2015) have reported effective management methods of okra seeds by producers. There is a positive influence of local knowledge on the performance of cultivars of okra. Indeed, the enthusiasm of farmers for improved local variety UAE 22 from a previous participative selection and accession G264 shows that they draw the maximum characters of interest from producers. This is confirmed by the findings of Beauval *et al.* (2011) that showed the low choice of improved varieties of exotic okra.

These results also show that the participative selection is effective for identifying characters of interest and genotypes directly usable.The passion of the producers for mucilage would explain the choice of the G298 varieties and O2 with short fruits which would be richer in mucilages. These results are similar to those of Ameena *et al.* (2010).

In Burkina Faso, most producers' characters of interest in the okra are related to the fruit because it is the most valued part. Although the stems, roots and leaves are weakly retained as a character of interest, they are useful in emerging areas of biofuel (Anwar *et al.*. 2009), nanotechnology (Jayaseelan *et al.*. 2012).

Performance of genotypes:-

The results of agro morphological evaluation confirm producers' preferences for okra. The study showed a predominance of green color of the fruit, elongated capsules and precocity of the accessions. According to Nana (2010), varieties whose cycle is ranged to 40-50 JAS are very precocious. Thus, fruiting stage, G298 and O2 varieties that have a cycle from 40 to 45 JAS and four varieties L2. X59. UAE22. G263 whose cycle is between 45 to 50JAS are very early. The other varieties are early. Varieties G116, B2, G259 that have longer cycles are the most productive. Similar results are found by Ahiakpa *et al.* (2014). Indeed, the length cycle allows them a very good photosynthetic activity and a good productivity. Physiologists Cochome and Franquin (1967) have shown a positive correlation between the cycle length and yield in the absence of a limiting factor.

The best varieties with green and long capsules in reference to producers' preferences are G175, G289 and KKO5. These producers' preferences for the long and green fruits are related to consumer demand. Sawadogo *et al.*, (2009) have shown a preference of the same characters by consumers. Secondary preferences for the other colors of fruit are related to an in situ conservation of the varietal diversity and of ritual uses. Varieties G298 and O2 having the shortest fruits would be chosen for their mucilage content.

The potential in mucilage and the short cycle gave to the selected varieties a resilience capacity to drought. These results corroborate those of Clifford *et al.* (2002) and Nana *et al*.(2009).

Accessions G259, E4 and L2 are the best according to the number of seeds per fruit. The average number of seeds per fruit for all varieties (91 seeds) is superior to previous results of Jiro *et al.* (2011) on okra's ecotypes of Yatenga. These three varieties are good genotypes for seed establishment and could be used for extraction of seed oil. The small number of seeds observed in improved local variety UAE 22 is a character of interest of consumers (Sawadogo *et al.*. 2009).

Secondary preferences of producers for production and resistance to water stress of okra varieties which are similar to previous results of Balma *et al.*. (2003).These results show that drought tolerance and yields could depend on genotype, edaphic qualities of land and rainfall which are the general constraints to any culture. Nevertheless, short cycle and high potential for local accessions in mucilage (Sawadogo *et al.*, 2009) give them a source of drought resistance (Nana *et al.*2009; Clifford *et al.*, 2002).

The high value of coefficients of determination (R^2> 50) for all characters and the high broad sense heritability show that variability among accessions is more due to the genotype than environment.

The value of heritability alone doesn't give indications about the importance of genetic progress resulting from the choice of the best types. But this value is more useful if it combined with expected genetic advance (Beninga *et al.*. 2011). Thus, the high values of broad sense heritability and expected genetic advance of characters, plant height, and number of seeds show possibility for improvement from these characters. Our results are consistent with those of Shahibhaskar *et al.* (2011).

Conclusion:-

This study showed that the farmers' preferences are related to the precocity of accession, high mucilage content of fruit, green fruit color and long fruit.Ten genotypes can be selected and among them two varieties UAE 22 and G264 best express the producers' characters of interest.

Biochemical studies such as evaluation of the mucilage content and nutritional composition and a molecular characterization using microsatellites markers of these varieties will help to supplement the results of this study.

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