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Evaluation of the agronomic performance of twelve okra accessions [*Abelmoschus esculentus* (L.) Moench] in the Sudano-Sahelian climate of Burkina Faso

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Abstract

Okra is a nutrient-rich vegetable and fruit, widely consumed in Africa and cultivated around the world, especially in Africa and Asia. Despite its many recognized benefits, however, production is low on a national level. This is due to the fact that the crop has not been developed, resulting in low yields, especially grain yields. In fact, research does not promote seed production, and seeds are not available to growers. It is in this context that the present study aims to evaluate the agronomic performance of 12 okra accessions in the Sudano-Sahelian climate of Burkina Faso. An experiment was carried out at INERA Kamboinsé during the 2022-2023 cropping season, using an alpha latice design. A total of 20 agro-morphological traits were studied, including 7 qualitative traits and 13 quantitative traits. Results for qualitative traits revealed variability in leaf shape, leaf, fruit and stem color, fruit position and fruit pubescence. With regard to quantitative traits, observations were made on the 13 traits related to the okra development cycle and growth, grain yield and grain yield component. For this purpose, an analysis of variance and matrix correlation was carried out. The best agronomic performances for seed production were obtained with the accessions Anader Bongoanou, KBG76, KBG24, V3-1 Mogtédo. In terms of grain yield, accession KBG24 from Burkina Faso was the best with 86.855 t/ha.

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Introduction

Okra, *Abelmoschus esculentus* (L.) Moench] is a staple food for rural populations and is the number one vegetable for urban dwellers in Burkina Faso (Sawadogo *et al.*, 2009). It is characterized by a diversity of fruit and stem shapes and colors (Seck, 1991). It is also an important plant, with all its parts (roots, stems, leaves, fruits, seeds) used for food, medicine, crafts and even industry (Marius *et al.*, 1997). The fruits are used in the preparation of numerous sauces, while the leaves are used as spinach. In Burkina Faso, okra has become part of the population's eating habits. What's more, a survey conducted by (Sawadogo *et al.*, 2009) revealed that okra producers and sellers derive substantial income from okra production. So, in Burkina Faso, okra could play an essential role in programs to improve people's diets, as well as in poverty alleviation programs.

According to NHD, (2019) India is the world's largest producer of okra, accounting for 72.90 % of global production. Its global production is estimated at 9,872,826 tonnes and in Africa its production is estimated at 3,179,9930 tonnes (FAO, 2018).

In Burkina Faso, according to FAOSTAT, (2019) its production was around 23021.85 tonnes. Okra has always been a marginalized crop, generally reserved for women. In fact, 97% of the 200 growers surveyed in central-western Burkina Faso were women (Bationo, 2005). However, okra cultivation continues to face the problems of climate change, degradation of natural resources (especially the soil), diseases and pests (natural enemies), as well as varietal selection, which does not make it possible to provide growers with high-performance varieties. In addition, the low availability of improved seeds adapted to agro-ecological conditions is the main constraint to increased production. Growers are therefore obliged to use low-yielding traditional seeds (Shanhua, 2008). Indeed, low yields (2-4 t/ha) can be explained by non-intensive cultivation methods and lack of mastery of production technology packages. Seed yields are around 500-1000 kg/ha (Kumar *et al.*, 2013). Unfortunately, low yields in Burkina Faso are due to the lack of value added to the crop. Okra, which is a traditional crop, has still not been improved in Burkina Faso, reflecting a lack of interest in the crop and a lack of valorization (Ouédraogo, 2016). This study, entitled "Evaluation of the agronomic performance of 12 okra accessions [*Abelmoschus esculentus* Moench(L.)] in the Sudano-Sahelian climate of Burkina Faso", aims to highlight the agronomic performance of okra accessions that can be used to increase yields.

The general objective of this study is to evaluate 12 okra accessions for their agronomic performance in the Sudano-Sahelian climate of Burkina Faso. Specifically, it aims to: (i)describe the characteristics of the accessions; (ii)compare the agronomic performance of the accessions, (iii)identify accessions with good productivity.

Materials and methods

Presentation of the study site

The study was conducted at the Centre Recherche Environnemental Agricole et de Formation de Kamboinsé, one of INERA's research stations. The center, which covers an area of 230 hectares (ha), is located in the Centre region, province of Kadiogo (fig. 1). It is located in the commune of Ouagadougou on the northeast side of the city, on the Ouagadougou-Kongoussi axis. Its geographical coordinates are latitude 12°28 North, longitude 1°32 West and an altitude of 296 m above sea level (Guinko, 1984).

The climate in the Kamboinsé area is of the northern Sudanian type. It is marked by two alternating seasons: a dry season from October to February and a rainy season from June to October (Guinko, 1984). Kamboinsé soils are leached tropical ferruginous soils underlain by deeper sandy material and low-humus pseudogley hydromorphic soils inherited in association with lithosols on ferruginous cuirasse.

These soils are predominantly sandy-clay at the surface and clayey at depth (Kaloga, 1969). Rainfall for the 2022-2023 crop year was 698 mm over 43 days (fig. 1).

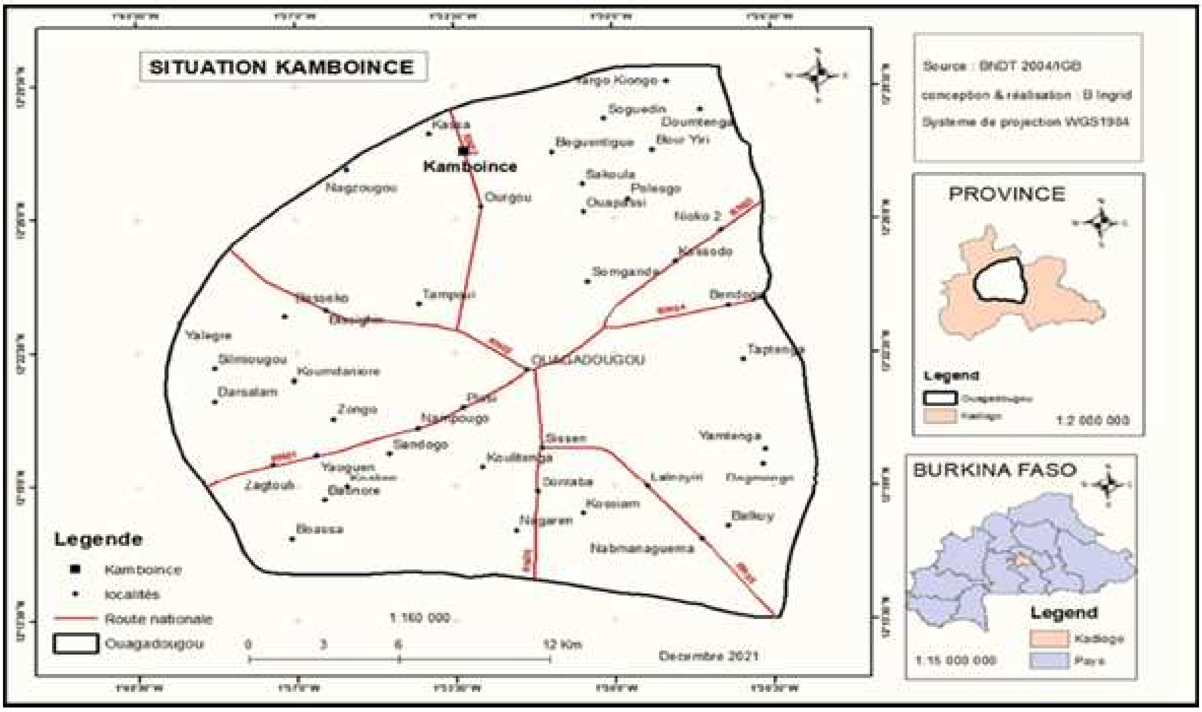

Fig. 1. Map of the geographical location of the Kamboinsé Environmental Agricultural Research and Training Center (Bambara, 2021).

Study materials

Plant material

The plant material used in this study comprises 12 okra accessions of various provenances, including two hybrids. Table 1 shows the list of accessions:

Study method

Experimental design and cultivation

The experimental layout of the trial was in alpha latice (α-latice) with three (03) replicates 21.8m long and 12m wide, each replicate being subdivided into two (02) sub-blocks each containing six (06) accessions on 12 lines. Each accession was sown in two 5m rows with a distance of 60cm between rows and 40cm between bunches, and each row consisted of 13 bunches. A distance of 1m was observed between replicates and 2m between sub-blocks. The total trial area was 261.6m2.

Sowing was carried out on July 18, 2023 on a 6.6m sub-block with a total area of 261.6m2.

The spacing between bunches was 40cm and between rows 60cm. So each line had 13 bunches. This means that each planter had 04 seeds.

Data collection

Qualitative characteristics

Qualitative characteristics were assessed by simple visual appraisal, mainly leaf shape (Ffe), leaf color (Cfe), stem color (CT), fruit color (CF) and fruit position on the stem (PFT). On the other hand, stem pubescence (PT) and fruit pubescence (Pf) were assessed by touch. These qualitative parameters were observed on the basis of the list of descriptors conforming to the CIRPG standard model (Charrier, 1983).

Quantitative characteristics

These are

date of 50% flowering (Flo 50%);plant height at flowering (Haut Flo) :stem diameter at flowering and budding (DTF and DTB) average number of fruits produced per plant (NMF);fruit length at maturity (LFM); fruit diameter at maturity (DFM); number of seeds per capsule at maturity (NGC) ;number of stops per fruit (NAR); seed weight per fruit at maturity (PGF) ;weight of 1000 seeds (P1000); average grain yield per plant (RMT/ Pl) : calculated according to the Garfius (1964) formula: W= XYZ/S (X: number of capsules per plant; Y: average number of seeds per capsule; Z: average seed weight, S: surface area in m2);

yield per accession (RMT): calculated by production per plant and number of plants per hectare, using the following formula

RDT= W*number of plants per hectare (792661 plants).

Data analysis

Data were collected by sampling and entered into Excel version 2016 before being analyzed. Analyses were performed using XLSTAT version 2016 software for analysis of variance (ANOVA) to compare means at the significant threshold of 5%, principal component analysis (PCA), correlation analysis and hierarchical ascending classification (HAC).

Results

Result of the description of qualitative characteristics

Table 1 below shows the modalities and mean frequencies of the modalities of the qualitative variables for the 12 okra accessions. However, there is considerable inter-accession variability for most of the characteristics.

There is also considerable variability in leaf shape parameters. Within the 12 accessions, we noted five different leaf shape modalities (fig. 3): simple leaves 14.35% (fig. 3, A), lobed leaves 24.95% (fig. 3, B), pedatillobed leaves 42.13% (fig. 2C), palmate leaves 7.87% (fig. 3D), palmate leaves 10.7% (fig. 3: E).

Table 1. Summary of modalities and averages of qualitative variables for 12 okra accessions.

Variables	Accession modality	Frequencies (%)
Leaf color	green	48,62
	green ribbed red	51,38
Stem color	green	35,87
	green with red petioles	54,41
	purple	9,72
Leaf shape	simple	14,35
	lobed	24,95
	pedatilobed	7,87
	palmate	42,13
	palmate	10,7
Stem pubescence	glabrous	23,61
	slightly	68,05
	very dense	8,33
Fruit color	Green	87,96
Leaf shape	green with reddish patches	11,11
	red	0,93
	erect	74,31
	horizontal	20,56
	fully drooping	5,09
Fruit pubescence	downy	27,78
	slightly rough	63,89
	thorny	8,33

With regard to leaf color, we observed two types of coloration (green and green with red veins, fig. 4), with an average of 48.62% green leaves (fig. 4 A) and 51.38% green leaves with red veins (fig. 4B). However, only the GB1230 accession gave 100% green leaves, Baporo (72.22% green), the pear maanan and Clemson accessions gave 66.66% green, Anader Bongoanou and V3-1 Mogtédo gave 88.88%

green leaves with red veins.

The stems of our accessions (fig. 5) showed three colors. On average, 35.87% of stems were green (fig. 5 A), 54.41% green with red petioles (fig. 5B) and 9.72% purple (fig. 5 C). We only have the GB1230 accession, which gave 100% green stems, Anader Bongoanou 94.44% green with red petioles and 27.77% purple coloration for Mogtédo Nopsin, V3-1 Mogtédo and V3-2 Mogtédo. With pubescence averaging 23.61% glabrous, 68.05% slightly glabrous and 8.33% very dense, accessions Anader Bongoanou and Mogtédo Nopsin had 100% glabrous stems, 100% slightly glabrous for accessions KBG76, KBG535, Indiana, Clemson, V3-1 Mogtédo, V3-2 Mogtédo, only Poire maanan was very dense (100%).

Table 2. Average performance of traits studied.

Variable	Minimum	Maximum	Moyenne	Standard deviation	C V (%)
DT1 (mm)	7,613	9,967	8,898	0,735	8,264
DT2 (mm)	13,957	16,650	15,086	1,017	6,739
50% Flo (JAS)	44,000	82,000	61,000	12,888	21,206
Haut Flo (cm)	33,497	90,243	61,254	13,350	21,795
NAR	5,000	9,000	8,000	1,352	18,867
NMF	3,000	6,000	4,000	1,058	27,414
LFM (cm)	5,750	20,947	10,251	4,378	42,709
DFM (mm)	13,930	27,780	34,745	4,572	13,159
NGC	43,000	97,000	82,000	15,841	19,260
PGF (g)	2,107	4,750	3,663	0,907	24,769
P1000 (g)	21,333	43,667	32,278	6,686	20,714
RMT/P (g/m²)	316,729	1095,734	817,962	248,141	30,337
RMT (t/ha)	25,106	86,855	64,837	19,669	30,337

DT: stem diameter, 50% Flo: date of 50% flowering, Haut Flo: plant height at flowering, NAR: number of stops, NMF: average number of fruits per plant, LFM: average fruit length, DFM: fruit diameter at maturity, NGF: number of seeds per fruit, PGF: average seed weight per fruit, P1000: weight of 1000 seeds, RMT/P: yield per plant, RMT: potential yield per accession. CV: coefficient of variation.

For fruit color, a total of three colors were observed in our 12 accessions (fig. 6). On average, we had 87.96% green fruit (fig. 6A), 11.11% green fruit covered with red patches (fig. 6B) and 0.93% red fruit (fig. 6C).

Thus, accessions GB1230, Anader Bongoanou, Baporo, Poire maanan, Mogtédo Nopsin, V3-2 Mogtédo gave 100% green fruit, KBG24 (55.53%), KBG76, KBG535, Clemson (16.66%) and 27.77% of Indiana, V3-1 Mogtédo (100%), gave green fruit with red patches, while only accessions KBG76 and KBG535 gave 5.56% red fruit. Three fruit positions on the stem were noted in our accessions (fig. 12), with an average of 74.31% of fruits erect (fig. 7 A), 20.56% horizontal (fig. 7 C) and 5.09% completely drooping (fig. 7 B). Accessions GB1230, Anader Bongoanou, Baporo, Poire maanan, Mogtédo Nopsin and V3-2 Mogtédo were 100% erect and 91.66% for Clemson, 100% horizontal for V3-1 Mogtédo, completely drooping for 33.33% of KBG24, 11.11% for KBG76 and Indiana, and 5.56% for KBG535.

With fruit pubescence averaging 27.78% downy, 63.89% slightly rough and 8.33% thorny, Anader Bongoanou, GB1230, only Mogtédo Nopsin has these fruits 100% downy, and 33, 33% for Baporo, fruits 100% slightly rough KBG24, KBG76, KBG535, Indiana, Clemson, V3-2 Mogtédo, V3-1 Mogtédo, only pear maanan obtained 100% thorny fruits to the touch.

Table 3. Analysis of variance table for okra development cycle and growth characteristics.

Variable	DT1	DT2	50% Flo	Haut Flo
Anader Bongoanou	8,890	16,047	79,333 f	69,387 b
V3-2 Mogtédo	9,360	14,577	68,000 d	64,443 b
KBG76	9,967	16,450	50,000 b	60,387 b
KBG24	9,857	14,590	50,000 b	56,940 b
Clemson	9,117	16,650	53,667 b	59,773 b
Poire maanan	8,843	14,563	65,000 cd	90,243 c
V3-1 Mogtédo	8,420	16,320	62,000 c	63,887 b
Mogtédo Nopsin	8,100	14,000	81,667 f	65,330 b
GB1230	7,613	14,433	74,667 e	66,387 b
KBG535	8,980	15,313	49,667 b	57,110 b
Baporo	9,550	14,133	43,667 a	33,497 a
Indiana	8,077	13,957	51,667 b	47,663 ab
CV	8,264	6,739	21,206	21,795
Probabilité	0,126 ns	0,591 ns	0,000***	0,000***

DT: stem diameter, 50% Flo: date of 50% flowering, Haut Flo: plant height at flowering, CV: coefficient of variation, ns: non-significant difference, p>0.05 ***: very highly significant difference p < 0.001, a, b, c, d, f : means affected by different letters are significantly different (Newman-Keulus test).

Quantitative characteristics

Descriptive analysis of the material studied enabled us to determine the minimum, maximum, mean, standard deviation and coefficient of variation for each parameter. Table 2 summarizes the average performance of the traits studied.

Table 4. Analysis of variance table for yield and yield components.

Variable	NAR	NMF	LFM	DFM	NGF	PGF	P1000	RMT/P	RMT
Anader Bongoanou	8,000 bcd	3,333 ab	7,403 a	25,273	88,333 bc	4,717 c	43,667 e	1002,222	79,442
V3-2 Mogtédo	9,333 d	3,000 ab	5,750 a	28,446	97,000 c	4,580 bc	37,000 cde	927,625	73,529
KBG76	7,000 abc	4,333 ab	13,160 a	18,427	88,667 bc	3,773 abc	32,667 bcd	1062,222	84,198
KBG24	7,000 abc	4,000 ab	11,487 a	17,807	96,000 bc	4,110 bc	32,000 bcd	1095,734	86,855
Clemson	6,667 ab	3,667 ab	12,620 a	19,560	89,667 bc	4,053 bc	33,000 bcd	965,838	76,558
Poire maanan	7,000 abc	2,667 a	5,943 a	28,100	93,000 bc	4,750 c	41,000 de	805,382	63,839
V3-1 Mogtédo	7,667 bcd	4,667 ab	7,350 a	18,780	83,667 bc	3,607 abc	29,333 abc	1071,120	84,904
Mogtédo Nopsin	9,000 cd	2,667 a	6,850 a	22,980	78,667 bc	3,987 bc	37,667 cde	739,102	58,586
GB1230	8,000 bcd	2,667 a	7,647 a	20,793	84,667 bc	3,273 abc	25,000 ab	529,213	41,949
KBG535	6,333 ab	4,333 ab	12,803 a	16,957	85,000 bc	2,773 ab	26,000 ab	725,243	57,487
Baporo	5,000 a	6,000 b	20,947 b	17,000	59,667 ab	2,220 a	21,333 a	575,113	45,587
Indiana	5,000 a	5,000 ab	11,053 a	13,930	42,667 a	2,107 a	28,667 abc	316,729	25,106
CV	18,867	27,414	42,709	13,159	19,260	24,769	20,714	30,337	30,37
Probabilité	0,000***	0,019**	0,007*	0,462 ns	0,001***	0,000***	0,000***	0,460 ns	0,460 ns

NAR: number of stops, NMF: average number of fruits per plant, LFM: length of an average fruit, DFM: diameter of fruit at maturity, NGF: number of seeds per fruit, PGF: average seed weight per fruit, P1000: weight of 1000 seeds, RMT/P: yield per plant, RMT: potential yield per accession. CV: coefficient of variation, ***: very highly significant difference P < 0.001, **: highly significant difference p <0.01; *: significant difference p < 0.05, a, b, c, d, e: means affected by different letters are significantly different (Newman-Keuleus test).

Characteristics related to the development cycle and growth of okra

Descriptive analysis showed that for the 50% flowering date, the minimum flowering was 44 JAS and the maximum was 82 JAS, with an average of 61 JAS. Stem diameter at budding reached its maximum at 9.967 mm and its minimum at 7.613 mm with an average of 8.898 mm, and stem diameter at flowering was maximum at 16.650 mm and minimum at 13.957 mm with an average of 15.086 mm. For plant height at flowering, the maximum was 90.243 cm and the minimum 33.497 cm, with an average of 61.254 cm.

Table 5.

	DT1	DT2	50% Flo	Haut Flo	NAR	NMF	LFM	DFM	NGF	PGF	P1000	RMT/P	RMT
DT1	1												
DT2	0,310	1											
50% Flo	-0,577	-0,102	1										
Haut Flo	-0,222	0,174	0,617	1									
NAR	-0,175	0,083	0,804	0,587	1								
NMF	0,335	0,058	-0,793	-0,824	-0,787	1							
LFM	0,479	0,003	-0,797	-0,820	-0,771	0,813	1						
DFM	0,196	-0,157	0,186	0,087	0,512	-0,267	-0,332	1					
NGF	0,351	0,435	0,299	0,639	0,665	-0,622	-0,447	0,301	1				
PGF	0,207	0,323	0,560	0,784	0,732	-0,743	-0,661	0,329	0,828	1			
P1000	0,068	0,189	0,605	0,729	0,573	-0,656	-0,669	0,233	0,488	0,866	1		
RMT/P	0,582	0,691	0,054	0,347	0,451	-0,188	-0,210	0,143	0,789	0,717	0,472	1	
RMT	0,582	0,691	0,054	0,347	0,451	-0,188	-0,210	0,143	0,789	0,717	0,472	1,000	1

Values in bold are different from 0 at significance level alpha=0.05

NAR: number of stops, NMF: average number of fruits per plant, LFM: average fruit length, DFM: fruit diameter at maturity, NGF: number of seeds per fruit, PGF: average seed weight per fruit, P1000: weight of 1000 seeds, RMT/P: yield per plant, RMT: potential yield per accession, DT: stem diameter, 50% Flo: date of 50% flowering, Haut Flo: plant height at flowering.

Yield-related characteristics and components

The results of the descriptive analysis (Table 2) for these parameters showed a minimum of 5 stops per fruit and a maximum of 9 stops per fruit, with an average of 8 stops. The average number of fruits per plant was 4, with a maximum of 6 and a minimum of 3. Average fruit length was a maximum of 20.947 cm and a minimum of 5.750 cm, with an average of 10.251 cm. Fruit diameter at maturity averaged 34.745 mm, with a minimum of 13.930 mm and a maximum of 27.780 mm.

The number of seeds per fruit averaged 82, with a minimum of 43 and a maximum of 97. Seed weight per fruit was a minimum of 2.107 g and a maximum of 4.750 g, with an average of 3.663 g. The 1000-seed weight averaged 32.278 g, with a maximum of 43.667 g and a minimum of 21.333 g. Grain yield per plant showed a minimum of 316.729 g/m2 , a maximum of 1095.734 g/m2 and an average of 817.962 g/m2 . Grain yield per accession averaged 64.837 t/ha with a minimum of 25.106 t/ha and a maximum of 86.885 t/ha.

Okra development cycle and growth characteristics

The results of the analysis of variance (ANOVA) for traits related to the development cycle and growth of okra (Table 3) showed a non-significant difference for stem diameters (DT1 and DT2) and a significant difference for 50% flowering date and plant height at flowering.

50% flowering date

For 50% flowering date, the analysis of variance was highly significant $p < 0.001$. It ranged from 44 to 82 JAS, with a coefficient of variation of 21.206%. The Baporo accession was the earliest (44 JAS) and the Mogtédo Nopsin accession the latest (82 JAS).

Plant height at flowering

A highly significant difference $P < 0.001$ was noted between the accessions 33.497 cm for the Baporo accession and 90.243 cm for the Poire maanan accession, with a coefficient of variation of 21.795%.

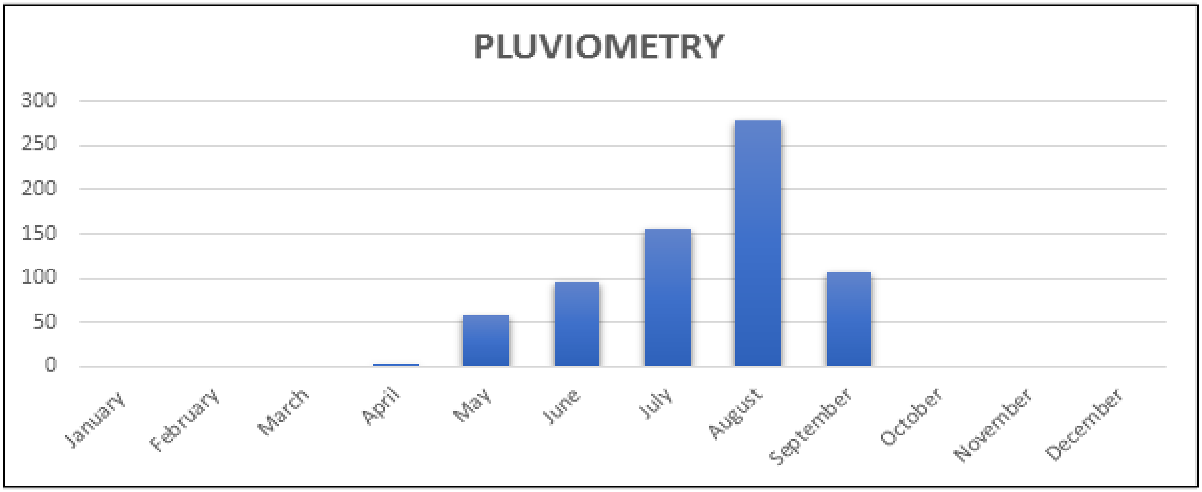

Fig. 2. Rainfall recorded during the 2022-2023 cropping season at the Centre Recherche Environnemental Agricole et de Formation/Kamboinsé site.

Yield and yield components

The results of the analysis of variance (ANOVA) in Table 5 showed a significant and non-significant difference for yield and yield components.

Number of stops, number of seeds per fruit and 1000-seed weight

The number of stops ranged from 5 in the Baporo and Indiana accessions to 9 in the V3-2 Mogtédo and Mogtédo Nopsin accessions, with a coefficient of variation of 18.867%. The number of seeds per capsule ranged from 43 to 97 seeds per fruit, with a coefficient of variation of 19.260%. The Indiana variety gave the lowest number of seeds per fruit, 43 seeds, while the highest number was obtained from the V3-2 Mogtédo accession.

The weight of 1000 seeds ranged from 21.333 g to 43.667 g for the Baporo and Anader Bongoanou accessions respectively, with a coefficient of variation of 20.274%. Analysis of variance was highly significant $p < 0.001$ for these different characters.

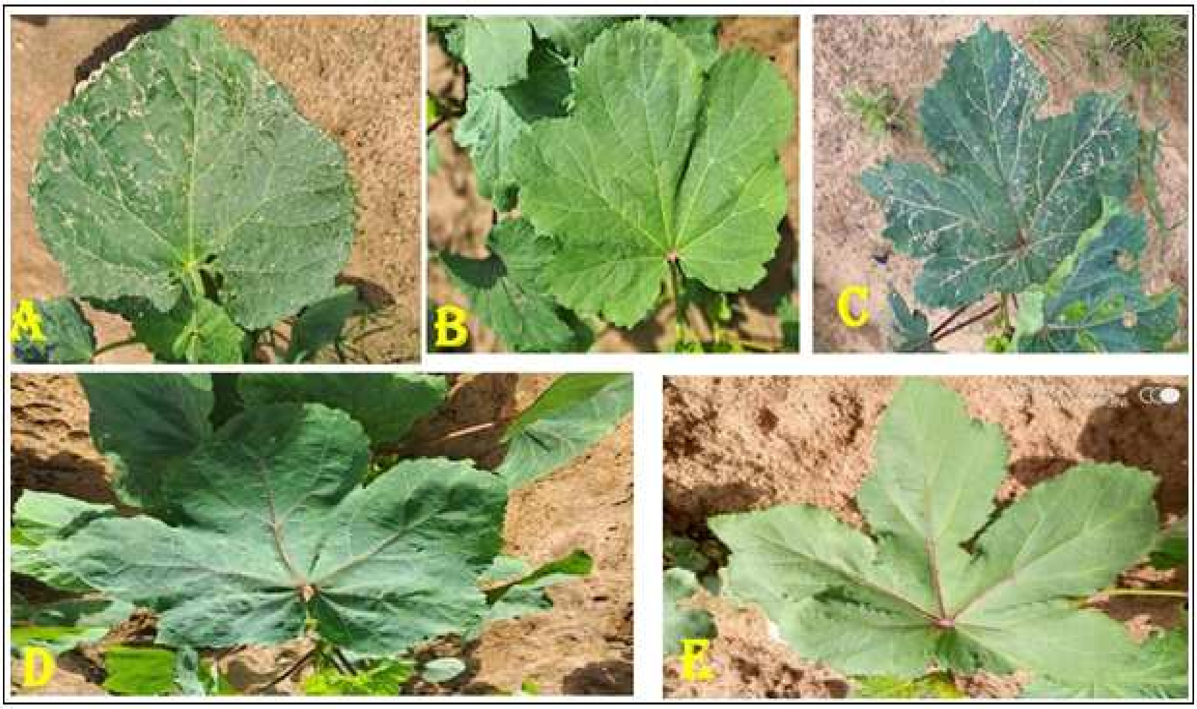

Fig. 3. Different leaf shapes. A: simple leaf; B: lobed leaf; C: pedatilobed leaf; D: palmate leaf E: palmate leaf.

Average number of fruit, fruit diameter at maturity, yield per plant and grain yield per accession

The results of the analysis of variance (Table 4) were non-significant p > 0.05 for the parameters fruit diameter at maturity, grain yield per plant and grain yield per accession and highly significant p < 0.001 for the parameter number of fruit per plant. The average number of fruits varied from 3 fruits for the accessions V3-2 Mogtédo, Poire maanan, GB1230, Mogtédo Nopsin, Anader Bongoanou to 6 fruits with the accession Baporo and a coefficient of variation of 27.414%.

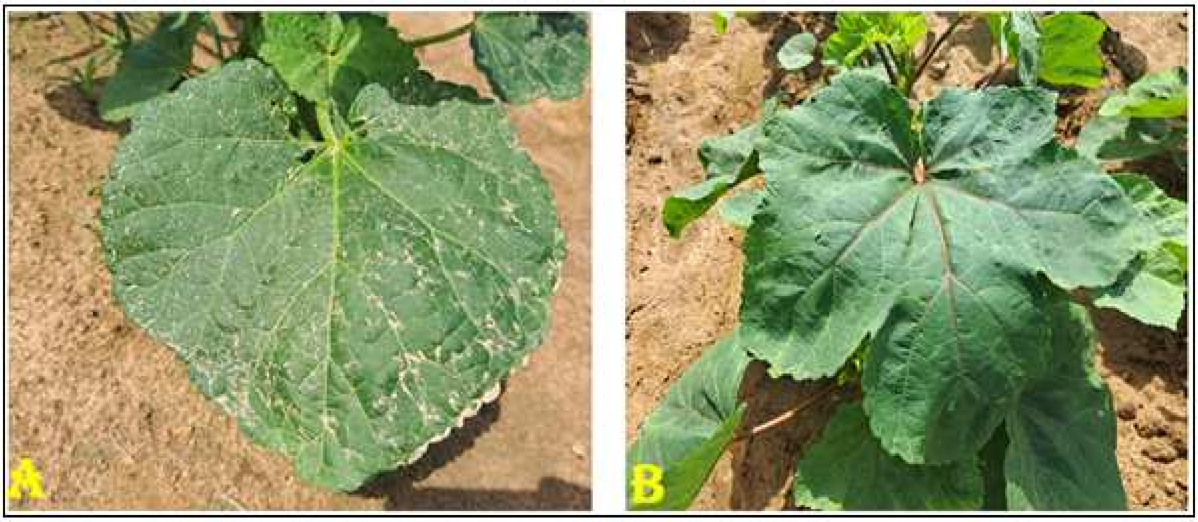

Fig. 4. Okra leaf colors. A: Green leaf B: Green leaf with red veins.

Characteristic correlation study

Pearson's correlation matrix revealed numerous strongly positive and strongly negative correlations between the various characters.

Date of 50% flowering (50% Flo) is positively correlated with plant height at flowering (Haut Flo) (r= 0.617), number of stops (NAR) (r= 0.804), and 1000-seed weight (P1000) (r= 0.605), but strongly and negatively correlated with mean fruit at maturity (NMF) (r= -0.793) and fruit length at maturity (LFM) (r= -0.797). There was a highly significant and positive correlation for plant height at flowering (Haut Flo) between number of stops (NAR) (r=0.587), number of seeds per fruit (NGFF) (r= 0.639), seed weight per fruit (PGF) (r= 0, 787) and 1000-seed weight (P1000) (r= 0.729), there was also a strong negative correlation between number of mature fruit (NMF) (r= -0.824) and mature fruit length (LFM) (r= - 0.820).

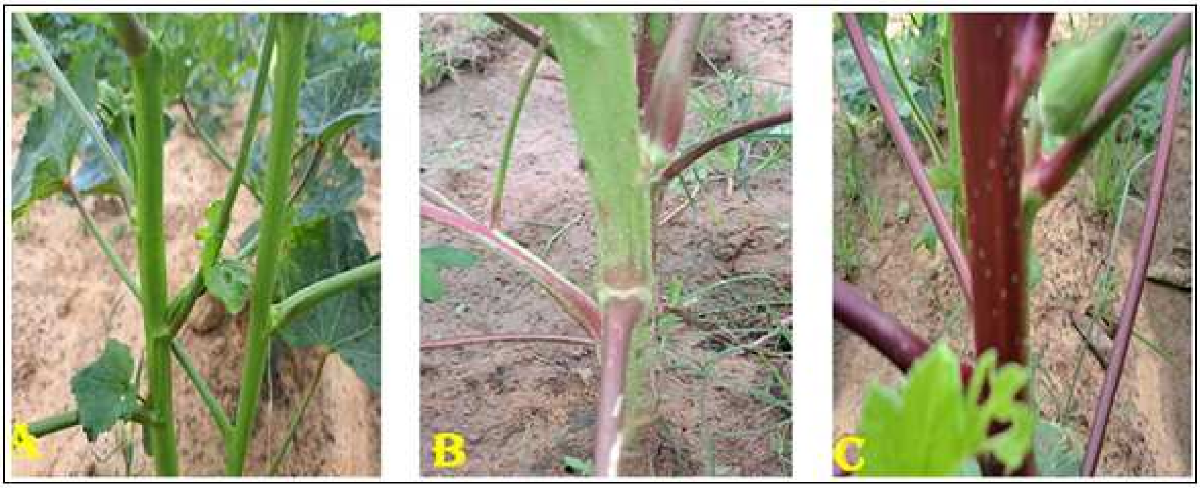

Fig. 5. Different stem colors. A: Green stem B: Green stem with red petioles C: Purple stem.

The number of stops is positively correlated with the number of seeds per fruit (NGF) (r=0.665) and seed weight per fruit (PGFF) (r=0.732). Fruit length at maturity is negatively correlated with seed weight per fruit (PGF) (r= -0.661) and 1000-seed weight (P1000) (r= -0.669). Positive and highly significant correlations were observed for number of seeds per fruit (NGF) and seed weight per fruit (PGF) (r=0.828), grain yield per plant (RMT/P) (r= 0.789) and grain yield per accession (RMT) (r= 0.789). Grain yield per plant (RMT/p) is strongly and positively correlated with grain yield per accession (RMT) (r=1.000).

Discussion

As regards qualitative characteristics, Hamon and Charier (1997) found considerable agromorphological variability in okra accessions grown in Burkina Faso. Indeed, a diversity of colors for stem, fruit and leaf parameters can be found within the accessions studied. This reflects intra-accession variability. Indeed, Ouédraogo (2016) had also obtained a multitude of colorations at the level of the characters, leaves, stems and fruits like those of our results.

The color diversity observed for fruit traits could be explained by the heterogeneity of the seeds used in our study. According to Ouédraogo (2016), the intra- and inter-accessional variability observed could be explained by unwanted hybridization due to the high rate of allogamy in okra, probably favored by the high frequency of okra intercropping and farmers' seed mixes. Demarly *et al* (1996) have shown that partial or total allogamy, which offers opportunities for cross-fertilization, favors natural genetic mixing, leading to significant genetic diversity.

The intra-accession difference between stem and fruit coloration has also been observed by Jiro *et al.* (2011). Charrier (1983), however, noted an intra-accessional uniformity in the coloration of okra organs, implying a simultaneous transmission of related characters.

According to Charrier, stem, petiole and fruit colorations are linked to a simple genetic determinism in okra.

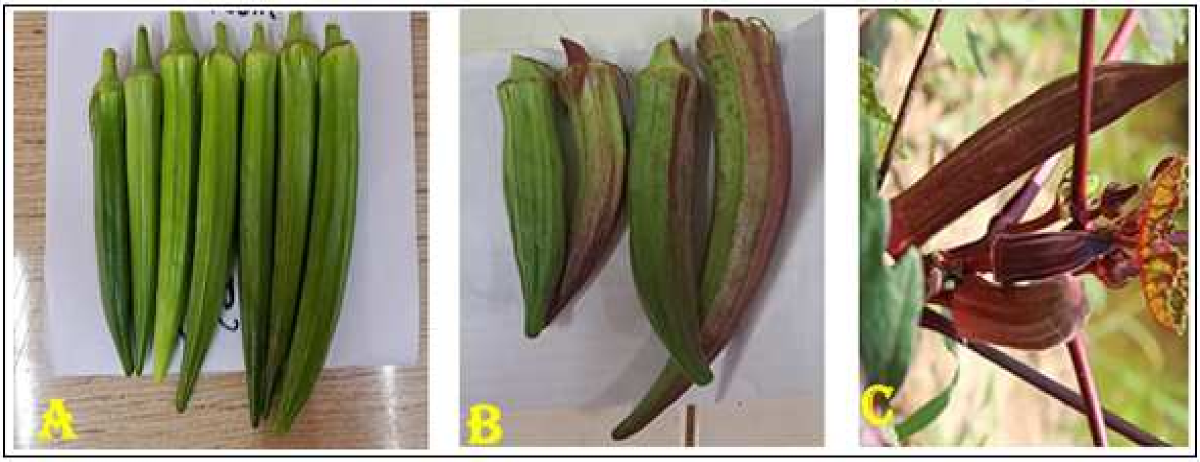

Fig. 6. Different fruit colors of okra accessions. A: green fruit; B: green fruit covered with red patches; C: red fruit.

The diverse variability of okra accessions could be influenced by the environment, depending on the climatic zone. The multiple variations in coloring (green, green covered with red patches, purple-red, green with red veins) of the organs can be explained by an accumulation of anthocyanin by the plant that varies from one climatic zone to another (Ouédraogo, 2016). With regard to qualitative traits, agromorphological variability linked to several phenotypic traits is thought to be genetic. Jiro *et al.* (2011), on the other hand, found great variability in okra varieties, but linked only to two traits, namely the cycle and the number of grains per fruit. According to Nana (2010), the performance of cycle length (50% flowering), which averages 52 days, shows that the accessions evaluated are early on the whole. In fact, for the study, the characters linked to the okra cycle showed a cycle variation between the 50% flowering parameters (44 to 82 JAS). Some of our accessions are therefore early. Our values are close to those obtained by Pizongo (2014) for the 50% flowering date (44 to 56 JAS). This difference in earliness could be explained by genetic variation between varieties and by the difference in sowing dates. According to Olowe (2007), flowering and maturity dates vary according to sowing dates. According to Olowe, the cycle is shortened when sowing is delayed in photoperiodic varieties. Also, according to Amjad *et al* (2001), the onset of flowering can be attributed to the genetic make-up of the cultivar. Stem diameters and plant height at flowering are key parameters in the genetic variability of okra growth. Indeed, stem diameters at sowing dates 38th to 53rd JAS evolved progressively for all accessions. The highest performance for plant height at flowering was obtained with the Poire maana accession, while the lowest performance was measured with the Baporo accession. This good performance could be explained by the level of soil fertility, soil moisture and vigour of the accession. According to Markose *et al.* (1990) and Koechlin *et al.* (1992), this growth trend can be explained by the fact that the mode of action of the genes for okra stem height and diameter is additive.

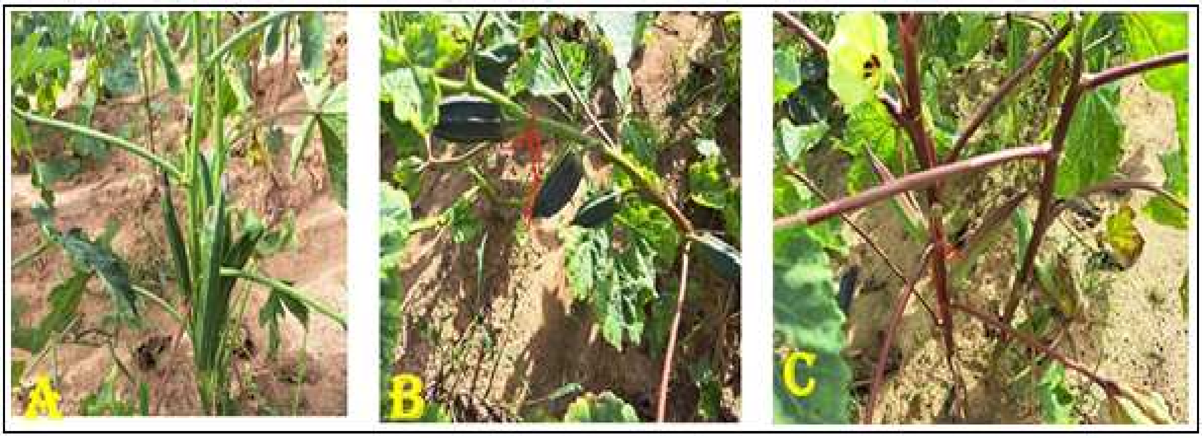

Fig. 7. Position of fruits on stem. *A: erect fruit position; B: fully drooping fruit position; C: horizontal fruit position.*

Analysis of variance showed a significant difference for length of fruit at maturity (LFM), average number of fruit per plant (NMF) and very high significance for number of stops (NAR), number of seeds per fruit (NGF) and 1000-seed weight (P1000). These traits are essentially linked to yield. Fruit length at maturity depends on various factors, such as the genetic make-up of cultivars and their response to environmental conditions Anjum and Amjad (1999). Grain yield is the ultimate result of various physiological, biochemical, phenological and morphological events occurring in the plant system Mansoor *et al.*, (2010). The highest grain yield was obtained with the accession KBG24 with a performance of 86.855 t/ha and the lowest grain yield with the variety Indiana with a performance of 25.106 t/ha. The low yield with the Indiana variety is explained by its hybrid status: the more hybrids are multiplied, the lower the yield, but it may also be due to the genetic characteristics of each species. According to Muwo *et al*, (2018) the differences in yield observed can be justified by the genetic characteristics specific to each variety.

The high performance of the seed weight trait expressed by the accessions is a genetic asset particularly in terms of the heritability of their traits of interest (Ouédraogo, 2016). The weight of 1000 seeds varied from 21.333 g to 43.667 g. Our results are close to those of Ouédraogo, (2009) who obtained 38.90 g to 54.84 g. This difference could be explained by the type of genotype contained in the seeds and the culture medium. This idea is supported by Khan *et al*,

(2010) who asserted that the accumulation of reserves in the seeds depends on the type of genotype, but also on climatic factorsCorrelation matrix studies showed a strong positive correlation between 50% flowering date and plant height at flowering and number of stops. This shows that small plants have a short cycle (the Baporo 44 JAS accession) and a lower number of stops (5 stops), while large plants have a late cycle (the Mogtédo Nopsin 82 JAS accession) and a high number of stops (9 stops). According to Hamon (1988), the early cycle of okra cultivars is favored by low rainfall.

Plant height at flowering is positively correlated with the number of fruit stops, but negatively correlated with fruit length at maturity. This means that small-sized accessions produce long fruit (Baporo 20.947 cm) but with a low number of stops (5 stops), and large-sized accessions produce short fruit (V3-2 Mogtédo 7.750 cm) with a high number of stops (9 stops). The number of fruit stops correlated negatively with fruit length at maturity, but positively with the number of seeds per fruit. This means that short fruits have a high number of stops but also contain many seeds per fruit (97 seeds) and long fruits have a low number of stops with few seeds per fruit (60 seeds). For Adéniji and Arému (2007), seed production in West African okra is strongly influenced by capsule width and the number of ridges per capsule. On the other hand, Koechlin (1989) reports that the number of ridges per capsule is a genetically influenced trait whose expression depends on environmental conditions.

The number of seeds per fruit is strongly positively correlated with grain yield per accession. This suggests that the number of seeds per fruit is a fundamental component for grain yield improvement.

Conclusion

At the end of this study, there was considerable modality variability for leaf shape, leaf color, stem color and fruit color, as well as for stem and fruit pubescence within the accessions studied for qualitative traits. Intra-accession variability was particularly marked, with only accession GB1230 yielding 100% green fruit, stems and leaves.

The study enabled us to compare the agromorphological performance of the 12 accessions. Analysis of variance showed significant differences for most of the quantitative traits studied. Strong positive and negative correlations were also noted between certain traits. Principal component analysis showed which traits contribute to the improvement of okra seed production. These include the number of sheaths per fruit, the number of stops per fruit, the diameter of the fruit at maturity, the weight of 1000 seeds, and the height of the plants at flowering, all of which are linked to grain yield. The study also enabled us to structure the diversity of variability into three classes showing the best performing seed-producing accessions. The accessions Anader Bongonanou, Clemson, KBG76, KBG24, V3-1 Mogtédo were the best-performing, characterized by the earliest 50% flowering date, the largest fruit diameter, the highest number of seeds per fruit and the highest grain yield. Given their agronomic performance, especially grain yield, these accessions could be integrated into a breeding program to improve seed production. We also think that they could be offered to seed producers in view of their grain yield. In addition, our three Burkina accessions with the highest grain yields are KBG24 (86.855 t/ha), KBG76 (84.198 t/ha) and V3-1 Mogtédo (84.04 t/ha).

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