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Assessment of the Agronomic Performance of Seven Okra (*Abelmoschus esculentus* (L.), Moench) Cultivars in Southern Côte d'Ivoire

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Abstract Okra (*Abelmoschus esculentus* L., Moench) is a perennial herbaceous plant of the Malvaceae family. It is cultivated for its fruits in tropical and subtropical countries. Its global yield is estimated at more than 11 million tons, 32.74% of which comes from Africa. However, this yield remains insufficient to cover the food needs of populations. This is why new high-yielding cultivars are proposed so as to achieve food security. This study aims to contribute to improving food security by evaluating the agronomic performance of seven (7) cultivars (Clemson spineless, Noura F1, Djonan F1, Teriman, Divo, Kopê F1 and Local) introduced into Côte d'Ivoire. Thus, a Fisher block trial was set up on the experimental plot of the Pedagogical and Research Unit of Plant Physiology and Pathology at the University Félix HOUPHOUPËT-BOIGNY, in September 2022 and replicated in March 2023. The growth parameters (height, collar diameter and number of leaves and branches) were assessed at the 30th, 45th, 60th days and at cycle end. Moreover, phenological stages and yield were assessed. The results showed that all the tested cultivars had a height between 62 and 112 m at cycle end. The collar diameter of the plants of all cultivars oscillated between 17 and 24 mm, while the number of branches varied between 6 and 9. Noura F1 cultivar was the first to reach 50% flowering at 40 DAS and Kopê F1 cultivar the last one (61 DAS). All the cultivars had a yield significantly higher than 13 t/ha with the exception of Local (7.82 t/ha) and Kopê F1 (6.99 t/ha) cultivars. It would be advisable to evaluate the agronomic and health behaviour of these cultivars in other agro-ecological zones of Côte d'Ivoire before any large-scale dissemination.

Keywords: *Abelmoschus esculentus, Cultivars, Okra, Malvaceae, Phenological stage, Yield*

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1. Introduction

Agriculture is one of the activities necessary to ensure the food security of populations, and provide some of them with financial resources [1]. It occupies a prominent place in the economy of the majority of African countries and therefore constitutes the main activity of sub-Saharan African countries [2]. Indeed, it employs more than 40% of the active population in the world, including more than 52% in Africa and Asia [3], in addition to providing a means of subsistence to a multitude of smallholders in rural areas [4].

In Côte d'Ivoire, the economy is essentially based on the agricultural sector, which constitutes a pillar of its economic development. Historically, the agricultural sector has always occupied a central place in the economy and development of Côte d'Ivoire, whether in terms of the active agricultural population or its contribution to the creation of wealth in the country. Even today, the agricultural sector represents a quarter of Côte d'Ivoire's Gross Domestic Product and employs nearly one in two people of working age. This gives it a place at the forefront for the production of several agricultural products, whether at the continental or even global level [5]. This agriculture is diversified and takes into account industrial crops as well as food crops and vegetable crops. These are used to directly feed the local population.

In Africa, truck farming has become a solution to the problems of supplying vegetables to populations around large cities [6]. Defined as highly specialized agriculture, truck farming constitutes one of the most productive agricultural systems in Africa [7]. In West Africa, it appears to be one of the main components of urban and peri-urban agriculture having paramount importance in the economic development of cities [8]. Considered as an activity of food sovereignty, truck farming plays a vital role in most nutrition and poverty reduction programs and contributes significantly to family income [9]. Among these vegetable crops, okra (*Abelmochus esculentus* (L.), Moench) occupies a special place. Thus, in 2021, global okra yield was estimated at 11 millions tons over a total cultivated surface area of 2 478 132 ha. Of this yield, 33.27% came from Africa (3 600 881.18 tons) with a cultivated area of 18 622 785 ha (75.17%). However, West Africa alone provided 3 087 497 tons of African yield with a cultivated area of 1 791 114 ha [10].

Annual production in Côte d'Ivoire, in 2021, was estimated at 193 193.65 tons over a cultivated area of 68 713 ha [10]. Okra is cultivated for its cone-shaped fruits and its leaves intended for food [11]. Okra presents a great varietal diversity and is cultivated throughout the Ivorian territory, due to its adaptation to the tropical climate [12]. Despite the general growth of the Ivorian economy and that of the agricultural sector in particular, food security and malnutrition still represent a concern in Côte d'Ivoire [5]. Indeed, its capacity to satisfy the entire population still remains low. Therefore, an increase in demand in relation to supply is recorded each year [13]. This situation results from constraints such as the reduction of arable land, the modification of crop calendars as well as the proliferation of pests caused by climate change. Faced with this situation, the need to overcome the problem of supplying the population, through a significant improvement in yield, is felt. This study was therefore initiated to help improve food security by assessing the agronomic performance of seven okra cultivars introduced into Côte d'Ivoire. Specifically, this involved determining the phenological stages of the seven cultivars, assessing the growth parameters and highlighting the yield components.

2. Presentation of the Study Area

On-farm trial was carried out at the University Félix HOUPHOUËT-BOIGNY (UFHB) in Cocody (Abidjan) on the experimental plot of the Pedagogical and Research Unit of Plant Physiology and Pathology (UPR PPV). This plot is located in Abidjan, an urban area in southern Côte d'Ivoire whose geographic coordinates are between latitudes 4°10 and 5°30 north and longitudes 3°50 and 4°10 west. The municipality of Cocody is limited to the north by the municipality of Abobo, to the south by the Ebrié lagoon, to the east by the municipality of Bingerville, to the west by the municipalities of Adjamé and Plateau (Figure 1). The study area is covered by a transitional climate whose annual cycle is divided into four seasons [14]. Indeed, it has a sub-equatorial type climate, hot and humid, subdivided into four seasons including a long and a short rainy season from may to july and from october to november, respectively ; then a long and a short dry season from December to April and august to september, respectively. Rainfall is abundant. There is more than 1500 mm of water per year. In the rainy season, it can rain constantly for several days in a row or rain intensely for an hour, followed by very strong sunshine. The monthly average temperatures of the city of Abidjan were between 25.02 and 28.70°C from 2013 to 2022. The monthly relative humidity from 2013 to 2022 varied between 80.82 and 89.96% for a general monthly average of 84.96%. Regarding monthly relative humidity, it oscillated between 84.65 and 93.15%. Unlike certain regions of the country, the autonomous district of Abidjan is regularly watered, which facilitates agricultural activities, especially truck farming.

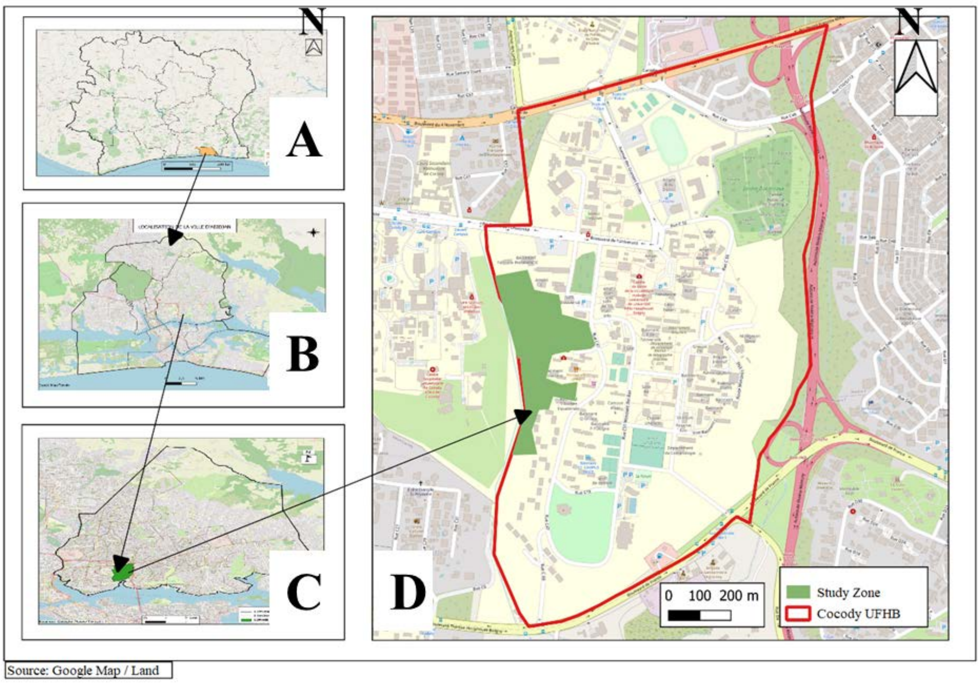

Figure 1. Map of the study area

3. Material and Methods

3.1. Material

3.1.1. Plant Material

The trial involved seven (7) *Abelmoschus esculentus* (L.), Moench cultivars, including 6 hybrids (Noura F1, Teriman, Djonan F1, Divo, Kopê F1 and Clemson spineless) and a local cultivar (acquired commercially) all belonging to the Malvaceae family, which constituted the plant material. The choice of these cultivars for the study was motivated by the fact that they are selected for cultivation in hot and humid climates. This choice was also justified by the availability of these cultivars commercially throughout the Ivorian territory for the whole year and also by their earliness and their interest for producers.

3.1.2. Chemical Material

The chemical material consisted of insecticide VETO 30 EC (Deltamethrin 10 g/l + Acetamiprid 20 g/l), compound mineral fertilizer NPK (12-22-22 + 2SO_3 + 1MgO + 5CaO) and simple mineral fertilizer Urea (46% N).

3.2. Methods

3.2.1. Physicochemical Characterization of the Experimental Plot Soil

3.2.1.1. Soil Sample Collection and Packaging

Before setting up the trial, soil samples were taken with a hand auger in the horizon [0-20] cm depth in five different points, in the center and at the four corners of the micro-plots according to the method of Koné *et al.* [15]. This soil horizon selection took into account the depth of okra root development. The subsamples were then mixed to obtain a composite sample of 1 kg [16]. These soil samples were packaged in polyethylene plastic bags then labeled and brought back to the UPR plant physiology and pathology analysis laboratory. They were then dried at room temperature in the laboratory for a week (7 days) until constant weight was obtained. After 7 days of drying, the soil samples were ground using a porcelain mortar and a suitable pestle before separating the coarse elements from the fine earth, using a 2-mm-mesh sieve. The fine soil samples were packaged in plastic bags then labeled according to the work of Dosso and Koné [17] as well as Ballot *et al.* **[16].**

3.2.1.2. Soil Sample Analysis

Soil physicochemical analysis focused on particle size, organic carbon (C), total nitrogen (N), Hydrogen potential (pH), electrical conductivity (EC), exchangeable bases (Mg^{2+}, K^+) and cation exchange capacity (CEC). Thus, the particle size distribution in five fractions was carried out following the standardized AFNOR NF X31-107 method using the Robinson pipette method [18]. Soil texture classification was made according to the USDA (United States Department of Agriculture) texture triangle. The analysis of total carbon and nitrogen was carried out using the methods described in the international standard NF ISO 10694, for carbon, and NF ISO 13878, for nitrogen. The C/N ratio used to assess soil biological activity [19] was calculated.

The water and KCl pH were determined according to the international standard NF ISO 10390 [20]. The cation exchange capacity was measured by the Metson method of AFNOR NF X31-130 standard [21]. The K^+, Mg^{2+} element content was determined by the fluoro-nitro-perchloric method. Total phosphorus and assimilable phosphorus were measured according to the international standard NF ISO 11263 [22].

3.2.2. Plot Set Up

The cropping history of the experimental plot was a 12-year-old fallow after plantain tree cultivation. This plot was therefore cleared using a machete followed by deep manual plowing by means of daba (Traditional African Hoe) three weeks before the sowing date, making it possible to bury the plant debris so as to make their decomposition easier and avoid transporting the fertilizing elements they contain through runoff. After plowing, staking was carried out one week before sowing. No background fertilizer was applied during plowing or after plowing. Sowing was carried out on september 29, 2022 and repeated on march 6, 2023 at a rate of 3 to 4 seeds per pocket at a maximum depth of 2 to 3 cm in order to increase emergence rate and facilitate the growth of the plants. A thinning of one plant per pocket was carried out 14 days after sowing (2 weeks) and on the same date a transplant was made to fill the pockets where there was no germination. Supplemental irrigation was necessary during periods of lack of rain so as to allow okra to successfully complete its crop cycle.

3.2.3. Experimental Design

The main factor studied was the cultivar with seven (7) modalities (Noura F1, Divo, Djonan F1, Clemson spineless, Kopê F1, Teriman and local cultivar). The experimental unit was the okra plant. The experimental design adopted was a completely randomized Fischer block with three repetitions. Each block included 7 micro-plots to which the cultivars were assigned (Modalities). The block was represented by the treatments (modalities or cultivars). Each micro-plot had one (1) cultivar represented by two rows of 10 plants each, for a total of 20 plants of each cultivar (Figure 2). Each repetition contained 140 okra plants, resulting in 420 okra plants for the entire trial. The distance between the pockets was 0.60 m while the one between the rows was 0.60 m (0.6 m x 0.6 m), which gave a seeding density of 27778 plants per hectare for each cultivar. The surface area occupied by the trial was approximately 250 m^2 including aisles and borders (Figure 2).

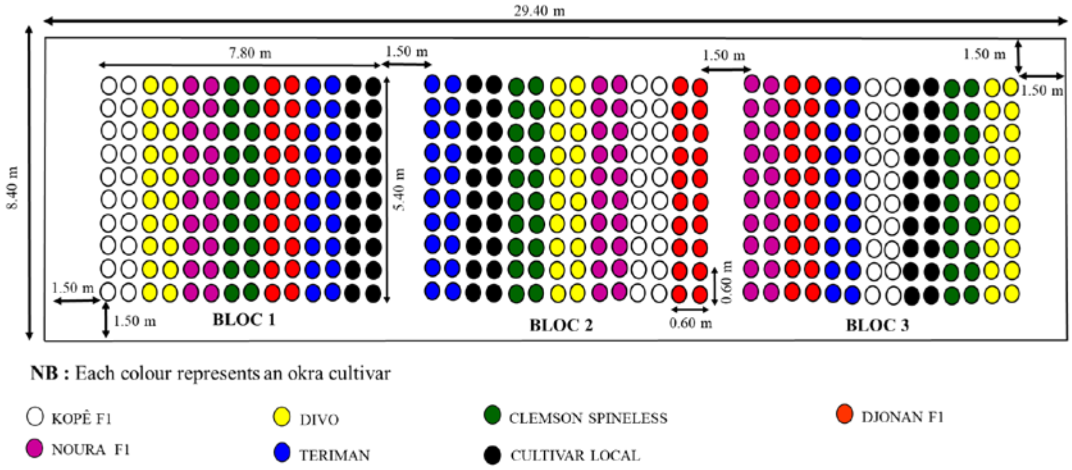

Figure 2. Fisher block experimental design

3.2.4. Trial Monitoring and Maintenance

Manual weeding was carried out at the same time as thinning 2 weeks after sowing followed by 4 more afterwards in order to avoid grassing of the experimental plot. During okra cultivation, fertilizer inputs at a rate of 240 kg/ha of NPK (12-22-22 + 2SO_3 + 1MgO + 5CaO) were applied in two fractions (14th and 21st day) after sowing followed by 240 kg/ha of Urea (46% N) in a single fraction as from emergence of the first flowers. Insecticide treatments with Deltamethrin 10 g/l + Acetamiprid 20 g/l (VETO 30 EC) were carried out every 2 weeks (14 days) at the recommended dose ranging from 40 to 75 ml in 15 liters of water (that is, 0.20 to 0.38 ml per liter of water) against caterpillars, biting-sucking insects, borers and to fight against all other insects harmful to okra cultivation. Harvests began 3 days after the first flowerings and continued at regular intervals of two to three days until the end of the crop cycle of each cultivar. These harvests concerned all the young fruits on each assessed plant.

3.2.5. Data Collection

Measurements of growth parameters and observations concerned 12 plants per treatment and per repetition. The measurements were taken at the 30th, 45th and 60th days after sowing (DAS) and at cycle end. Observations also focused on phenological dates (50% flower buds, 50% flowering, first harvest and last harvest periods). These different dates made it possible to determine the earliness and cultivation cycle of each cultivar. Yield parameters were assessed at harvest.

3.2.5.1. Assessment of Growth Parameters

- Assessment of emergence rate : The emergence rate was assessed on the 14th day after sowing (DAS) by counting the number of pockets where germination has occurred and making the ratio between the number of pockets where germination has occurred and the total number of sown pockets. The result of this ratio was expressed as a percentage. It was calculated according to the following formula :

$$\textbf{Emergence rate}(\%) = \frac{\Sigma ni}{N} x100$$

With ni : Number of plots where germination has occurred and N : Total number of sown pockets

- Assessment of plant height : Plant height (Ph) was measured from the plant collar to the last bud using a tape measure and expressed in centimeters.
- Assessment of plant collar diameter : Collar diameter (Cd) of the plants was measured using a Steel digital 150 mm electronic caliper, Stainless Hardened brand. Diameter measurements were expressed in millimeters.
- Assessment of the number of functional leaves and branching of plants : The number of expanded leaves and the number of branches were counted from the base upwards.

3.2.5.2. Determining Phenological Stages

Bud setting and flowering parameters were observed visually and the periods at which 50% of the plants bore at least one flower bud or blooming flower were noted on a sheet. The first harvest and last harvest periods were also noted and yield duration was obtained by the difference between these two periods.

3.2.5.3. Assessment of okra Cultivar Yield Parameters

Harvesting was carried out every three days from first flowering to prevent the fruit from becoming too mature.

The first three fruits harvested from the selected plants were collected in previously labeled polyethylene plastic bags. They were then transported to the laboratory where the different parameters were assessed. This involved peduncle length and diameter, fruit diameter and length, the number of awns of each fruit, the number of seeds and the fresh weight. The other fruits, that is to say from the 4th fruit, were only counted and weighed using a Baxtran brand electronic scale and the yield per hectare was calculated from the average weight of fruit produced per plant multiplied by plant density.

- Fruit length was measured on the back of the fruit using a tape measure, starting from the base to the top,
- Fruit and peduncle diameters were measured using the caliper, in the middle of them,

- Peduncle length was measured with a tape measure, from the limit between the fruit and the base of the peduncle,
- The awns of each fruit were counted considering a starting awn,
- The seeds were removed from the fruit and counted using piles of 10 seeds,
- Fresh and dried fruit were weighed using a 10^{-2} precision balance to determine fresh and dry weight. The water content of the fruit was then calculated and expressed as a percentage using the following formula :

$$\textbf{Fruit water content}(\%) = \frac{\textbf{Pf} - \textbf{Ps}}{\textbf{Pf}} \text{x}100$$

With **Pf:** Fruit fresh weight and **Ps:** Fruit dry weight.

It should be noted that the dried fruit was obtained after drying the fresh fruit in an oven at a temperature of 45°C for 72 hours.

3.2.6. Statistical Analyses

The Shapiro-Wilk test allowed us to check the normality of our data. Thus, the data collected relating to growth and yield parameters were subjected to a one-way analysis of variance (ANOVA I) using STATISTICA version 12.5 software. Then, the means were compared according to the Newman-Keuls test. The differences were considered significant at 5% threshold (means followed by different letters). The graphs were produced using Excel 2021 software.

4. Results

4.1. Physicochemical Characteristics of the Experimental Plot Soil

Table 1 shows the results of the physicochemical analysis of the experimental plot soil. It appeared that the soil was significantly richer in sand (76.87%) and silt (17.73%), and poor in clay (5.39%). The experimental plot soil was therefore sandy-loamy in texture. Table 1 also indicates that the experimental plot soil was slightly acidified because the pH_{water} (6.55) and pH_{KCl} (6.50) were less than 7. The contents of organic carbon (2.78%), total nitrogen (5.33%) and assimilable potassium (3.33%) were low. Regarding total organic matter, its content was 5.01%. As for the Carbon/Nitrogen ratio (C/N), it was 0.52 (C/N < 15) so the nitrogen needs were not covered. The low contents in nitrogen, phosphorus and potassium, mineral elements essential for good growth of cultivated plants, reflect the poor condition of the experimental plot soil.

Table 1. Physicochemical characteristics of the experimental plot soil

Types of analyses	Parameters	Values
Physical analyses (Texture)	Sands (%)	76.87 ± 1.48
	Silts (%)	17.73 ± 1.36
	Clay (%)	5.39 ± 0.39
Physicochemical analyses	pH_{Water}	6.55 ± 0.01
	pH_{KCl}	6.50 ± 0.00
	MO (%)	5.01 ± 0.06
	CO (%)	2.78 ± 0.04
	N (ppm)	5.33 ± 0.33
	C/N	0.52 ± 0.12
	P (ppm)	183.57 ± 6.01
Adsorbent complex	Conductivity (mS/cm)	0.17
	Mg ($cmol.kg^{-1}$)	0.28± 0.01
	K (ppm)	3.33± 0.33

4.2. Growth Parameters

4.2.1. Emergence Rate

Figure 3 shows the seed emergence rate of the okra cultivars used. This rate exceeded 50 % overall in all cultivars. It oscillated between 53.17% (Noura F1) and 95% (Kopê F1), for an average of 83.48%. Statistical analysis showed a highly significant difference (p = 0.0025) in the emergence rate according to the Newman-Keuls test at 5% threshold. Thus, cultivars Kopê F1, Teriman, Clemson spineless, Djonan F1, Local and Divo respectively showed the highest emergence rate values ranging from 95 to 84.84%. In contrast, Noura F1 cultivar had the lowest emergence rate (53.17%).

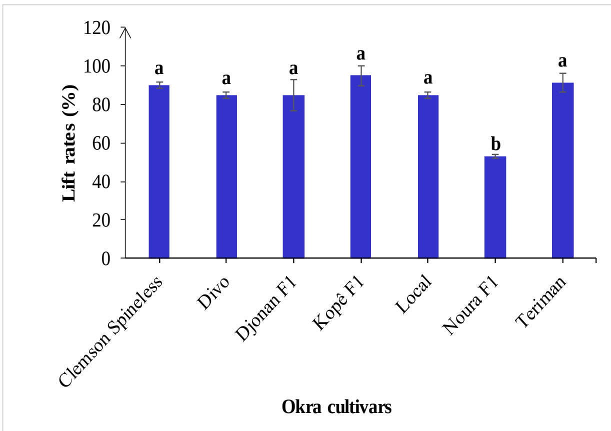

Figure 3. Seed emergence rate of okra cultivars used

4.2.2. Plant height and Collar Diameter

The results showing plant height and collar diameter evolution over time are illustrated in Table 2. The statistical analysis showed a highly significant difference between the cultivars (p < 0.001) according to the Newman test -Keuls at 5% threshold. These data reflect regular plant growth. Plant height varied depending on cultivars. Thus, on the 30th day after sowing (30 DAS), the greatest plant heights were noted on Clemson spineless cultivar (15 cm). In contrast, the smallest plants in height were obtained with Noura F1 and local cultivars, 9.79 and 9.63 cm, respectively. At the 45th day after sowing, a difference was noted between the different cultivars. The heights varied from 19.64 to 35.79 cm with an average of 26.91 cm. Furthermore, the height measurements were higher with Clemson spineless cultivar (35 cm) unlike local cultivar with a low height of 19.64 cm. On the 60th day after sowing, a significant height was observed in cultivars Noura F1 (69.09 cm) and Clemson spineless (62.38 cm), while cultivar Kopê F1 revealed a low height of 32.65 cm. At cycle end, the highest plant height was obtained in Noura F1 cultivar with 110.08 cm and the smallest height was obtained in the plants of local cultivar (62.93 cm). Regarding plant collar diameters, cultivars Clemson spineless and Teriman showed the highest diameters at the 30th day after sowing, 7.01 and 6.88 mm, respectively. In contrast, Noura F1 cultivar had a low collar diameter value of 4.44 mm. At the 45th day after sowing, Clemson spineless cultivar showed the largest collar diameter (16.26 mm), while cultivars Kopê F1, Local and Noura F1 got the lowest collar diameter values (11.21 to 11 .07 mm). At the 60th day after sowing, the largest collar diameter was obtained in Clemson spineless cultivar with 21.55 mm, while the smallest collar diameter was obtained in Kopê F1 and Local cultivars (15 and 15 .65 mm respectively). At cycle end, Local and Noura F1 cultivars had the lowest plant collar diameters, respectively 18.47 and 20.62 mm. In contrast, Clemson spineless cultivar had the largest collar diameter (23.76 mm).

Table 2. Variation in plant height and collar diameter during okra development cycle

Cultivars	Plant height (cm)				Plant collar diameters (mm)			
	30 DAS	45 DAS	60 DAS	Cycle end	30 DAS	45 DAS	60 JAS	Cycle end
Clemson spineless	15.34 ± 0.35 a	35.79 ± 0.63 a	62.38 ± 1.81 b	80.60 ± 3.13 bc	7.01 ± 0.17 a	16.26 ± 0.35 a	21.55 ± 0.40 a	23.76 ± 0.45 a
Divo	10.66 ± 0.33 bc	24.67 ± 0.80 c	46.13 ± 1.75 c	77.40 ± 1.95 c	6.12 ± 0.22 b	14.32 ± 0.46 b	18.73 ± 0.54 b	20.39 ± 0.47 b
Djonan F1	11.08 ± 0.25 b	26.35 ± 0.50 bc	50.76 ± 1.36 c	81.42 ± 1.48 bc	6.50 ± 0.19 ab	15.30 ± 0.35 ab	20.01 ± 0.38 b	20.77 ± 0.34 b
Kopê F1	10.82±0.26 bc	26.36 ± 0.83 bc	45.60 ± 1.73 c	88.03 ± 3.03 b	5.35 ± 0.16 c	11.21 ± 0.37 c	15.00 ± 0.41 d	18.47 ± 0.35 c
Local	9.63 ± 0.18 c	19.64 ± 0.40 d	32.65 ± 0.53 d	62.93 ± 1.04 d	4.99 ± 0.16 c	11.04 ± 0.23 c	15.65 ± 0.35 d	17.95 ± 0.36 c
Noura F1	9.79 ± 0.47 c	28.58 ± 1.35 b	69.09 ± 2.83 a	110.08 ± 3.21 a	4.44 ± 0.21 d	11.07 ± 0.52 c	17.10 ± 0.54 c	20.62 ± 0.55 b
Teriman	10.81 ± 0.25 bc	26.96 ± 0.58 bc	50.79 ± 1.36 c	80.16 ± 1.47 bc	6.88 ± 0.18 a	15.57 ± 0.35 ab	19.65 ± 0.39 b	20.92 ± 0.38 b
Overall mean	**11.16 ± 0.14**	**26.91 ± 0.36**	**51.06 ± 0.81**	**82.94 ± 1.06**	**5.90 ± 0.08**	**13.54 ± 0.17**	**18.24 ± 0.19**	**20.41 ± 0.18**
Coefficient of variation (%)	**28.41**	**29.65**	**55.42**	**28.67**	**30.68**	**28.88**	**23.57**	**19.35**
Probability (p)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

NB: In the same column, the values (mean + standard error) followed by the same letter do not differ significantly according to the Newman-Keuls test at 5% threshold.

4.2.3. Number of Functional Leaves and Branches Per Plant

Table 3 shows the results of the evolution of the number of leaves and branches over time. Analysis of this table indicates that there was a very highly significant difference (p < 0.001) between the cultivars regarding the number of leaves and branches. At the 30th day after sowing, Clemson spineless cultivar got the highest number of leaves (8.94 leaves). In contrast, Local and Noura F1 cultivars had the lowest leaf number values (7.19 and 7.15 leaves respectively). At the 45th day after sowing, local and Noura F1 cultivars showed a lower number of leaves of 17.22 and 15.36 leaves, respectively; while Clemson spineless, Divo, Kopê F1 and Teriman cultivars showed significant numbers of leaves ranging from 20.56 to 22.39 sheets. Finally, on the 60th day after sowing, the number of leaves of Divo, Djonan F1 and Teriman cultivars was greater than that of Clemson spineless, Kopê F1 and local cultivars. At cycle end, the highest number of leaves (34.89 and 38.69 leaves) was noted in Kopê F1 and Local cultivars, while the lowest number of leaves (10.49 leaves) was noted in Clemson spineless cultivar. The number of branches varied depending on the cultivars and over time. At 45 DAS, the branches were the most numerous with Djonan F1 (7.65) and Teriman (7.53) cultivars while they were low with Kopê F1, Local and Noura F1 cultivars (4.56 to 4.88). On the 60th day, the branches were the lowest with Clemson spineless (5.86) and Noura F1 (5.89) cultivars while the most numerous were obtained in Divo, Djonan F1 and Kopê F1 cultivars with 8.08 to 8.50, respectively. At crop cycle end, the lowest branches were shown by Clemson spineless (6.24) and Noura F1 (6.46) cultivars.

4.3. Phenological Parameters

The results recorded in Table 4 provide information on the phenological parameters studied (50% bud setting period, 50% flowering period, first harvest period, last harvest period and yield duration). Statistical analysis showed a very highly significant difference between the cultivars (p < 0.001) according to the Newman-Keuls test at 5% threshold for these parameters studied. Thus, the 50% bud setting period of the different okra cultivars varied between 33 and 49 days after sowing (DAS) for an average of 39.49 DAS. Clemson spineless and Noura F1 cultivars were the first ones to reach 50% flower buds at 33.53 and 34.56 DAS, respectively. Kopê F1 cultivar was the latest to reach 50% flower buds at 48.89 DAS. As for the 50% flowering period, it oscillated between 40 and 61 DAS with an average of 50.88 DAS. Kopê F1 cultivar was the latest to reach 50% flowering (60.56 DAS). In contrast, Noura F1 and Clemson spineless cultivars were the earliest to reach 50% flowering at 40.94 and 43.39 DAS, respectively. The first harvest period varied depending on the cultivar between 46 and 63 DAS for all cultivars, with an average of 55.07 DAS. Clemson spineless and Noura F1 cultivars were the earliest (46 DAS) while the Kopê F1 (62.50 DAS) and Local (63 DAS) cultivars were the latest. The last harvest of Teriman and Divo cultivars took place at 96.50 DAS, respectively, and that of the other cultivars between 87.50 and 94.50 DAS. Yield duration (harvest duration) of the different cultivars oscillated between 31 and 46 DAS for all the tested cultivars. Noura F1 cultivar was the cultivar which had a more spread-out harvest over time (46 DAS).

Table 3. Variation in the number of leaves and the number of branches of plants during okra development cycle

Cultivars	Number of leaves				Number of branches			
	30 DAS	45 DAS	60 DAS	Cycle end	30 DAS	45 DAS	60 DAS	Cycle end
Clemson spineless	8.94 ± 0.26 a	20.56 ± 0.60 a	29.64 ± 1.02 b	10.49 ± 0.76 c	-	6.83 ± 0.41 ab	5.86 ± 0.22 c	6.24 ± 0.25 b
Divo	8.53 ± 0.33 ab	21.35 ± 0.86 a	33.76 ± 1.27 a	24.35 ± 2.56 b	-	5.89 ± 0.30 b	8.08 ± 0.48 a	8.67 ± 0.47 a
Djonan F1	8.60 ± 0.19 ab	22.39 ± 0.68 a	35.63 ± 1.05 a	21.56 ± 2.40 b	-	7.65 ± 0.35 a	8.39 ± 0.37 a	8.69 ± 0.35 a
Kopê F1	7.50 ± 0.13 b	21.33 ± 2.18 a	26.58 ± 0.97 b	34.89 ± 1.33 a	-	4.67 ± 0.31 c	8.50 ± 0.32 a	7.78 ± 0.39 a
Local	7.19 ± 0.21 c	17.22 ± 0.58 b	27.25 ± 0.80 b	38.69 ± 1.48 a	-	4.56 ± 0.28 c	7.00 ± 0.17 b	8.78 ± 0.42 a
Noura F1	7.15 ± 0.61 c	15.36 ± 0.79 b	27.49 ± 1.15 b	22.61 ± 1.78 b	-	4.88 ± 0.41 c	5.89 ± 0.32 c	6.46 ± 0.37 b
Teriman	8.54 ± 0.26 ab	23.21 ± 0.99 a	36.06 ± 1.02 a	22.61 ± 2.36 b	-	7.53 ± 0.33 a	7.74 ± 0.31 ab	8.83 ± 0.33 a
Overall mean	**8.06 ± 0.12**	**20.20 ± 0.42**	**30.91 ± 0.43**	**25.03 ± 0.81**	**-**	**6.00 ± 0.14**	**7.35 ± 0.13**	**7.92 ± 0.15**
Coefficient of variation (%)	**34.74**	**47.13±**	**31.19**	**73.07**	**-**	**52.83**	**40.00**	**41.92**
Probability (p)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**-**	**< 0.001**	**< 0.001**	**< 0.001**

NB: In the same column, the values (mean + standard error) followed by the same letter do not differ significantly according to the Newman-Keuls test at 5% threshold.
- No observation at this level

Table 4. Phenological parameters of the different okra cultivars

Cultivars	Period of 50 % bud setting	Period of 50 % flowering	Period of first harvest	Period of last harvest	Yield duration
Clemson spineless	33.53 ± 0.63 d	43.39 ± 0.33 d	46.00 ± 0.17 c	87.50 ± 0.42 d	41.50 ± 0.25 b
Divo	39.19 ± 0.45 c	50.69 ± 0.64 c	56.00 ± 0.68 b	96.50 ± 0.42 a	40.50 ± 1.10 b
Djonan F1	39.03 ± 0.59 c	50.97 ± 0.65 c	56.00 ± 0.68 b	92.00 ± 0.34 c	36.00 ± 0.34 c
Kopê F1	48.89 ± 1.47 a	60.56 ± 0.92 a	62.50 ± 0.25 a	94.00 ± 0.01 b	31.50 ± 0.25 d
Local	43.22 ± 0.17 b	58.89 ± 0.21 b	63.00 ± 0.17 a	94.50 ± 0.25 b	31.00 ± 0.17 d
Noura F1	34.56 ± 0.62 d	40.94 ± 0.41 e	46.00 ± 0.17 c	92.00 ± 0.34 c	46.00 ± 0.51 a
Teriman	38.03 ± 0.61 c	50.69 ± 0.72 c	56.00 ± 0.68 b	96.50 ± 0.42 a	40.50 ± 1.10 b
Overall mean	**39.49 ± 0.41**	**50.88 ± 0.48**	**55.07 ± 0.44**	**93.21 ± 0.22**	**38.14 ± 0.40**
Coefficient of variation (%)	**16.64**	**14.90 ±**	**12.66**	**3.75**	**16.81**
Probability (p)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

NB: In the same column, the values (mean + standard error) followed by the same letter do not differ significantly according to the Newman-Keuls test at 5% threshold.

4.4. Yield Parameters of Okra Cultivars

4.4.1. Characteristics of the First Three Fruits

Table 5 indicates the characteristics of the first three fruits of the different okra cultivars harvested at maturity, namely fruit length and diameter, peduncle length and diameter, the number of seeds, the number of awns and the fresh weight. The analysis of variance at 5% probability threshold showed very highly significant differences ($p < 0.001$) between the fruits of the cultivars. Concerning peduncle length, the highest value was observed in Clemson spineless cultivar with 4.46 cm in length, unlike Divo and Teriman cultivars in which the lowest values of 2.97 and 2.93 cm in length were respectively observed. Then, the lowest peduncle diameter was obtained by Noura F1 cultivar (4.42 mm) while the highest (6.83 to 6.96 mm) were produced by Clemson spineless, Divo, Djonan F1 and Teriman cultivars. In terms of fruit length, the largest one was generated by Noura F1 cultivar (13.42 cm) while the smallest ones (7.06 to 7.34 cm) were obtained with Divo, Djonan F1, Kopê F1 and Teriman cultivars. The largest fruit diameters were observed in Kopê F1 and local cultivars (29.05 and 27.15 mm) while the smallest one was obtained in Noura F1 cultivar (15.06 mm). Furthermore, local cultivar showed a high number of awns of 8.15 while Noura F1 cultivar revealed a low number of 5.37. As for the number of seeds, Noura F1 cultivar indicated the lowest value of 50.62 unlike Djonan F1 and Teriman cultivars with 81.36 and 81.32 seeds, respectively. Finally, the lowest fresh weight (17.05 g) was noted in Noura F1 cultivar unlike the highest weights (23.17 to 24.70 g) obtained by Clemson spineless, Kopê F1 and local cultivars respectively.

4.4.2. Yield of Okra Cultivars

Table 6 shows the results relating to the mean number of harvests, mean number of fruits per plant, mean weight of a fruit as well as potential yields. The analysis of variance showed a highly significant difference for these assessed parameters ($p < 0.001$). Thus, the average number of harvests varied between 8 and 10 with an average of 9.43. Kopê F1 and Local cultivars showed the lowest number of harvests with 8 harvests. Concerning the mean number of fruits per plant, the highest number of fruits was obtained in Noura F1 cultivar with 31.29 fruits harvested while Kopê F1 and Local cultivars showed the lowest numbers of fruits harvested, 11.32 and 10.92 fruits. The highest mean fruit weights (28.48 and 27.77 g) were obtained by Clemson spineless and Local cultivars, respectively, while the lowest mean weight (17.71 g) was noted for Noura F1 cultivar. The highest yield was that of Djonan F1 cultivar with a yield per hectare of 16.68 tons unlike Kopê F1 (6.99 t/ha) and Local (7.82 t/ha) cultivars.

4.4.3. Biomass and Water Content of Fruits

Table 7 contains the results relating to fruit biomass and water content. Analysis of variance at 5% probability threshold of the Newman-Keuls test showed very significant differences between the fruits of the cultivars. A very highly significant difference was observed between cultivars with regard to capsule weight ($p < 0.001$). Regarding fruit fresh weight, the highest one was indicated by Djonan F1 cultivar with 36.42 g while the lowest one was obtained by Kopê F1 cultivar with a fresh weight of 23.67 g. Djonan F1 cultivar revealed a significant dry weight (3.57 g) while the lowest dry weights (2.46 and 2.51 g) were noted in Divo and Local cultivars. A highly significant difference was observed between cultivars in fruit water content ($p = 0.003$). Thus, the water content of the different okra cultivars varied between 85.61 and 90.38% for a mean of 88.66%. The highest fruit water contents were obtained with Noura F1, Local, Djonan F1, and Divo cultivars (90.38; 89.88; 89.68 and 89.38% respectively) and the lowest fruit water content value was obtained with Kopê F1 cultivar (85.61%).

Table 5. Characteristics of the first three fruits harvested at maturity from the different okra cultivars

Cultivars	LPM (cm)	DPM (mm)	LFM (cm)	DFM (mm)	NAF	NSF	WFF (g)
Clemson spineless	4.46 ± 0.06 a	6.83 ± 0.08 a	10.95 ± 0.27 b	21.10 ± 0.41 c	7.46 ± 0.34 b	75.32 ± 1.82 b	24.70 ± 1.06 a
Divo	2.97 ± 0.05 d	6.96 ± 0.12 a	7.34 ± 0.13 d	24.06 ± 0.36 b	7.88 ± 0.60 ab	74.61 ± 1.49 b	20.35 ± 0.59 b
Djonan F1	3.16 ± 0.05 c	6.87 ± 0.12 a	7.06 ± 0.13 d	23.39 ± 0.37 b	7.80 ± 0.06 ab	81.36 ± 1.02 a	20.31 ± 0.63 b
Kopê F1	2.37 ± 0.02 f	5.84 ± 0.06 c	7.06 ± 0.08 d	29.05 ± 0.56 a	8.00 ± 0.05 ab	63.34 ± 1.23 c	23.17 ± 0.61 a
Local	2.51 ± 0.02 e	6.50 ± 0.07 b	8.04 ± 0.13 c	27.15 ± 0.34 a	8.15 ± 0.06 a	71.04 ± 1.08 b	24.66 ± 0.83 a
Noura F1	3.77 ± 0.04 b	5.42 ± 0.07 d	13.42 ± 0.30 a	15.06 ± 0.25 d	5.37 ± 0.05 c	50.62 ± 1.35 d	17.05 ± 0.65 c
Teriman	2.93 ± 0.07 d	6.89 ± 0.11 a	7.26 ± 0.14 d	23.60 ± 0.32 b	7.81 ± 0.07 ab	81.32 ± 0.96 a	20.03 ± 0.63 b
Overall mean	**3.17 ± 0.04**	**6.47 ± 0.04**	**8.73 ± 0.12**	**23.35 ± 0.23**	**7.50 ± 0.07**	**71.09 ± 0.67**	**21.47 ± 0.30**
Coefficient of variation (%)	**24.92**	**14.84**	**31.84**	**22.53**	**19.87**	**21.11**	**31.21**
Probability (p)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

NB: In the same column, numbers assigned the same letter do not differ significantly according to the Newman-Keuls test at 5% threshold.
LPM: Length of the peduncles of the first three fruits at maturity; **DPM**: Diameter of the peduncles of the first three fruits at maturity; **LFM**: Length of the first three fruits at maturity; **DFM**: Diameter of the first three fruits at maturity; **NAF**: Number of awns of the first three fruits; **NSF**: Number of seeds per fruit of the first three fruits; **WFF**: Weight of the first three fresh fruits

Table 6. Agronomic parameters of okra cultivars

Cultivars	Mean number of yield	Mean number of fruit per plant	Mean number of fruit (g)	Potential yield (t/ha)
Clemson spineless	10 a	18.53 ± 1.72 c	28.48 ± 1.06 a	14.66 ab
Divo	10 a	24.28 ± 1.80 b	23.24 ± 0.59 ab	15.67 b
Djonan F1	10 a	23.65 ± 1.64 ab	25.38 ± 0.63 b	16.68 a
Kopê F1	8 b	11.32 ± 1.27 d	22.26 ± 0.61 ab	6.99 c
Local	8 b	10.92 ± 0.89 d	27.77 ± 0.83 a	7.82 c
Noura F1	10 a	31.29 ± 1.89 a	17.71 ± 0.65 c	15.40 b
Teriman	10 a	23.04 ± 1.54 ab	23.25 ± 0.63 ab	14.88 ab
Overall mean	**9.43**	**20.43 ± 1.54**	**23.73 ± 0.71**	**13.16**
Coefficient of variation (%)	**13.02**	**32.47**	**15.88**	**35.64**
Probability (p)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

NB: In the same column, the numbers assigned the same letter do not differ significantly according to the Newman-Keuls test at 5% threshold.

Table 7. Fruit biomass and water content

Cultivars	Fruit fresh weight (g)	Fruit dry weight (g)	Fruit water content (%)
Clemson spineless	29.79 ± 2.56 bc	2.78 ± 0.18 bc	87.07 ± 1.24 ab
Divo	26.86 ± 1.62 bc	2.46 ± 0.17 c	89.38 ± 0.93 a
Djonan F1	36.42 ± 1.99 a	3.57 ± 0.19 a	89.68 ± 0.42 a
Kopê F1	23.67 ± 1.15 c	2.94 ± 0.17 bc	85.61 ± 0.94 b
Local	28.28 ± 1.30 bc	2.51 ± 0.17 c	89.88 ± 0.94 a
Noura F1	27.85 ± 1.78 bc	2.06 ± 0.13 d	90.38 ± 0.96 a
Teriman	31.49 ± 1.55 b	3.29 ± 0.22 b	88.63 ± 1.01 ab
Overall mean	**29.20 ± 0.68**	**2.80 ± 0.07**	**88.66 ± 0.34**
Coefficient of variation (%)	**48.12**	**49.64**	**8.44**
Probability (p)	**< 0.001**	**< 0.001**	**0.003**

NB: In the same column, the numbers assigned the same letter do not differ significantly according to the Newman-Keuls test at 5% threshold.

5. Discussion

Analysis of the physicochemical characteristics of the soil of the University of Félix HOUPHOUËT-BOIGNY (UFHB) experimental plot revealed a sandy-loamy texture. Indeed, the significant quantity of sand in this soil could be explained by the fact that the plot is located in a lowland between two slopes. The transportation of granulometric elements on both sides would therefore favor this significant concentration of sand. As for the low proportion of clay, it would be adequate for this crop. Consequently, the sandy-loamy texture of this soil would correspond perfectly to the cultivation of okra in which clayey soils should be avoided according to a study carried out by Fondio *et al.* [23]. These results obtained contradict those of Saleh *et al.* [24] for whom, sandy soils, which are the most common in Chad, are not suitable for this species and would rather recommend tropical eutrophic brown soils (loamy, loam-clay or loam-clay-sand and hydromorphic clay). Furthermore, the acidity of this soil which is expressed by pH_{Water} and pH_{KCl} lower than 7, as well as the low content of total organic matter could be explained by the nature of the soil in the study area. Moreover, the results obtained during this study are consistent with those of Yao and Allou [25] who showed that the soil of the Abidjan district is acidic and low in organic matter. However, okra tolerates slightly acidic soils and these values correspond to the optimal pH which varies between 6.2 and 6.5 [26]. In addition, the state of poverty of the plot in mineral elements resulted in these low contents. Indeed, these mineral elements are essential for the good growth of okra plants which require a high content of phosphorus and potassium, according to Fondio [27]. Consequently, the requirements for mineral elements are not covered. It is therefore advisable to carry out fertilization if one wants to obtain a good yield. The seed emergence rates of the okra cultivars used showed the behavior of these different cultivars in relation to the soil of the experimental plot. Indeed, the highest emergence rates were observed in Kopê F1, Teriman, Clemson spineless, Djonan F1, Local and Divo cultivars. The high emergence rate of these cultivars could be explained by the fact that these cultivars were able to adapt to the soil of the experimental plot unlike Noura F1 cultivar which had a low emergence rate. In addition, direct sowing without prior soaking of seeds would constitute a cause of the low emergence rate in this cultivar, due to dormancy for seed conservation. This dormancy would influence germination by increasing the emergence time of these seeds. Furthermore, soaking the seeds would be a way to break dormancy and thus increase emergence rate. These results are consistent with those of Harris *et al.* [28], Coulibaly *et al.* [29] and Zerome *et al.* [30] who revealed that seed soaking is beneficial in shortening germination time, good seeding density and plant vigor in Mali, Sudan and Ethiopia. Noura F1 and Clemson spineless cultivars were the first to reach 50% bud setting, 50% flowering and first harvest, while Kopê F1 and Local cultivars were the last for these assessed parameters. Indeed, these analyses indicate that these cultivars are early cultivars. This earliness would constitute an intrinsic characteristic of these cultivars. However, in Kopê F1 cultivar, the lateness could be explained by sensitivity to the extended photoperiod of the experimental period (dry season). Indeed, according to Fondio [27], the period between the emergence of the first flower bud and anthesis generally becomes longer when the photoperiod lengthens. Our results would be in line with those of Njoku [31], in Nigeria, who observed a delay in floral initiation in *Abelmoschus esculentus* local cultivars, when the photoperiod exceeded 12 and a half hours daily, as well as those of De lannoy [32] who showed that floral initiation and flowering are delayed as temperature rises. The largest plants in Clemson spineless and Noura F1 cultivars could be explained by the intrinsic character of these cultivars. Indeed, the variability observed in relation to vegetative development and plant height would result from their capacity to adapt to the environment [33,34]. The work of Gwennael [35] also reported that the phenotype which is the visible expression of the genotype can be influenced by external factors. Indeed, according to him, the expression of a given character can be the result of the interaction between genetic factors and those of the plant's living environment. The significant increase in diameter in Clemson spineless and Teriman cultivars and low in Kopê and Local cultivars could be linked to their genetic characteristic. Furthermore, this significant increase testifies to their resistance to bad weather. Indeed, this allows the plant to maintain itself solidly in order to cope with external forces resulting from climatic hazards (winds, rain). Which is the opposite for Kopê and Local cultivars. According to M'Sadak and Tayachi [36] and Boa *et al.* [34], plants with a large collar diameter generally have well-developed lateral roots while giving the plants a better survival rate. Regarding leaves and branches, the results showed that their number was generally linked to the height of the plants. Indeed, the significant numbers of leaves and branches were obtained in cultivars showing intermediate sizes except local cultivar in which the number of leaves was low despite the large size. In contrast, these results would therefore be linked to the genetic factors of the cultivars. Furthermore, the work of Fondio *et al.* [37] on the assessment of the agronomic performances of nine varieties of tomato in truck farming such as okra, showed that the difference observed in the growth of various varieties of tomato would be linked to their genotype and the environment in which they were tested. Differences between cultivars regarding yield parameters such as average number of harvests, mean number of fruits per plant, mean fruit weight and yield per hectare would depend on each cultivar. Indeed, the poverty of the soil of the experimental plot in nutrient elements revealed by the physicochemical analysis was improved by additions of fertilizing elements in particular NPK 12-22-22 and urea 46% which made it possible to correct nutrient deficiencies. The cultivars therefore received the same doses of fertilizer and urea. Consequently, these parameters would constitute characteristics specific to cultivars. Furthermore, generally speaking, the yield of each crop would depend on the characteristics of the natural environment, the plant material used, its origin and the production techniques applied. The diversity of these factors would reflect the great variability of produced yields [33]. According to Nana [38], the yield potential of each cultivar depends on the yield period. Indeed, one cultivar could lose its agronomic superiority to the benefit of another depending on the yield season. Clemson spineless cultivar was a variety very sensitive to diseases and pests so that its cultivation is not recommended without intensive phytosanitary control [39]. The introduced cultivar Djonan F1 was therefore able to adapt to the climatic and environmental conditions of the country. When analyzing the first three fruits of the cultivars, the differences observed would result from their genetic characteristics. Indeed, these would result from the intrinsic characteristics of each cultivar. Thus, according to Soro *et al.* [40], if a difference is observed between varieties during the same season, it is due to the variety alone. The difference between the weights of these cultivars as well as water content would be linked to their intrinsic character. In addition, this water content could influence fruit storage time.

6. Conclusion

The main objective of this study was to assess the agronomic performance of seven okra hybrids introduced in Côte d’Ivoire. At the end of this study, it appears from the results obtained that the vegetative development was distinct regarding cultivars. Divo, Kopê F1, Local, Djonan F1 and Teriman cultivars performed the best at this level. As for growth parameters, the best height was provided by Noura F1 cultivar. The largest diameter was induced by Clemson spineless cultivar. Kopê F1 and local cultivars indicated the best leaf numbers. In contrast, the best branches were obtained by Divo, Kopê F1, Local, Djonan F1 and Teriman cultivars. Concerning the phenological parameters, only Clemson spineless and Noura F1 cultivars were the earliest (46 DAS). As for yield components, Divo, Noura F1, Clemson spineless, Djonan F1 and Teriman cultivars reported the best numbers of harvest. The largest mean number of fruits was obtained in Noura F1 cultivar and the best mean weights were obtained by Clemson spineless and Kopê F1. Djonan F1 cultivar provided the best potential yield per hectare. Noura F1 cultivar was the most resistant to pathologies. All these introduced cultivars were able to adapt to the soil and climatic conditions of the southern zone of Côte d’Ivoire and could be recommended to producers. However, more in-depth studies need to be carried out.

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