World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

Phenology and performance of okra (*Abelmoschus* spp.) morphotypes from Benin

Marcelline Gnawe [1], Hounnankpon Yedomonhan [1], Aristide C Adomou [1] and Fortuné Azihou [2]

[1] *Laboratory of Botany and Plant Ecology (LaBEV), Plant Biology department, Faculty of Science and Technology, University of Abomey-Calavi, 01 BP 4521 Cotonou (Benin).*

[2] *Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey-Calavi, Benin.*

World Journal of Advanced Research and Reviews, 2024, 23(02), 2519–2531

Publication history: Received on 16 July 2024; revised on 25 August 2024; accepted on 28 August 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.2.2587

Abstract

Okra is currently a highly profitable crop for the farming community because of its high consumption potential across rural and urban areas. Thus, it is important to evaluate the yield of various morphotypes of the three species grown in Benin. Assessing the production yield will enable efficient selection of the best morphotypes for the benefit of the population. A total of 53 morphotypes, characterized from okra species cultivated in Benin, were sown in a field at the University of Abomey-Calavi. For each morphotype, 5 plants were selected, and data were collected from germination until the fruits reached total senescence. Among the three species of okra cultivated in Benin, *A. moschatus* has the longest vegetative phase (68 ± 3 days). The average flowering time ranges from 51 days in *A. caillei* to 71 days in *A. moschatus*. The longest average fruiting time was also observed in *A. moschatus* (48 days). The analysis of variance showed that the duration of fruit set varied significantly among the species ($p = 0.003$). In terms of production yield, *A. esculentus* is the most productive species, yielding 10.50 tonnes of fruit per hectare. It is followed by *A. moschatus* and *A. caillei*, which yield 5.9 tonnes and 5 tonnes of fruit per hectare, respectively. Morphotype M25 of *A. esculentus* is the most profitable among the 53 morphotypes of the three species, producing 520.23 grams per stem, or 20.8 tonnes of fruit per hectare.

Through this study, an annual sowing calendar was developed, enabling producers to plan okra cultivation for the entire year.

Keywords: Phenology profile; Okra; Morphotypes; Fruits

1. Introduction

Agriculture is the basis of the socio-economic development of any country. In Benin, it employs 70% of the working population and contributes 75% to export earnings and then 35% of the Gross Domestic Product (GDP). However, its development is hampered by multiple disadvantageous factors (INSAE, 2013). Among these constraints are the low farming technology level and small stakeholders' dominance. In addition, agricultural research efforts are, for the most part, focused on major crops such as cereals and cotton (MEDEV, 2005). As a result, other agricultural products sought after on the national and international markets for their important nutrient content are neglected (Agbo et al., 2008). For instance, traditional vegetables have been the subject of very little scientific work, although they are important food and medicinal supplements and sources of income for a large number of rural people (Marius et al., 1997; Nzikou *et al.*, 2006; Sawadogo *et al.*, 2006; Sawadogo et al., 2009). Among these vegetables is okra, which is widely consumed by all socio-linguistic groups and very remunerative for sellers (Dansi *et al.*, 2010). When assessing the state of biodiversity in southwestern Benin, Akoègninou *et al.* (2008) found that okra exists in various local varieties. These observations were later confirmed by inventories of traditional vegetables in Benin (Achigan-Dako *et al.*, 2010; Gnawé *et al.*, 2016). The existence of several local varieties of okra in Benin raises several research questions, namely: What are the reasons

* Corresponding author: Gnawe Marcelline

for varietal diversification in okra production in Benin? What are the preference criteria for varieties by producers and consumers? Are these criteria linked to the culinary, nutritional, and market values of local varieties? Are there more profitable local varieties for extension? In Africa, previous investigations on okra varieties have been carried out, especially in Burkina Faso (Sawadogo et al., 2009; Nana et al., 2010). Sawadogo et al. (2009) showed the existence of four varieties, including two local ones appreciated for their high mucilage content, low seed content, and pleasant flavor. However, these varieties tend to be neglected due to their late cycle and low yield. Nana et al. (2010), meanwhile, demonstrated that okra varieties can reduce the number and opening of stomata as well as vertical and radial growth, which constitutes an alternative to resist water deficit. In Benin, the work of Gnawé et al. (2016) revealed the existence of 380 local varieties according to the vernacular name out of the 683 samples identified by producers. Additionally, Gnawé et al. (2018) showed the existence of three species in Benin out of the four occurring in West Africa. These three species have been subdivided into 53 morphotypes. Thus, this work has already highlighted some agro-morphological criteria necessary for variety selection that can be accepted by producers in Burkina Faso and Benin. However, no study on the yield of local varieties has been carried out. The present work aims to study the phenological cycles of the different morphotypes of characterized okra and evaluate the yield rate in fruit production of the different morphotypes of okra cultivated in Benin.

2. Material and Methods

The surveys were conducted in Benin, across 134 villages sampled in 41 Districts, with a total of 683 seed samples collected from 760 producers. After sowing for the agromorphological characterization of 683 samples at the experimental site at the University of Abomey-Calavi, 573 samples germinated and were subjected to this characterization. In total, the 573 samples were discriminated into 3 species: 463 belonging to *Abelmoschus esculentus*, 107 to *Abelmoschus caillei*, and 3 to *Abelmoschus moschatus*. All three species were further subdivided into 53 morphotypes, including 43 for A. esculentus, 9 for *A. caillei*, and 1 for *A. moschatus*.

For this study, the experiment was conducted on the seeds of the 53 morphotypes resulting from the agromorphological characterization of local okra varieties cultivated in Benin. A total of 20 plots, each measuring 10 meters by 1 meter wide with a spacing of 1 meter between consecutive plots, were established (Figure 3). Before planting the seeds, each seedling pocket received 1 kilogram of compost all around, following the recommendations of Baguinéda (1994). The seedlings were planted on June 1, 2016, in batches of morphotype, at a rate of 3 seeds per pocket and 8 pockets per morphotype. The distance between two consecutive seedlings was 2 meters. Of the 53 morphotypes, seedlings from 42 morphotypes germinated. Two weeks after germination, the number of plants was reduced to one plant per pocket. Phytosanitary treatment was carried out three times, at intervals of 21 days, using the insecticide Cypercal 3E.

Stakes labeled with the number of each okra variety sown were driven into the ground in front of each plot. After the rains ceased, the young plants were watered regularly every 3 days until fruiting and once a week until senescence. Data related to phenology and fruit yield were collected on the different okra morphotypes at each stage of their development. The data collected included the date of flowering and the date of fruiting, as well as the number of fruits harvested per day on each stem of each variety. The length and circumference of fruits were measured with a tape measure (decimeter), and the fresh mass of the fruits was measured using an electronic scale (OHAUS CL 501).

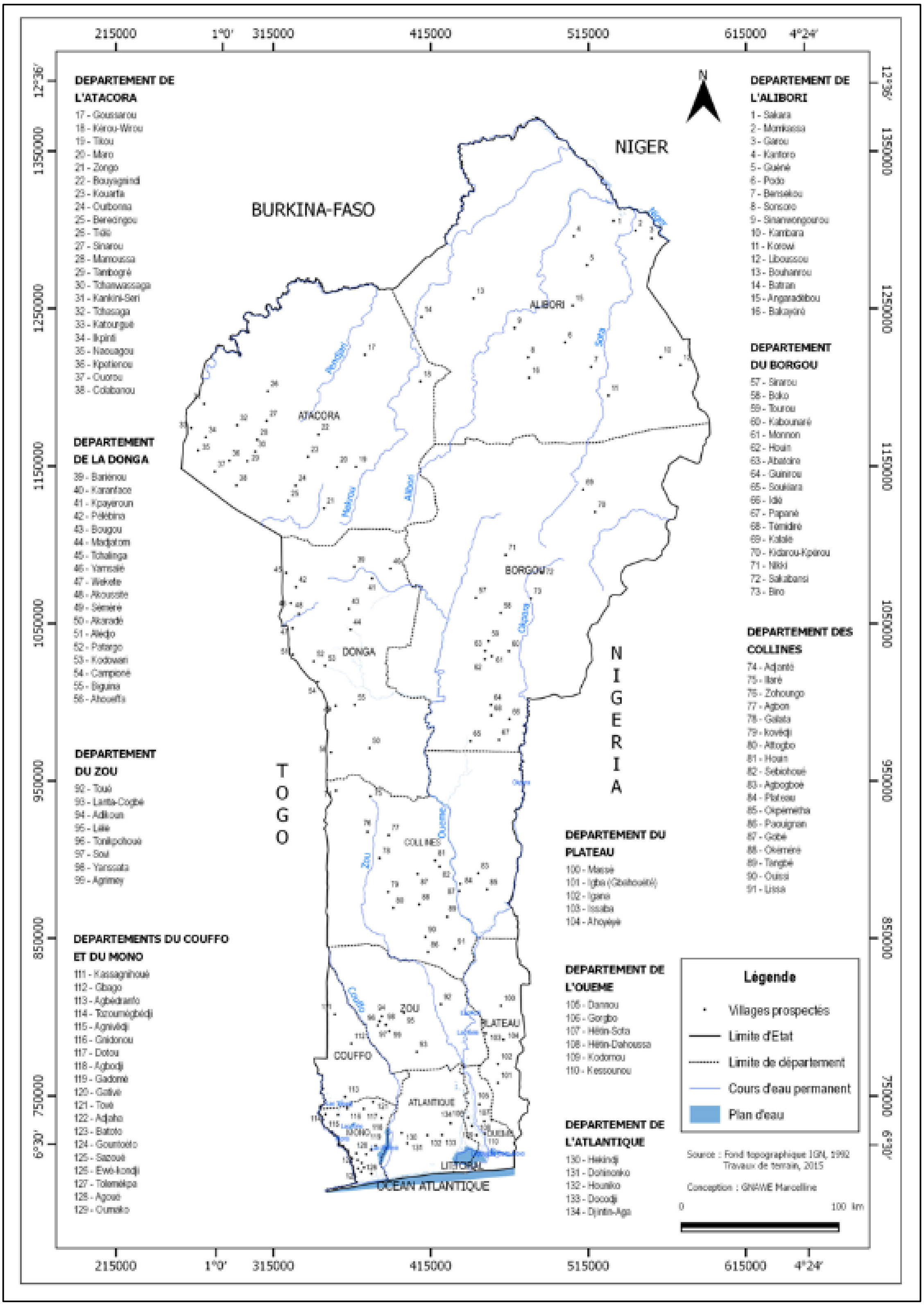

Figure 1 Map of Benin showing the villages covered

Figure 2 Arrangement of varieties per plot in the okra experimental field for fruit productivity

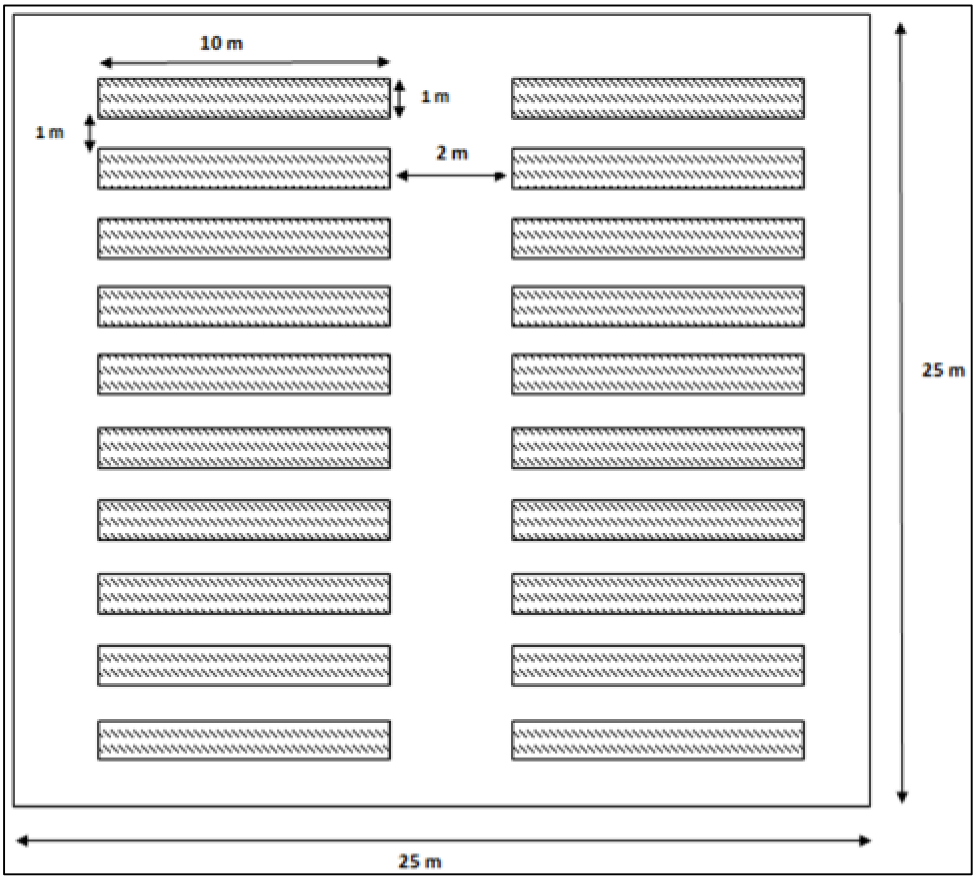

Figure 3 Experimental design on the field

2.1. Data processing

The data collected (date of flowering and fruiting) were used to calculate the durations of the development phases (vegetative phase, flowering, fruit set, fruiting) for each of the 42 germinated morphotypes. Additionally, fruit yield was assessed by considering the number of fruits and the biomass of fruits produced, expressed as g/plant and t/hectare. Analysis of variance (ANOVA) was performed to determine if there were significant differences in the phenological parameters between the morphotypes. Hierarchical clustering was then used to identify groups of morphotypes with similar performance. Finally, a linear regression analysis was conducted to investigate the correlation between the various productivity parameters and the phenological variables. The statistical analyses were performed using MINITAB 14.0 software.

The phenological status of the morphotypes was determined based on the duration of their vegetative phase, which indicates their precocity or lateness in the reproductive phase (flowering and fruiting). Four classes of morphotypes were considered, namely:

- Early morphotypes which are those with a short vegetative phase (1 month at most);
- Late morphotypes which are those having an average vegetative phase (1 month to 1 month and a half);
- Very late morphotypes which are those having a long vegetative phase (1 and a half to 2 months);
- Extremely late morphotypes which are those having a very long vegetative phase (2 months to 2 and a half months).

The yield in fruit production per hectare (PT) was estimated using the average production of a stem and the density (Dp) of the plantation of the taxon using the formula of Kouyaté *et al*. (2006):

$$PT = (\sum pi / N) \times (\sum ni / 10000), \text{ where}$$

pi is the average production per plant i (in number or weight of fruit per ton) and N is the total number of plants from which the fruit was harvested, ni is the number of plants per hectare.

3. Results

3.1. Development stages of okra cultivated in Benin

3.1.1. Duration of the vegetative and reproductive phases of okra species cultivated in Benin

The duration of each of the development phases in the okra species cultivated in Benin is given in Table 1. Among the 3 okra species cultivated in Benin, *A. moschatus* is the one which has the longest vegetative phase (68 ± 3 days). Then come the vegetative phase of *A. caillei* (41 ± 9 days) and that of *A. esculentus* (35 ± 9 days).

The average flowering time varied from 51 days in *A. caillei* to 71 days in *A. moschatus*.

The longest average fruiting time was observed in *A. moschatus*, lasting 48 days, while it was 43 and 34 days respectively in *A. esculentus* and *A. caillei*.

Table 1 Duration of the vegetative and reproductive phases in the 3 species **-**

Development Phases	***A. esculentus***	***A. caillei***	***A. moschatus***
Vegetative phase	35 ± 9^a	41 ± 9^a	68 ± 3^b
Flowering	56 ± 10^a	51 ± 9^a	71 ± 5^b
Fruiting	43 ± 10^a	34 ± 8^b	48 ± 6^a

For the same line, the values having different letters in superscript are different ($p < 0.05$) from one species to another and those having the same letters are similar ($p > 0.05$)

The proportional analysis indicates that the durations of the vegetative phase and flowering are statistically similar between *A. esculentus* and *A. caillei* (Table 1). Regarding fruiting, its durations are statistically similar between *A. esculentus* and *A. moschatus*. However, the duration of fruiting observed in *A. caillei* is statistically shorter than that of the other two species.

3.1.2. Variability in the duration of development phases within identified morphotypes

Figure 4 illustrates the variability in the duration of the different development phases within species. Considering the curve related to the vegetative phase, the duration of the vegetative phase varied from 28 days (M4, M24, M34, and M43) to 72 days (M20) among the morphotypes of *A. esculentus*, from 32 days (M47 and M50) to 52 days (M46 and M51) in the morphotypes of *A. caillei*, and was 68 days in A. moschatus (Figure 4). All morphotypes were divided into four classes based on the length of their vegetative phase, which corresponds to the time required for their entry into the reproductive phase. The first class consists of early morphotypes, characterized by a short duration of the vegetative phase (at most 1 month) and comprising 43% of the morphotypes of *A. esculentus*. The second class comprises late morphotypes, having an average duration of the vegetative phase (1 month to 1.5 months) and grouping together 54% of the morphotypes of *A. esculentus* and 67% of those of *A. caillei*. The third class is the class of very late morphotypes, characterized by a long duration of the vegetative phase (1.5 to 2 months) and including 33% of the morphotypes of *A. caillei* and the only morphotype of *A. moschatus*. The fourth class is the class of extremely late morphotypes, grouping together the very long-lasting morphotypes of the vegetative phase (2 to 2.5 months). It consists of only one morphotype of *A. esculentus*. Considering the flowering phase, it ranges from 29 days (M20) to 74 days (M43) in the morphotypes of *A. esculentus*, from 34 days (M45) to 62 days (M50) in *A. caillei*, and is 71 days in A. moschatus (Figure 5). Among all morphotypes, those whose flowering spreads over 1.5 to 2 months are in the majority, with a rate of 63% in *A. esculentus* and 66% in *A. caillei*, which are the two species with several morphotypes (Figure 5). The percentage of morphotypes flowering for more than 2 months is very low, at 28% and 17% respectively in *A. esculentus* and *A. caillei*.

The duration of fruiting varied from 18 days (M20) to 65 days (M43) in *A. esculentus*, from 24 days (M46) to 44 days (M52) in *A. caillei*, and was 48 days in *A. moschatus* (Figure 5). The majority of *A. esculentus* morphotypes (49%) fruit for 1 to 1.5 months. They are followed by those whose fruiting spans between 1.5 and 2 months (39%). In contrast, in *A. caillei*, morphotypes with a short fruiting period (1 month) are equally proportioned (50%) as those fruiting over 1 to 1.5 months (Figure 5).

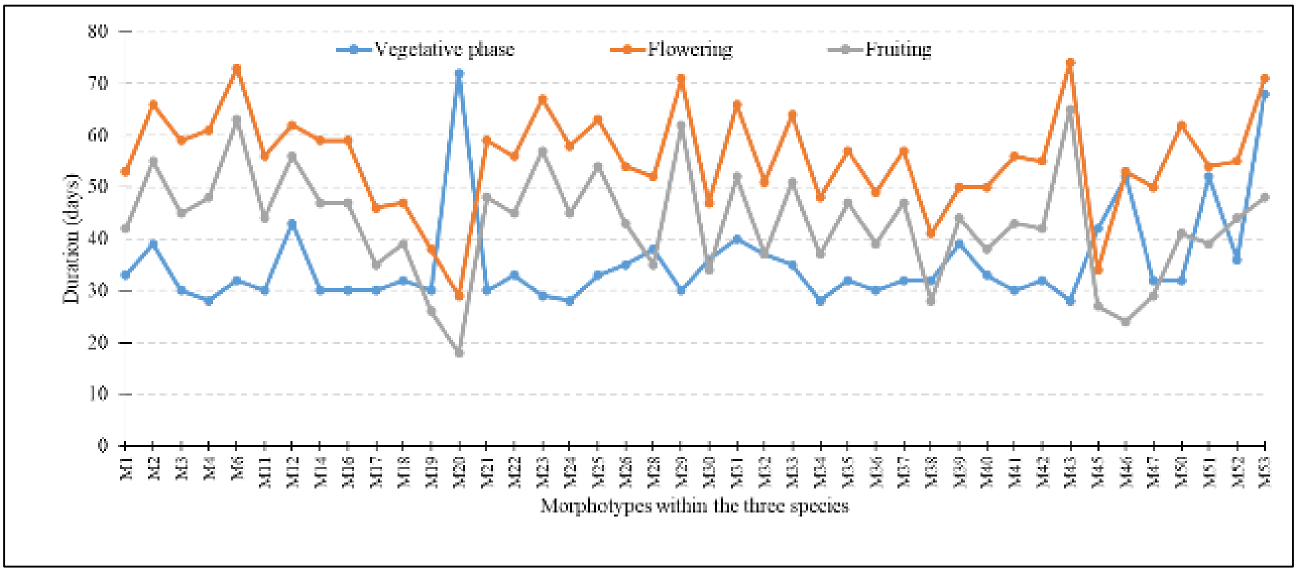

Figure 4 Duration of the different phonological phases of okra morphotypes within the three species (M1-M43: A. esculentus; M45-M52: *A. caillei*; M53: *A. moschatus*) -

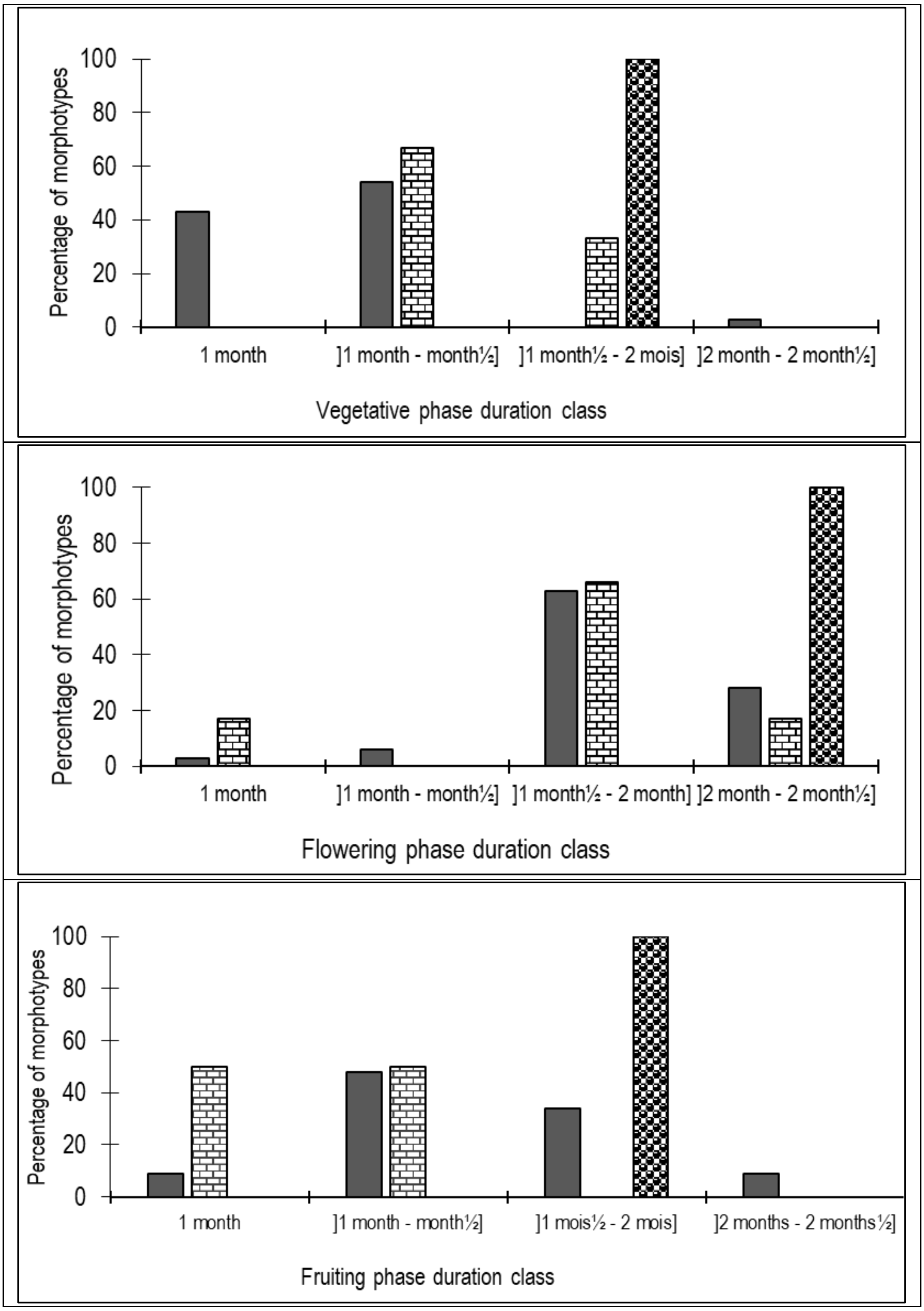

Figure 5 Variation in the percentage of morphotypes by species across different duration classes of each development phase

At the level of *A. esculentus*, Pearson's correlation revealed a significant and negative correlation between the duration of the vegetative phase and the duration of flowering (r = -0.418; R^2 = 17.46%; p = 0.013) and between the duration of the vegetative phase and the duration of fruiting (r = -0.381; R^2 = 14.48%; p = 0.024). However, the correlations between these variables were weak, as indicated by the low coefficients of determination (R^2). The variation in the duration of the vegetative phase could only be explained by the variation in the duration of flowering with 17.46% success and by the variation in the duration of fruiting with 14.48% success. Regarding the duration of flowering and the duration of fruiting, they were significantly, strongly, and positively correlated (r = 0.976; R^2 = 95.34%; p = 0.000). In 95.34% of cases, the variation in one of these two variables was explained by the variation in the other.

In the case of *A. caillei*, no significant correlation exists between these variables (duration of the vegetative phase, duration of flowering, and duration of fruiting) when taken two by two.

3.1.3. Duration of fruit set

Analysis of variance revealed that the duration of fruit set varied significantly among the three species (p = 0.003). It ranged from 7 to 24 days with an average of 12 ± 3 days in *Abelmoschus esculentus*, from 12 to 22 days with an average of 14 ± 5 days in *A. caillei*, and was 24 days in *A. moschatus* (Table 2). Table II indicates that within the same species with multiple morphotypes, the fruit set time was identical for some morphotypes but different for others. Additionally, some morphotypes of a given species exhibited the same fruit set time as those belonging to other species.

Table 2 Variation in fruit set duration at the level of species

Fruit setting duration (days)	***Abelmoschus esculentus***	***Abelmoschus caillei***	***Abelmoschus moschatus***
7	M12, M39		
8	M45		
9	M18, M43		
10	M19, M25, M29, M30, M42		
11	M6, M23, M31, M35, M36, M37		
12	M2, M17, M20, M21, M22, M26, M34	M50, M52	
13	M11, M14, M16, M40		
14	M3, M4, M24, M38, M41	M46	
15	M1		
16		M51	
17	M28, M32		
22		M47	M53
24	M33		

3.2. Fruit yield of morphotypes

3.2.1. Quantity of fruit produced by cultivated okra morphotypes

The fruit yields of the different okra morphotypes, in terms of the number of fruits and the biomass of fruits produced per plant and per hectare, are presented in Table 3.

Considering the number of fruits produced, the average production per plant ranges from 4 to 23 fruits/plant for *A. esculentus*, from 5 to 11 fruits/plant for A. caillei, and is 21 fruits/plant for *A. moschatus*. Regarding the yield per hectare, it varies from 160,000 to 920,000 fruits/ha in *A. esculentus*, from 200,000 to 440,000 fruits/ha in *A. caillei*, and is 840,000 fruits/ha in *A. moschatus*.

In terms of weight, *A. esculentus* records the highest average value, which is 262.91 ± 110.28 grams of fruit per plant, or 10.50 tons of fruit per hectare. Its morphotypes have a production ranging from 80 grams of fruit per plant (3.2 tons of fruit per hectare) to 520.23 grams of fruit per plant (20.80 tons of fruit per hectare). For *A. caillei*, the fruit yield is on average 140 ± 59 grams of fruit per plant, or 5 tons of fruit per hectare.

Table 3 Variation in fruit yields of cultivated okra morphotypes

Morphotypes	Number of fruits / plant	Number of fruits / ha	Masses of fruit / plant (in grams)	Masses of fruit / ha (in tons)
A. esculentus				
M1	8 ± 3	320000	189.96 ± 90.45	7.60
M2	17± 8	680000	170.90 ± 81.29	6.80
M3	12 ± 6	480000	275.00 ± 180.79	11.00
M4	6 ± 3	240000	189.42 ± 73.83	7.60
M6	20 ± 8	800000	287.30 ± 118.45	11.50
M11	12 ± 5	480000	317.90 ± 154.19	12.70
M12	16 ± 10	640000	313.24 ± 97.52	12.60
M14	18 ± 10	720000	308.74 ± 106.13	12.30
M16	15 ± 6	600000	386.26 ± 132,14	15.50
M17	10 ± 2	400000	180.34 ± 159,22	7.20
M18	5 ± 2	200000	123,16 ± 109,29	4.90
M19	8 ± 3	320000	189.96 ± 90.45	7.60
M20	15 ± 4	600000	336.30 ± 79.31	13.50
M21	8 ± 4	320000	171.24 ± 102.31	6.80
M22	10 ± 5	400000	190.50 ± 75.74	7.60
M23	15 ± 4	600000	210.88 ± 156.03	8.40
M24	18 ± 11	720000	369.52 ± 246.77	14.70
M25	23 ± 4**	920000	520.23 ± 74.50**	20.80**
M26	6 ± 1	240000	109.52 ± 29.99	4.40
M28	9 ± 5	360000	80.00 ± 34.77*	3.20*
M29	10 ± 2	400000	424.50 ± 189.22	17.00
M30	17 ± 7	680000	157.76 ± 97.50	6.30
M31	7 ± 3	280000	224.24 ± 34.93	8.90
M32	8 ± 7	320000	234.26 ± 172.21	9.40
M33	16 ± 5	640000	403.24 ± 134.63	16.10
M34	9 ± 4	360000	398.72 ± 92.96	15.90
M35	12 ± 4	480000	405.93 ± 99.89	16.20
M36	4 ± 2*	160000	236.56 ± 139.05	9.40
M37	23 ± 8**	920000	154.55 ± 54.94	6.10
M38	20 ± 4	800000	369.68 ± 172.08	14.80
M39	6± 3	240000	117.50 ± 68.13	4.70
M40	7± 4	280000	159.85 ± 80.85	6.40
M41	10 ± 6	400000	236.26 ± 148.59	9.40
M42	8 ± 4	320000	353.49 ± 166.28	14.10

M43	11 ± 3	440000	404.88 ± 119.92	16.20
Average	12 ± 5	479676	262.91 ± 110.28	10.50
A. caillei				
M45	7 ± 3	280000	80.30 ± 21.40	3.21
M46	5 ± 2	200000	67.85 ± 12.25*	2.71*
M47	11 ± 5**	440000	227.80 ± 128.49**	9.11**
M50	11 ± 7**	440000	167.96 ± 114.76	6.71
M51	10 ± 7	400000	149.80 ± 124.88	5.99
M52	11 ± 4**	440000	146.38 ± 77.35	5.85
Average	9 ± 3	366667	140 ± 59	5.00
A. moschatus				
M53	21 ± 6	840000	147.96 ± 33.57	5.90

Morphotype M47 recorded the highest value (227.80 grams of fruits per plant or 9.11 tons of fruits per hectare), while morphotype M46 recorded the lowest value (67.85 grams of fruits per plant or 2.71 tons of fruits per hectare). Finally, *A. moschatus* has a production of 147.96 ± 33.57 grams of fruits per plant, or 5.9 tons of fruits per hectare.

Morphotype M25 of *A. esculentus* has the highest yield among all morphotypes of the three species, producing 23 fruits per plant or 920,000 fruits per hectare, and 520.23 grams of fruits per plant or 20.80 tons per hectare.

3.2.2. Correlation between quantitative productivity variables

There is a significant positive correlation between the number and the weight of fruits per plant when considering all morphotypes of the three species ($r = 0.429$; $R^2 = 18.40\%$; $p = 0.005$). Additionally, these two variables showed a positive correlation in A. esculentus ($r = 0.441$; $R^2 = 19.48\%$; $p = 0.008$) and *in A. caillei* ($r = 0.876$; $R^2 = 76.74\%$; $p = 0.022$). The respective coefficients of determination (R^2) indicate that the correlation between these variables is explained with a higher success rate in *A. caillei* (76.74%) compared to A. esculentus (19.48%) and the three species considered together (18.40%).

Overall, the duration of fruiting has a positive and significant correlation with the number of fruits produced per plant ($r = 0.306$; $R^2 = 9.36\%$; $p = 0.049$) and with the weight of fruits produced per plant ($r = 0.366$; $R^2 = 13.39\%$; $p = 0.017$). However, specifically, no significant correlation exists between the duration of fruiting and the productivity variables (number and weight of fruits) in either A. esculentus or *A. caillei* ($p > 0.05$).

4. Discussion

The phenological profile of cultivated okra was approached through its four phenological phases: the vegetative phase, flowering, fruit set, and fruiting. Most studies on the duration of okra's development cycle have primarily focused on the vegetative phase and the total length of the life cycle (Siemonsma, 1982; Fondio et al., 1999; Nana et al., 2009; Aziadekey et al., 2013; Kouassi et al., 2013; Fondio et al., 2003; Tshomba et al., 2015). For these authors, the fundamental question is to determine the time required for okra to enter flowering after sowing, on the one hand, and the total lifespan of the plant, on the other hand. However, this approach implicitly takes into account the phases of flowering, fruit set, and fruiting, which constitute the reproductive phases. Since okra is cultivated for its fruits, knowledge of the duration of the vegetative phase and the fruiting phase is crucial and contributes significantly to the production of different morphotypes of this crop.

The vegetative phase durations recorded in the present study were 28 to 72 days in A. esculentus, 32 to 52 days in *A. caillei*, and 68 days in A. moschatus. In A. esculentus, certain morphotypes had vegetative phase durations falling within the range of 45 to 70 days reported by previous work (Siemonsma, 1982; Fondio *et al*., 1999; Nana *et al*., 2009; Aziadekey *et al*., 2013; Kouassi *et al*., 2013), while others had durations below or beyond these limits. In contrast, in *A. caillei*, the duration of the vegetative phase was clearly shorter than the 75 to 120 days reported by the same authors (Siemonsma, 1982; Fondio *et al*., 1999; Nana *et al*., 2009; Aziadekey *et al*., 2009; Aziadekey *et al*., 2013; Kouassi et al., 2013). This could be attributed to the existence of morphotypes not studied in previous work and included in the present study. However, the high precocity observed in the morphotypes of *A. caillei* compared to previous work might indicate the influence of the short dry season in August, as sowing was conducted on June 1st. In fact, sowing dates closer to the dry season can lead to a reduction in the duration of the vegetative phase (Fondio et al., 1999). According to Aziadekey *et al*. (2013), prolonged water stress accelerates flowering in certain okra varieties. Sawadogo et al. (2006) have already demonstrated that water stress during the budding phase can lead to early flowering in some varieties and delayed flowering in others. The rapid flowering of some plants grown in dry conditions can be interpreted as an adaptive strategy to cope with water scarcity (Singh *et al*., 1999). According to these authors, plants seem to avoid extinction in challenging water conditions by flowering early. This corroborates the work of Siemonsma (1982), who showed that *A. caillei* is a Guinean type okra highly sensitive to photoperiodicity. Moreover, the flowering dependent on the climatic conditions of the dry season is what causes *A. caillei* to produce fruit in the dry season, earning it the name "dry season okra" among producers.

The results revealed variability in the duration of the different development phases of morphotypes within the same species, with a high proportion of early morphotypes in terms of the onset of flowering in A. esculentus. However, all morphotypes benefited from the same climatic conditions influencing their vegetative development because they were monitored at the same experimental site. According to Fondio et al. (2003), sunshine and temperature are the limiting factors for vegetative development in okra. These authors have shown that the height growth and vegetative development of okra plants of A. esculentus and *A. caillei* undergo a decrease and early flowering at the transition from the rainy season to the dry season. Indeed, water stress affects several variables of the plant's functioning, such as leaf temperature (Patel et al., 2001; Laquet et al., 2004), stomatal conductance, and leaf area (Lowlor and Cornic, 2002), as well as photosynthesis (Yuan et al., 2004). In the case of the present study, the sowings were made on June 1, and yet, precocious flowering was already observed for 43% of the morphotypes of A. esculentus on June 28, while the experimental site was in the midst of the rainy season. The variability in phenological profiles observed among morphotypes cannot be explained by environmental conditions. This confirms the genotypic dissimilarities and the diversity existing within the accessions of the species A. esculentus and *A. caillei*, which are the two species with multiple morphotypes.

The existence of such a pool of genetic diversity among morphotypes could be exploited to plan okra cultivation over time and optimize its yield and economic profitability. Indeed, morphotypes with different phenological profiles could be sown from the start of the rainy season, but eventually, they would start to bear fruit one after the other. The advantage is that late morphotypes would have undergone vegetative development over a long period, leading to a very positive impact on their yield, as according to Fondio *et al*. (2003), the vegetative development of okra plants depends on the sowing period, which in turn determines the fruit yield.

4.1. Fruit yield of okra grown in Benin

In *Abelmoschus esculentus*, morphotype M25 outperforms other morphotypes in terms of fruit weight per hectare, yielding 20.8 tons per hectare. Its productivity is significantly higher than the 3.3-4 tons per hectare reported in Congo (Muzingu, 2010; Tshomba *et al*., 2015), the 7.4 tons per hectare of Koto varieties in Côte d'Ivoire (Fondio et al., 2003), the 11.51 tons per hectare of three ecotypes in Lomé (Aziadekey *et al*., 2013), and the 15 tons per hectare obtained by Ouédraogo (2009) in Bobo-Dioulasso. It is also substantially higher than the yield of the selected variety UAE19, which is 2.85 tons per hectare. For *A. caillei*, morphotype M47 is the most productive, yielding 9.11 tons per hectare. This yield is higher than the 6.7 tons per hectare yield of the Tomi variety in Côte d'Ivoire (Fondio et al., 2003). The species A. moschatus, with its single morphotype, has a productivity of 5.9 tons per hectare. Therefore, the fruit yields of the morphotypes of the three okra species cultivated in Benin are all higher than those obtained in Burkina Faso, Congo, and Côte d'Ivoire. According to Nana (2005), the production potential of each morphotype depends on the season, climate, and soil conditions.

The comparative analysis of the fruit yields of the three species revealed that *Abelmoschus esculentus* is the most productive with an average yield of 10.50 tonnes / ha, followed by *A. moschatus* (5.90 tonnes / ha) and *A. curd* (5 tonnes / ha). The low yield of the latter contradicts the results of 13.92 tonnes/ha obtained in an experimental field in Bouaké (Ivory Coast) by Fondio *et al*. (1999). The low yield of *A. caillei* in the context of the present study could be attributed to the early flowering observed in the species due to its sensitivity to photoperiod, contrasting with the late sowing. Indeed, the existence of a positive correlation between vegetative characteristics (plant size, height of insertion of the first fruit, end of cycle) and yield components (Fondio et al., 2003) indicates that a well-developed plant produces more fruits. These authors have also concluded that early flowering does not induce good production. In the case of the present study, the seedlings sown in June did not allow the plants of *A. caillei* to reach their maximum development before starting flowering, following the low rainfall recorded in August.

In *A. esculentus*, the average yield of 10.50 tons per hectare is similar to the 11.35 tons per hectare found in Côte d'Ivoire for an unspecified cultivar of the species (Fondio et al., 1999). However, it is slightly lower than the average yield of 11.51 tons per hectare obtained for three ecotypes of A. esculentus in Togo in the subequatorial zone (Aziadekey *et al*., 2013).

The results also revealed variability in the yield components (number and weight of fruits) among morphotypes. This difference in behavior in terms of yield could be attributed to the existence of more productive genomes within the collection, as all morphotypes benefited from the same cultivation practices and environmental conditions.

It is noted from this discussion that the different phases of the development cycle (flowering and fruiting) of morphotypes within a single okra species have not been investigated in previous studies by other authors. Additionally, there is variability in the vegetative cycle at the level of the *A. caillei* species. The yields obtained in the present work are similar to the yields obtained in previous studies by other authors.

5. Conclusion

This chapter highlighted the variability of different development phases and fruit income among species and, sometimes, among morphotypes within the same species. Fifteen early morphotypes (entering flowering after 1 month or less) were identified, all belonging to the species Abelmoschus esculentus. Additionally, 16 morphotypes, including 15 for A. esculentus and 1 for A. moschatus, were recorded as fruiting over a longer period (1.5 to 2.5 months).

Knowledge of the phenological profile of various cultivated okra morphotypes is valuable for establishing an annual sowing calendar, allowing producers to plan okra cultivation throughout the year. This can lead to a phased production of okra over time, ensuring its abundance in the market at certain times and its scarcity at others. Regarding yield results, they can help producers make their production profitable by selecting the most productive morphotypes.

The two aspects discussed in this chapter addressed agronomic elements that can enable the selection of morphotypes with the aim of improving the economic profitability of okra cultivation for poverty reduction. However, these aspects should be complemented by knowledge of the chemical and biochemical characteristics of okra to better understand their nutritional values.

Compliance with ethical standards

Acknowledgement

We would like to thank IFS for funding the fieldwork for this study.

Disclosure of conflict of interest

The authors declare no conflicts of interest.

References

[1] Aziadekey M., Odah K., Atayi A. (2013). Effect of different forms of water stress on the production and content of okra (*Abelmoschus esculentus* (L.)) mineral elements

[2] Dansi A., Vodouhè R., Azokpota P., Yedomonhan H., Assogba P., Adjatin A., Loko Y. L., Dossou-Aminon I., Akpagana K. (2012). Diversity of the Neglected and Underutilized Crop species of importance in Benin. Sci. World J. ID 932947, DOI 10.1100 / 2012/932947. p. 19

[3] Doumbia S., (2010). Seasonal products, Fresh okra, Les Echos.

[4] Fondio L., Kouame C., Traore D., Djidji A. H. (1999). Sowing densities, growth and production of two lines of okra (*Abelmoschus* spp) in Côte d'Ivoire. Notebooks / Agriculture 8 : 413.

[5] Fondio L., Djidji. H. A., Kouame C., Traore D. (2003). Effect of sowing date on okra (*Abelmoschus* spp.) Production in central Côte d'Ivoire. African Agronomy 15 (1) 13-34.

[6] Hamon S., Van Sloten D. H. (1995). Okra.ln: Smartt J., Simmonds N.W. (Eds). Evolution of crop plants. Documentary Collection (ORSTOM), Longman London, United Kingdom, United Kingdom l : 350-357.

[7] INSAE (2013). Provisional results of the fourth General Census of Population and Housing. Demographic Studies Department (RGPH4) p. 35

[8] Kouassi J. B., Cissé-Camara M., Sess D. E., Tiahou G. G., Monde A. A., Djohan F. Y. (2013). Determination of the iron, calcium, copper and zincs contents of two varieties of okra. Bul. of the Royal Society of Sciences of Liège 82: p. 22-32

[9] Lowlor D., Cornic W. (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficit in higher plant cell. About. 25 : 275-294.

[10] Luquet D., Vidal A., Dauzat J., Begue A., Olioso A., Clouvel P. (2004). Using directional tir measurements and 3d simulations to assess the limitations and opportunities of water stress indices. Remote Sensing of Environment, 90 (1) : 53-62.

[11] Muzingu M. (2010). The cooperative market gardening sites of Kinshasa in DR Congo. Environmental constraints and stakeholder strategies. Doctoral thesis, Louvain-la

[12] Nana R. (2005). Influence of the frequency and the watering period on the water saving: physiological adaptation of okra (*Abelmosehus esculentus* (L.) Moench) in off-season cultivation. DEA thesis. UFR / SVT, University of Ouagadougou, Burkina Faso 67 p. New, Catholic University of Louvain p.180

[13] Nana R. Zombres G, Tamin Z., Sawadogo M. (2009). Effect of water regime on okra yields in off-season crops (*Abelmoschus esculentus* (L.) Moench) in off-season crops. Sciences & Nature 6 (2): 107 –116.

[14] Patel N. R., Mehta A. N., Shekh A. M. (2001). Canopy temperature and water stress quantification in rainfed pigeon pea (Cajanus cajan (L.) Millsp.). Agricultural and Forest Meteorology 109 (3) : 223-232.

[15] Sawadogo M., Zombres G., Balma D. (2006). Expression of different okra (*Abelmoschus esculentus* (L.)) ecotypes with water deficit occurring during buttoning and flowering. Biotechnol. Agron.Soc. About 10 : 43-54.

[16] Siemonsma J. S. (1982a). West African okra- morphological and cytogenetical indications for the existence of a natural amphidiploid of (*Abelmoschus esculentus* (L.) Moench) and A. *Manihot* (L.) Medikus. Euphytica 31 : 241-252.

[17] Siemonsma J. S. (1982b). Growing okra (*Abelmoschus* spp.). Tropical fruit vegetable with special reference to Côte d'Ivoire.Uni-agro-Wageningen thesis, Netherlands, p. 297

[18] Siemonsma J. S., Kouame C. (2004). *Abelmoschus esculentus* (L.) Moench In : Grubben, GJH and Denton, OA (Editors). PROTA 2 : Vegetables / Vegetables. [CD-ROM]. PROTA, Wageningen, Netherlands.

[19] Singh B., Mai-Kodomi Y., Terao T. A. (1999). Sample screening method for drought tolerance in cowpea.India J. Genet. 59 : 211-220.

[20] Tshomba K. J., Ntumba Ndaye F., Emmanuel M. M., Kirika A. B., Nkulu M. F. (2015). Market gardening and access to production factors in the socio-economic context of Lubumbashi.International Journal of Innovation and Applied Studies 13 (3) : 527-537

[21] Yuan G., Luo Y., Sun X., Tang D. (2004). Evaluation of a crop water stress index for detecting water stress in winter wheat in the north china plain.Agricultural Water Management 64 (1): 29-40.