



Influence of Water Regime and Fertilization on the Vegetative Parameters of Two Varieties of Okra (*Abelmoschus esculentus* (L.) Moench, Malvacea) in the Daloa Region, Côte d'Ivoire

Beugré Manéhonon Martine¹, Kouame N'Guessan^{1*}, Kouassi N'dri Jacob¹, Kouamé Ahou Leatitia¹ and Kouadio Yatty Justin¹

¹Laboratory for the Improvement of Agricultural Production, University Jean Lorougnon Guédé, UFR Agroforestry, BP 150 Daloa, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. Authors KN and KNJ designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors BMM and KAL managed the analyses of the study. Author KYJ is the laboratory manager. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to evaluate the effect of water stress and organo-mineral fertilization on the morphological parameters of two varieties of okra. The treatments used (fertilizers) are: T0 (controls without amendment), T1 (4 kg chicken manure), T2 (4 kg sawdust, T3 (1 kg NPK 15-15-13 fertilizer). Three (3) types of water regimes were applied, R3 (watering 3 times per week), R5 (watering 5 times per week), and R7 (watering 7 times per week). The results obtained in terms of fertilizers applied to the soil did not show any significant influence on plant growth ($p > 0.05$). As for the other results, they showed that 100% of the parameters studied were influenced by the variety effect, while 33% were influenced by the watering frequency effect. Four parameters were influenced by the interaction between variety and frequency of watering, which shows that the variety used and frequency of watering play an important role in okra production. Both the organic

*Corresponding author: E-mail: maximekouamelma@yahoo.fr;

and mineral fertilizers applied to the soil showed no significant effect on the measured parameters, which could be as a result of non-decomposition of organic matter and insufficiency in the amount of mineral fertilizers required to supply the plant needs.

Keywords: Vegetative parameters; watering frequency; fertilization; variety; okra.

1. INTRODUCTION

The structure of the economy of Côte d'Ivoire is based on the agricultural sector, which represents 33% of the GDP [1]. To take advantage of this sector, the Ivorian State has initiated improvement programs and the development of industrial crops, in particular the coffee-cocoa combination to the detriment of food crops [2,3]. With the fall in the price of cash crops (coffee and cocoa) due to their poor sales on the world market, most food crops, once considered subsistence crops, have gained importance and now play a key role in intercommunity and interregional trade, [4]. Among these crops, we can mention okra (*Abelmoschus esculentus* (L.) Moench) which plays a leading role in these changes. Despite its importance, its production is still very low. This could be due to the impoverishment of the soil in organic matter and the irregularity of the rains. Indeed, most farmers use expensive mineral fertilizers which in the long term show negative effects on both surface and groundwater. Their poor distribution is the major constraint to the vegetative growth of okra [5]. Unlike chemical fertilizers, organic amendments to poor and acidic soils provide the nutrients necessary for growth and production [6].

In such a context, organic fertilization should be one of the appropriate solutions for restoring soil fertility. Thus, different organic products are used for the fertilization of crops.

The irregularity of rainfall manifested by water stress affects several plant functioning variables, such as stomatal conductance, leaf area [7], as well as photosynthesis [8]. These physiological disturbances result in a reduction in the vegetative growth of various organs [2] and a decrease in the number and volume of organs, seeds, or fruits [9]. Starch, protein, and oil levels as well as carbohydrates are also affected [10]. Faced with the damage caused by climate change on the vegetative parameters of plants, especially okra, an adaptation program for okra cultivation in a drought situation is proving important.

The main objective of this study is to determine the appropriate watering frequency for improving okra production, specifically on the vegetative parameters of the two varieties of okra through the use of organo-mineral fertilization.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is located in the Department of Daloa, Haut-Sassandra region in west-central Côte d'Ivoire. The Department of Daloa is located between 6 ° 53'58 "N latitude and 6 ° 26'32"W W longitude. The experiment site is located near the library of the University Jean Lorougnon Guédé. This area is subject to four seasons distributed as follows: a large rainy season from April to mid-July, a small dry season from mid-July to mid-September, a small rainy season from mid-September to November and the great dry season from December to March. Precipitation dropped from 1868.5 mm in 1968 to 1120.4 mm of rain on average in 2005; the region experiences a decrease in rainfall of around 40% [11].

2.2 Materials

2.2.1 Plant materials

The plant material for our study consisted of plants grown from seeds of two varieties of okra from various origins. This is an improved variety of okra called «*Clemson spineless*», and a local variety «Koto ou Soudais» obtained from markets in Daloa.

2.2.2 Fertilizing materials

Chicken manure is a heterogeneous mixture of faeces, feathers, eggs or eggshells and litter. Its appearance varies depending on the water content. As part of this study, chicken manure was collected from surrounding farms. The sawdust used was shown to activate the metabolic activity of microfauna in the soil. Mineral fertilization in okra cultivation was provided by application of NPK 15-15-13 mineral fertilizer.

2.3 Methods

2.3.1 Experimental apparatus

The experiment was performed from April 6 to June 17, 2020. The trial was conducted using the fully randomized block device. Three (3) blocks were formed representing the three water regimes R3; R5 and R7. Each block, separated by 1 m, includes 2 sub-blocks, one corresponding to the local variety and the other to the improved variety. The sub-blocks are divided into 4 elementary plots representing the three fertilizers and the witness. Each elementary plot is repeated 3 times giving a total of 24 elementary plots for each water regime and 72 elementary plots for the experiment. Each elementary plot is 4 m long and 1 m wide, with an area of 4 m². The quantity of organic fertilizer for each elementary plot is 4 kg, and a total of 10 t / ha. In terms of mineral fertilization, the dose used is 2.5 t / ha.

2.3.2 Establishment and monitoring of culture

2.3.2.1 Spreading fertilizer

After making the ridges according to the experimental design, the different doses of fertilizers were spread according to the treatments. The fertilizer was applied a week before sowing. This lag time before sowing was marked by watering so that the minerals dissolve in the soil solution. These doses are:

- treatment (Te), without addition of fertilizers (0kg);
- treatment (FP), soil amended with organic chicken manure fertilizer (4 kg);
- treatment (Mi), soil amended with NPK complex fertilizer (15-15-13) (1 kg);
- treatment (SB), soil amended with organic fertilizer made from sawdust (4 kg).

2.3.2.2 Planting and application of water regimes

Sowing was carried out one week after fertilization, which was at the rate of three seeds per pocket at a depth of 3 cm. Three different water regimes were applied to the three blocks in the evening. Block 1 received watering 5 times a week (R5) or 150 l of water / board / week. The second block received watering 3 times a week (R3) giving 90 l of water / board / week. Block 3, meanwhile, received 7 daily waterings (R7) making 210 l of water / board / week.

2.4 Collection of Data

Data were collected on 18 plants for each bed and by variety. Variables such as crown

circumference, number of leaves, leaf area, plant height, wingspan, and number of branches were measured on each of these plants at flowering. Our observations were limited to vegetative parameters because they are of great nutritional and economic importance in several regions of the Ivory Coast. The method of data collection is summarized in Table 1.

2.5 Statistical Analysis

For each variable studied, the means were compared by taking into account the water regimes, varieties and doses of fertilizer through a three-factor analysis of variance (ANOVA 3). The significance of the test was determined by comparing the probability (P) associated with the statistics at the threshold $P = 0.05$. When a significant difference was observed between traits, ANOVA was supplemented by the Smallest Significant Difference test (SSDT). The SSDT allows us to see homogeneous groups, since it situates us at what level this significant difference occurs. The statistical software used for this work is STATISTICA version 7.1.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Effect of the frequency of watering on the agromorphological parameters of okra

The results of the effect of water stress on vegetative parameters are shown in Table 2. It reveals that 2/6 or 33.33% of the parameters were influenced by water stress. These are the number of leaves (NLe) and the diameter of the neck (Col), with the largest values obtained by the R7 regime (35.30 ± 42.84 and 1.47 ± 1.25 cm), respectively. For each of the parameters mentioned, values of P less than 0.05 ($P < 0.05$) were observed. However, the other parameters of plant height, leaf area, plant wingspan, number of branches, and leaf area all obtained P values greater than 0.05 ($P > 0.05$), thus giving statistically identical values.

3.1.2 Effect of fertilizers on the agromorphological parameters of okra

The results of the statistical analysis showed no significant difference between the parameters analyzed with the fertilizers ($P > 0.05$). The results obtained are statistically identical (Table 3).

Table 1. Summary of measurements taken during the study

Morphological parameters	Sample measurement
Plant height (cm) : PHe	Measurement of the distance separating the farthest leaf from the soil surface using a tape measure.
Number of leaves :NLe	Counting of the first leaves from the base of the main stem at the collar to the last leaf at the tip.
Leaf area (cm ²) : LAr	Product of the length and width of a leaf measured with a tape measure
Span(cm) : Sp	Measurement of the distance separating the farthest side leaves
Neck circumference (cm): NCi	Measurement of the diameter of the plant part in contact with the soil using a tape measure
Ramifications : Ram	Count of the number of branches

Table 2. Effect of the frequency of watering on the agro-morphological parameters of okra

	Water Regime			Statistic tests	
	R3	R5	R7	P	F
PHe (cm)	64.81±25.11 ^a	66.72±26.90 ^a	69.43±35.49 ^a	0.747	029
NLe	27.77±24.68 ^b	19.29±15.50 ^{ab}	35.30±42.84 ^a	0.037	3.36
Col (cm)	0.95±0.781 ^b	0.88±0.74 ^{ab}	1.47±1.25 ^a	0.005	5.35
Sp (cm)	67.88±30.1 ^a	64.74±27.36 ^a	78.43±34.33 ^a	0.083	2.53
Ram	9.66±7.32 ^a	8.02±5.91 ^a	11.00±8.24 ^a	0.140	1.98
LAr (cm ²)	387.87±284.09 ^a	420.00±319.01 ^a	517.36±382.81 ^a	0.147	1.94

Values with the same letters on the row are statistically equal; PHe: Plant height; NLe: Number of leaves; Col: Collar; Sp: Span of the plant; Ram: Ramifications; LAr: leaf area; R3: Watering 3 times a week; R5: Watering 5 times a week; R7: Watering 7 times a week

3.1.3 Effect of okra variety on agro-morphological parameters

This table reveals that all parameters studied as a function of the variety have P values of less than 0.05 ($P < 0.05$). The variety therefore has a significant effect on the vegetative parameters of okra. The largest values were obtained with the local variety for the parameters studied (Table 4).

3.1.4 Effect of the interaction between watering frequency and variety

Four out of six parameters (4/6) were influenced by the water stress-variety interaction as P is less than 0.01 ($P < 0.05$). These are parameters of plant height, number of leaves, crown circumference, and leaf area. The local variety combined with daily watering resulted in the highest values of 99.45 ± 26.67 cm, 63.81 ± 47.86 , 2.56 ± 0.90 cm, and 805.44 ± 348.70 cm², respectively. However, the other two parameters gave statistically identical values (Table 5).

3.2 Discussion

3.2.1 Effect of water regime

The results of our work revealed that 2 of the 6 parameters studied were influenced by the

frequency of watering. High values were also obtained with daily watering (R7) when compared with R3 and R5. Similar result on four varieties of okra was reported by Kouakou et al. [12]. This could be explained by the fact that watering every day increases the water potential of the soil [13]. This would promote water availability for the roots and better development of the plant. Likewise, Ayolié et al. [14] working on three varieties of tomato, showed that the height of plants increases with increasing water regimes (capacity in the field). However, the low values obtained with irregular watering (watering every three and five days) for the number of leaves and crown circumference parameters, would be due to the water deficit. Likewise, the low values recorded for the number of leaf parameters could be explained both by the reduction in assimilating surfaces and by a slowing down of photosynthesis [15]. This would be due to a reduction in the size and number of leaves caused by early senescence of the latter in limiting water conditions. In addition, the water deficit would also induce a deficit in mineral nutrition (nitrogen and phosphate), which is caused mainly by reductions in the flow of elements to the roots, which would cause a reduction in the growth of the plants [16] and consequently a narrowing of the stem.

Table 3. Effect of fertilizers on the agro-morphological parameters of okra

Vegetative parameters	Types of fertilization				Statistic tests	
	SD	CD	MF	Wi	P	F
PHe (Cm)	57.11±25.21 ^a	74.16±30.36 ^a	66.64±30.44 ^a	69.97±29.37 ^a	0.08	2.26
NLe	28.88±41.10 ^a	31.47±29.13 ^a	25.52±26.61 ^a	23.51±20.78 ^a	0.69	0.47
Col (Cm)	0.99±0.91 ^a	1.30±1.07 ^a	1.08±1.01 ^a	1.02±0.92 ^a	0.52	0.74
Sp (Cm)	61.12±29.08 ^a	75.72±31.48 ^a	71.41±34.65 ^a	73.00±27.95 ^a	0.20	1.53
Ram	9.11±7.59 ^a	10.22±7.07 ^a	10.29±7.93 ^a	8.60±6.57 ^a	0.71	0.45
LAr (Cm ²)	339.86±288.09 ^a	513.67±357.15 ^a	463.15±366.37 ^a	448.07±302.82 ^a	0.15	1.76

Values with the same letter on the row are statistically equal; Fert: Fertilizer; Phe: Plant height; NLe: Number of leaves; Col: Collar; Sp: Span of the plant; Ram: Ramifications; LAr: leaf area; SD: sawdust; CD: Chicken dung; MF: mineral fertilizer; Wi: Witness.

Table 4. Effect of okra variety on agro-morphological parameters

Parameters	Varieties		Statistic test	
	IV	LV	P	F
PHe (cm)	44.91±12.66 ^b	89.95±23.41 ^a	0.001	204.15
NLe	8.88±2.67 ^b	46.72±33.71 ^a	0.001	90.10
Col (cm)	0.34±0.29 ^b	1.89±0.80 ^a	0.001	233.66
Sp (cm)	47.79±13.97 ^b	93.73±26.19 ^a	0.001	170.77
Ram	3.62±1.82 ^b	15.73±5.40 ^a	0.001	323.43
LAr (cm ²)	209.65±119.53 ^b	682.05±311.92 ^a	0.001	143.22

Values with the same letters on the row are statistically equal; IV: Improved variety; LV: Local variety; Fert: Fertilizer; PHe: plant height; NLe: Number of leaves; Collar: Circumference of the collar; Sp: Span of the plant; Ram: Ramifications; LAr: leaf area

Table 5. Effect of the interaction between the frequency of watering and the variety of okra on agro-morphological parameters

Vegetative parameters	Improved			Local			Test	statistics
	Regime	Regime	Regime	Regime	Regime	Regime		
	IV X R3	IV X R5	IV X R7	LV X R3	LV X R5	LV X R7	P	F
PHe (cm)	47.04±13.38 ^d	45.79±11.74 ^e	41.91±12.78 ^f	82.58±21.22 ^c	88.56±19.80 ^b	99.45±26.67 ^a	0.01	4.40
NLe	8.79±2.58 ^e	8.70±2.51 ^f	9.16±3.00 ^d	46.75±22.05 ^b	30.34±15.67 ^c	63.81±47.86 ^a	0.001	6.54
Col (cm)	0.27±0.19 ^e	0.27±0.21 ^f	0.47±0.38 ^d	1.62±0.51 ^b	1.52±0.52 ^c	2.56±0.90 ^a	0.0001	9.36
Sp (cm)	45.68±11.50 ^a	44.25±12.00 ^a	53.45±16.58 ^a	90.08±26.31 ^a	86.13±21.88 ^a	105.68±27.09 ^a	0.43	0.83
Ram	3.16±1.20 ^a	3.08±2.28 ^a	4.62±1.43 ^a	16.16±4.46 ^a	13.17±3.65 ^a	17.95±6.79 ^a	0.07	2.61
LAr (cm ²)	205.64±116.99 ^e	170.02±56.79 ^f	253.29±153.47 ^d	570.11±286.23 ^a	680.84±264.79 ^a	805.44±348.70 ^a	0.01	2.24

Values with the same letters laqline are statistically equal; IV: Improved variety; LV: Local variety; Fert: Fertilizer; PHe: Height of the plant; NLe: Number of leaves; Col: Collar; Sp: Span of the plant; Ram: Ramifications; LAr: leaf area; R3: Watering frequency 3 times a week; R5: Watering frequency 5 times a week; R7: Watering frequency 7 times a week

3.2.2 Effect of fertilization

Regarding the effect of fertilization, our work has shown that the nature of the substrate has no significant influence on the vegetative parameters of okra. The values recorded at the fertilized soil level are statistically identical to the control in the case of this study. This could be explained by the non-decomposition of the organic matter resulting from these fertilizers. Furthermore, Cobo et al. [17] showed that the rate of organic matter decomposition and the resultant increased yields were closely related to the timing between nutrient release and uptake by the plant. Chicken droppings and sawdust were unable to decompose normally to release the mineral elements necessary for the plant to grow. Consequently, the plants having received these fertilizers behaved like the control. In addition, the fact that sawdust is very difficult to be digested by microorganisms [18] would delay the accessibility of the roots to soil nutrients. The same values obtained with mineral fertilization could be explained by an insufficient amount of mineral fertilizer to cover the nutritional needs of the plant as Arnjad and Anjurn [19] reported, that okra's response to insufficient dose of NPK is poor.

3.2.3 Effect of variety

This study also noted that all parameters were influenced by the variety effect and the one for which the highest values were obtained is the local variety. This could be as a result of the adaptation of the local variety to the pedoclimatic conditions of the town of Daloa. The results obtained from the varieties studied are different from those obtained by [20]. Indeed, these authors, during a study carried out in Daloa on the influence of activated charcoal on the evolution of the agronomic parameters of a local variety of okra, obtained much higher values. These differences are said to be due to the fact that well-decomposed activated charcoal promotes the fixation of nutrients such as calcium, phosphorus, nitrogen, and potassium, which are essential for the harmonious functioning of plants. The low values obtained with the improved variety could be explained by the fact that it could have retained some of its characteristics, but also lost others as shown by Kouame et al. [21].

4. CONCLUSION

At the end of this work on the influence of water stress and fertilization on the vegetative

parameters of two varieties of okra, it appears that the best result in terms of these parameters is observed with daily watering. The variety suitable for good vegetative development of okra is the local variety. Our work has shown that the fertilizers provided did not have a significant effect on the parameters studied, which could be explained by a delay in their decomposition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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