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Evaluation of the Agro-morphological and Physiological parameters of Okra (*Abelmoschus esculentus*) under the effect of two Liquid hydroponic Fertilizers in soilless Cultivation in Greenhouses

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Abstract

Okra (Abelmoschus esculentus (L.) Moench) is a tropical plant in the Malvaceae family, all parts of which have nutritional and medicinal uses. With a view to improving productivity, a study was conducted in Ouagadougou by Agrostore Production, a company specializing in soilless cultivation in Burkina Faso. The objective was to evaluate the effect of two types of liquid fertilizers on the agro-morphological and physiological parameters of okra in soilless cultivation in greenhouses. The device adopted is a completely randomized block of 4 blocks divided into elementary plots made up of 4 treatments (T0: control, T1: Hydroponic A fertilizer, T2: Hydroponic B fertilizer, and T3: combination of the two fertilizers, Hydroponic A and Hydroponic B). The Amina F1 okra variety was chosen. The cultivation consisted of the creation of a nursery followed by transplanting on substrate in crop bags. Agromorphological and physiological parameters were measured. The results showed that plants fertilized with the combination of the two fertilizers (Hydroponic A + Hydroponic B) had the highest values on all parameters, followed by those fertilized with the Hydroponic B fertilizer. An average of 11± 0.88 fruits per plant were obtained with the two fertilizers combined, 7±1.20 with the Hydroponic B fertilizer, 5±0.99 with the Hydroponic A fertilizer, and 4±0.7 fruits for the control treatment with significant differences ($p<0.001$). The yield per hectare is estimated at 9.55±1.19 t/ha for the two fertilizers combined, 6.34 ±0.82 t/ha for the Hydroponic B fertilizer, 4.58±0.48 t/ha for the Hydroponic A fertilizer, and finally 2.58±0.22 t/ha for the controls. In view of these results, the combination of the two fertilizers (Hydroponic A + Hydroponic B) is therefore suitable for the cultivation of okra in soilless cultivation in greenhouses in Burkina Faso.

Keywords: Nursery, Hydroponic fertilizer, *Abelmoschus esculentus*, substrate, yield.

Introduction

Agricultural activities employ 39.9% of the world's working population, 48.2% of that of developing countries, and 58.4% in sub-Saharan Africa[1].

In Burkina Faso, agriculture employs 92% of the working population. It has an important place in the country's development since it contributes to 33.8% of total GDP[2]. Market gardening is an important source of income for market gardening households in Burkina Faso, as it contributes to 78% of total household income[3]. Thus, okra occupies second place in the production of fruiting vegetables after tomatoes. Okra (*Abelmoschus esculentus* (L.) Moench) is an annual herbaceous plant belonging to the Malvaceae family[4]. Its cultivation is an essentially female activity in Burkina Faso[5]. The different parts of okra (leaves, flowers, fruits, seeds, and stems (bark)) have nutritional and medicinal uses[6].

Okra cultivation faces several challenges, including poor soils. Indeed, about 6,498,610 hectares of arable land in Burkina Faso are degraded and are subject to recovery and restoration[7]. In addition, okra is a crop that is sensitive to water logging, drought, and many fungal, bacterial, and viral diseases, as well as pests such as nematodes and fruit borers[8]. Market gardening in sub-Saharan Africa, particularly in Burkina Faso, is often based on intensive, even abusive, use of inputs (mineral fertilizers, organic waste, phytosanitary products, wastewater), with often harmful consequences for human health and the environment[9]. There is also the strong population growth, which generates a high spatial occupancy.

Soilless agriculture can then overcome the difficulty of access to land and the water problem because it occupies little space and is water-efficient[10]. It allows vegetables and fruits to be grown with up to 90% less water, offering high yields in small spaces (greenhouses) and reducing reliance on chemical fertilizers. Also, liquid fertilizers used for fertilization in soilless cultivation are often non-toxic and environmentally friendly[11].

However, very few studies have been conducted on okra grown soilless in greenhouses. In addition, the cultivation of okra in greenhouses could be considered as a promising solution to the difficult climatic conditions, problems related to the soil, diseases and pests, the scarcity of water, and the lack of arable land, especially in urban areas. It is in this dynamic that this study was conducted with the overall objective of improving the productivity of okra in soilless cultivation in greenhouses.

Materials and Methods

Presentation of the study area: The study was conducted in the commune of Ouagadougou. It is located in the province of Kadiogo, which is itself located in the Centre region of Burkina Faso. The city of Ouagadougou has twelve (12) districts and fifty-five (55) sectors. It is the capital of Burkina Faso and the largest city in the country. It covers an area of 518 km², or 0.2% of the national territory. It is bordered to the north by the rural communes of Pabré and Loumbila, to the east by Saaba, to the south by those of Koubri and Komsilga, and finally to the west by the rural commune of Tanghin-Dassouri[12] (Figure-1)[13].

The climate of the commune of Ouagadougou is Sudano-Sahelian. It is divided into two seasons, including a rainy season and a dry season. The rainy season lasts from June to September and is full of nearly 80% of the rainfall and more than 65% of the rainy days[14]. The dry season concentrates less rainfall (October-May) and is marked by the appearance of harmattan and by high temperatures that can reach 40°C in the shade during the second quarter of the year.

The soil of the commune of Ouagadougou is the result of the alteration of the granito-gneissic basement deposited in the Lower Precambrian[12]. The increase in erosion is causing many gullies to appear. The soil study of the city of Ouagadougou made it possible to inventory four classes of soils: raw mineral soils, poorly evolved soils, iron and/or manganese sesquioxide soils, and hydromorphic soils[15].

Material: Plant material: The okra variety *Amina F1* (Figure-2) was chosen for the experiment. It is a variety of seed selected and improved, marketed by the company SIGRI SEMENCE. The *Amina F1* variety is a fairly early hybrid variety with a 50-day cycle and a potential yield of 12 to 18 t/ha. It is grown for its fruits because it is a variety with a fairly short stem, with few leaves and branches at the base, and gives many fruits per plant.

Fertilizers: Two types of fertilizers were used for the experiment: Hydroponic A and Hydroponic B, two liquid fertilizers of the EMIRATES BIOFERT brand from the Arab Emirates (Figure-3).

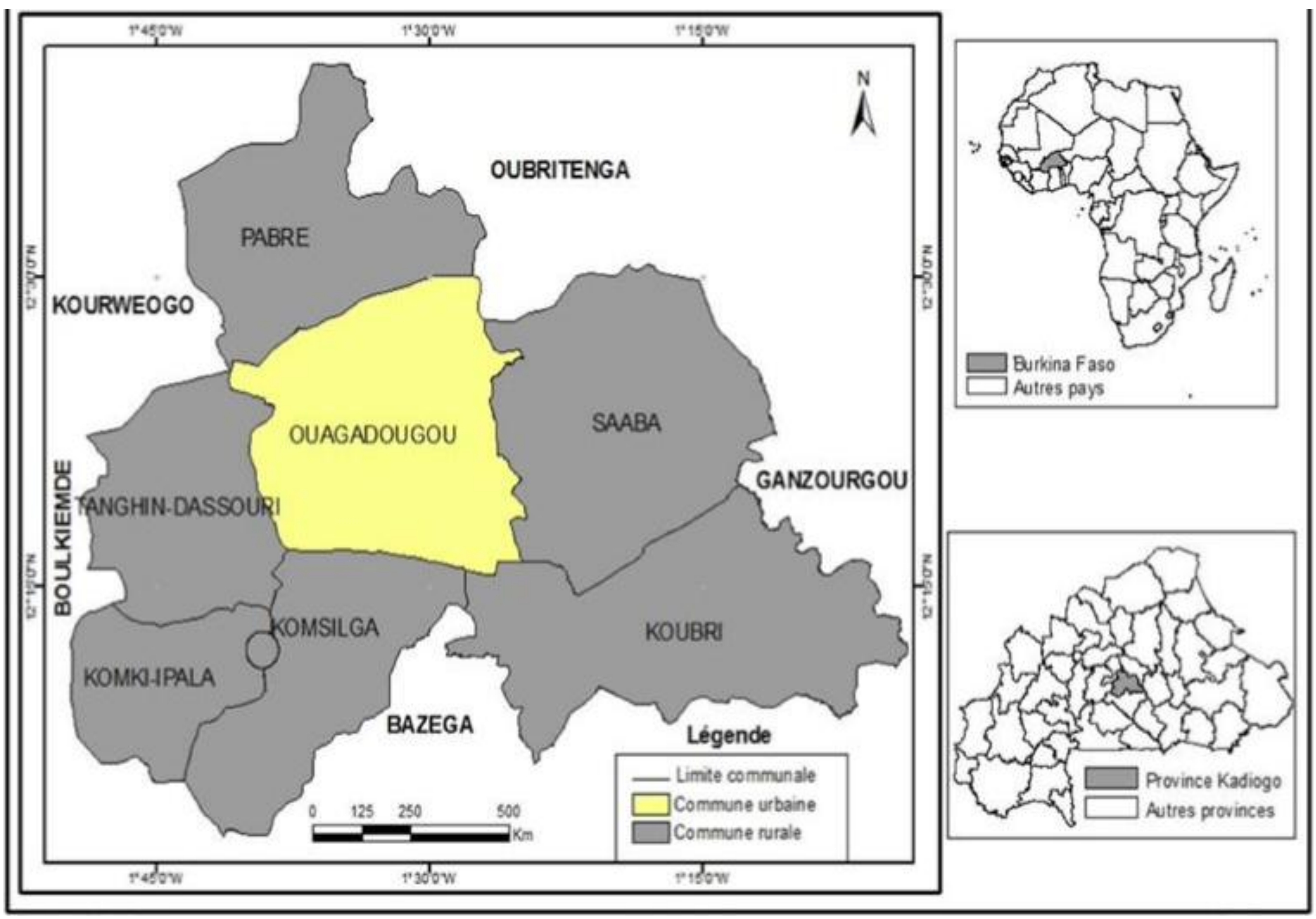

Figure-1: Geographical location of the study site[13].

Figure-2: The seeds and fruits of okra, *Amina F1* variety.

Figure-3: The different fertilizers used.

Their chemical composition, according to their indication, is as follows: i. Hydroponic A fertilizer: nitrates 3%, phosphorus 2%, calcium 5.5%, and iron 800 ppm. ii. Hydroponic B fertilizer: nitrates 2%, potassium 9%, phosphorus 3%, magnesium 2%, Mn 165 ppm, B140 ppm, Cu 119 ppm, Zn 116 ppm, Mo 56 ppm, Fe 400 ppm. Foliar fertilizer (FOLIGA), composed of NPK + MgO + trace elements, was used for the nursery.

Methods: Experimental design: The completely randomized block device was used. It consists of four blocks, and each block includes four experimental plots with four treatments and four replicates. The treatments are: i. Treatment 0 (T0): unfertilized control; ii. Treatment 1 (T1): fertilization with Hydroponic A fertilizer; iii. Treatment 2 (T2): fertilization with Hydroponic B fertilizer; iv. Treatment 3 (T3): combination of the two fertilizers Hydroponic A and Hydroponic B.

The rate per hectare was 15 L / 11250 L of water from each fertilizer, or 4 mL / 3 L of water.

The distance between the blocks is 70cm and between the plots is 40 cm. The distance between the plants is 31 cm.

Conduct of the experiment: The nursery was carried out on August 19, 2023, and fertilized with foliar fertilizer on the 8th day after emergence (August 30, 2023) at a rate of 2 ml/liter of water. Potting soil was used for the construction of the nursery. A greenhouse and growing bags filled with substrate made from rice husks mixed with sawdust were needed for the transplanting, which was done on September 04, 2023. It was from September 05 that fertilization with liquid fertilizers and manual watering began. Each fertilizer was diluted prior to mixing at a dose of 4 ml/3 liters of water for the two hydroponic fertilizers. Fertilization was done twice a day (morning and evening) until harvest. As a phytosanitary protection, neem oil is used every week at a rate of 5 ml diluted in one liter of water as a foliar spray for one month.

Data collected and measurement methods: Data collection was carried out on agro-morphological and physiological parameters on four plants randomly selected from each elementary plot. The collection of data on morphological parameters (plant height, number of leaves, and stem collar diameter) began at the 27th DAS and is repeated every seven (07) days. The number of leaves (NL) per plant was determined by manual leaf count, plant height (HP) using metric tape, and stem collar diameter (DC) using an electronic caliper. Fruit size and length (SF and LF) were obtained by measuring the width and length of each fruit harvested with a caliper.

Physiological parameters (flowering date, 50% flowering date, and maturity date) were determined by counting the number of days from the sowing date to the day the plants started to flower, or 50% of the plants flowered or when the fruits are mature in the elementary plot. They are expressed in days after sowing (DAS).

The number of fruits per plant (NF/P) was determined by counting the fruits formed on each plant. The mass of fruit per plant (MF/P) was determined by weighing with an electronic scale, and the yield in kg/ha is obtained by weighing the total mass of fresh fruit harvested during the experiment and related it to the hectare.

Statistical analysis: The data collected was entered into an Excel 2016 spreadsheet. A statistical analysis was performed using the XLSTAT 2023 software version 2.1414.1414. An analysis of variance (ANOVA) was performed to detect significant differences between the different treatments for each parameter studied. Separation of means was performed using the Student-Newman-Keuls (SNK) test at the 5% probability level.

Results and Discussion

Effect of treatments on okra morphological parameters: Table-1 presents the means of the morphological parameters measured according to the treatments. The analysis of variance shows a very highly significant variation ($p<0.001$) for all morphological parameters studied (HP, DC, NL, SF, LF). Plants treated with Hydroponic A fertilizer combined with Hydroponic B fertilizer had the highest average values for all parameters, followed by those treated with each fertilizer separately. Unfertilized plants had the lowest values for all parameters.

In the same column, values with identical letters are not significantly different according to the Newmann Keuls test at the 5% threshold.

Effect of treatments on okra physiological parameters: The emergence date for the nursery occurred at 3 days in almost all cells, and the appearance of the first fruit was noticed on the 36th day from T3 treatment.

Table-2 shows a very highly significant variation ($p<0.001$**)** between treatments. Flowering began on the 34th day of the season in the plots fertilized with both fertilizers, followed by those fertilized with Hydroponic B fertilizer on the 35th day of the season, then those of the Hydroponic A fertilizer on the 39th day, and finally those not treated on the 41st day of the season.

The analysis of the table shows that 50% of the plants that received the two fertilizers flowered on the 38th DAS, followed by those of the Hydroponic B fertilizer on the 40th DAS, those of Hydroponic A on the 44th, and finally the 47th DAS for those not treated. Fruit maturity was observed on the 39th DAS for the two fertilizers, the 43rd DAS for Hydroponic B, the 46th DAS for Hydroponic A, and the 49th DAS for the controls. Flowering and maturity were early in the fertilized plants. Unfertilized plants flowered and matured late.

Effect of treatments on okra agronomic parameters: The number of fruits per plant: Figure-4 shows a variation in the number of fruits per plant depending on the treatment. The analysis of variance indicates very highly significant differences ($p<0.001$) between treatments. Plants that received the treatment with both fertilizers (Hydroponic A+ Hydroponic B) produced more fruit, followed by those of the Hydroponic B fertilizer, then those of the Hydroponic A fertilizer, and finally those that were not treated. In fact, the treatment with the two fertilizers (A+B) gave an average value of 11 fruits per plant, that with Hydroponic B fertilizer gave 7, then 5 for the Hydroponic A fertilizer, and 4 fruits for the untreated control.

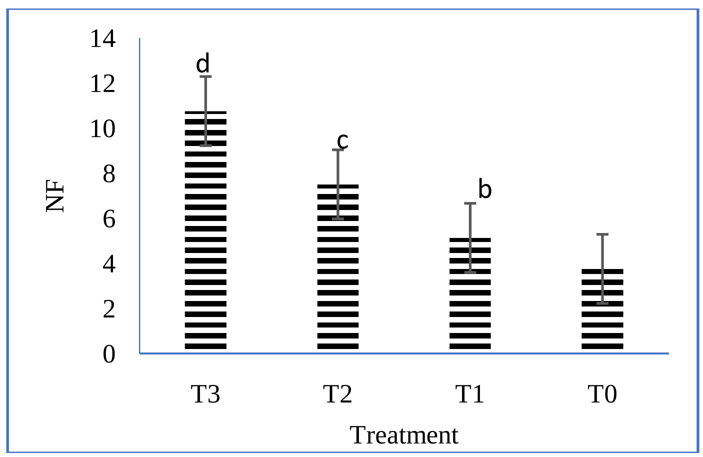

Figure-4: Evolution of the number of fruits per okra plant according to treatments. Legend: T0: Untreated control; T1: treatment with Hydroponic A fertilizer; T2: treatment with Hydroponic B fertilizer; T3: treatment with Hydroponic A fertilizer + Hydroponic B fertilizer; NF/P: number of fruits per plant.

Fruit mass per plant: Figure-5 shows a variation in the mass of fruit per okra plant. The analysis of variance indicates very highly significant differences ($p<0.001$) between treatments. Thus, the plants that received the treatment with the Hydroponic A fertilizer + the Hydroponic B fertilizer have a higher fruit mass (175 g) than those treated with the Hydroponic B fertilizer (125 g), then those with the Hydroponic A fertilizer (75 g), and finally those not treated (50 g).

Table-1: Mean morphological parameters of okra according to treatments.

Treatment	HP (Cm)	NL	DC (mm)	SF (mm)	LF (mm)
T3	45.50± 11.69^{b}	8.66± 3.74^{b}	12.18± 1.39^{b}	17.02± 1.21^{b}	132.51± 8.36^{b}
T2	32.16± 6.67^{ab}	4.58± 0.71^{a}	10.65± 1.10^{b}	15.75± 0.66^{b}	113.87± 21.69^{ab}
T1	31.16± 6.12^{ab}	4.54± 0.77^{a}	8.82± 0.56^{a}	11.63± 0.69^{a}	112.36± 5.34^{a}
T0	25.66± 4.94^{a}	3.45± 0.77^{a}	7.86± 1.55^{a}	10.38± 0.44^{a}	105.72± 3.32^{a}
Probability (p)	<0.001	<0.001	<0.001	<0.001	<0.001
Significance	VHS	VHS	VHS	VHS	VHS

Legend: T0: Control treatment; T1: treatment with Hydroponic A fertilizer; T2: treatment with Hydroponic B fertilizer; T3: treatment with Hydroponic A fertilizer + Hydroponic B fertilizer, p**:** probability; HP: the height of the plants, NL: the number of leaves, DC: the diameter at the stem collar, SF: the size of the fruit and LF:the length of the fruit; VHS: very highly significant.

Table 2: Flowering and maturity dates of okra plants according to treatments

Treatment	Flowering start date (DAS)	Date of 50% flowering (DAS)	Maturity date (DAS)
T0	41±1.70^{b}	47±2.16^{b}	49±2.16^{b}
T1	39±2.16^{b}	44±0.81^{b}	46±0.81^{b}
T2	35±0.81^{a}	40±0.81^{a}	43±0.81^{a}
T3	34±2.16^{a}	38±1.41^{a}	39± 2.16^{a}
Probability (p)	0.000	<0.001	<0.001
Significance	VHS	VHS	VHS

Legend: T0: Untreated control; T1: treatment with Hydroponic A fertilizer; T2: treatment with Hydroponic B fertilizer; T3: treatment with Hydroponic A fertilizer + Hydroponic B fertilizer; DAS: Days after sowing. In the same column, values with identical letters are not significantly different according to the Newmann Keuls test at the 5% threshold.

Effect of treatments on okra yield: Figure-6 shows that the treatment with Hydroponic A+ Hydroponic B fertilizer achieved the highest yield of 9.56 t/ha, followed by the Hydroponic B fertilizer treatment with 6.34 t/ha, then the Hydroponic A fertilizer treatment with 4.58 t/ha, and finally by T0 with 2.58 t/ha. The analysis of variance shows a very highly significant difference (p<0.001) between treatments.

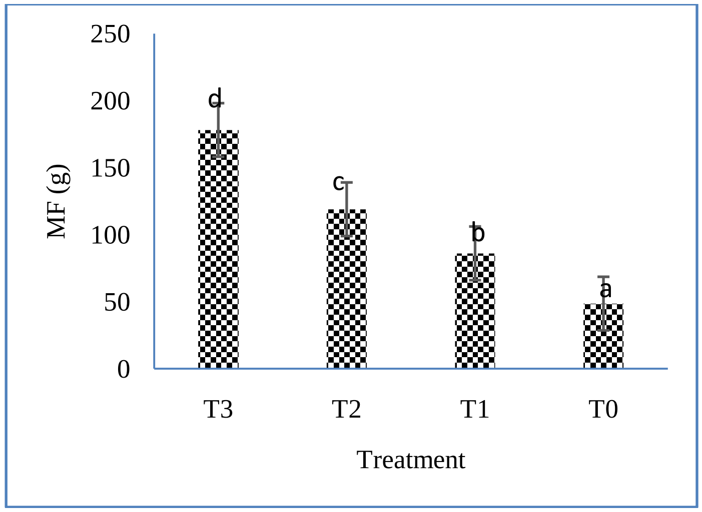

Figure-5: Evolution of the mass of fruits per okra plant as a function of treatments. Legend: T0: Untreated control; T1: treatment with Hydroponic A fertilizer; T2: treatment with Hydroponic B fertilizer; T3: treatment with Hydroponic A fertilizer + Hydroponic B fertilizer; MF/P: Fruit mass per plant.

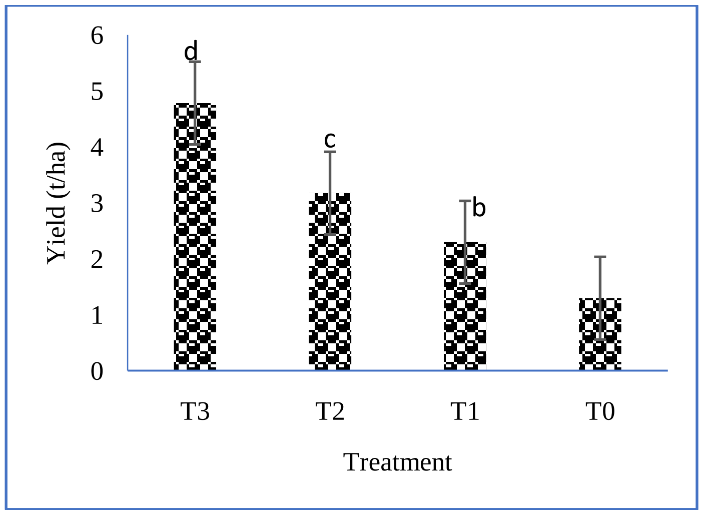

Figure-6: Evolution of okra yield in soilless cultivation as a function of treatment. Legend: T0: Control treatment; T1: treatment with Hydroponic A fertilizer; T2: treatment with Hydroponic B fertilizer; T3: treatment with Hydroponic A+ Hydroponic B fertilizer.

Discussion: The results obtained during this experiment showed very highly significant differences for all morphological (GF, LF, NF, HP), physiological (flowering start date, 50% flowering date, and maturity date), and agronomic (NF/P, MF/P, and yield) parameters.

In general, plants fertilized with the combination of Hydroponic A and Hydroponic B fertilizers showed higher average values for all these parameters. These results could be explained by the richness of the two liquid fertilizers combined in essential mineral elements such as nitrogen (N), phosphorus (P), and Potassium (K), which promote the good growth, flowering, and maturity of okra plants. Indeed, these three elements (N, P, K) are major elements essential for the growth and development of plants. The nitrogen present in liquid fertilizers is in the form of nitrates, the main form directly assimilated by plants. Liquid fertilizers also contain essential micronutrients such as iron, which is involved in the formation of chlorophyll, and boron, which promotes tissue growth and fruit formation. NPK has a positive impact on yield and growth parameters due to the availability of nutrients that are easily absorbed by plants[16]. Highly significant differences were obtained in the growth parameters of tomatoes in soilless cultivation according to the treatments[17]. In addition, a significant variation was obtained in okra yield depending on NPK fertilizer treatment[18]. The use of liquid digestate in organic market gardening is both an economic and environmental advantage. If used in the right dose, liquid digestate has no negative effects on soil fertility, plant health, and the environment[19].

Plants treated with Hydroponic A fertilizer showed lower average values than plants treated with Hydroponic A fertilizer + Hydroponic B fertilizer or Hydroponic B fertilizer alone. This could be explained by the absence of potassium, magnesium, and certain trace elements in Hydroponic A fertilizer, which are essential nutrients for the development of plants in general and okra in particular. Indeed, potassium is involved in the regulation of plant functions and provides great rigidity to plant tissues. Magnesium is the main constituent of the chlorophyll molecule and is therefore essential for its formation; it therefore plays a key role in plant growth because it acts directly on photosynthesis.

The low values obtained in the control plants on all parameters could be explained by the fact that these plants were watered with water without fertilizer. In addition, the substrate composed of rice husks + sawdust is neutral, and therefore low in nutrients. These results are similar to those who obtained low plant development from the mixture of rice husks and sawdust[17]. They attributed this result to a high permeability of the rice husk, which makes water unavailable to plants.

Conclusion

The study consisted of evaluating the effect of two types of liquid fertilizers, Hydroponic A and Hydroponic B, on okra grown soilless in greenhouses. The results revealed that there is a variation in production depending on the treatment. In addition, the study showed that plants that received Hydroponic A liquid fertilizer combined with Hydroponic B liquid fertilizer showed superior results compared to other treatments, followed by those of Hydroponic B liquid fertilizer. These results indicate that it is appropriate to use Hydroponic A and Hydroponic B fertilizers in combination or only Hydroponic B fertilizer for good growth and development of okra plants. As for the Hydroponic A fertilizer, it would be appropriate to combine it with other fertilizers because it is low in potassium, magnesium, and trace elements.

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