



## OPTIMIZING NUTRIENT LEVELS FOR EARLY GROWTH OF AFRICAN SPINACH (*AMARANTHUS SPP.*) IN A HYDROPONIC SYSTEM

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### ABSTRACT

The experiment was carried out to determine how varied nutrient levels affect the growth and development of African spinach at the screen house of the department of agriculture and industrial technology, Babcock University, the experiment was conducted during the month of March to April 2024. The treatments consisted of four different nutrient concentration (control, 0.2mL, 0.6mL, and 0.8mL of Agriful© Fertilizer solution) and soil as conventional planting method. African Spinach seeds were grown into a wick hydroponic unit containing coco coir. Data were collected of plant height, number of leaves, stem girth, and root length over a period of five weeks. Analysis of Variance (ANOVA) along with Duncan Multiple Range Test was carried out to determine the impact of nutrient content on the observed agronomic attributes. Results obtained shows a clear influence of nutrient content on the early development of African spinach. The result further revealed that, higher nutrient concentrations were associated with taller plants, thicker stems, and longer roots. However, the results indicated that wick hydroponic system did not perform as well as the soil control. These findings highlight the necessity of regulating nutrient contents in wick hydroponic systems for efficient African spinach growth. Nutrient availability must be balanced to achieve optimal early development and long-term growth of the crop. More research on the long-term impacts of nutrient concentration on yield and quality is recommended to improve nutrient management for commercial hydroponic production of African spinach.

**Keywords:** Hydroponics, African spinach, Soil cultivation, Nutrient concentration

### INTRODUCTION

Hydroponics has been described as the farming for the future of agriculture. (Dubey & Nain, 2020) Hydroponics is the new way in which the ever-increasing population of the world can be sustainably fed looking deeper into the 21st century in accordance with the MDG's (Lagomarsino & Senft, 2019). Hydroponics, as a term is the cultivation of crops without the aid of a soil medium (Jan, et al., 2020). This method assumes that a water-based setup incorporates all the essential that are required for the development of plants and the developing plants can absorb the nutrients directly from the liquid medium. The term hydroponics stems from two Greek words "hydro" and "ponos" which translate to water and labor respectively. Hydroponics is an approach of plant cultivation in a nutrient solution with or without the aid of an inert media such as peat moss, sawdust, coconut coir to provide mechanical support to plants without the utilization of soil. Hydroponics as a word was first utilized in the early 1930s by Dr. William Gericke 1882-1970 ( 1940) who described it as the cultivation of crops without the aid of soil by suspending the roots in a nutrient solution (Jan, et al., 2020).



There are various hydroponic systems which are utilized today include the Ebb and Flow method, Nutrient Film Technique, Deep Water Culture, Drip hydroponic system, and the Wick hydroponic system (Dubey & Nain, 2020). The Wick hydroponic system is the most basic and easiest to utilize out of all the various hydroponic systems. The wick system has no moving parts i.e., it is passive. Therefore, it is easier and cheaper to maintain. A wick system is made up of the grow tray which contains the growing medium (Vermiculite, Coconut coir, Perlite etc.), the reservoir which contains the nutrient solution that supplies the nutrients and water that is then placed beneath the grow tray, the wicks themselves; which connects both the grow tray and reservoir. The wicks make use of capillarity to move the nutrient solution from the reservoir to the growing media and finally to the roots of the plant (D'anna, 2022); (Sanchaya, *et al.*, 2023). Amaranthus, (*Amaranthus spp*) which is also referred to as Amaranth, is a short-lived annual, dicotyledonous, herbaceous plant from the *Amaranthaceae* family which is widely dispersed all around the world. The family *Amaranthaceae* is made up of 65 genera and 900 species, the majority of which are native to Africa and they can be found in tropical and subtropical climates, as well as Central and South America (Managa & Nemadodzi, 2023). African spinach is rich in fiber, vitamins (which includes niacin, vitamin A, folate, vitamin C, and B6), minerals (which include calcium, iron, manganese, potassium, zinc, and magnesium), riboflavin, and thiamine, as well as carotenoids like beta-carotene, which have been studied and found to benefit human health in a variety of ways (Finelib.com, 2017).

The urgency for sustainable agricultural methodologies has led to increased interest in hydroponic farming, a soilless cultivation technique. Among various hydroponic systems, the wick system is noted for its minimalistic design and potential efficiency (Brown & Green, 2022). Despite its growing popularity, comprehensive research on its effects on specific crops, such as African spinach, is scant. There is also a need for the identification of the optimum nutrient concentration for improved early development and performance of African spinach in a wick hydroponic system setup. The study was therefore carried out to investigate the impact of nutrient concentration in a wick hydroponic system on early development of African spinach and ascertain the effect of varying nutrient concentrations on growth characters of lettuce in a wick hydroponic system.

## **MATERIALS AND METHODS**

### **Experimental Site**

The experiment was carried out at the screen house of the Department of Agriculture and Industrial Technology, Babcock University, Ilishan-Remo, Ogun State. The project was hosted in Babcock University, located in Ogun State, in Ikenne Local Government, within latitude 6° 54 N and 7° 28 N of the equator and longitude 3°42 E and 4° 15 E of the Greenwich Meridian. The annual rainfall is 1500mm, with altitude above 300 above sea level, while the mean annual temperature is about 27° C. Ikenne Local Government area, Ogun State is located in the South-Western part of Nigeria. It is bound in the west by the Republic of Benin, in the east by Ondo State, in the south by Lagos State, and in the north by Osun and Oyo States. It lies within the latitude 6° N and 8° N and longitude 2° E and 5° E. It has a land area of about 16,762 square kilometres and a population of about 3,728,098. Farming is the major occupation of the people, particularly those living in the rural areas. Administratively, Ogun State is divided into four divisions which include, Egba, Ijebu, Yewa, and Remo. In all there are 20 local government areas in the state.

### **Experimental Materials**

The following materials were used to conduct this experiment



### **Material**

African Spinach Seeds  
Coconut Coir  
3 Liter Buckets  
Cotton Wool  
Agriful® Liquid Fertilizer  
Water  
Soil  
Tape  
Ruler  
Measuring Cylinder  
Caliper  
Micro-pipette

### **Use(s)**

The crop being grown  
The growing medium  
To serve as the growing tray and reservoir  
To serve as the wicking material  
Nutrient source  
For dilution and to irrigate the control  
To serve as a control  
To mark the various treatments  
For measuring plant height and root length  
For measuring the volume of water  
For measuring stem girth  
For measuring the volume of Fertilizer

### **Experimental Medium Set-up**

#### **Control:**

Holes were made at the bottom of the bucket to ensure drainage of excess water, the buckets were filled with sand, wet with water and the seeds sown in damp soil and watered daily.

#### **Wick Hydroponic:**

Holes were made at the bottom of the buckets to allow the wicking material to pass through from the solution to the growth media. Holes were also made on the sides of the buckets and the reservoir to allow the set up to be suspended. The wicks were put through the holes before growing medium was added to the buckets. 1L of water was added to the reservoirs. 0.2mL, 0.6mL, and 0.8mL of Agriful® liquid fertilizer was diluted in water and placed in the reservoirs. The buckets containing the growing medium were suspended over the reservoir and held in place with nails before sowing seeds in the growing medium. The water and nutrient concentrations were changed on weekly basis to ensure nutrients supply and prevent algae growth.

### **Soil Analysis**

Initial core samples (at 15cm deep) were collected from the field. The soil samples were bulked, thoroughly mixed, shade-dried and sieved through a 2mm screen after which a composite sample was taken from the bulk soil for determination of some physico-chemical characteristics of the soil on the field. Total N was determined by the Kjeldahl method described by (Bremner & Mulvaney, 1982); Available phosphorus was determined according to the method of Bray and Kurtz (Bray & Kurtz, 1945); soil pH (1:1 soil: water) as determined by the pH meter, the %C was determined by the Walkley and Black method (Walkley & Black, 1934) and the particle size analysis was done by the hydrometer method of Bouyoucos (Bouyoucos, 1962).

### **Treatments and Experimental Design**

The treatments consisted of three concentrations of nutrient solution (0.2mL, 0.6mL and 0.8mL of Agriful Fertilizer) and two (2) controls (Water and Soil), these were laid out in a screen house using Completely Randomized Design (CRD) replicated three times.

#### **Preparation of Nutrient Concentration**

Agriful (Organic liquid fertilizer) was diluted in 1 Liter of water in varying concentrations (0.2mL, 0.6mL, and 0.8mL). This was replaced every week to replace nutrients taken up by the plants and also to prevent the growth of algae.



### **Data Collection and Analysis**

Data were collected weekly on plant height, number of leaves, stem girth and root length. All data collected were subjected to Analysis of Variance (ANOVA) using IBM Statistical Product and Service Solutions (SPSS) version 27. Significantly different treatment means were separated using Duncan's Multiple Range Test (DMRT) at 95% confidence level.

## **RESULTS AND DISCUSSION**

### **Physico-chemical Properties of Soil Used for the Experiment**

Table 1 showed result of the physical and chemical properties of soil used for the experiment. Based on the result obtained, the textural class is sandy loam. This is a generally favorable texture for agriculture this fact is agreed as discussed by Gougoulia et al (2013), as it provides good drainage, aeration, and allows for root growth while also retaining some moisture and nutrients. The pH of the soil used is 5.56, which is slightly acidic. Most plants prefer a slightly acidic to neutral soil pH (between 6.0 and 7.0) (Shaaban, 2024, Zhu & Shen, 2023)). Considering the available Phosphorus level (23.66 mg/kg) can be said to be moderate. This does not totally agree with a previous study that found out that acidic soil pH can immobilize phosphorus (P) (Bolan et al., 2023). This may be sufficient for some vegetable varieties. The organic matter content is 3.68%. Organic matter improves soil structure, water retention, and nutrient availability for plants. This also does not agree with an earlier study done earlier that says organic matter can increase acidity by forming organic acids (Shaaban et al., 2013a) Exchangeable Bases: Calcium (Ca): The calcium level (2.00 c mol kg<sup>-1</sup>) is good. Calcium is essential for plant cell wall strength and other functions. Magnesium (Mg): The magnesium level (3.86 c mol kg<sup>-1</sup>) is very good. This doesn't agree with an earlier study that opined that Acidic soil pH can immobilize magnesium (Mg), and calcium (Ca), which are essential for plant growth (Bolan et al., 2023; Neina, 2019). Magnesium is important for chlorophyll production and other plant processes. Potassium (K): The potassium level (0.28 c mol kg<sup>-1</sup>) is considered low this agrees with earlier studies and may be because it is a soil from a tropical rainforest where leaching has taken place, leaving behind a higher concentration of H<sup>+</sup> ions, which results in more acidic soils (Weil & Brady, 2017; White & Brantley, 2018). Potassium is essential for plant growth, fruit quality, and disease resistance. You may need to supplement the soil with potassium fertilizer. Sodium (Na): The sodium level (0.42 c mol kg<sup>-1</sup>) is within a normal range for most plants.

**Table 1:** Physico-chemical Properties of Soil Used for the Experiment

Parameters	Values
pH (H <sub>2</sub> O. 1:1)	5.56
Sand (gKg <sup>-1</sup> )	750
Silt (gKg <sup>-1</sup> )	68
Clay (gKg <sup>-1</sup> )	72
Exchangeable bases	
Na (c mol kg <sup>-1</sup> )	0.42
K (c mol kg <sup>-1</sup> )	0.28
Ca (c mol kg <sup>-1</sup> )	2.00
Mg (c mol kg <sup>-1</sup> )	3.86
Ex. Acidity H <sup>+</sup> (c mol kg <sup>-1</sup> )	0.19
C.E.C (c mol kg <sup>-1</sup> )	7.26
Av. Phosphorus (mg kg <sup>-1</sup> )	23.66
Org. Carbon (%)	2.59
Org. Matter (%)	3.68
N (%)	0.19
Textural class	Sandy loamy

### Plant Height

Results of the effects of nutrient concentration on plant height of African spinach is presented in Table 2. The result shows that except at 1WAS, where no significant ( $P \leq 0.05$ ) was observed, this is likely to be because at 1WAS agronomic characteristics were still developing. a significant ( $P \leq 0.05$ ) difference exist among the treatments used throughout the study period. Plant Height in Amaranthus is influenced by relative increase in water supply (Shongwe *et al*, 2008, Shongwe *et al*, 2010) and hydroponics system has more than adequate water supply, the study by Shongwe *et al*, 2010 disagrees with the current study, it may be due to other factors not measured in this experiment like, elevation, pressure, temperature and so on. The result further indicated that, by week 2, the crop planted within soil had a significant height advantage amongst the treatments with all the remaining treatments except the 0.2mL of Agriful Fertilizer having similar heights. the explanation of week one is also relevant in week 2, other factors not measured may cause this. (Masarirambi *et al*, 2012). In the third week, the soil treatment was still significantly taller than the other treatments; while the other treatments had a similar height range. At week 4, the soil was still significantly taller while, that of 0.8mL of Agriful Fertilizer was significantly taller than the water and 0.2mL of Agriful Fertilizer treatments but the height was comparable to that of 0.6mL of Agriful Fertilizer. By the fifth week, the soil remained consistently the tallest plant group while, the plants that had the nutrient concentrations had a similar height range while the plants grown in just water were the shortest among the treatments. This trend does not agree with trends done in a study by Oseni, 2011, that says hydroponic setup do better in plant height. A previous study shows that all the parameters of plants show that on comparing the hydroponic system with traditional plants growing method we can say that plants grown in a hydroponic system are taller (Upadhyay *et al.*, 2021). They



showed better and rapid growth in the hydroponics system. This agrees with this study that a higher growth rate was reported in a hydroponic system. (Upadhyay *et al.*, 2021).

**Table 2:** Effect of Nutrient Concentration on Plant Height of African Spinach

Treatments	WAS				
	1	2	3	4	5
Water	1.5000	2.7000 <sup>b</sup>	3.1667 <sup>a</sup>	3.5667 <sup>a</sup>	3.9667 <sup>a</sup>
Soil	1.4667	4.4000 <sup>c</sup>	6.2333 <sup>b</sup>	6.7333 <sup>c</sup>	7.2333 <sup>c</sup>
0.2mL	1.5000	2.4000 <sup>a</sup>	3.0000 <sup>a</sup>	3.5667 <sup>a</sup>	4.3667 <sup>b</sup>
0.6mL	1.4333	2.7667 <sup>b</sup>	3.3000 <sup>a</sup>	3.7667 <sup>ab</sup>	4.5667 <sup>b</sup>
0.8mL	1.3000	2.6000 <sup>ab</sup>	3.4333 <sup>a</sup>	4.0000 <sup>b</sup>	4.6333 <sup>b</sup>
LS	NS	**	**	**	**
SE±	0.506	0.864	0.915	0.722	1.001

Note. Means with the same superscript are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT), LS = LS = Level of significance, \*, \*\*, & \*\*\* = significant @ 0.10, 0.05 & 0.01 probability level, SE = Standard error

### Stem Girth

Table 3 presented result of the effect of nutrient concentration on stem girth of African spinach. The result showed that during the first week the plants grown in soil had the largest stem girth, while the stem girths of the other plants grown in the other treatments fell within a similar range. At week 2, the crops in the soil medium maintained the largest stem girth, while plants in 0.2 and 0.6mLs of Agrifol Fertilizer and to a certain degree 0.8mL of Agrifol Fertilizer had similar stem girths. The smallest stem girth for the second week belonged to the crops planted in just water. At week 3, the crops planted in 0.8mL of Agrifol Fertilizer had the largest stem girth, while the crops planted in the soil had the second largest stem girth. The plants within the water, 0.2mL, and 0.6mLs of Agrifol Fertilizer had similar stem girths. By the fourth week, the soil and 0.8mL of Agrifol Fertilizer had the largest stem girths while, the remaining treatments had a similar range of stem girths. In week 5, a similar pattern from the previous week emerged with soil and 0.8mL of Agrifol Fertilizer having the largest stem girths, followed by 0.6mL of Agrifol Fertilizer. The crops planted in just water had the smallest stem girths followed by the crops planted within the 0.2mL of Agrifol Fertilizer. Stem girth increases for all treatments over the five weeks, indicating overall growth of the test crop. In most weeks, stem girth tends to be higher in treatments with nutrients (Soil and Agrifol) compared to the Water control. Other reports also suggest high daily temperatures for maximum amaranth vegetative growth (NRC, 1984). Grubben (1980) reported rapid growth and high yields of amaranth at 30–35°C. so higher soil temperatures can improve stem girth This suggests that nutrients contribute to increased stem growth in the test crop. The effect of Agrifol concentration on stem girth seems to be non-linear. There's no clear pattern of increasing or decreasing girth with higher Agrifol application. For example, in week 3, 0.8mL Agrifol has the highest value, but in week 5, 0.6mL Agrifol has the highest girth. This table suggests that the effect of nutrients on stem girth becomes more pronounced over time. This experiment is similar to that of an earlier research conducted by Kumar 2023 using chickpea

**Table 3:** Effect of Nutrient Concentration on Stem Girth of African spinach

Treatment	WAS				
	1	2	3	4	5
Water	0.0267 <sup>a</sup>	0.1200 <sup>a</sup>	0.2300 <sup>a</sup>	0.3100 <sup>a</sup>	0.3533 <sup>a</sup>
Soil	0.0900 <sup>b</sup>	0.2100 <sup>c</sup>	0.3400 <sup>b</sup>	0.4233 <sup>b</sup>	0.4967 <sup>d</sup>
0.2mL	0.0200 <sup>a</sup>	0.1500 <sup>b</sup>	0.2367 <sup>a</sup>	0.3167 <sup>a</sup>	0.3900 <sup>b</sup>
0.6mL	0.0367 <sup>a</sup>	0.1667 <sup>b</sup>	0.2300 <sup>a</sup>	0.3333 <sup>a</sup>	0.4367 <sup>c</sup>
0.8mL	0.0300 <sup>a</sup>	0.1400 <sup>ab</sup>	0.4033 <sup>c</sup>	0.4500 <sup>b</sup>	0.5133 <sup>d</sup>
LS	**	**	**	**	**
SE±	0.002	0.019	0.021	0.008	0.010

Note. Means with the same superscript are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT), LS = Level of significance, \*, \*\*, & \*\*\* = significant @ 0.10, 0.05 & 0.01 probability level. SE = Standard error

Table 4 Shows result of the effect of nutrient concentration root length of African spinach. The table reveals that all the treatments apart from 0.6mL of Agrifol fertilizer had a similar range of root length during the first week. During the second week the table shows that 0.6mL of Agrifol Fertilizer and water treatments had a similar range of root length being the longest out of all the treatments; Hale *et al.* (2015) shows that by 2 weeks agronomic traits have to been fully developed the plants grown within the 0.8mL and 0.2mL treatments were similar in root length while the plants that were grown within the soil had the shortest root length. From week 3 till week 5 all treatments apart from the soil treatment had similar range in terms of root length. These results agreed with those obtained by Hale *et al.* (2015) whose found that the aeroponics produced fastest growth rates even faster than hydroponic systems that are faster than soil systems.

**Table 4:** Effect of Nutrient Concentration on Root Length of African Spinach

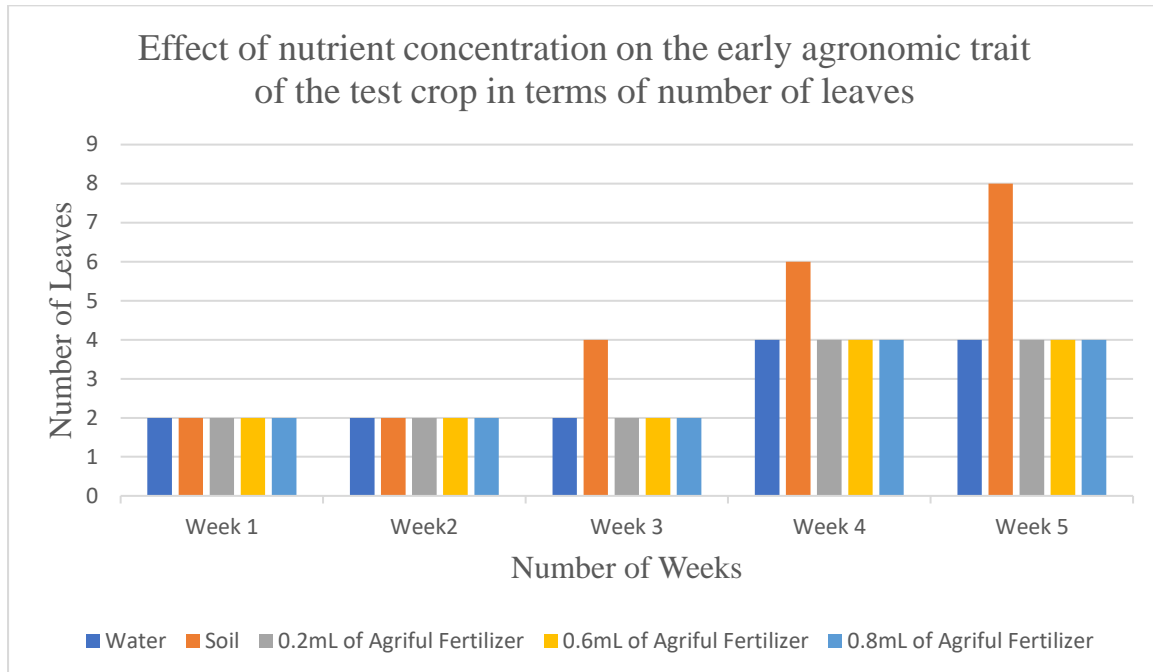
Treatment	Week 1	Week 2	Week 3	Week 4	Week 5
Water	0.4000 <sup>a</sup>	1.4000 <sup>b</sup>	2.4667 <sup>b</sup>	3.2333 <sup>b</sup>	3.7333 <sup>b</sup>
Soil	0.4000 <sup>a</sup>	1.1000 <sup>a</sup>	1.4333 <sup>a</sup>	1.8667 <sup>a</sup>	2.5333 <sup>a</sup>
0.2mL	0.3333 <sup>a</sup>	1.2667 <sup>ab</sup>	2.3000 <sup>b</sup>	2.8667 <sup>b</sup>	3.4000 <sup>b</sup>
0.6mL	0.6333 <sup>b</sup>	1.4667 <sup>b</sup>	2.5333 <sup>b</sup>	3.0333 <sup>b</sup>	3.6000 <sup>b</sup>
0.8mL	0.4000 <sup>a</sup>	1.3000 <sup>ab</sup>	2.7000 <sup>b</sup>	3.3333 <sup>b</sup>	3.9000 <sup>b</sup>
LS	**	**	**	**	**
SE±	0.047	0.018	0.620	0.882	1.008

Note. Means with the same superscript are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT), LS = Level of significance, \*, \*\*, & \*\*\* = significant @ 0.10, 0.05 & 0.01 probability level. SE = Standard error

### Number of Leaves

Figure 1 presented result of the Effect of nutrient concentration on number of leaves of African spinach. The result shows that, during the first and second weeks all the plants had the same number of leaves. At week three, the plants that were grown within the soil medium had two more leaves than the other treatments while the plants of the other treatments remained constant. By week 4 the plants in the soil medium gained an additional two leaves bringing the total leaf count to four while the plants in the other treatments gained leaves. By the fifth week, the plants in the soil continued to gain leaves while the plants in the hydroponic system remained constant. This study disagrees with a study by Imtiaz *et al.*, 2015 that states that in

the hydroponic system, the plants have more leaves than those plants grown in the soil for chickpeas, (*Cicer arietinum* L.) the study indicates the greater yielding in the hydroponics grown plants over soil grown plants



**Figure 1:** Effect of Nutrient Concentration on Number of Leaves of African Spinach

## CONCLUSION AND RECOMMENDATION

In line with the research objective, by increasing the nutrient concentration in the wick hydroponic system the agronomic traits of the test crop performed well. Also, in line with the specific objectives stated earlier the wick hydroponic system did not perform as well as the standard practice which was planting within a soil medium. Also, by varying the concentration of the nutrients, although there is a difference in the expression of the agronomic traits, it is not significant. The study recommends that a further study into the how the various hydroponic systems can be utilized for the cultivation of African spinach. I would also recommend that further study into tailored nutrient management practices, considering factors such as the soil composition, and environmental conditions so as to optimize African spinach cultivation in diverse agricultural settings should be done.

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