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Research Article

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Evaluation of an Automated Bamboo-Based Fertigation System on Growth and Yield of Dry Season Vegetable

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Abstract Dry season vegetables and the use of bamboo pipe in irrigation systems play a key role in the economy of Nigeria as a basic source of food, income, and employment generation, especially in the off-season of rainfall agriculture. This study was carried out to evaluate the effect of an automated bamboo-based fertigation discharge rate on the growth and yield of *Amaranthus cruentus* during the dry season period. The fertigation discharge rate from the piping system was varied at 10, 20, 30, 40 drops/min and control. The result of the study revealed that the *Amaranthus cruentus* had the highest growth stage (23.81cm), number of leaf emergence (17) and leaf area (806.66cm^2) at the preset fertigation discharge of 40 drops/min, with the lowest yield at the control at a growth stage (16.79cm), number of leaf emergence (9) and leaf area of (503.06cm^2) at harvest. The statistical analysis of the data collected revealed that the growth stage and number of leaves emergence/leaf area ratio of *A. cruentus* are more steady at the control, while the yield in leaf area and number of leaves emergence are more steady at 10 and 40 drops/min, respectively. The preset fertigation discharge rate was significant to the growth and yield of *Amaranthus cruentus* for all the plots considered, while the bamboo pipe was able to convey water evenly throughout the period of the study.

Keywords Septum, Fertigation, *A. cruentius*, Field capacity, Leaching, Hydraulic conductivity

1. Introduction

Urban agriculture is rapidly improving around all the cities in Africa with the increase in urban populations and consequently rising demand for vegetables. Irrigated agriculture will need to increase rapidly in the future in order to meet these rising demands. [9]. The introduction of small-scale, low-cost irrigation technologies by small-holder farmers in Africa has great potential and could be one of the solutions for increasing vegetable production, farmers' incomes, and improving food security [2,9]. Vegetable production is majorly established during the rainy season in some parts of Nigeria. Vegetables are easy to grow during raining season as water is available and farmers can afford the cost of irrigation [8]. The inadequate consumption of fresh vegetables may be worrisome during the dry season when soil moisture stress and scarcity limit the limited space available for their cultivation, thereby reducing the quantity and quality of vegetables that can be grown and supplied to urban areas. According to Kintomo et al. (1997), it was reported that it would be more lucrative to grow vegetables during the dry season when irrigation water is an alternative. Cultivation of vegetables during this period produced an improved quality harvest because of reduced disease pressures compared to vegetables produced under rainfed conditions.

The search for and use of alternative piping materials, i.e. bamboo pipe in drip irrigation or fertigation systems, is one of nature's gifts to mankind. It is utilized by removing its septum, either as a whole or halved, which has enabled many peasants, average farmers, and rural communities to carry out less expensive and less complicated construction of water conveyance schemes for irrigation, drainage, and water supply in countries such as Tanzania, Ethiopia, China, and Indonesia [8]. Also, the yield of vegetables in a drip irrigation system can be improved through fertigation. Deficiencies of N, P, and K are major production constraints in sandy soils, which lead to constraints like phosphorus fixation, rapid hydraulic conductivity, faster infiltration rate, leaching of basic cations, and low CEC. Hence, the cultivated crops in this soil require a large quantity of nutrients to support their growth and yield. Fertigation scheduling requires the following considerations, crop and site-specific nutrient management, timing nutrient delivery to meet crop needs, and irrigation system control to minimize soluble nutrient leaching.

Ogunjimi and Adekolu (2002) advised that the introduction and adoption of irrigation systems for the establishment of vegetable production in Nigeria needs to be further assessed. Hence, the objective of this work was to evaluate the performance of an automated bamboo-based drip fertigation system on the growth and yield of selected dry-season vegetables.

2. Material and Methods

2.1 Plant and other materials used in the research

The seed of Amaranthus cruentus was obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, at the agricultural seed unit. Amaranthus cruentus seed was subjected to no treatment before planting [1]. Other materials used in the research include bamboo pipes, two plastic refill and gravity drums, plastic pipes, irrigation water and organic fertilizer for fertigation, micro pumps, a battery, and a soil moisture sensor for automation.

2.2 Description of experimental site

This research was carried out at the research plot of the department of Civil Engineering Technology, Auchi Polytechnic, Auchi. Auchi has a tropical savanna climate with an annual average precipitation of 1,205 mm and an air temperature of 28^0C.The highest and lowest dry periods are February and July, with a maximum temperature of 38oC and 29^0C. The coordinates of the research plot are (7.0668^0N, 6.2748^0E). The selected area of the research plot was 8.0m x 4.7m ($37.6m^2$) while the experimental study and data collection from the site was done for six weeks between (25^{th} January -5th March, 2022). The research was completely carried out under completely dry conditions, with an approximate temperature range of 24^0C *to* 33^0C *on average for the period.* The soil type of the field was classified as sandy loam with (51% sand, 43% silt, 6% clay, and a pH of 6.8). The soil textural analysis was carried out at Auchi Polytechnic, Auchi, at the laboratory of the Civil Engineering Technology Department. The top 30 cm of the soil contained 16.8 mg kg1 of P, 215 mg kg1 of K, 653 mg kg1 of Ca, 306 mg kg−1 of Mg, and 13.7mg kg−1 of Na, respectively.

2.3 Experimental design and treatments

The trial was carried out in a randomised complete block design with three replications for the plot of A. Cruentus. The treatments evaluated were three different plant densities of the same number of plants (0.6 m inter-row by 0.2 m intra-row) for A. cruentus [3]. Each plot had three crops with polythene-filled sandy soil. Three drip emmiters are meant to discharge fertigation water into the polythene filled sandy soil at a preset discharge rate while the growth and yield of the vegetable are monitored.

2.4 Experimental procedure and method of connections

The bamboo pipelines used for the irrigation system were readily available and locally sourced for while irrigation tanks, plumbing work accessories, and drippers were purchased. The bamboo pipe was cut to a length of 60 x 100 cm for the lateral and main pipes, respectively, with the aim of conveying water from the reservoirs for even distribution into the plant root zones. It contains one main and five lateral bamboo pipes. At a spacing of 12.5 cm, the Medi emmiters were attached to the lateral pipe of the bamboo at a spacing of 12.5 cm while PVC abro gum was used to prevent leakages around the connected plumbing work. A steel support was utilized as a support for both the gravity and refill tanks. The joints of the bamboo pipe are connected to each other with the aid of plastic T and elbow joints.

2.5 Planting and discharge calibration

Three planting cellophane bags were filled with sandy loam soil while A. cruentus was broadcast on the soil for germination to occur. The irrigation water was fertigated with organic liquid fertilizers at a mixing ratio of 1 litre of organic liquid fertilizer to 200 litres of irrigation water (1:200) based on manufacturer's recommendation. After all the necessary connections had been made, the medi emitters were properly, straightly stretched and attached. The soil-filled polythene was irrigated for thirty minutes to keep the soil in the polythene bags at a field capacity. This was done in order to determine any points with leakages around the bamboo mains and laterals. Where leakages were suspected, they were corrected through loosening, retightening, and the application of abro PVC gum. After the test run, emitters were calibrated at the preset discharge rates of 10, 20, 30, and 40 drops/min for the 1st, 2nd, 3rd, and 4th laterals, respectively, at a spacing of 12.5 cm for the selected vegetables. The control of the study was established with the application of irrigation water alone and calibrated at a preset average of the preset fertigation discharge rate above.


(A)


(B)


(C)


(D)

Plate 1: Installation (a & b) Image on connection of bamboo and PVC T junction.
(c & d) Image of complete installation and automation of the fertigation system.

2.6 Automation of the system

The irrigation system was automated through the use of an onboard processor and soil moisture sensors, which were remotely triggered and monitored through the use of an android application program. The system was designed to monitor the soil surface dryness of the vegetable plot through the use of a soil moisture sensor, which triggers and controls the irrigation pump accordingly. The system was programmed and backed up through the use of C^{++} programs and lithium batteries. The soil moisture sensor was dipped close to the soil surface at a depth of 2 cm.

2.7 Data collection

Data collection, such as plant growth stage, number of leaves, and leaf area of the plant, were observed throughout the growing periods of *A. cruentus*. Three plants from each of the preset discharge rates on each plot were chosen for data collection in terms of observation of the vegetable's growth and physiological parameters.

Collection of data was started after the first week of planting, after three days of observation. All measurements were taken on leaves that had at least 50% green in plant height, number of leaves, and leaf area throughout the observation period. Plant height was measured using a measuring tape from the ground level to the tip or apex of the tallest stem (Innocent et al., 2015). The increase in the plant number of leaves was counted every three days of observation, while the leaf area of A. cruentus was measured using LA = LxWxNx0.72, a method adopted by (Kariithi et. al. 2018).

2.8 Statistical analysis

The data collected from the study was analysed using a statistical metric. It was adopted in displaying the trend in the growth and yield of vegetable with time, while the regression coefficient was adopted in establishing the level of relationship between the preset fertigation discharge rate and the vegetables' physiological growth parameters. t Test (two samples assuming unequal variances) was used in establishing the level of significance of the effect of the preset fertigation discharge rate on the physiological growth parameters of the vegetable.

3. Results and discussion

The results of the study are graphically displayed in the figures below.

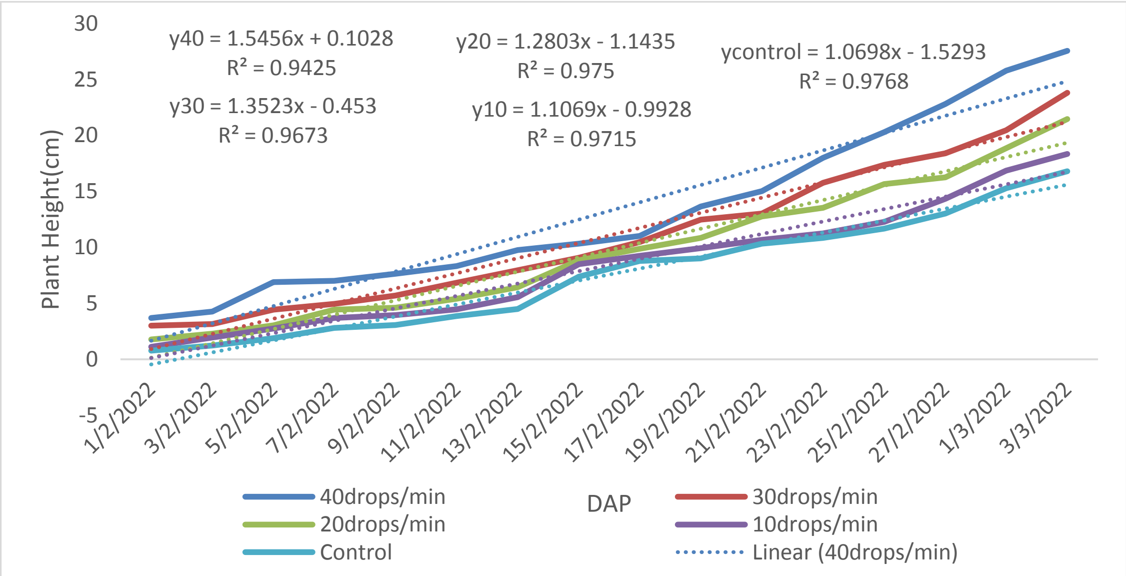


Figure 1: The growth stage of A. cruentus with time under variable fertigation discharge

From fig 1 above, it was validated from the graph that the maximum growth stage of *A. cruentus* at harvest was obtained at the preset fertigation discharge rate of 40 drops/min with a value of 23.81 cm, while the lowest yield was obtained at the control with a value of 16.79 cm. The regression analysis revealed that the growth stage of *A. cruentus* with time was more steady at the control and at the least at 40 drops/min. The preset fertigation discharge from the five plots considered was significant to the growth stage of the plant.

It was deduced from fig 2 that the maximum yield in terms of the number of leaves emerging from Amaranthus cruentus at harvest was obtained at the preset fertigation discharge rate of 40 drops/min with 17 leaves, while the lowest yield was obtained at the control with 9leaves. The regression analysis revealed that the yield in the number of leaf emergence of A. cruentus with time was more steady at the preset fertigation discharge rate of 40 drops/min and at least at 10 drops/min. The preset fertigation discharge from the five plots considered was significant to the yield in the number of leaf emergence of the plant.

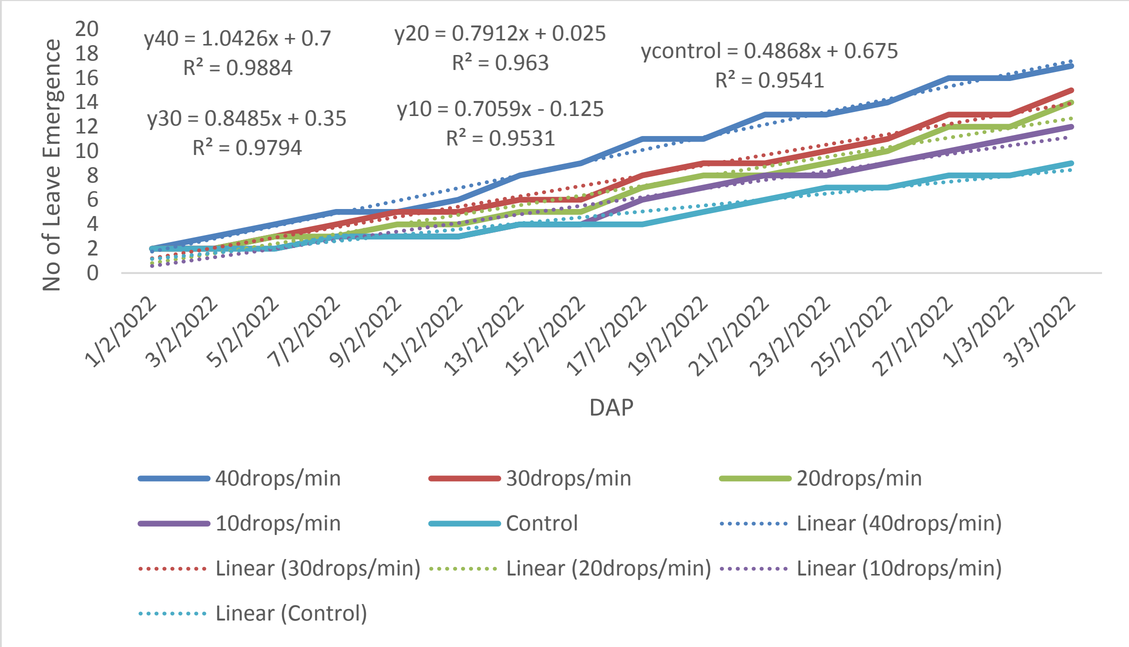


Figure 2: The yield in number of leaves of A. cruentus with time under different preset fertigation discharge

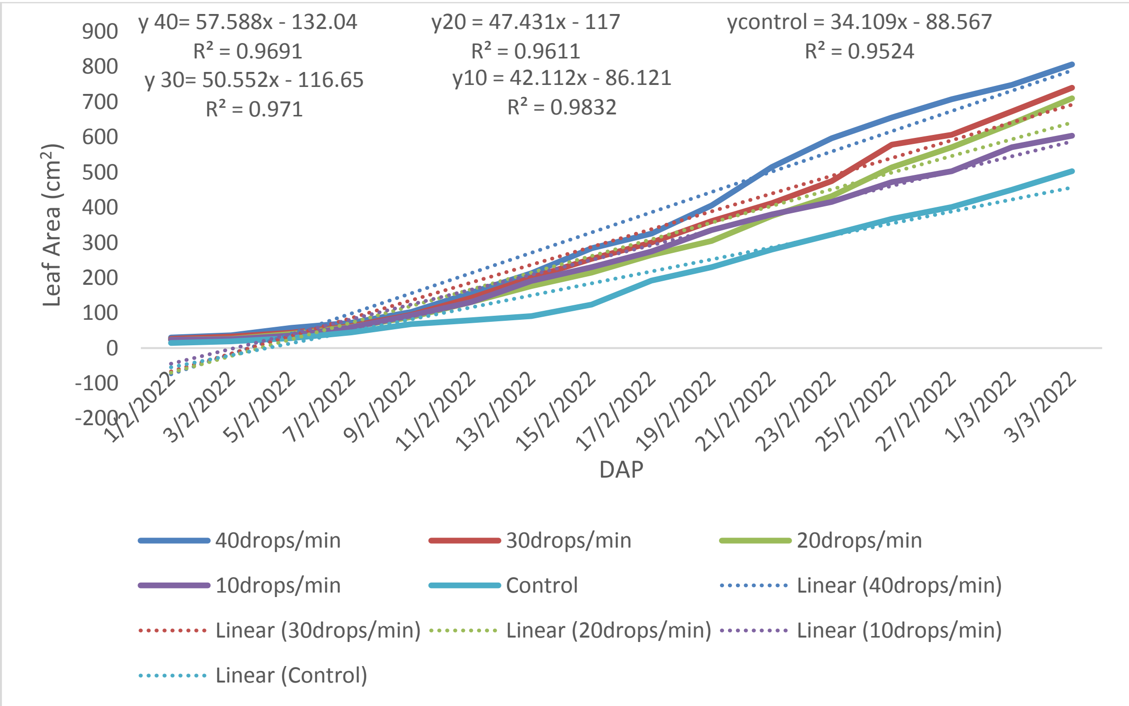
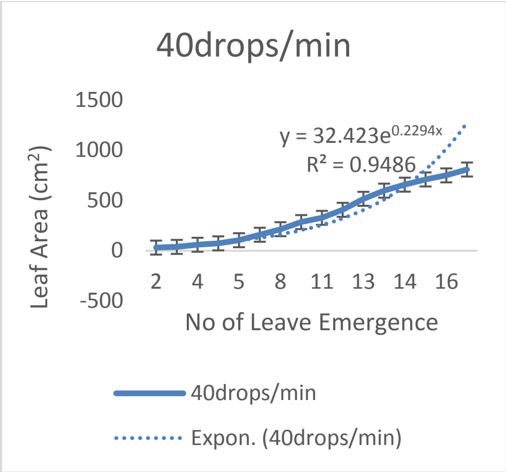
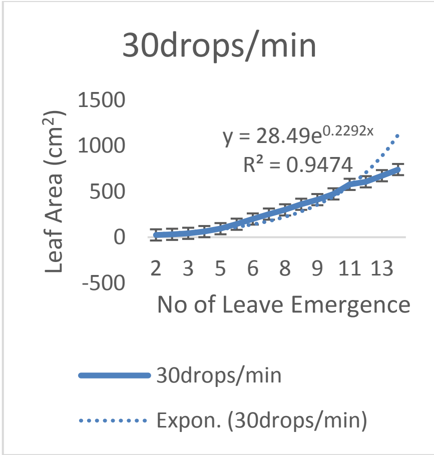


Figure 3: The yield in leaf area of A. cruentus with time under different preset fertigation discharge

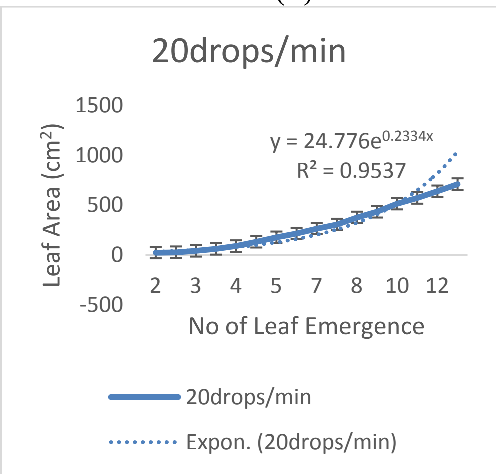
Fig. 3 above revealed that the maximum yield in leaf area of Amaranthus cruentus was obtained at the preset fertigation discharge of 40 drops/min with a value of 806.66cm^2 at harvest, while the lowest yield was obtained at the control with a value of 503.06cm^2. The regression analysis revealed that the yield in the leaf area of A. cruentus with time was more steady at the preset fertigation discharge of 10 drops/min and at least at the control. The preset fertigation discharge from the five plots considered was significant to the yield in the leaf area of the plant.



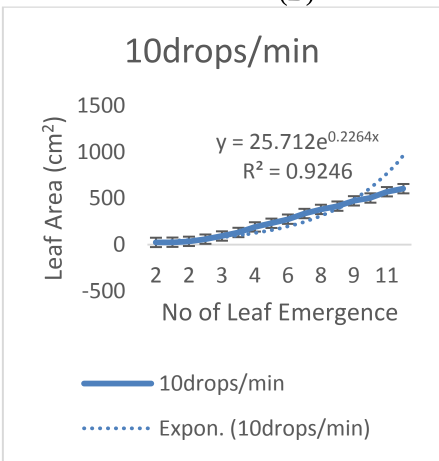
(A)



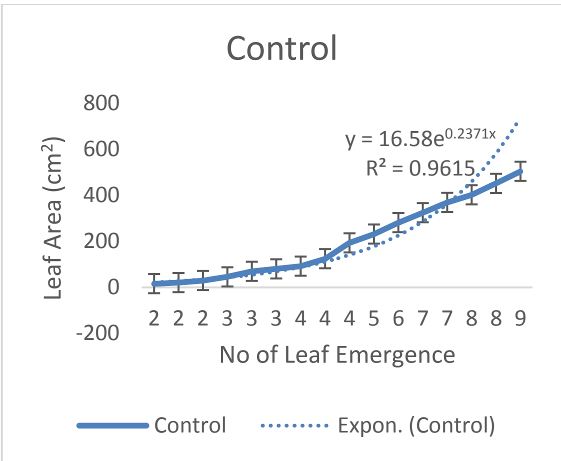
(B)



(C)



(D)



(E)

Figure 4: A, B C, D and E (regression analysis between number of leaf emergence and leaf area (cm^2) of A. cruentus for each of the preset fertigation discharge rate

Fig. 4 above revealed that the relationship established by the yield in number of leaves and leaf area (cm^2) of A. cruentus was more steady at the control and at the least at the preset fertigation discharge rate of 10 drops/min. The relationship between the number of leaf emergences and leaf area (cm^2) is more steady at the control and at the lowest at 10 drops/min.

4. Conclusion

The study investigates the effects of variable fertigation discharge rate on the growth and yield of *A. cruentus* in an automated bamboo based drip fertigation system. The overall results revealed that the fertigation system improved the growth and yield of the plant, i.e., plant height, number of leaves, and leaf area when compared to the yield at the control during harvest. Hence, the choice of fertigation application using bamboo pipe somehow depends on the period and purpose of cultivation. The productivity of dry season vegetables should be assisted through the introduction of organic fertilizers in irrigation water so as to meet people's demand for dry season vegetables and generate more income for the farmer. The bamboo pipe was able to convey water through medi emmiter to the plant root zones without any cracks and with minimal and negligible leakage throughout the period of the study.

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References

[1]. Abigail, L. and Promise, J. A. (2020). Effect of temperature treatments on seed germination and seedling growth of Amaranthus cruentius and Corchorious olitorious, International Journal of Environment, Agriculture and Biotechnology, DOI: 10.22161/ijeab.56.29.

[2]. Hillel, D. (2001). Small scale irrigation for arid zones, principles and options. FAO development series No. 2, Rome, Italy.

[3]. Innocent, M., Yacob, G. B., Noluyolo, N., Du Plooy, C.P., and Tafadzwanashe, M. (2015). Growth, physiology and yield responses of Amaranthus cruentus, Corchorus olitorius and Vigna unguiculata to plant density under drip irrigated commercial production, South African Journal of Plant and Soil, 32:2, 87-94, DOI: 10.1080/02571862.2014.994142.

[4]. Kariithi, T., Thagana, W., and Gweyi-Onyango, J. P. (2018). Morphological Characteristics of Amaranthus cruentus and Amaranthus tricolor as Influenced by Integration of Organic and Inorganic Fertilizers in Kiambu County, Kenya. Asian Research Journal of Agriculture 8(1): 1-18, 2018; Article no. ARJA.39123 ISSN: 2456-561X.

[5]. Kintomo, A.A., Ogunkeyed, O.O., and Ogungbaigbe, L.O. (1997). Peri-Urban dry season vegetable production in Ibadan, Nigeria. Tropicultural 15 (2): 61-65.

[6]. Ogunjimi, O.L.A. and Adekalu, K.O. (2002). Problems and constraints of small-scale irrigation (FADAMA) in Nigeria. Food Reviews International 18(4):295-304

[7]. Olasantan, F.O. (1996). Meeting the future vegetable needs in Nigeria: The potential role of out of season vegetables. Outlook Agric., 25(2): 95-105.

[8]. Van Leeuwen, N. H. (2001). Irrigation reforms in Africa. In proceeding of Regional seminar on private sector participation and irrigation expansion in sub-Sahara Africa Oct. 2001, Accra, Ghana. Edited by Hilmy Sally and C.L. Abernetthy, pp. 50-58; 22-26.

[9]. Quintans, K.N. (1998). The National Bamboo Project of Costal Rica: A case study of the Role of Bamboo in International Development. INBAR Working Paper Series. Published by International Network for Bamboo and Rattan, Beijing. P.R. of China. Pp 3-9.