# Growth and yield performance of hot pepper using aquaculture wastewater

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**Abstract:** A field experiment was conducted to determine the growth and yield performance of hot pepper using aquaculture wastewater. The research was carried out at the Department of Fisheries and Aquaculture Technology, Teaching and Research Farm, the Federal University of Technology Akure. The experimental set up consisted of a randomized complete block of three treatments and nine replicates. The three treatments were untreated wastewater (UT), treated wastewater (TW) and control treatment (CT) respectively. Some parameters used as indicies to ascertain the usability of wastewaters were considered in the analysis and soil parameters was carried out to determine the quantity of the nutrients that affect the growth and yield performance of the pepper. Also, agronomic parameters were measured to determine the response of the hot pepper to the wastewater treatments. These parameters were subjected to statistical analysis. The responses of the growth of hot pepper plants to the various treatments showed that the average plant height and number of leaves for each of the treatments UT, TW and CT at 11 weeks after transplanting (WAT) were 40, 43 and 37 cm; and 242, 275 and 209 respectively. However, the highest average yield of 201.1 kg ha$^{-1}$ was obtained in treatment UT, while treatment TW and CT gave average yield of 164.3 kg ha$^{-1}$ and 88.2 kg ha$^{-1}$. Thus, wastewater reuse is recommended for agricultural purpose.

**Keywords:** aquaculture wastewater, constructed wetlands, hot pepper

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## 1 Introduction

For continued sustainability of agricultural productivity and food security, pepper production in Nigeria is of great significance (Akinbile and Yusoff, 2011). According to Iqbal et al. (2011), hot pepper is important because of its economic value and mostly for its nutritional and medicinal value. Hot Pepper (*Capsicum annum*) is a vegetable that is widely cultivated in Nigeria during rainy season or dry season under irrigation. The vegetable is the world's most highly important after tomato as it can be used as fresh or dried and usually used for salads and other meals (Acquaah, 2004; Mazourek et al., 2009). According to Weiss (2002), the total land area for the cultivation of pepper worldwide is estimated to be four million hectares with an average annual increase of 5%. However in Nigeria, low production of hot pepper is attributed to poor varieties, poor cultural practices and prevalence of fungal, bacterial and viral diseases (Fekadu and Dandena, 2006). It can be grown entirely under irrigation, due to its sensitivity to an abundance of moisture and excessive temperatures (Almuktar et al., 2015) and can also be grown in a well-drained, fertile loam soil. However, its maximum growth occurs at a temperature range between 21°C and 29°C (Nickels, 2012) and is sensitive to high levels of salinity, requiring salinity conditions below 1280 mg L$^{-1}$ (FAO, 2003). Peppers normally grow in light and well-drained soil that is rich in organic matter such as sandy loam or loams with a pH value between 6.5 and 7.5 (Haifa Chemicals, 2014). The maturity period is between 60 to 90 days

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(FAO, 2013) and germinates between 5 to 14 days well in moist and nutrient-rich soil in a warm climate (Almuktar et al., 2015) with temperature ranging between 18 to 27°C during the day and between 15°C to 18°C at night (Campiglia et al., 2010).

Like all other plants, pepper requires some macro elements (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) and micro elements (boron, potassium, iodine and chlorine) for its growth and germination. Like every other vegetable, peppers are very important due to their economic importance in the global world. The importance of irrigation in agriculture cannot be ruled out because of its enormous effect in the globalization of food security. Irrigation can ensure adequate and reliable supply of water which increases yields of most crops by 100% to 400% (Alatise, 2010). Therefore cultivating vegetables such as pepper using irrigation not only increases yield but also enables planting all year-round. According to Jaimez et al. (1999) irrigation is essential in other to enable the availability and storage of water in the soil strata for plants use and complement for evaporative loss and other losses. Also, Khan et al. (2005) stated that irrigation played a very important role in maintaining sustainable growth by reducing 60% to 80% crop loss caused by wilting. Drip irrigation system applies water at a lower rate for a longer period at frequent intervals near the plant root through lower pressure delivery system, which increases the availability of nutrients near the root zone with a reduction in leaching losses (Paul et al., 2013). However, to meet the increase in demand of water supply for agriculture because of the ever increasing competitive demand due to burgeoning population, scarcity due to seasonal variation and water abuse, farmers opt for the use of wastewater for irrigation. And it has been scientifically proven that crops irrigated with wastewater have some deposited elements which have detrimental effect on human health. Also, demand in freshwater supply, high cost of conventional wastewater treatment techniques and availability of wastewater. Hence, there is need for treatment of the wastewater in other to promote its use in agriculture. This study was therefore carried out to evaluate the growth and yield performance of hot pepper plant using treated and raw aquaculture wastewater. This is to ascertain alternative water source for sustainable hot pepper production especially in Nigeria, irrespective of the season based on water availability.

## 2 Material and method

### 2.1 Study area

The study was carried out at the Department of Fisheries and Aquaculture Technology Teaching and Research farm, the Federal University of Technology Akure, Nigeria, from December, 2016 to May, 2017. This site was selected for easy accessibility and availability of aquaculture wastewater. The Research farm is located at the latitude 7°17′N and longitude 5°14′E within the humid region of Nigeria and lies in the rain forest zone with a mean annual rainfall of between 1300 and 1800 mm and an average temperature is 27°C. The relative humidity ranges between 85% and 100% during rainy season and less than 60% during the dry season.

### 2.2 Experimental materials

*Avernir F1* specie of hot pepper was used for the experiment and the seeds were raised in the nursery. The seed bed was covered with palm fronds shade to protect seedlings from direct sunlight and to minimize damage as a result of impact of water droplets when watering. After 8 weeks of planting, healthy and viable seedlings were transplanted to the experimental field at the rate of one seedling per stand. Weeds were controlled manually during the growth period of the pepper plants.

### 2.3 Experimental design and field layout

The field was prepared manually using conventional means of land preparation and divided into two parts. The first part was the aquaculture wastewater treatment experimental set up which comprised of the reservoir, sedimentation tank and the charcoal based constructed wetlands, each of 1000 Litres capacity. The second part was the farmland prepared with a Randomized Complete Block Design with an area of 89.04 $m^2$ of three treatments and nine replicates (3×9). Each of the replicates has dimensions (1.2m×1.1m) and was planted with four plants per bed at a spacing of 0.7 m×0.5 m making a population of 36 plants per treatment. Irrigation of all the plots was through drip irrigation system with respect to the consumptive use of hot pepper (Akinbile and Yusoff, 2011). Treatment UT (Untreated Wastewater Plot) were plants irrigated with untreated wastewater from the reservoir, Treatment TW (Treated Wastewater Plot) were plants irrigated with treated wastewater from the constructed wetlands and Treatment CT (Control Plot) were plants irrigated with Groundwater, this served as the control. On these plots were viable seedlings of hot pepper from the nursery transplanted. The overview of the farm layout shows the experimental set-up of the wastewater treatment unit and the drip irrigation system design is shown in Figure 1.

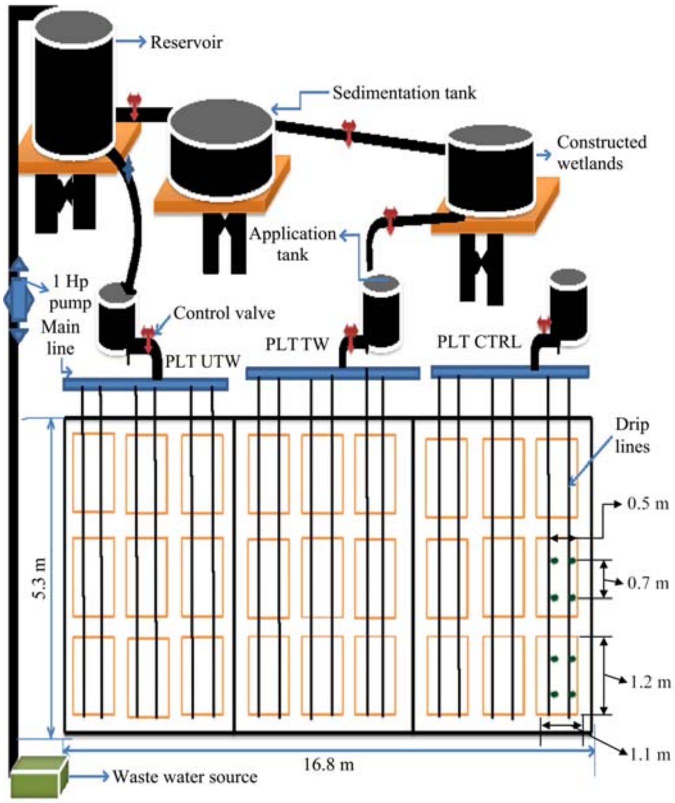


Figure 1 Farm layout

Note: PLT UTW: Plot irrigated with Untreated Wastewater (UT);
PLT TW: Plot irrigated with Treated Wastewater (TW);
PLT CTRL: Control Plot irrigated with Groundwater (CT).

### 2.4 Soil analysis

50±0.5 g of soil samples from the experimental field taken at depths 0-10 cm, 10-20 cm and 20-30 cm were analyzed for soil moisture content. Some other physical and chemical properties were analyzed in the laboratory using standard procedures and methods. Soil pH was determined using the digital electronic pH meter, soil particle size distribution was determined using hydrometer method and organic matter using walkey-black wet oxidation method. Total Nitrogen was determined using kjeldahl digestion method (Jackson, 1962). Calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$) and available phosphorus were extracted using ammonia acetate (Jackson, 1962). Potassium ($K^+$) was determined on a flame photometric method and Cation Exchange Capacity (CEC). The bulk density was determined using Blake and Hartage (1986) method. Also, water holding capacity and field capacity were determined using conventional computational procedure.

### 2.5 Water sampling and analysis

The aquaculture wastewater samples were collected from one of the Fisheries and Aquaculture Technology Departmental fishpond. The fishpond is a concrete pond of 1.8 m×1.8 m×0.9 m. The specie type of fish reared in this pond was catfish of 150 populations and between ages of 3-6 weeks. Untreated wastewater samples from the pond (Influent), treated wastewater samples from the constructed wetlands (Effluent) and borehole water samples were sampled and moved under standard methods of sampling at 4°C to the water quality testing laboratory where they were analyzed using standard methods and procedures (APHA, 2005). The parameters determined in the water samples were: physical (Total Suspended Solids (TSS), Temperature), chemical (pH, Ammonia, Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO), Electrical Conductivity (EC), Nitrate, Phosphate and Biological Oxygen Demand (BOD). $NH_4^+$–N was determined using (4500-$NH_3$D) method. TSS was determined using 2540D method and COD was also determined using 5220C method. pH was determined using a portable pH meter (HANNA 016), EC was determined using Conductivity Meter (DDS-307), DO was determined using Oxygen Meter (DO-5510HA), $BOD_5$ was determined with the 5-day BOD test. Also, $NO_3^-$–N was determined using spectrometric method (4500B) and $PO_4^{3-}$–P was determined using Ascorbic Acid method (4500-P).

### 2.6 Agronomic measurements

In evaluating the performance of the three treatments of water applied on the growth and yield of the pepper plant, six agronomic parameters were determined weekly from 2 weeks after transplanting till harvest. These include, the number of leaves and plant height which were determined using measuring rule, stem diameter was determined using micrometer screwguage, leaf area was determined weekly using a portable living leaf area metre, model YMJ. Also, the fruit yield and biomass yield were determined after harvest. The proximate analysis was also determined on the pepper fruit to know its suitability for consumption.

### 2.7 Statistical analysis

Data obtained were subjected to statistical analysis of data using Microsoft Excel. The comparison between the agronomic parameters was done using one- way ANOVA.

## 3 Results and discussion

### 3.1 Irrigation water quality

Table 1 shows the result of the water analysis carried out on the aquaculture wastewater and groundwater used for irrigating the hot pepper. The pH of the treated wastewater (effluent) and the untreated wastewater (influent) were 6.91±0.01 and 6.68±0 respectively, however theses values are below the value of the groundwater (borehole). Also, the effluent had the highest concentration of EC, and DO with corresponding values of 610±14.14 μs $cm^{-1}$ and 6.30±0.06 mg $L^{-1}$ respectively while the highest concentration value of 0.70±0.15 mg $L^{-1}$ and 108.70±6.66 mg $L^{-1}$ for TSS and COD respectively. The concentration of nitrate, ammonia and phosphate was not found in the effluent as they were totally removed during treatment. Also, there was no trace of ammonia and phosphate in the groundwater. In summary, the wastewater quality was within permissible limit as compared with standard by Pescod (1992) and FAO (1985) for irrigation of agricultural crops.

**Table 1 Characteristics of aquaculture wastewater and groundwater**

| Parameters | Influent | Effluent | Borehole | Standard limit for irrigation[b] |
|---|---|---|---|---|
| pH | 6.68±0.03 [a] | 6.91±0.01 | 7.07±0.03 | 6.50-8.40 |
| Temperature ($^oC$) | 27.80±0.12 | 25.90±0.16 | 26.70±0.46 | - |
| TSS (mg $L^{-1}$) | 0.70±0.15 | 0.35±0.05 | 0.40±0.03 | - |
| EC(μs $cm^{-1}$) | 400±45.39 | 610±14.14 | 300±8.66 | <3000 |
| Nitrate (mg $L^{-1}$) | 8.50±0.06 | ND | 2.50±0.01 | - |
| Ammonia (mg $L^{-1}$) | 0.08±0.01 | ND | ND | - |
| Phosphate (mg $L^{-1}$) | 2.50±0.08 | ND | ND | 2 |
| DO (mg $L^{-1}$) | 4.17±0.08 | 6.30±0.06 | 7.40 ±0.20 | <9 |
| COD (mg $L^{-1}$) | 108.70±6.66 | 12.60±0.30 | 12.40±0.04 | 80-500 |
| BOD (mg $L^{-1}$) | 46.80±0.88 | 3.40±0.22 | 2.67±0.03 | 100 |

Note: [a] Mean± Standard deviation; [b] FAO (1985) and Pescod (1992) wastewater standard limit for irrigation; ND=Not detected.

### 3.2 Physico-chemical properties of soil at the experimental site

The result in Table 2 shows the physical and chemical properties of the farmland where hot pepper was planted. The average bulk density of the study area was found to be 1.36 g $cm^{-3}$. The bulk density of soil in the study area is found to be suitable for root penetration. According to Hoorman et al. (2011), a compacted soil has a bulk density of 1.50 g $cm^{-3}$ or higher, hence the lower the bulk density of a soil, the less compacted the soil and the less difficult it is for roots to penetrate thereby increasing root activity (Ogban and Babalola, 2003). The result of percentage composition of sand, clay and silt in the soil at the study area showed that sand had the highest proportion of 52.73%, followed by 28.88% clay and 18.40% silt. According to the soil classification using the USDA textural triangle, the soil is sandy clay loam and is suitable for the proper germination of hot pepper. At the study area, the average moisture content at various depth 0-10 cm, 10-20 cm and 20-30 cm were 5.20%, 6.20% and 7.10% respectively. It can therefore be deduced that moisture content at the study area increases with increase in depth.

**Table 2 Physicochemical properties of soil in the study area**

| Parameters | Values |
|---|---|
| pH | 5.80±0.02 |
| Magnesium (mg $kg^{-1}$) | 119.50±0.35 |
| Calcium (mg $kg^{-1}$) | 31.00±1.08 |
| Potassium (mg $kg^{-1}$) | 62.40±0.50 |
| Nitrogen (%) | 0.34±0.03 |
| CEC (cmol $kg^{-1}$) | 11.91±0.07 |
| Phosphorus (mg $kg^{-1}$) | 2.42±0.03 |
| Organic matter (%) | 2.33±0.02 |
| Water Holding Capacity (%) | 37.31±0.06 |
| Sand (%) | 52.73±0.22 |
| Clay (%) | 28.88±0.07 |
| Silt (%) | 18.40±0.01 |
| Bulk Density (g $cm^{-3}$) | 1.36±0.02 |

The soil pH of the soil at the study area was found to be acidic. According to Akinbile and Yusoff (2011) and Salako et al. (2007), soil with pH between the range of 5.0-6.0 is suitable for good growth and optimum yield of pepper. Also, Brady and Weil (2002) reported a corellation between soil pH and nutrient availability in that, soil within this pH promotes the availability of plant nutrients. The average values of the soil organic matter, magnessium, calcium, potassium, nitrogen, CEC and phosphorus were 2.33%, 119.50 mg $kg^{-1}$, 31.00 mg $kg^{-1}$, 62.40 mg $kg^{-1}$, 0.34%, 11.91 cmol $kg^{-1}$ and 2.42 mg $kg^{-1}$ respectively. According to Adepetu et al. (1979) soil CEC classification, values between 6-12 cmol $kg^{-1}$ is moderate. These chemical properties are similar to the findings of Akinbile and Yusoff (2011) that the nutrients are suitable for crop optimum germination under standard environmental conditions.

### 3.3 Effect of treated wastewater on the growth and yield of irrigated hot pepper

#### a. Plant height

Figure 2 shows the measured average plant heights with their corresponding weeks after transplanting in all the treatments. There was almost a uniform gradual increase in height for all the treatments from 2-6 weeks After Transplanting (WAT), but there was a marked difference in plant heights in all the treatments from 7-11 WAT. Treatment TW (treated wastewater plot) emerged with the highest plant height in all the treatments. At 7 WAT, the height was 34 cm and reached about 37 cm in 8 WAT. Also, there were slight differences in the heights in Treatment UT (untreated wastewater plot) and treatment TW because the difference in their values was about 2 cm. The maximum heights obtained by each of the treatments UT, TW and CT (control plot) at 11 WAT were 40, 43 and 37 cm respectively. According to El-Tohamy et al. (2006), increase in plant height could be attributed to the better availability of soil nutrients that enhance the vegetative growth of plants by increasing cell division and elongation in the growing area.

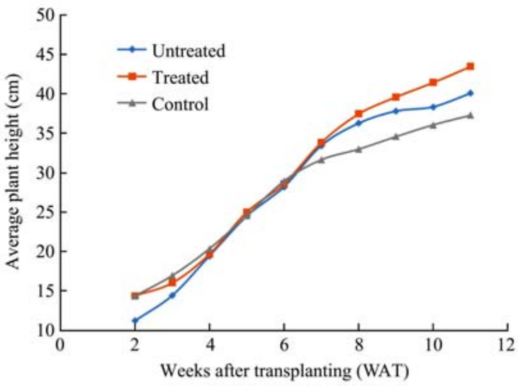


Figure 2 Average plant height versus weeks after transplanting in all the treatments

#### b. Number of leaves

Figure 3 shows the average number of leaves with the corresponding weeks after transplanting. There was no difference in the average number of leaves from 2-7 WAT and a marked significant difference from 7-11 WAT. At the initial stage between 2 WAT and 4 WAT, the numbers of leaves in the three treatments were within close range. But from 7 WAT there was a significant difference in the number of leaves as treatment TW exhibited the highest number of leaves than the other two treatments because the treated wastewater from the constructed wetlands had undergone removal of toxic nutrients which could have limited the plant growth.

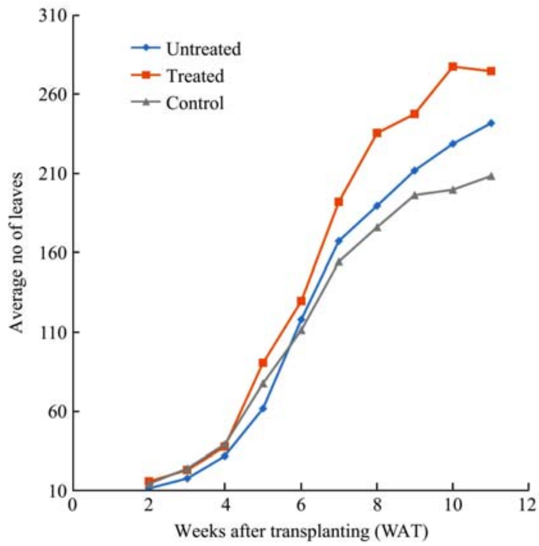


Figure 3 Average number of leaves versus weeks after transplanting

#### c. Stem diameter

As shown in Figure 4, the average stem diameter of the plants in each of the treatments showed significant but gradual increase at different weeks after transplanting. Thus, unlike the other agronomic parameters, the stem diameter showed a significant treatment difference from 5 WAT. Treatment TW having the highest average stem diameter of 2.1 cm at 11 WAT while Treatment CT had the lowest of 1.7 cm at the same week.

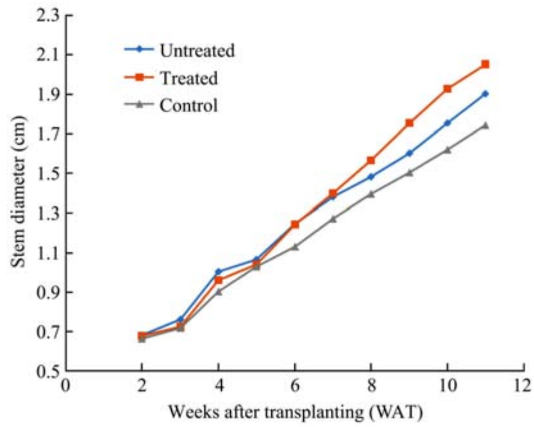


Figure 4 Average stem diameter versus weeks after transplanting

**d. Leaf area**

Figure 5 shows the result of the leaf area of the hot pepper plants in each of the treatment plots. Treatment TW had higher leaf area from 2-7 weeks after transplanting than the other two treatments. However, at 8 WAT, the leaf area for Treatment TW and CT started declining while Treatment UT started its decline at 9 WAT. This decline in leaf area in all the treatments indicated that the effect of nutrients in the wastewater for development was not significant beyond 8-9 WAT. Also, the nutrient necessary for plant growth has been exhausted. According to Liu et al. (2008), high leaf area of plants results to enhancement of photosynthesis thereby leading to high yield of plants. The various values of leaf area in each treatment attributes to the yield obtained.

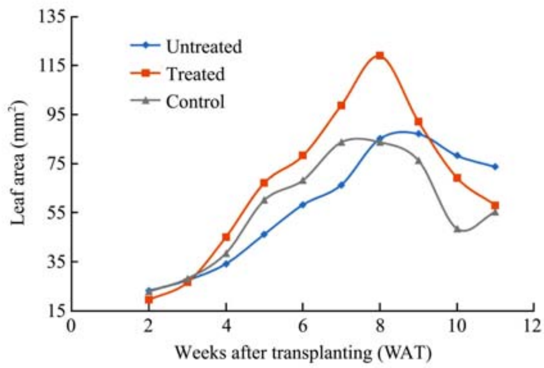


Figure 5 Hot pepper leaf area at different WAT

### 3.4 Comparative yields of hot pepper at the experimental site

Table 3 shows the graphical representation of the average fruit yield and biomass yield of hot pepper obtained from each treatment. Treatment UT had the average highest yield of 201.1 kg ha$^{-1}$ when compared with values from treatments TW and CT which were 164.3 kg ha$^{-1}$ and 88.2 kg ha$^{-1}$ respectively. The result of the statistical analysis showed a significant difference in the yield of the hot pepper in the various three treatments. Though other agronomic parameters in Treatment TW had the highest values than that of UT, the average yield in treatment UT was highest. Also, the biomass yield obtained from each of the treatment plots. Treatment TW had the highest biomass of 10047.4 g, followed by Treatment UT of biomass 9951.6 g while the lowest biomass was recorded in Treatment CT of biomass 6436.4 g. The lowest biomass yield in Treatment CT could be attributed to low plant features.

**Table 3 Average yield and biomass yield in all the treatment**

| Treatment | Yield (kg ha$^{-1}$) | Biomass yield (g) |
|---|---|---|
| Untreated | 201.1 | 9951.6 |
| Treated | 164.3 | 10047.4 |
| Control | 88.2 | 6436.4 |

### 3.5 Proximate analysis of hot pepper

Figure 6 shows the proximate analysis of the hot pepper fruit harvested from each of the treatment plots. Treatment UT had the highest moisture content of 83.1%, highest fat content of 1.88% and protein content of 5.19% but with the lowest carbohydrate and ash content of 6.60% and 1.11% respectively. Treatment TW had the highest fibre content of 4.03% and lowest moisture content of 81.36%. Treatment CT had the highest carbohydrates content and ash content of 8.44% and 2.37% and lowest fat and protein content of 1.17% and 3.62% respectively. The proximate composition of the hot pepper fruits in all the three treatments was however similar to the findings of Ogunlade et al. (2012). This showed that the fruit of hot pepper irrigated with aquaculture wastewater was suitable for consumption and that the wastewater applications does not have detrimental effect on the produce.

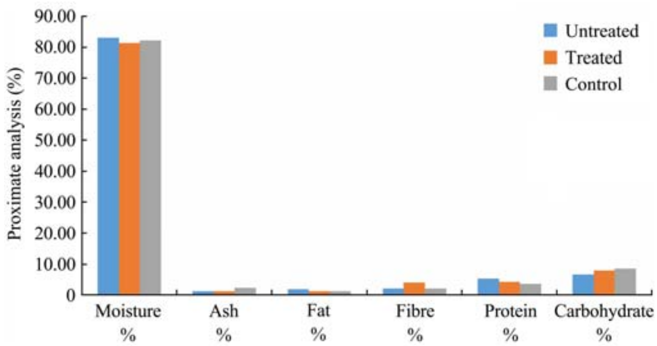


Figure 6 Proximate Analysis conducted on hot pepper fruit per treatment

## 4 Conclusion

In a developing country, food security and environmental sustainability are two crucial factors for national growth and development. Hot pepper plants irrigated with treated aquaculture wastewater irrigated had the highest agronomy values compared to the other treatments irrigated with untreated aquaculture wastewater and groundwater. However, hot pepper plants irrigated with untreated wastewater had the highest average yield compared to the other treatments and the highest biomass yield from the treated wastewater plot. Thus, in other to meet the water demand for pepper cultivation, aquaculture wastewater can be used for irrigating hot pepper plants for high yield so as to meet the ever increasing demand for pepper consumption.

## References


Acquaah, G. 2004. *Horticulture: Principles and Practices*. 2nd ed. New Delhi, India: Prentice Hall of India Private Ltd.

Adepetu, J.A., A.A. Adebayo, E.A. Aduayi, and G. O. Alofe. 1979. A preliminary survey of the fertility status of soils in Ondo state under traditional cultivation. *Ife Journal of Agriculture,* 1(2): 134–149.

Akinbile, C. O., and M. S. Yusoff. 2011. Growth, yield and water use pattern of Chilli Pepper under different irrigation scheduling and management. *Asian Journal of Agricultural Research*, 5(2): 154–163.

Alatise, M. O. 2010. Fostering irrigation practices in the humid tropics of (southwestern) Nigeria to sustain life and development.CSBE100901. In *XVIIth World Congress of the international commission of Agricultural Engineering (CIGR),* CSBE100901. Canada, 13-17 June, 2010.

Almuktar, S. A. A. A. N., M. Scholz, R. H. K. Al-Isawi, and A. Sani. 2015. Recycling of domestic wastewater treated by vertical-flow wetlands for irrigating chillies and sweet peppers. *Agricultural Water Management*, 149, 1–22.

*APHA*, 2005. Standard methods for the examination of water and wastewater, 21th ed. Washington, DC: American Public Health Association.

Blake, G. R., and K. H. Hartage. 1986. Bulk density. In *Methods of Soil Analysis*, ed. A. Klute, part 1, 363–376. Madison, WI: Soil Science Society of America.

Brady, N. C., and R. R. Weil. 2002. *The Nature and Properties of Soils*. 13th ed. New Jersey: Pearson Education, Inc.

Campiglia, Z. E., R. Mancinelli, E. Radicetti, and S. Marinari. 2010. Legume cover crops andmulches: Effects on nitrate leaching and nitrogen input in a pepper crop (*Capsicum annuum* L.). *Nutrition Cycle Agroecosystem*, 89(3): 399–412.

El-Tohamy, W. A., A. A. Ghoname, and S. D. Abou-Hussein. 2006. Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. *Journal of Applied Science Res*ources, 2(1): 8–12.

FAO. 1985. Guidelines: Land Evaluation for Irrigated Agriculture. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO. 2003. Users Manual for Irrigation with Treated Wastewater. Cairo, Egypt: Food and Agriculture Organization (FAO) of the United Nations, FAO Regional Office of the Near East.

FAO. 2013. Production Guideline for Sweet Pepper. Republic of South Africa: Department of Agriculture, Forestry and Fisheries.

Fekadu, M., and G. Dandena. 2006. Status of Vegetable Crops in Ethiopia. *Ugandan Journal of Agriculture,* 12(2): 26–30.

Haifa Chemicals. 2016. Nutritional Recommendations for Pepper. Available at: http://www.haifa-group.com/articles/crop-guide-pepper. Accessed 16 November, 2016.

Hoorman, J., I. Aziz, R. Reeder, A. Sundermeier and R. Islam. 2011. *Soil Terminology and Definitions. Agriculture and Natural Resources*. USA: Ohio State University Extension.

Iqbal, Q., M. Amjad, M. R. Asi, and A. Arino. 2011. Assessment of hot peppers for aflatoxin and mold proliferation during storage. *Journal of Food Protection,* 74(5): 830–835.

Jackson, M. L. 1962. *Soil Chemical Analysis*. New Delhi: Prentice Hall of India.

Jaimez, R. E., F. Rada, and C. Garcia-Nunez. 1999. The effect of irrigation frequency on water and carbon relations in three cultivars of sweet pepper (Capsicum Chinese jacq) in a tropical semiarid region. *Scientia Horticulturae*, 81(3): 301–308.

Khan, M. H., T. H. Chattha, and N. Saleem. 2005. Influence of different irrigation intervals on growth and yield of bell pepper (Capsicum Annuum Grossum Group). *Research Journal of Agricultural and Biological Sciences,* 1(2): 125–128.

Liu, B., M. L. Gumpertz, S. Hu, and J. B. Ristaino. 2008. Effects of prior tillage and soil fertility amendments on dispersal of Phyto phthoracapsici and infection of pepper. *European Journal of Plant Pathology,* 120(3): 273–287.

Mazourek, M., A. Pujar, Y. Borovsky, I. Paran, L. Mueller, and M.M. Jahn. 2009. A dynamic interface for capsaicinoid systems biology. *Plant Physiology*, 150(4): 1806–1821.

Nickels, J. 2012. *Growing Chillies-A Guide to the Domestic Cultivation of Chilli Plants*. UK: Jason Nickels.

Ogban, P. I., and O. Babalola. 2003. Soil characteristics and constraints to crop production in inland valley bottoms in southwestern Nigeria. *Agricultural Water Management*, 61(1): 13–28.

Ogunlade, I., A. A. Alebiosu, and A. I. Osasona. 2012. Proximate, mineral composition, antioxidant activity and total phenolic content of some pepper varieties (Capsicum species). *International Journal of Biological and Chemical Sciences*, 6(5): 2221–2227.

Paul, J. C., J. N. Mishra, P. L. Pradhan, and B. Panigrahi. 2013. Effect of drip and surface irrigation on yield, water use efficiency and economics of capsicum (c*apsicum annum* L.) grown under mulch and non mulch conditions in Eastern Coastal India. *European Journal of Sustainable Development*, 2 (1): 99–108.

Pescod, M. B. 1992. Wastewater treatment and use in agriculture. In *FAO Irrigation and Drainage Paper*, pp.47. Food and Agriculture Organization of the United Nations.

Salako, F. K., P. O. Dada, J. K. Adesodun, F. A. Olowokere, and I. O. Adekunle. 2007. Variation in soil strength, bulk density and gravel concentration along a toposequence in Abeokuta Southwestern Nigeria. *Australian Journal of Soil Research*, 45(8): 643–650.

Weiss, E. A. 2002. *World Production and Trade*. Wallingford, UK: CABI Publishing, CAB International.