

Effect of effluent from Nile tilapia fish ponds on soil quality, growth and shelf life of *Amaranthus palmeri* seedlings

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Abstract

Soil nutrient management is required to maintain the plant system's constant productivity while also maintaining good soil quality. This study documented the effluent quality, soil quality, growth, shelf life and proximate analysis of *Amaranthus palmeri* as well as the effect of the resulting nutrients on soil properties, growth, and yield. The experiment was set up in a completely randomized block design, with four factors (tilapia effluent, combination of effluent and NPK 15-15-15 fertilizer, only fertilizer and only tap water) each at six replicate per treatment (T1-T6: Tilapia effluent, T7-T12: Tilapia effluent + fertilizer, T13-T18: Only fertilizer and T19-T24: Only tap water) at the University for Development Studies fish farm on the Nyankpala campus. During the experimental period, the growth characteristics such as number of seed emergence, plant height, number of leaves, fresh biomass before and after shelf life and the proximate analysis of *Amaranthus palmeri* were evaluated. The soil properties and effluent nutrient content were measured and compared before and after experiment. Field and laboratory results on growth indices measured, shelf life and proximate analysis of *Amaranthus palmeri*, soil nutrient properties, effluent and tap water nutrient measured were statistically analysed with ANOVA and Duncan Multiple Range Test at ($P < 0.05$). The findings indicate that tilapia effluent significantly influenced all the growth parameters measured compared to other treatment at ($P < 0.05$). Shelf life and proximate analysis were enhanced in tilapia treated plant. Soil quality such as soil pH, percentage nitrogen, available phosphorus and exchangeable potassium concentration was significantly enhanced in the tilapia effluent treatment. The findings therefore suggests that tilapia effluent has the potential to improve soil quality, improve growth and shelf life of *Amaranthus palmeri* as an additional benefit of culturing Nile tilapia.

Introduction

Despite rising demand for *Amaranthus* in Tamale, Ghana, farmers are facing high production costs and soil fertility issues, necessitating increased productivity to compensate for its rising demand (Guerrero et al., 2013; Abdel-Shafy and Mansour, 2018). Soil fertility challenges necessitated long-term management of soil resources in order to increase fertility to levels suitable for vegetable production (Ojobor and Tobih, 2015; Iren et al., 2016). Soils are frequently susceptible to continuous degradation once they are used for cultivation; however, inorganic fertilizers used to mitigate the effects of poor yield are facing a lot of criticism on both the health and environmental fronts (Ndor & Dauda, 2013). Because of the intensification of tilapia fish culture in and around our fresh water system, most Ghanaian fresh water systems have high concentrations of fish culture effluent. Organic fertilizer (Fishpond effluent) has been successfully used to produce vegetables in the past (Ojobor and Tobih, 2015; Iren et al., 2016; Devi et al., 2017), but there is no information on the use of tilapia fish pond effluent on the initial germination, growth and shelf life of *Amaranthus palmeri* seeds and on soil quality. Because its nutrients are released gradually, organic fertilizer can sustain continuous vegetable production (Prein, 2002; Muendo et al., 2014; Urra et al., 2019; Wang et al., 2022). It also has the potential to improve soil organic matter (Iren et al., 2016). Quality soil is essential for long-term and continuous vegetable production (Kleber and Johnson, 2010; Kallenbach and Grandy, 2011). *Amaranthus palmeri* is commonly referred to as "poor

man's spinach," and it is one of the most affordable, widely accepted, and commercially grown leafy vegetables (Wang et al., 2022). It is primarily grown in Tamale and other regions in Ghana. It is a very nutritive crop that is ideal for both kitchen gardening and commercial cultivation. It has the potential to be a very valuable source in the fight against undernutrition and malnutrition. Iron (305 mg/100g), calcium (397 mg/100g), vitamin A (8340mg/100g), and vitamin C (99mg/100 g) are all found in the leaves and succulent stem (Dunsin et al., 2016). Because of its short duration and high yield per unit area, it works well in crop rotations (Wang et al., 2022). Despite these benefits, the vegetable is feared and expensive in the market due to the high cost of production (Anjorin et al., 2021). A lot of effort has been made to improve its production by using a variety of soil improving chemicals, but no permanent and eco-environmentally friendly ways to boost soil fertility have been found. As a result, there is a need to increase fertility to a level that can support the growth and yield of *Amaranthus palmeri* using tilapia fish pond effluent since it can serve as an additional benefit and also reduce the consequences of its discharge into the environment. Proximate analysis of vegetable crops following packaging and storage reveals the importance of the treatment on the nutrient and mineral content of vegetable crops (Ihekoronye & Ngoddy, 1985; Mohammed & Sharif, 2011; Anjorin et al., 2013). According to studies, tilapia fish pond effluent contains a high level of organic matter, nitrogen, phosphorus, potassium, and micronutrients (Jamu and Piedrahita, 2001; Khodaomi et al., 2007). The effluent can be used to fertilize the vegetables as a liquid organic fertilizer (Prein, 2002; Lin and Yi, 2003). Inorganic nutrients in effluent are readily available to plants, whereas organic nutrients are available through microbial decomposition (Muendo et al., 2014). The nutrient in the effluent can be used to an advantage by comparing the additional benefits that can be acquired through its effect on the initial germination of *Amaranthus palmeri* production and shelf life against fertilizer and municipal water. The purpose of this study was to assess the best effect on the initial germination and growth, shelf life response of *Amaranthus palmeri* seed and soil quality improvement through to the use of tilapia fish pond effluent, combination of effluent and fertiliser, only fertiliser and tap water as a possible source of soil fertility booster in Tamale-Northern Region of Ghana.

Materials And Method

1.2.1 Preparation of study site

The research was carried out on the University for Development Studies' campus fish farm between August and November of the 2020 and 2021 crop years. The location is approximately 250 meters from the main library block of the university, with coordinates 90° 24' 49.6" N and 0° 58' 48.1" W. A sandy soil was identified from the University for Development Studies' soil science department and used because it is the most common soil sample used in farming in Northern Region, Ghana and it was confirmed according to USDA classification (Egbuchua, 2007).

1.2.2 Site preparation and experimental design

The study made use of twenty-four plastic containers of size 30cm x 25cm. It had a perforated bottom and was filled with 1 kg of sandy soil. The experiment was set up in a randomized complete block design (RCBD) with six replications per treatment thus tilapia effluents, effluent plus fertilizer, only fertiliser and only tap water. The fish pond effluent (FPE) used as a treatment was obtained from a 60 x 25m circular concrete pond used for tilapia fish production. It was stocked with 50 pieces of tilapia of average size 30 grams in triplicate, and the fish were kept in the same water for 14 days to allow for adequate nutrient accumulation before use. AGRA *Amaranthus palmeri* seed was purchased from AGRA Seed Company in Tamale's open market. Four *Amaranthus palmeri* seeds were sown per hole with a half-inch planting plumine at a 10 x 10 cm spacing between and within rows (Oroka, 2015). Weeds were manually uprooted when it became necessary. The treatments were applied immediately following sowing. During the fertilizer application, each fertilizer treatment group received 20 grams of commercial fertilizer (NPK 15-15-15). Throughout the experimental period, 50 ml of both effluent and tap water were used to water each treatment as required at 4 p.m.

1.2.3 Data collection

1.2.3.1 Plant growth

Plant height, leaf length, and leaf width were measured using a rule, and the total number of leaves was calculated by counting all visible leaves on days 3, 6, 9, and 12. The leaf area (cm²) was calculated using Akoroda's (1993) equation: $LA = 0.9467 + 0.2475 LW + 0.9724 LWN$. Where LA denotes leaf area, L denotes the length of the central leaflet, N denotes the number of leaflets in a leaf, and W denotes the maximum width of the central leaflet. Total plant weight, stem weight, and leaf weight were determined by harvesting and weighing one plant from each replicate per treatment using a weighing scale.

1.2.3.2 Plant shelf life and proximate analysis

Following the conclusion of the experiment, the entire plant from each replicate per treatment was sampled using a sickle, yielding three *Amaranthus* plants per pot. It was then placed on a plastic tray measuring 100mm by 100mm and monitored and observed for three days at room temperature on how each treated *Amaranthus* plant withered. Moisture, ash, crude fat, crude fat and crude fiber were determined in accordance with the official methods of the association of official analytical chemists (AOAC, 1999), at the CSIR - Savanna Agriculture Research Institute (SARI) [CSIR/SARI], Nyankpala near Tamale.

1.2.3.3 Soil sampling and laboratory analysis

Soil samples were taken at 0-30 auger cm depth before and after the treatment application experiment to determine the relevant chemical properties [Soil pH, Nitrogen (N), Phosphorus (P), Potassium (K)] (Albuquerque et al., 2012; Meena et al., 2019) at the CSIR - Savanna Agricultural Research Institute (SARI) [CSIR/SARI].

1.2.3.4 Effluent sampling and laboratory analysis

Effluent from Nile tilapia, *Oreochromis niloticus* cultured tanks was collected using a sampling bottle provided by the Council for Scientific and Industrial Research (CSIR) - Water Research Institute (WRI) laboratory in Tamale. Through the outlet of the cultured tanks, effluent samples were collected and immediately transported to the Council for Scientific and Industrial Research (CSIR) - Water Research Institute (WRI), laboratory Tamale, for Nitrate, Nitrogen, Potassium, and Phosphorus analysis.

1.2.4 Data analysis

The data was analyzed using analysis of variance (ANOVA), and differences in mean were tested using Duncan's Multiple Range Test (DMRT) at a 5% level of probability.

Results

1.3.1 Number of seed germinating at day 3 and 6

Figure 1 shows the effect of treatment ability on the number of seed emergence of *Amaranthus* at days 3 and 6. At days 3 and 6, there was a clear decreasing trend in seed emergence, with the tilapia effluent treatment exhibiting the highest number of seeds emerging, which was significantly superior to the other treatments ($P < 0.05$), and the tap water treatment recording the least. It's worth noting that tilapia effluent increased the total number of seedlings that emerged at the end of the experiment (figure 1).

1.3.2 Total number of leaves at day 3, 6, 9 and 12

The number of leaves gradually increased as the days progressed on the third, sixth, ninth, and twelfth days (Figure 2). The total number of leaves increased from 5 to 18 on days 3 and 12, then decreased gradually. It was discovered that the tilapia effluent group had significantly higher in number of leaves emerging per sampling day ($P < 0.05$) than the other groups, whereas the tap water treated plant group had significantly lower levels of leaves emerging.

1.3.3 Mean plant weight, stem weight and leaf weight after day 12 after germination

Figure 3 depicts the mean plant weight (PW), stem weight (SW), and leaf weight (LW) of the experimental seed at the 12th day.

At the end of the study, the tilapia effluent treated group had a significantly higher final weight increase in total plant weight, stem weight, and leaf weight than the TE/FERT, Fert., and Tap water treated plants. Overall, tap water-treated plants had significantly lower weight measurements (plant weight, stem weight, and leaf weight) than the other treated plant groups.

1.3.4 Average plant height at day 6 and 12 after germination

Figure 4 depicts the average plant height on days 6 and 12. It was discovered that plants treated with tilapia effluent had the highest plant height on both days 6 and 12 and were significantly superior to the other groups ($P < 0.05$). Similarly, despite a decreasing trend in plant height, the TE, TE/FERT, FERT, and TAP treated plant groups and it was significantly the same ($P < 0.05$) between the TE/FERT, FERT, and Tap water treated groups on days 6 and 12.

1.3.5 Leaf area index of *Amaranthus palmeri*

As the number of sampling days increased, so did the leaf area. In comparison to other treated groups, the tilapia effluent treated group increased significantly in the leaf area index as sampling days increased ($P < 0.05$). The other treated group showed a reverse decreasing trend as the number of days increased, with the tap water treated group having the lowest leaf area index.

Table 1: Leaf area of *Amaranthus* plant (cm²) as affected by different germination treatment

Treatment	Day 3	Day 6	Day 9	Day 12
T/E	18a	58a	67a	79a
T/E + FERT	12b	44b	63b	71b
FERT only	26c	37c	56c	68c
Tap	18c	29c	48d	54d
Standard Error	4.33	7.96	9.77	13.65

Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water

Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water

Note: Treatment with the same alphabet per sampling days are not statistically different

1.3.6 Average final weight of plants following shelf life at room temperature

The average weight of treated germinated *Amaranthus* plants at room temperature after shelf life is shown in table 1. When compared to other groups, the average weight of tilapia effluent germinated plant had a significantly higher shelf life weight after day 3 ($P < 0.05$). It was observed that the combination of tilapia effluent and fertilizer resulted in a decreasing trend in plant weight, which was also superior when compared to fertilizer and tap water germinated plants. Tap water germinated *Amaranthus* plants had the lowest plant weight following shelf life. In comparison to the other treated groups, the tilapia effluent germinated plant retained its fresh appearance, succulent, and deep green color.

Table 2 Average final weight of *Amaranthus* plants after shelf life

Treatment (Per pot)	Final average weight after shelf life(g)
T1	5.32a
T2	4.89a
T3	4.96a
T4	5.01a
T5	4.88a
T6	5.11a
T7	4.77b
T8	4.65b
T9	4.47b
T10	3.98b
T11	4.42b
T12	4.39b
T13	3.66c
T14	3.29c
T15	3.91c
T16	3.22c
T17	3.52c
T18	3.11c
T19	2.98c
T20	2.86c
T21	2.61c
T22	2.79c
T23	2.94c
T24	2.85c
TREATMENT	Standard Error (S.E)
T1-T6; Tilapia effluent	0.84
T7-T12; Tilapia effluent + Fertiliser	0.98
T13-T18; Only fertilizer	0.88

T1-T6 is TE treatment, T7-T12 is TE/FERT treatment, T13-T18 is FERT treated group, T19-T24 is TAP water treated group. Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water

Note: Treatment with the same alphabet per sampling time are not statistically different

1.3.7 Proximate analysis of *Amaranthus palmeri* after shelf life exposure

Proximate percentage analysis of the various treatment on the *Amaranthus palmeri* plant after shelf life exposure is presented in table 3. Of all the tested parameters for the analysis, thus moisture content, ash content, fat content, crude protein, crude fiber and carbohydrate were significantly enhanced in the tilapia effluent treated crop ($P < 0.05$). No statistical difference existed between the treatment (combination of tilapia effluent + fertiliser and only fertiliser) at $P < 0.05$.

1.3.8 Samples of soil properties analysed before and after the experiment

Table 3 and 4 shows the soil properties before and after the experimental period. It was observed that all the properties of the soil had the same soil pH (3.76 ± 0.47), percentage nitrogen (0.3 ± 0.01), available phosphorus (5.14 ± 0.61) and available potassium (58 ± 1.97). However, a significant increase was noticed after the experiment within the different application of germination treatment to *Amaranthus* seed. Soil properties were seen increasing significantly in the tilapia effluent treated group recording the highest mean values in all the soil properties measured which were in the range of soil pH (7.63 ± 1.01), percentage nitrogen (1.9 ± 0.21), available phosphorus (13.41 ± 1.10) and available potassium (82 ± 2.39) respectively at ($P < 0.05$).

1.3.9 Tilapia effluent and tap water nutrients analysis

Table 5 shows the results of effluent and tap water on the nutrient levels found in them.

The levels of phosphorus, nitrogen and potassium in the samples were significantly higher in the tilapia effluent than in the tap water. All of the tested soil nutrient parameters in tilapia effluent were significantly higher than in tap water ($P < 0.05$).

Discussion

The application of tilapia fish pond effluent significantly increased the number of seedlings emerging, total number of leaves, whole plant weight, stem weight, leaf weight, and leaf area measured over the other treatments according to the results of the study. This could be because the nutrient content of the fish pond effluent used as a treatment is high (Utof et al., 2016; Sadat et al., 2017). The increased number of seedlings, leaves, whole plant weight, stem weight, leaf weight, and leaf area in the tilapia-treated pots could be attributed to the high levels of N, P, and K released by the treatments, which maintained optimal soil conditions for *Amaranthus palmeri* growth (Iren et al., 2016; Opiyo et al., 2018). The study found that

as the days of various treatment application increases, more especially, tilapia fish pond effluent, so did the number of leaves, leaf area, and yield indices of *Amaranthus palmeri* increased. Increase in levels of effluent nutrient release may promote faster vegetative growth (Ndor et al., 2013; Manwani et al., 2022). The lower number of leaves, leaf area, and yield indices in the other treatment could be linked to the low nutrient level sufficiently needed to improve the vegetable's growth. The increase suggests that crop availability of soil nutrients is a major factor in photosynthesis (Oroka, 2015). The higher growth rate and yield indices observed with the application of tilapia fish pond effluent also suggest that, *Amaranthus palmeri* can produce optimally well when nutrients are available, i.e. when soil fertility is optimal. Fish pond effluent contains nutrients that are required for photosynthesis and dry matter production, as well as improvements in soil properties (Asaolu et al., 2012; Ojobor and Tobih, 2015).

Soil nutrient management and amendment are critical for preserving biomass and dry matter vegetable production while also maintaining soil quality (Ojobor and Tobih, 2015).

Vegetable storage and packaging knowledge is essential for achieving a long shelf life for the vegetable after cultivation (Iren et al., 2016). Water activity and moisture content are important indicators of vegetable shelf life and freshness (Mohammed & Sharif, 2011). Furthermore, significant differences in weight and moisture contents after shelf life of the tilapia effluent over the other treatments demonstrated the best effect in terms of plant freshness and weight after shelf life, implying the ability of the tilapia effluent to preserve and increase the water and moisture content found in the *Amaranthus palmeri* by maintaining the qualities mentioned above that reflect on the freshness, weight, and succulence (Bigdeloo et al., 2021). As a result, growing *Amaranthus palmeri* with tilapia effluent adds additional benefits by extending shelf life, lifespan, and quality for good and acceptable market performance (Erkmen and Bozoglu, 2016).

According to the results, the proximate analysis (percent) of the *Amaranthus palmeri* after shelflife exposure significantly increased the percentage of moisture content, ash content, fat content, crude protein, crude fiber, and carbohydrate compared to other treatments. Because of the high moisture content, water-soluble enzymes and co-enzymes required for metabolic activities in leafy vegetables are more active (Iheanacho and Udebuani, 2009). Increase in the afore mentioned proximate parameters of *Amaranthus palmeri* confirms that there are more minerals in *Amaranthus palmeri* (Udosen, 1995; Iheanacho & Udebuani, 2009). Furthermore, plant foods that contain more than 12% protein by calorific value have been shown to be a good source of protein (Ali, 2009). This demonstrates that tilapia effluent germinated. *Amaranthus palmeri* is an excellent candidate for protein enhancement (Isong & Idiong, 1997) in addition to dietary fiber which aids in the prevention of constipation, bowel problems, and piles.

The preliminary chemical properties of the experimental soil samples revealed that the soil was deficient in N, P, and K. The values were below the FMARD (2012) critical level for crop production in the ecological zone. The results showed that the contents of the three important elements could not support crop production, necessitating soil amendment, which is typically organic, such as fish pond effluent. Nutrient elements are required for growth and the formation of leaves. As shown in the results, the tilapia fish

pond effluent increased soil pH, and the ability to increase soil pH could be due to the presence of some basic cations. According to Ojobor and Tobih (2015), fish pond effluent contains exchangeable Ca, Mg, and K, which can increase soil pH when released. This could be responsible for the increased soil pH in tilapia effluent treated pots. In addition, the fish pond effluent increased the percentage of nitrogen, available phosphorus, and exchangeable potassium. As a result, using tilapia effluent as waste will no more be a burden to environmental health issues but could be effective in improving growth and shelf life of *Amaranthus palmeri* and other leafy vegetables as well as the ability to improve and amend the chemical properties of soil quality. According to Ojobor and Tobih (2015), fish pond effluent can increase both micro and macronutrients in soil.

Conclusion

The study evaluated the effects of tilapia effluent, a combination of tilapia effluent and fertiliser, only fertiliser, and only tap water on the germination and shelf life of *Amaranthus palmeri* seed, as well as the effect on soil quality. Following the application of the effluent, all of the tested growth indices, soil quality parameters, and effluent nutrient variables showed a significantly positive effect. In general, the order of significant difference in application of treatment on tested variables were in the following order: tilapia effluent > combination of tilapia effluent and fertiliser > only fertiliser > only tap water on the overall germination and shelf life of *Amaranthus palmeri* seed and its effect on soil quality. The effluent could be used as soil amendment alternative for inorganic fertiliser as an additional benefit of farming tilapia as it improves the chemical properties and increase growth and yield of *Amaranthus palmeri*.

Declarations

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Competing and Interest

Authors have declared no conflict of interest for this research.

Authors contribution

All authors contributed to the study conception and design including materials and methods, data collection and analysis, and the write up of the manuscript.

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Tables

Table 3-6 are available in the Supplemental Files section.

Figures

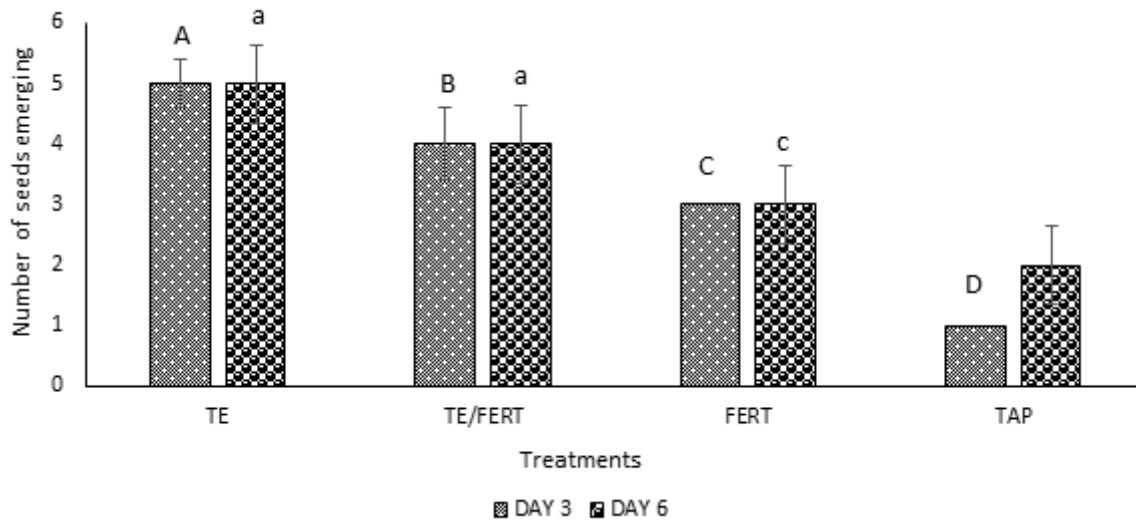


Figure 1

Number of seed emerging at day 3 and 6 for TE, TE/FERT, FERT and TAP treatments

Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water.

Note: Bars with the same alphabet per sampling time are not statistically different

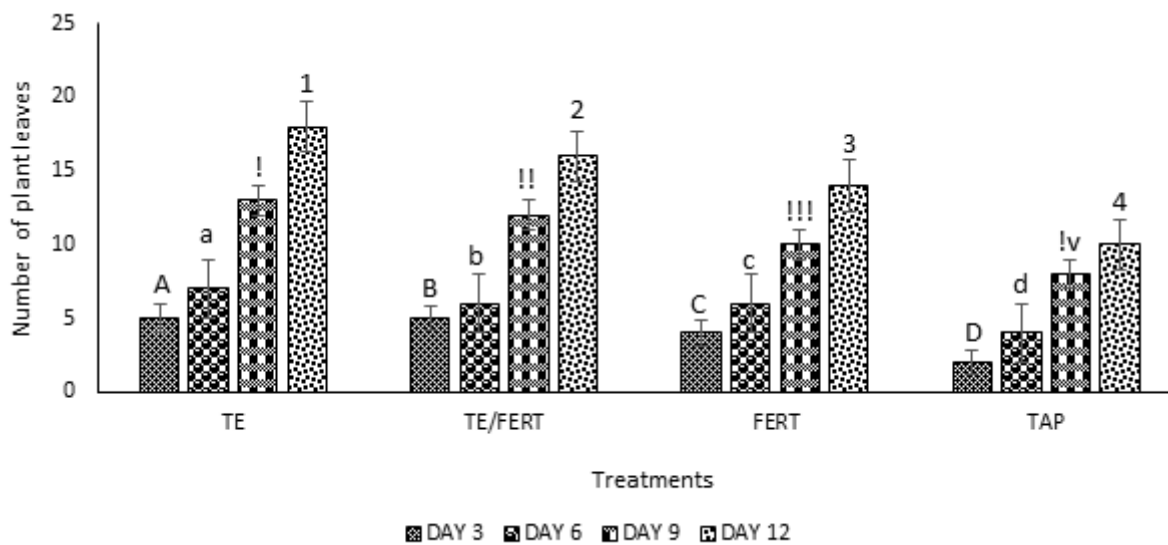


Figure 2

Number of *Amaranthus* plant leaves at day 3, 6, 9 and 12 for TE, TE/FERT, FERT and TAP groups.

Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water

Note: Bars with the same alphabet, numbers and punctuation mark per sampling time are not statistically different

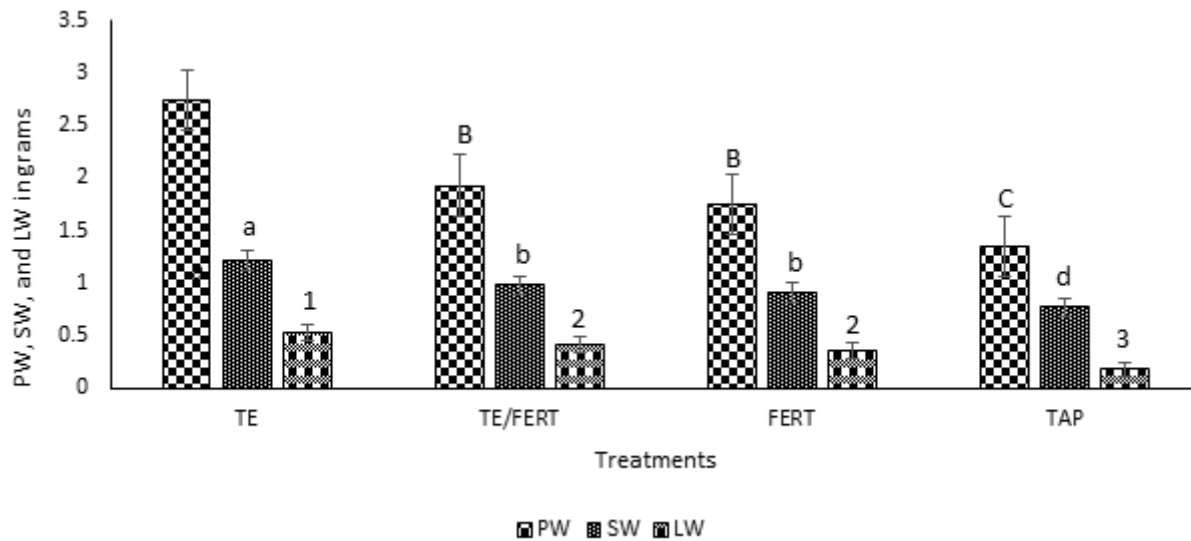


Figure 3

Plant weight (PW), stem weight (SW) and leaf weight (LW) at the 12th day for TE, TE/FERT, FERT and TAP treatments

Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water

Note: Bars with the same alphabet and numbers per sampling time are not statistically different

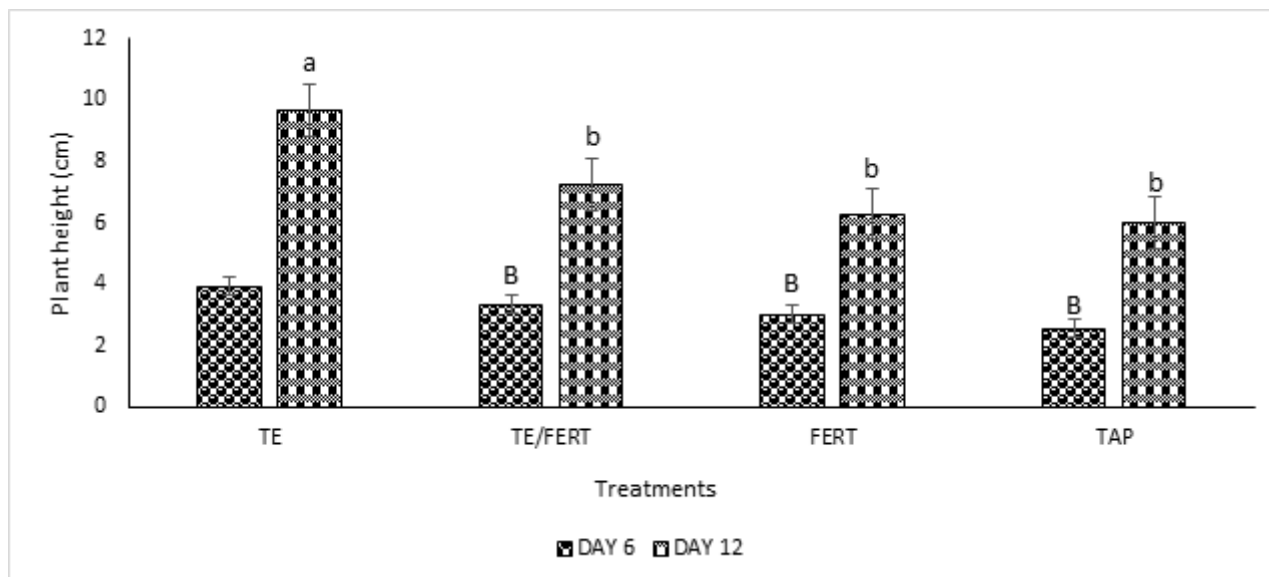


Figure 4

Plant height (PH) at the 6th and 12th day for TE, TE/FERT, FERT and TAP group

Where TE is tilapia effluent, FERT is fertilizer, TAP is tap water

Note: Bars with the same alphabet per sampling days are not statistically different

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table36.docx](#)