



The Effect of Soil Amendments (Poultry Manure, Biochar and Enzymes) and Bio Stimulant (Calcifet Foliar Fertilizer) on the Yield and Quality of *Talinum Triangulare* Leaves

Isaac Charles Amoako^{1*}, Newton Amaglo², Umar Saeed Baba³, Ebenezer Ntiri⁴ and Emmanuel Bafiile⁴

¹Senior Agriculture, Officer, Department of Agriculture, New Juaben South Municipal, Ghana

²Senior Lecturer, Department of Horticulture, Faculty of Agriculture, College of Agriculture and Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

³Senior Technical Officer, Cocoa Health and Extension Division, Ghana Cocoa Board, Ghana

⁴Teaching Assistants, Department of Horticulture, Faculty of Agriculture, College of Agriculture and Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

***Corresponding Author:** Isaac Charles Amoako, Senior Agriculture Officer, Department of Agriculture, New Juaben South Municipal, Ghana.

Received: September 01, 2025

Published: October 15, 2025

© All rights are reserved by

Isaac Charles Amoako., *et al.*

Abstract

Waterleaf (*Talinum triangulare*) is known for its high antioxidant content and potential health benefits. This study was conducted at the Horticulture Department of the Kwame Nkrumah University of Science and Technology to evaluate the effects of soil amendments (Poultry manure, Biochar and Enzymes) along with bio-stimulants (Calcifet Foliar Fertilizer) on the growth and leaf yield and quality waterleaf. A Randomize Complete Block Design with four (4) treatments and three (3) replicates was employed. The variables studied include leaf yield, proximate composition, and mineral content. Results showed that Poultry manure, Biochar, and Calcifet application significantly increased biomass with a higher non-edible portion. Protein content in waterleaf treated with poultry manure, Biochar, Calcifet, and Enzymes, reached 20.94%, with a maximum moisture level of 94.3%. The study revealed that combining poultry manure, Biochar, Calcifet, and Enzyme significantly ($P \leq 0.01$) enhanced mineral leaf quality, with the highest zinc and total copper content of 225.52 mg/kg and 35.83 mg/kg, respectively. Waterleaf had the highest magnesium content in the control (0.79%). Furthermore, Poultry manure, Biochar, and Calcifet produced the highest levels of phosphorus (0.34%), potassium (3.07%), iron (220.48 mg/kg), and calcium (3.2%). The findings indicated that Poultry manure, Biochar, and Calcifet had the highest yield and mineral quality while the inclusion of enzymes improved proximate composition.

Keywords: Soil Amendment; Green Leafy Vegetables; Leaf Quality; Biostimulants

Introduction

How could humans have survived if nature had never provided us with any type of vegetation, such as vegetables, plants, or trees? Could there have been any other options? [1]. According to Bechthold., *et al.* [2], vegetables and fruit are essential for human nutrition as well as illness prevention as sources of nutrients and non-nutritive dietary ingredients. Vegetables provide vitamins, minerals, essential amino acids, and antioxidants [3,4]. According to Taha., *et al.*, [5], the vitamins, minerals, phytochemicals, and dietary fibre found in vegetables make them essential for human health. Dietary fibre, antioxidant and vitamins (vitamins A, C, and E) are crucial for maintaining good health in people. Foods contain a wide range of bioactive chemicals that are chemically varied [6,7]. Vitamins, Fibers, Minerals, phenolic compounds such as flavonoids, phytoestrogens, monoterpenes, sulfur compounds, and bioactive peptides are all nutritionally important components of fruits and vegetables. Consuming vegetables can lower risk factors for chronic illnesses including diabetes, obesity, metabolic syndrome, and cardiovascular disease. Vegetables can also protect against chronic diseases like cancer and diabetes [5].

Increased consumption of fruits and vegetables, which are high in nutrients, has been scientifically proven to prevent several chronic illnesses [8,9]. A critical evaluation of the literature was done by Boeing., *et al.* [10] to determine the impact of fruit and vegetable consumption on the prevention of chronic diseases.

It is well established that a diet rich in fruits and vegetables supports overall human health, particularly in managing weight gain [11,12]. Many organizations consider fruit and vegetable intake to be a major public health concern, including the World Health Organization (WHO), Food and Agriculture Organization (FAO), United States Department of Agriculture (USDA), and the European Food Safety Authority (EFSA). As a result, it is the focal point of global dietary guidelines [13,14]. In fact, the 2016 Dietary Guidelines for Americans recommend that we include fruits and vegetables in half of our meals. Because of the health advantages that fruits and vegetables offer, many public health initiatives encourage individuals to consume more of them [15,16].

Also, eating vegetables and fruits helps meet fiber requirements while providing fewer calories compared to processed meals [17].

More than 8000 chemicals have been identified in fruits and vegetables and classified into five major types based on their chemical composition: stilbenes, flavonoids, lignans, phenolic acids, and curcuminoids [18]. Plant products high in polyphenols have gotten a lot of attention in recent years due to their vast therapeutic properties, which comprise hypoglycemic, antioxidant, anti-inflammatory and hypolipidemic characteristics [19-21].

The researchers examined the impact of eating fruits and vegetables on the following diseases: type 2 diabetes mellitus, obesity, coronary heart disease, hypertension, cerebrovascular accident (stroke), different malignancies, dementia, chronic obstructive pulmonary disease, asthma, rheumatoid arthritis, osteoporosis, eye illnesses, chronic inflammatory bowel disease.

A greater fruit and vegetable diet, according to Boeing., *et al.* [10], lowers the risk of hypertension, stroke and coronary heart disease. They discovered that eating more fruits and vegetables lowers the chance of developing certain malignancies. They also observed that consuming more fruits and vegetables helps reduce weight gain, which may lessen the incidence of type 2 diabetes mellitus.

There is "potential evidence" that increasing fruits and vegetables diet lowers the threat of chronic obstructive pulmonary disease, rheumatoid arthritis, asthma, osteoporosis, some eye disorders, and dementia, according to Boeing., *et al.* [10].

Obesity, cardiovascular disease (CVD), diabetes, chronic kidney disease (CKD), inflammatory bowel disease, osteoporosis, sarcopenia, and neurodegenerative diseases such as Huntington's disease (HD), rheumatoid arthritis (RA), chronic lung diseases, and many cancers are the leading causes of long-term disability and death worldwide [22].

Chronic conditions are remarkably individual, national and global health issues, influencing both morbidity and mortality. They are the leading causes of disease burden globally, accounting for roughly 70% of all deaths [23].

The statistic becomes even more worrying, according to Boeing., *et al.* [10], when considering the most recent epidemiological predictions, which anticipate that by 2030, they would account for 80% of all diseases globally.

Reduced consumption of fruit, nuts, seeds and vegetables reduced consumption of whole grains were the main dietary contributing factors to deaths, according to Boeing, *et al.* [10].

According to residents and scientists worldwide, there has been a spike in interest in the consumption of natural plant parts (vegetables) in recent years, among which locally accessible medicinal vegetables cannot be disregarded.

The move to a "Western" diet is marked by an increase in sugar, calories, animal proteins, and saturated fat, as well as a decrease in fruit, vegetable, and fiber consumption. This change in eating habits is associated with a rise in physical inactivity. These variables all contribute to an increase in the prevalence and incidence of non-communicable degenerative illnesses as obesity, diabetes, cardiovascular disease, and so on [24]. These chronic diseases appear to be connected to the development of an unhealthy digestive system microbiome [25].

Consumption of high-energy foods, such as processed meals high in fats and sugars, has been shown to increase obesity when compared to low-energy foods such as fruits and vegetables [26].

It is critical to use neglected indigenous vegetables such as waterleaf, which are rich sources of micronutrients required by the human body, to reduce economic dependency and chronic and degenerative diseases [27].

Vegetables are herbaceous plants whose parts are used as a side dish or main course. They can have aromatic, bitter, or mild flavors [28]. They provide a low-cholesterol, low-saturated-fat, and low-dry-matter form of food that is frequently consumed alongside starchy foods to enhance palatability. Because of their high antioxidant content, vegetables have been proven to be not only extremely nutritious but also preventive against chronic and degenerative illnesses. Vegetables have therapeutic value because they help to neutralize stomach acidity and promote digestion. They are also good suppliers of crude fibers, and hence good laxatives.

Waterleaf (*Talinum triangulare*) is one of these important yet underutilized green crops, according to globalfoodbook.com [1], most ailments and nutritional deficits could be significantly reduced if everyone worldwide, particularly in Ghana, made this vegetable a priority in their diet.

Talinum triangulare is known as "waterleaf" (family: Portulacaceae). It is a leafy vegetable that is commonly grown as an annual, herbaceous, coalescent, and glabrous plant in tropical regions [29].

Talinum triangulare is an upright plant standing 0.3-1 m tall with spherical near-tip leaves that taper to a wedge shape at the base (3-15 cm long and 1-6 cm wide). A corymboid thyrse flower cluster grows on the inflorescence stem, which has a triangular cross-section. It produces dry, dehiscent fruit capsules that range in shape from elliptical to globular; with 2-3 compartments storing tiny seeds. The leaves can be picked for eating at 2-week intervals from 40-55 days after sowing to 6 months after seeding.

A leaf and root extract are used to treat asthma [30]. "Waterleaf consumption has favourable effects on cerebrum neurons and may likely increase cognitive performance in Swiss albino mice," write [31]. In Edo State, Nigeria, *Talinum triangulare* is used as a diuretic and to treat gastrointestinal problems [32]. It is used to treat hypertension, scabies, fresh wounds, Shistosomiasis, and anemia [33].

The leaves or roots of *Talinum triangulare* are used as diuretics in gastrointestinal illnesses, either alone or in combination with other medicinal herbs, according to Mensah, *et al.* (2008) [32]. The leaves are also used to treat oedema, dropsy, swellings and scabies, according to Ogunlesi, *et al.* [33] documented how the roots were used to make rat poison.

According to research conducted by Mensah, *et al.* [32], a vegetable consumption can be increased by adding them to good and appealing meals.

The most widely produced vegetables in Ghana are shallots (*Allium esculonicum*), tomato (*Lycopersicon esculentum*), eggplant (*Solanum melongena*), okra (*Hibiscus esculentus*), onion (*Allium sativum*), local spinach (*Amaranthus* spp.), Indian or Gambian spinach (*Basella alba*), sweet and chili pepper (*Capsicum annum*), among many others.

This study aims to investigate the effects of different soil amendments and bio stimulants on the leaf yield, proximate composition, and mineral content of *Talinum triangulare*.

Materials and Methods

Location of experimental site

The research was conducted at the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST), located about eight miles (13 km) to the east of Kumasi, the Ashanti Regional Capital (06°41'5.67"N, 01°34'13.87"W), from June 4th, 2022, to August 10th, 2022.

Climate

The experimental site's rainfall pattern is bimodal, with an average annual rainfall of 1500 mm; the main rainy season starts from mid-March to July, with a relatively short dry period in August. Minor rainy season starts from September to November and the main dry season starts from late November to early March (Meteorological Department, KNUST, 2012).

Experimental materials

The following materials were used in the study: a hoe, rake, spade, a 50-meter tape measure, seeds of *Talinum triangulare*, a weighing scale, a lorry tire, A4-size brown envelope, a knife, a big black polyethene bag, a 5-meter measuring tape, a water hose, a bucket, rope, an oven, poultry manure, Biochar, eco enzyme CPC, and Calcifet liquid organic fertilizer.

Planting material sources

Seeds of *Talinum triangulare* were obtained from the wild around a farmer's field at New Tafo in the Eastern Region of Ghana. No seed treatment was done. Seeds were nursed at the Department of horticulture on a seedbed made with a lorry tire. It took 13–15 days for *Talinum triangulare* seeds to germinate.

Irrigation

Rainwater and tap water from the Department were used for irrigation and partial rainfall, respectively.

Field preparation and layout

The field was levelled with a hoe, rake, and shovel. The field was demarcated into 12 plots of equal size (0.8 m (80 cm) by 0.8 m) using a 50m rule, giving a total area of 0.64 m² (6400 cm²).

Statistical analysis

The experiment was designed using the Randomized Complete Block Design (RCBD). Three (3) treatments (Poultry manure, Calcifet foliar fertilizer, enzyme, and Biochar) were imposed, and each treatment was replicated three (3) times.

Treatment number	Treatments
Control	No application
T1	Poultry manure + Biochar
T2	Poultry manure + Biochar and Calcifet
T3	Poultry manure + Biochar, Enzyme and Calcifet

Table 1: Treatment number and the treatments to be used in the experiment.

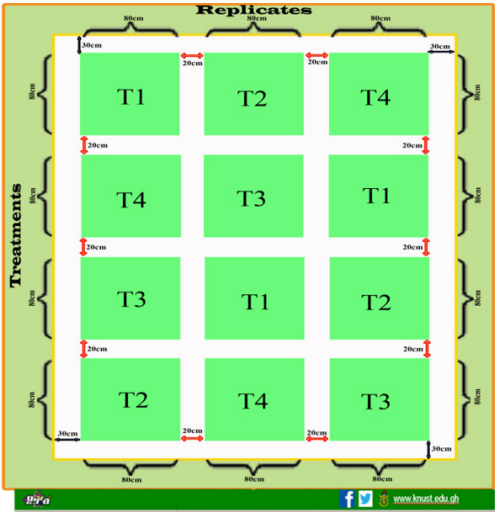


Plate 1: Field layout.



Plate 2: Experimental site showing seedlings of *Talinum triangulare*.



Plate 3: Experimental site showing growing *Talinum triangulare*.

Planting distance

Both intercrop and intra-crop distances were 20 cm by 20 cm for square planting. Between the plots was a walkway of 20 cm. A border of 30 cm was created. Plants were planted around the border to protect the crops from being attacked by insect pests.

Transplanting

Seeds of *Talinum triangulare* were nursed on a raised nursery bed in a lorry tire. Due to the small size of seeds, the broadcasting method of sowing was employed. Seedlings of the *Talinum triangulare* were transplanted in their respective plots in each replication randomly.

Seedlings were transplanted three (3) weeks later after sowing onto the experimental field which had been lined and pegged using a planting distance of 20cm by 20cm between and within plants.

Cultural practices

The nursery area was cleared, a nursery bed was prepared, and seeds were scattered on it.

Various treatments were applied to the plots for three (3) weeks before transplanting. Weeds were controlled by the use of a hoe. Mulching was done 7 days (one week) before transplanting to limit evapotranspiration, control weed spread and also create a conducive microclimate for the plant's optimum growth.

Data collection

The leaves yield

- Weight of fresh leaves (g)

- Weight of dry leaves (g)
- Fresh stem weight (g)
- Dry stem weight (g)
- Biomass Total (g)

The proximate content

- Fat content (%)
- Crude fibre (%)
- Moisture content (%)
- Ash content (%)
- Protein (%)
- Carbohydrate (%)

Mineral parameters content

- Zinc (mg/kg)
- Potassium (%)
- Phosphorus (mg/kg)
- Magnesium (%)
- Iron (mg/kg)
- Copper (mg/kg)
- Calcium (%)

Data analysis

Six plants were randomly selected from each plot in each replication as samples for data collection. Harvested leaves, biomass, and stems were measured and oven dried for three days before mineralization and proximate analysis were made.

The data was compiled in Microsoft Excel 2019 and analyzed using the statistical software GenStat Release 12.1. A 5% least significant difference (LSD) ($P = 0.05$) separated the differences in treatment averages. Microsoft Word 2019 was used to draw all the tables, and Microsoft Excel 2019 was also used to draw all the Figures.

Results and Discussion

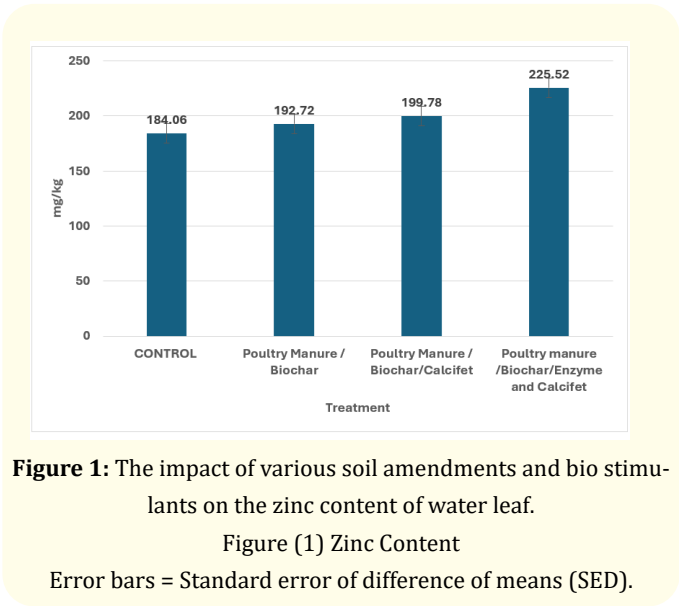
Influence on soil amendments and bio stimulant on leaf colour of waterleaf

Observably, there were notable differences in the colour of water leaf, as the control appeared more yellowish compared to the other soil amendments and bio stimulants.

CONTROL			
Poultry Ma-nure/Biochar			
Poultry Ma-nure/Biochar/ Cal Cifet			
Poultry ma-nure/Biochar/ Enzyme and Calcifet			

Table 2: Treatments effect on leaf colour.

The influence of various soil amendments and bio stimulants on the mineral quality of waterleaf



From Figure 1, the influence of different soil amendments and bio stimulants caused a significant difference ($p < 0.05$) in the zinc content of water leaf. Furthermore, comparing the control to the best-performing treatment (T3), there was an increase of 41.46 mg/kg. Treatment 1 and Treatment 2 showed a significant difference when compared to the control, which had a marginal increase of 8.66 mg/kg and 15.72 mg/kg, respectively.

Always choose one method for presenting the Data: either a table or a chart.

Measuring the potassium content of water leaf as affected by bio stimulant and different soil amendments, there was a significant statistical difference as control recorded the lowest potassium content of 2.28%, followed by treatment 3, 1, and 2.

Figure 3 showed the different levels of magnesium as affected by different soil amendments and bio stimulants. Treatment 3

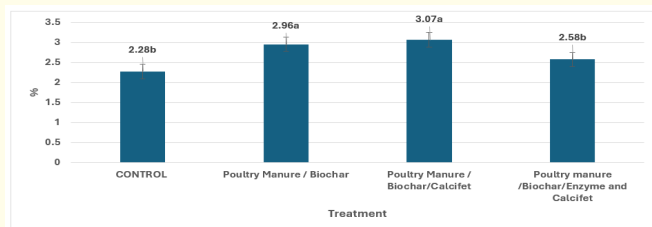


Figure 2: The impact of soil amendments and bio stimulants on the potassium content of water leaf.

Figure (2) Potassium Content

Error bars = Standard error of difference of means (SED).

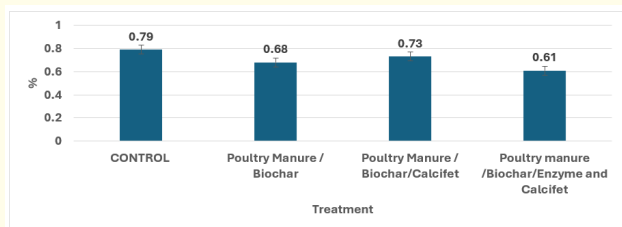


Figure 3: Outcome of different soil amendments and bio stimulant on magnesium content of waterleaf.

Figure (3) Magnesium Content

Standard error of difference of means (SED) = error bars.

showed a reduced effect on the magnesium content of water leaf by 0.6%. Marginally, treatment 3 reduced the content of magnesium by 0.18%.

With an alpha level of 0.05, there was negligible difference in water leaf plants treated with different bio stimulants and soil amendments, as the control had the lowest phosphorus content of 0.27. Furthermore, the treatment applied also had no effect on the phosphorus content of water leaf, as treatment 2 recorded the highest value of 0.32. Numerically, the phosphorus content was increased by 7% (T2).

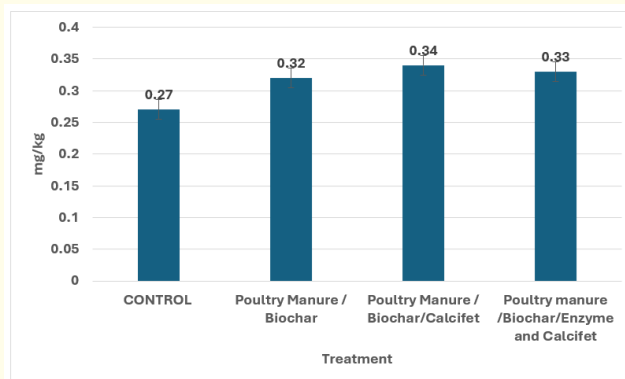


Figure 4: Impact of different soil amendments and bio stimulant on phosphorus content of water leaf.

Figure (4) Phosphorus Content

Error bars = Standard error of difference of means (SED).

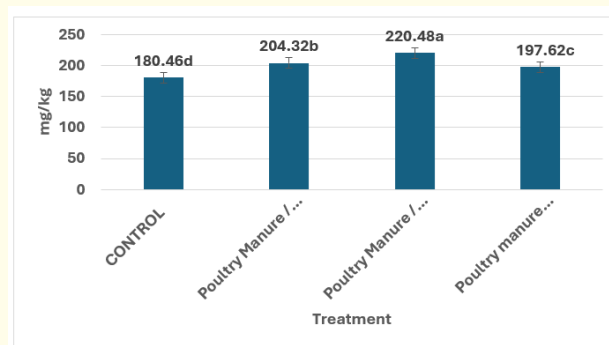


Figure 5: Impact of different soil amendments and bio stimulant on iron content of water leaf.

Figure (5) Iron Content

Error bars = Standard error of difference of means (SED).

As iron is needed by the body to produce hemoglobin, a significant amount was produced by T2 (220.48 mg/kg). Additionally, T2 caused a marginal difference of 40.02 mg/kg when evaluated by comparing to the experiment's control.

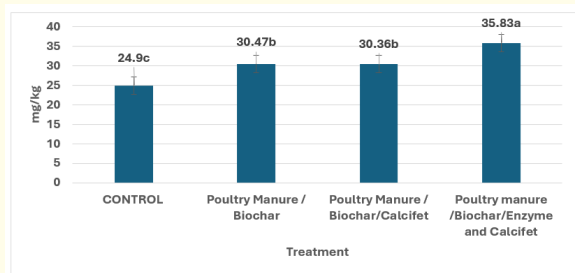


Figure 6: Impact of different soil amendments and bio stimulant on copper content of waterleaf.

Figure (6) Cupper Content

Error bars = Standard error of difference of means (SED).

There was a substantial difference in the copper content of waterleaf, as the control recorded 24.9 mg/kg and the highest copper content was shown by T3. Observably, T3 had 44% increase in the copper content of waterleaf.

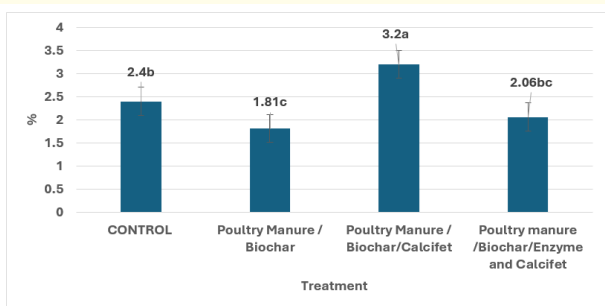


Figure 7: Influence of different soil amendments and bio stimulant on calcium content of water leaf.

Figure (7) Calcium Contents

Error bars = Standard error of difference of means (SED).

The results demonstrated significant difference between the control of the experiment and T2 with 33% increase in calcium content of waterleaf. Additionally, T3 was statistically indifferent when compared to both the control of the experiment and treatment 1 as T3 recorded a mean percent of 2.06. Observably, there was a negative effect on the calcium content of waterleaf when T1 was applied reducing with a percentage of 32.6%.

Influence of different soil amendments and bio stimulant on the proximate quality of waterleaf

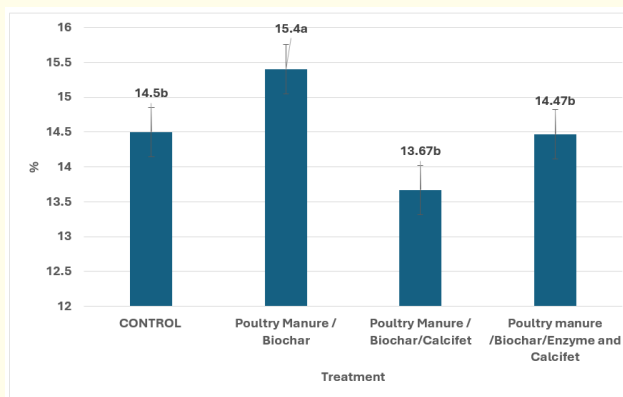


Figure 8: Impact of different soil amendments and bio stimulant on ash content of waterleaf.

Figure (8) Total Ash Content

Error bars = Standard error of difference of means (SED).

Statistically, there was no substantial difference amongst T3, T1, and the control, as the lowest value of 13.67 was recorded by T2. With a percentage increase of 6.2, treatment 2 was substantially different in comparing to the control and the other applied treatments.

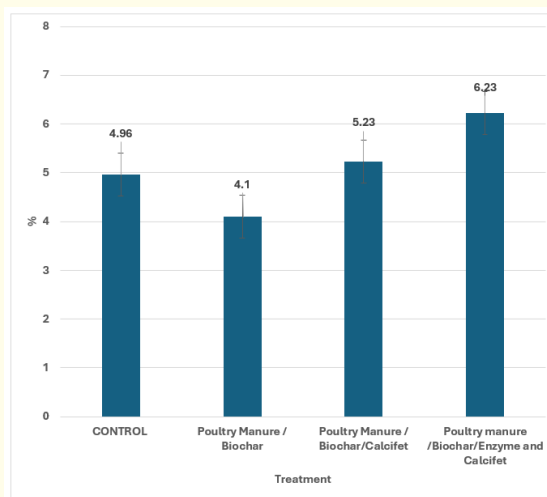


Figure 9: Impact of different soil amendments and bio stimulant on fat content of waterleaf.

Figure (9) Fat Content

Error bars = Standard error of difference of means (SED).

As stated by Figure 9 above, there was a 25.6 percentage increase in the fat content of water leaf treated with different soil amendments and enzyme under treatment 3. Also, T3 was significantly different from all the other treatment and the control of the experiment. Subsequently, treatment 2 had a negative effect on the fat content of water leaf as it recorded 4.1 percentage mean.

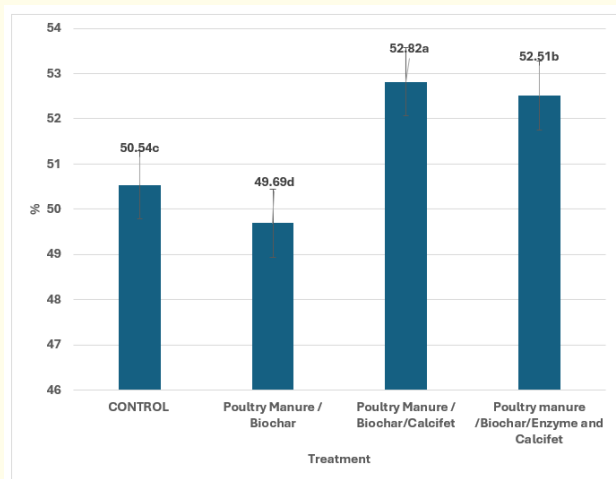


Figure 10: Impact of different soil amendments and bio stimulant on crude fibre content of waterleaf.
Figure (10) Crude Fibre Content
Error bars = Standard error of difference of means (SED).

Soil amendment consisting of poultry manure and Biochar was used to produce water leaf under treatment condition 1, which had a negative impact on the leaf's crude fiber content, which was 49.69. The best-performing treatments were treatments 2 and 3, which recorded mean values of 52.82 and 52.51 percentage points for crude fiber content, respectively. Also, treatment 2 caused a 4.51% increase in the crude fiber content, as 50.54 was recorded by the control of the experiment.

Using bio stimulants and soil amendments to provide optimum conditions for water leaf growth, there was a 32% increase in the protein content of water leaf. Treatment 3 was significantly different from treatment 1 and the control of the experiment.

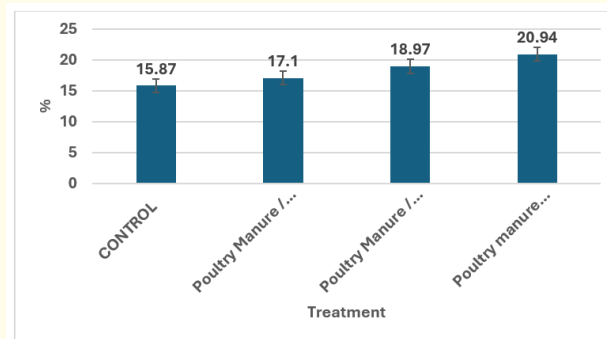


Figure 11: Effect of different soil amendments and bio stimulant on protein content of waterleaf.
Figure (11) Protein Content
Error bars = Standard error of difference of means (SED).

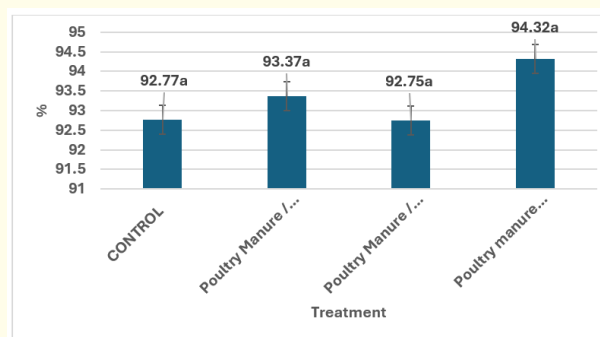


Figure 12: Effect of different soil amendments and bio stimulant on moisture content of waterleaf.
Figure (12). Moisture Content.
Error bars = Standard error of difference of means (SED).

The results from Figure 12 show substantial difference in the moisture content of waterleaf produced under soil amendments, bio stimulants, as well as the control. Numerically different was observed for all the treatments, with the least value recorded by treatment 2. The highest numerical difference was recorded in treatment 3, which was 94.32 and a marginal difference of 1.7 per cent.

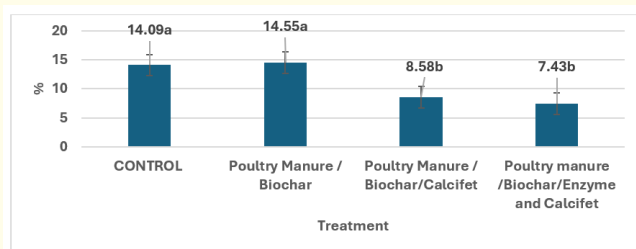


Figure 13: Impact of different soil amendments and bio stimulant on NFE carbohydrate content of water leaf.

Figure (13). NFE Carbohydrate Content.

Error bars = standard error of the difference of means (SED).

The Figure above shows the variation in the carbohydrate content of water leaf. When grouping treatments 2 and 3 as one and comparing it with treatment 1 and the control of the experiment, there was a substantial difference between them. Furthermore, there was no substantial difference between treatment 3 and 2, as treatment 3 recorded a 7.43 percentage mean.

Impact of different soil amendments and bio stimulant on the weights of waterleaf

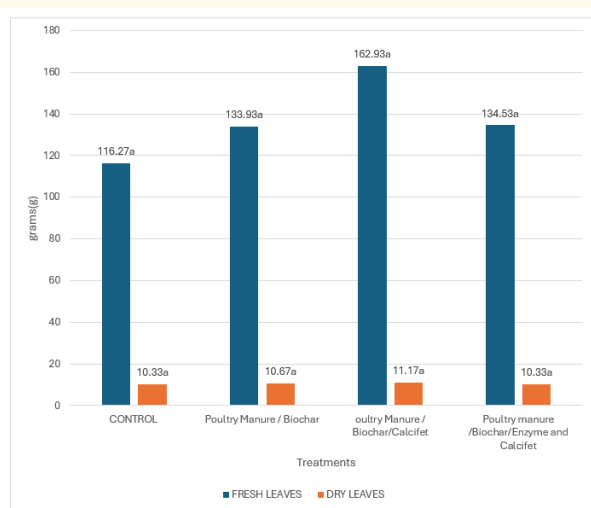


Figure 14: Impact of different soil amendments and bio stimulant on the fresh and dry leaves of water leaf.

Figure (14) Fresh and Dried Leaves of Waterleaf

Error bars = Standard error of difference of means (SED).

The weight displaced by the leaves of the water leaf was measured and statistically analyzed. There was no big variation in the fresh weight of waterleaf leaves between the experiment's control and the other treatment. Observably, there was a numerical difference with treatment 2, producing 162.93g. When the leaves of waterleaf were subjected to drying; there was no statistically significant difference amongst all the treatments applied.

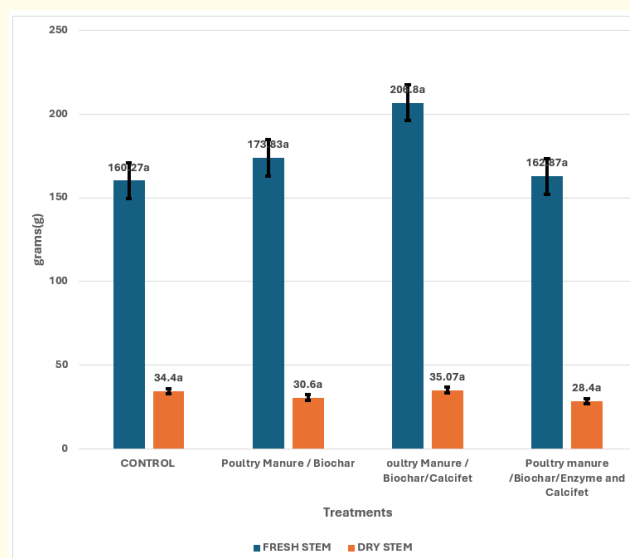


Figure 15: Impact of different soil amendments and bio stimulant on the fresh and dry stem weight of water leaf.

Figure (15). Fresh and Dried Stems of Waterleaf.

Standard error of difference of means (SED) = Error bars.

The stem of the water leaf was separated and the weight displaced was weighed, there was no statistically significant different amongst the control and all the treatment applied as treatment 2 recorded the highest stem weight of 206.8g. Further subjection of the stem to dry at 60 degrees Celsius, there was no significant different amongst the applied treatment and treatment 3 was able to dry to a numerically low weight of 28.4 in comparison to 34.4 for the control.

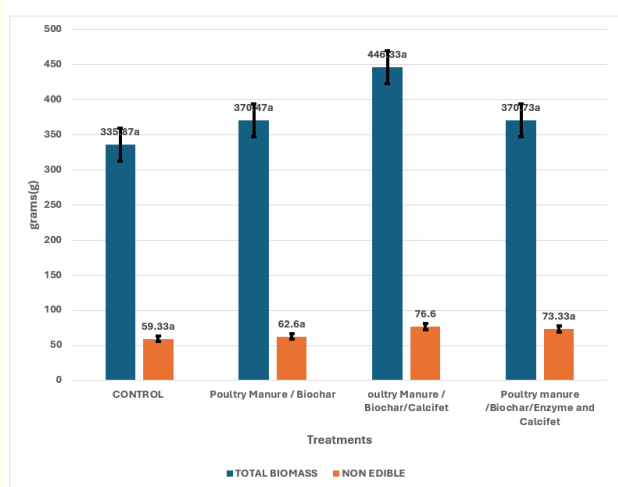


Figure 16: Impact of different soil enhancements and bio stimulant on the total biomass and non-edible parts of waterleaf. Figure (16). Total Biomass and Non-Edible Portions of Water-leaf.

Standard error of difference of means (SED) = Error bars.

The biomass yield of each treatment was examined, and statistically there was negligible significant difference ($p > 0.05$) amongst the applied treatments. Numerically, the highest recorded weight was 446.33 for treatment 2, compared to the control of the experiment, which recorded 335.87. Also, when the non-edible parts of the water leaf as affected by different soil amendments and bio stimulants were measured, there was no significant statistical difference as treatment 1 had a more reduced non-edible portion.

Discussion

Impact of soil amendments and bio stimulant on mineral content of water leaf

The leaves of *Talinum triangulare* (waterleaf) had zinc content ranging from 184.06 mg/kg to 225.56 mg/kg. This recent research discovered significant increase in zinc content when compared to the zinc concentrations reported by Olaleye., *et al.*, [34] which ranged from 0.6mg/kg to 1.0mg/kg, and the zinc concentration stated by Amagloh and Nyarko [35] which was 3.88 mg/kg.

Zinc is an important element required by the human body as a catalyst activating many enzyme systems. It also contributes in the management of the immune system's functioning, the healing of wounds, and the repair of tissues.

However, taking zinc in excess may cause gastrointestinal disorders such as abdominal pain, diarrhea, and vomiting. This study suggests that waterleaf is a good source of zinc and it can therefore be incorporated into the diets of people who are suffering from zinc deficiency.

The potassium content of the leaves of *T. triangulare* also ranged from 2.28 to 3.07. Azubuike., *et al.* [36] found that *Colocasia esculenta* had a potassium value of 4.24 mg/kg, which is higher than the potassium content (2.28% to 3.07%) of *T. triangulare* leaves. The low value of potassium in this experiment could be due to variations in treatment and processing or species differences. It could also be attributed to the differences in time of cultivation and place of cultivation.

From this experiment, it was observed that *T. triangulare* leaves had magnesium content between 0.61% and 0.79%. According to Azubuike., *et al.* [36] fresh, boiled, and sun-dried *Colocasia esculenta* leaves had magnesium levels of 1.21 mg/kg, 1.12 mg/kg and 2.22 mg/kg respectively. Magnesium, a mineral found in bones and teeth, acts as an enzymatic activator and facilitates nucleic acid function [37].

Comparatively, this current study had magnesium mineral content ranging from 0.61% to 0.79%, which is lower than what has been recorded in earlier studies. These differences could be due to species variation.

Phosphorus content recorded ranged from 0.27 mg/kg to 0.34 mg/kg for *Talinum triangulare* leaves, Rao., *et al.* [38] discovered phosphorus levels ranging from 0.33% to 0.35% in *Colocasia esculenta* leaves. The phosphorus levels found in waterleaf in this experiment was lower than those reported by Rao., *et al.* [38] and these variations might be related to species differences and processing methods.

In this study, *T. triangulare* had iron values ranging from 180 mg/kg to 220 mg/kg. According to research conducted by Amagloh

and Nyarko [35], some selected vegetables, such as taro (*Colocasia esculenta*) leaves, had an iron concentration of 10.59, 4.34 mg/kg. Comparing the iron content in current research to the previous experiments, this research indicated that the iron concentration was substantially greater in *T. triangulare* leaves than taro and cocoyam leaves. This is very significant to human and animal health because iron plays a very important role in fighting anaemia. Incorporating waterleaf into the daily diet of humans and animals will aid in the eradication of iron deficiency challenges.

This research proved that *T. triangulare* leaves had a dietary mineral calcium content ranging from 1.81% to 3.2%, which is much higher than what Rao, *et al.* [38] reported for *Colocasia esculenta* leaves (0.62%) but less than the 11% found in the Journal of Medical Studies (2018) for *Colocasia esculenta*.

Calcium has been linked to bone and tooth formation, as well as blood clotting. In contrast, a lack of calcium can lead to osteoporosis in adults and rickets in children.

Impact of different soil amendments and bio stimulant on proximate quality of waterleaf.

Ash percentage in dehydrated waterleaf leaves were between 13.67% and 15.40%. Rao, *et al.* [38] reported that the ash content in *Colocasia esculenta* leaves ranged from 9.75% to 10.50%. This study found that the ash content in waterleaf was relatively high and this could be attributed to the differences in species and possible treatments used in the present and earlier research. Due to their low volatility in comparison to other dietary ingredients, minerals are not significantly affected by heat application. Additionally, the concentration of nutrients tends to ascent when moisture is removed, making the nutrients more accessible according to Morris, *et al.* [39]. The various drying techniques and species or variations could have produced different outcomes. According to this study, moisture loss and an increase in the dry matter content of *Talinum triangulare* leaves led to substantial increases in fat content [40]. The results of this study confirmed that leafy vegetables have low lipid content, making them important dietary sources for preventing obesity.

Majority of plant components contain the insoluble carbohydrates hemicellulose, cellulose, and lignin, which make up fat (crude fiber). According to Kwenin, *et al.* [41], edible leafy vegetables have a crude fiber content of 10%, while *Colocasia esculenta*

leaves provide 3.7mg of dietary fiber. In contrast to the reported results of 10% and 3.7mg, the fiber content of dried *Talinum triangulare* leaves (49.69%-52.82%) was higher in this investigation. This can be because the plant species examined in the two studies differ from each other. By absorbing dietary fiber components and quickly excreting them, diets high in fiber promote the elimination of possible mutagens, steroids, bile acids, and carcinogens [42]. The high fiber content observed in *Talinum triangulare* leaf makes it better and highly preferable than other vegetables with low fiber content.

Proteins contain amino acids, which are necessary for cellular activity and the creation of energy. Crude protein content of *Talinum triangulare* leaves ranges between 15.87% and 20.94%, according to the findings of this study. *Colocasia esculenta* leaves had raw protein contents from 2.9% to 3.2% according to Azubuikwe, *et al.* [36].

According to the current study, dried *Talinum triangulare* had a crude protein content of 15.87% for the (control) but the treatment had a higher crude protein content ranging from 17.1% to 20.94%.

These results were better than what [36] found for sun-dried *Colocasia esculenta* leaves (6.0%). The different treatment materials that were utilized during the soil amendment processes could be the cause of the variation in moisture content that was observed in this experiment. An indicator of a leafy vegetable's moisture content is whether it is fresh, has a short shelf life, or is easily perishable.

In order to provide the body with energy for muscular activity, carbohydrates are oxidized. Foods high in carbohydrates are the body's primary fuel source, and vegetables are a significant source of carbohydrates. Most foods high in carbohydrates also include fiber. A carbohydrate that the body cannot process is fiber. It is present in many plant-based meals, including vegetables like cocoyam leaves. Fiber-rich foods can help improve cholesterol and blood sugar levels while also preventing digestive or intestinal problems such as constipation.

Total sugars are the sum of all the sugars, both naturally occurring and added, in a given food. Sucrose and Dextrose, sugars from honey and syrups, sugars packaged as sweeteners, sugars from

concentrated vegetable and fruit juices, and sugars from all of these are examples of sugar added to foods during production. The body can readily digest and absorb sugar, the smallest type of carbohydrate. In addition, they can be found as added sugars in desserts, baked goods, sweetened beverages, and fruits, dairy products, and vegetables that are naturally present in food. Despite having molecular similarities to both alcohol and sweets, sugar alcohols are a type of carbohydrate that the body does not fully absorb. In comparison to sugar, they taste sweeter and have fewer calories per serving. These compounds are commercially produced and widely used in low-calorie sweetener foods such as desserts, chewing gum, frostings, baked products, and sweets.

Calories, or energy, are provided to the body by carbohydrates. Per gram of carbohydrate, four calories are thought to be delivered. The human body converts carbohydrates into glucose. Blood sugar, known as glucose, is the main source of energy for human cells, tissues, and organs like the brain and muscles. The muscles and liver both have the capacity to store glucose for future energy needs.

Impact of different soil amendments and bio stimulant on the weights and leaf colour of Waterleaf.

Yield, which is expressed in Metric tons per hectare, is the weight gained or dry matter amount of an agricultural crop in a specific unit of an area.

The application of modern farming methods and the explored breeding lines, which stand out for their desirable morphological, physical, and chemical qualities, homogeneous ripening, appropriateness for mechanical harvesting, performance improvement, and resistance to pests and diseases can have substantial impacts on crop yields (leaf yield), quality (weight, wholesomeness, and lifespan), and, as a result, economic productivity, is of great interest to crop producers.

The average plant weight, including leaves, roots and stems were not significantly affected by the different soil amendments and bio stimulant. The average weight of dried Leaves or stem ranged from 28.4g to 35.07g, whereas the weight of fresh leaves varied from 160.27g to 206.8g. Although the addition of bio stimulants and soil amendments had no discernible effects on these parameters, the T2 had the highest fresh leaf weight values of 206.8g, while the control had the lowest fresh leaf weight values (160.27g).

The treatment (soil amendments and bio stimulant) barely affected the waterleaf's fresh and dried leaves, fresh and dried stems as well as total biomass. A comparison of marketable (edible component) and total leaf yield data showed that T2 had higher weights for fresh and dried stems, total biomass, and non-edible sections. In terms of leaf colour, *T. triangulare* responded differently to the various tested combinations of soil amendments and bio stimulants. As seen in Figure 1, it is clear that the various soil amendment techniques and bio stimulants had a significant impact on the leaf colours. According to Dobromilska [43], foliar titanium spray increased tomato yields and dramatically improved tomato plant vegetative growth, including an increase in plant height, stem diameter, and the number of leaves per plant. Under identical growing conditions, normal vegetative growth and development improve crop quality, with a significant genetic component.

Conclusion and Recommendation

Conclusion

Waterleaf (*Talinum triangulare*) is known for its antioxidant content and potential health benefits. A series of field and laboratory studies were conducted at the Horticulture Department of the Kwame Nkrumah University of Science and Technology to investigate the effects of soil amendments (Poultry manure, Biochar and Enzymes) and bio-stimulants (Calcifet Foliar Fertilizer) on the growth and leaf yield and quality waterleaf. A Randomized Complete Block Design with four (4) treatments and three (3) replicates. The variables studied include growth parameter, leaf yield, proximate, and mineral content. The results analysis showed that Poultry manure, Biochar, and Calcifet produced the highest fresh and dry leaf weight, highest biomass with a higher non-edible portion. In Poultry manure, Biochar, Calcifet, and Enzyme, the protein content of Waterleaf was 20.94%, and its maximum moisture level was 94.3%. The study revealed that combining poultry manure, Biochar, Calcifet, and Enzyme significantly ($P \leq 0.01$) enhanced mineral leaf quality, with the highest zinc and total copper content of 225.5 mg/kg and 35.83 mg/kg, respectively. Waterleaf had the highest magnesium content in the control (0.79%). Poultry manure, Biochar, and Calcifet produced the highest concentrations of phosphorus (0.34%), potassium (3.07%), iron (220.48 mg/kg), and calcium (3.2%). The findings indicated that Poultry manure, Biochar, and Calcifet had the highest yield and mineral quality, while Poultry manure, Biochar, Calcifet and Enzyme had the highest proximate quality attributes.

Recommendation

Considering the effect obtained from Poultry manure, Biochar and Calcifet and Poultry manure, Biochar, Calcifet and Enzyme, varying rates of applications using the stated treatments as a reference can be employed to obtain an optimum application rate of poultry manure, Calcifet, enzymes, and Biochar. Furthermore, consumers should be informed on the nutritional quality of locally available vegetables like *T. triangulare*. In addition, several processing and drying techniques can be employed to make high-quality *T. triangulare* available all year.

APPENDICES

Analysis of variances for proximate leaf quality

Randomized Complete Block AOV Table for MOISTURE

Source DF SS MS F P

BLK 2	1.5475	0.77373		
TRT 3	4.8852	1.62839	1.92	0.2272
Error 6	5.0823	0.84705		
Total 11	11.514			
Grand Mean	93.305	CV 0.99		

Randomized Complete Block AOV Table for NFE_CARBO

Source DF SS MS F P

BLK 2	1.547	0.7737		
TRT 3	121.806	40.6019	47.93	0.0001
Error 6	5.082	0.8470		
Total 11	128.435			
Grand Mean	11.163	CV 8.25		

Randomized Complete Block AOV Table for PROTEIN

Source DF SS MS F P

BLK 2	1.5475	0.7737		
TRT 3	44.3149	14.7716	17.44	0.0023
Error 6	5.0823	0.8470		
Total 11	50.9446			
Grand Mean	18.220	CV 5.05		

Randomized Complete Block AOV Table for CRUDEFIBR

Source DF SS MS F P

BLK 2	0.0241	0.01203		
TRT 3	20.7300	6.91001	681.16	0.0000
Error 6	0.0609	0.01014		
Total 11	20.8150			
Grand Mean	51.392	CV 0.20		

Randomized Complete Block AOV Table for FAT

Source DF SS MS F P

BLK 2	0.05032	0.02516		
TRT 3	6.92940	2.30980	254.06	0.0000
Error 6	0.05455	0.00909		
Total 11	7.03427			
Grand Mean	5.1333	CV 1.86		

Randomized Complete Block AOV Table for TOTAL_ASH

Source DF SS MS F P

BLK 2	0.02247	0.01123		
TRT 3	4.53390	1.51130	16.89	0.0025
Error 6	0.53700	0.08950		
Total 11	5.09337			
Grand Mean	14.508	CV 2.06		

Analysis of variances for mineral leaf quality

Randomized Complete Block AOV Table for Ca

Source DF SS MS F P

BLK 2	0.04533	0.02267		
TRT 3	3.29051	1.09684	50.56	0.0001
Error 6	0.13017	0.02170		
Total 11	3.46601			
Grand Mean	2.3686	CV 6.22		

Randomized Complete Block AOV Table for Cu

Source DF SS MS F P

BLK 2	0.199	0.0994		
TRT 3	179.224	59.7413	3292.54	0.0000
Error 6	0.109	0.0181		

Total	11	179.532			
Grand Mean	30.392	CV	0.44		
Randomized Complete Block AOV Table for Fe					
Source	DF	SS	MS	F	P
BLK	2	0.20	0.099		
TRT	3	2470.95	823.651	45394.1	0.0000
Error	6	0.11	0.018		
Total	11	2471.26			
Grand Mean	200.72	CV	0.07		
Randomized Complete Block AOV Table for K					
Source	DF	SS	MS	F	P
BLK	2	0.03264	0.01632		
TRT	3	1.16879	0.38960	22.69	0.0011
Error	6	0.10302	0.01717		
Total	11	1.30445			
Grand Mean	2.7223	CV	4.81		
Randomized Complete Block AOV Table for Mg					
Source	DF	SS	MS	F	P
BLK	2	0.01284	0.00642		
TRT	3	0.05251	0.01750	2.96	0.1195
Error	6	0.03546	0.00591		
Total	11	0.10081			
Grand Mean	0.7040	CV	10.92		
Randomized Complete Block AOV Table for P					
Source	DF	SS	MS	F	P
BLK	2	0.00143	0.00071		
TRT	3	0.00979	0.00326	3.61	0.0849
Error	6	0.00543	0.00091		
Total	11	0.01665			
Grand Mean	0.3157	CV	9.53		
Randomized Complete Block AOV Table for Zn					
Source	DF	SS	MS	F	P
BLK	2	0.20	0.099		
TRT	3	2871.79	957.262	52757.9	0.0000

Error	6	0.11	0.018		
Total	11	2872.09			
Grand Mean	200.52	CV	0.07		
Analysis of variances for leaf yield					
Randomized Complete Block AOV Table for D_LEAVES					
Source	DF	SS	MS	F	P
BLK	2	0.12500	0.06250		
TRT	3	1.39583	0.46528	0.69	0.5902
Error	6	4.04167	0.67361		
Total	11	5.56250			
Grand Mean	10.625	CV	7.72		
Randomized Complete Block AOV Table for D_STEM					
Source	DF	SS	MS	F	P
BLK	2	1.607	0.8033		
TRT	3	90.090	30.0300	1.25	0.3728
Error	6	144.500	24.0833		
Total	11	236.197			
Grand Mean	32.117	CV	15.28		
Randomized Complete Block AOV Table for LEAVES					
Source	DF	SS	MS	F	P
BLK	2	2817.2	1408.60		
TRT	3	3353.6	1117.87	1.05	0.4350
Error	6	6363.2	1060.54		
Total	11	12534.0			
Grand Mean	136.92	CV	23.79		
Randomized Complete Block AOV Table for NON_EDIBL					
Source	DF	SS	MS	F	P
BLK	2	70.65	35.323		
TRT	3	620.01	206.671	0.74	0.5635
Error	6	1665.25	277.541		
Total	11	2355.91			
Grand Mean	67.967	CV	24.51		
Randomized Complete Block AOV Table for STEM					
Source	DF	SS	MS	F	P

BLK 2 3908.7 1954.36

TRT 3 4120.0 1373.34 1.64 0.2769

Error 6 5021.5 836.92

Total 11 13050.2

Grand Mean 175.94 CV 16.44

Randomized Complete Block AOV Table for TOTAL_BIO

Source DF SS MS F P

BLK 2 14399.2 7199.59

TRT 3 19565.2 6521.73 1.16 0.3981

Error 6 33612.0 5602.01

Total 11 67576.4

Grand Mean 380.85 CV 19.65

Bibliography

1. Global Food Book. *Waterleaf (Talinum triangulare) - Nutrition and health benefits*. Global Food Book (2016).
2. Bechthold A., *et al.* "Critical review: Vegetables and fruit in the prevention of chronic diseases". *European Journal of Nutrition* 51.6 (2012): 637-663.
3. Fasuyi AO. "Nutritional potentials of some tropical vegetable leaf meals: Chemical characterization and functional properties". *African Journal of Biotechnology* 5.1 (2006): 49-53.
4. Pennington JAT and Fisher RA. "Food component profiles for fruit and vegetable subgroups". *Journal of Food Composition and Analysis* 23.5 (2010): 411-418.
5. Taha SH., *et al.* "Vegetables as natural sources of antioxidants and their role in human health". *International Journal of Current Research in Biosciences and Plant Biology* 5.1 (2018): 1-10.
6. Kris-Etherton PM., *et al.* "Bioactive compounds in foods: Their role in the prevention of cardiovascular disease and cancer". *The American Journal of Medicine* 113.9 (2002): 71-88.
7. Rickman JC., *et al.* "Nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds". *Journal of the Science of Food and Agriculture* 87.6 (2007): 930-944.
8. World Health Organization, and Food and Agriculture Organization of the United Nations. Diet, nutrition and the prevention of chronic diseases: Report of a joint FAO/WHO expert consultation" (WHO Technical Report Series, No. 916). World Health Organization (2003).
9. Cooper A., *et al.* "Fruit and vegetable intake and type 2 diabetes: EPIC-InterAct prospective study and meta-analysis". *European Journal of Clinical Nutrition* 66.10 (2012): 1082-1092.
10. Boeing H., *et al.* "Critical review: Vegetables and fruit in the prevention of chronic diseases". *European Journal of Nutrition* 51.6 (2012): 637-663.
11. Mozaffarian D. "Dietary and policy priorities for cardiovascular disease, diabetes, and obesity". *Circulation* 133.2 (2016): 187-225.
12. Estruch R., *et al.* "Primary prevention of cardiovascular disease with a Mediterranean diet". *New England Journal of Medicine* 368.14 (2013): 1279-1290.
13. Ragaert P., *et al.* "Consumer perception and choice of minimally processed vegetables and packaged fruits". *Food Quality and Preference* 15.3 (2004): 259-270.
14. Su LJ and Arab L. "Salad and raw vegetable consumption and nutritional status in the adult US population: Results from the Third National Health and Nutrition Examination Survey". *Journal of the American Dietetic Association* 106.9 (2006): 1394-1404.
15. Djuric Z. "The Mediterranean diet: Effects on proteins that mediate fatty acid metabolism in the colon". *Nutrition Reviews* 69.12 (2011): 730-744.
16. Tiwari U and Cummins E. "Factors influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operations". *Food Research International* 50.2 (2013): 497-506.
17. Chang SK., *et al.* "Review of dried fruits: Phytochemicals, antioxidant efficacies, and health benefits". *Journal of Functional Foods* 21 (2016): 113-132.
18. Manach C., *et al.* "Polyphenols: Food sources and bioavailability". *The American Journal of Clinical Nutrition* 79.5 (2004): 727-747.

19. Andriantsitohaina R., *et al.* "Molecular mechanisms of the cardiovascular protective effects of polyphenols". *British Journal of Nutrition* 108.9 (2012): 1532-1549.
20. Coban D., *et al.* "Dietary curcumin inhibits atherosclerosis by affecting the expression of genes involved in leukocyte adhesion and transendothelial migration". *Molecular Nutrition and Food Research* 56.8 (2012): 1270-1281.
21. Tresserra-Rimbau A., *et al.* "Inverse association between habitual polyphenol intake and incidence of cardiovascular events in the PREDIMED study". *Nutrition, Metabolism and Cardiovascular Diseases* 24.6 (2014): 639-647.
22. Di Renzo L., *et al.* "Role of personalized nutrition in chronic-degenerative diseases". *Nutrients* 11.8 (2019): 1707.
23. World Health Organization. "World health statistics 2017: Monitoring health for the SDGs, Sustainable Development Goals" (2017).
24. Popkin BM. "Nutrition transition and the global diabetes epidemic". *Current Diabetes Reports* 15.9 (2015): 64.
25. Ramchandran L. "Nutritional and therapeutic significance of protein-based bioactive compounds liberated by fermentation. In *Fermented foods, part I* (pp. 304-317). CRC Press (2015).
26. Alwan A., *et al.* "Monitoring and surveillance of chronic non-communicable diseases: Progress and capacity in high-burden countries". *The Lancet* 376.9755 (2010): 1861-1868.
27. Robert Beaglehole., *et al.* "Priority actions for the non-communicable disease crisis". *The Lancet* 377.9775 (2011): 1438-1447.
28. Ezekwe CI., *et al.* "The effect of methanol extract of *Talinum triangulare* (water leaf) on the hematology and some liver parameters of experimental rats". *World Applied Sciences Journal* 25 (2013): 1000-1006.
29. Ikewuchi CC., *et al.* "Bioactive phytochemicals in an aqueous extract of the leaves of *Talinum triangulare*". *Food Science and Nutrition* 5.3 (2016): 696-701.
30. Ogie-Odia EA and Oluowo EF. "Assessment of some therapeutic plants of the Abbi People in Ndokwa West L.G.A. of Delta State, Nigeria". *Ethnobotanical Leaflets* 13 (2009): 989-1002.
31. Ofusori DA., *et al.* "Waterleaf (*Talinum triangulare*) enhances cerebral functions in Swiss albino mice". *Journal of Neurological Sciences* 25.4 (2008): 239-246.
32. Mensah JK., *et al.* "Phytochemical, nutritional and medical properties of some leafy vegetables consumed by Edo people of Nigeria". *African Journal of Biotechnology* 7.14 (2008): 2304-2309.
33. Ogunlesi M., *et al.* "Vitamin C contents of tropical vegetables and foods determined by voltammetric and titrimetric methods and their relevance to the medicinal uses of the plants". *International Journal of Electrochemical Sciences* 5 (2010): 105-115.
34. Olaleye AO., *et al.* "Chemical Composition of red and white cocoyam (*Colocasia esculenta*) leaves". *International Journal of Sciences and Research* 2.11 (2013): 121-124.
35. Amagloh FK and Nyarko ES. "Mineral nutrient content of commonly consumed leafy vegetables in Northern Ghana". *Journal of Food, Agriculture and Environment* 5.5 (2012): 6405.
36. Azubuike NC., *et al.* "Nutritional profile, proximate composition and health benefits of *Colocasia esculenta* leaves: An underutilized leafy vegetable in Nigeria". *Pakistan Journal of Nutrition* 17 (2018): 689-695.
37. Grober U., *et al.* "Magnesium in prevention of and therapy". *Nutrients* 7 (2015): 8199-8226.
38. Rao VR., *et al.* "The global diversity of taro: Ethnobotany and conservation". *Bioversity International* (2010).
39. Morris A., *et al.* "Effect of processing on nutrient content of foods". *Cajarticle* 37 (2010): 160-164.
40. Adenike OM. "The effect of different processing methods on the nutritional quality and microbiological status of cat fish (*Clarias lezera*)". *Journal of Food Processing Technology* 5 (2014): 333.

41. Kwenin WKJ., *et al.* "Assessing the nutritional value of some African indigenous green leafy vegetables in Ghana". *Journal of Animal and Plant Sciences* 10.2 (2011): 1300-1305.
42. Ayoola PB and Adeyeye A. "Proximate analysis and nutrient evaluation of some Nigeria pawpaw seeds varieties". *Science Focus* 14.4 (2009): 554-558.
43. Dobromilska R. "The influence of Tytanit treatment on the growth and yield of small-sized tomatoes". *Roczniki Akademii Rolniczej w Poznaniu. Ogrodnictwo* 41 (2007): 451-454.