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Article

The potential of organic amendment (*Icacina oliviformis* tuber compost and animal manure) in savannah ochrosol soil in the era of sustainable agriculture

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Abstract: Soil nutrient levels have decreased due to continuous cultivation. To amend depleted soils, this study explored false yam (Icacina oliviformis) compost mixed with aged topsoil at 12, 14, and 16 weeks (W) in ratios of 1:1, 1:2, and 2:1, with topsoil (T4) serving as the control. After assessing for effectiveness, the best performing aged topsoil to false yam compost was integrated with animal manure (cow dung and pig droppings) as follows: topsoil: false yam: cow dung (FYCD)- (2:1:1), topsoil: false yam: pig droppings (FYPD)- (2:1:1), topsoil: false yam: cow-dung: pig droppings (FYCDPD)- (2:1:1/2:1/2) and topsoil: false yam (FY)- (2:1) as the control. The four treatments were evaluated using cucumber as the test crop and were replicated three times in Completely Randomized Design (CRD). FY and FYCD recorded similar results in the leaf area, followed by FYCDPD, and FYPD. FY and FYCD recorded similarly in plant girth at 2 weeks after planting (2WAP) and 4WAP. FYCD and FY recorded pH values of 5.57 and 5.61 respectively. These indicated that the period of decomposition had a significant effect on the performance on amendment quality. False yam compost aged 12 weeks at 2:1 topsoil to false yam compost ratio performed best. Also, false yam compost combined with cow dung offered positive support to crop performance although not significantly different from false yam compost (12W) only. This indicates that decomposed false yam tuber within 12W with or without cow dung may be used to amend the soil for better performance with enhanced soil properties.

Keywords: Organic farming; compost; nutrient depletion; false yam; biofertilizer

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1. Introduction

The production of crops and wholesome food for the world's expanding population depends on plant nutrients. The crops obtain their nutrient requirement from the soil and continuous cultivation of crops on the same piece of land has led to the depletion of nutrients in the soil [1]. To amend the soil, chemical fertilizers, manure, mulch, and compost have been used [2–4]. The widespread use of chemical fertilizers creates severe collateral issues such environmental pollution, the emergence of pest resistance, and a reduction in food safety [5].

Additionally, using chemical fertilizers raises production costs, which is costly for farmers in rural areas (Figure 1 A). In arable crop production systems, regular application of chemical fertilizer and compost was essential for soil management [6,7]. These amendments were primarily employed to increase the availability of nutrients to plants, but they can also have an impact on soil microorganisms [8]. In sustainable farming, bio-fertilizer has been discovered as an option for increasing crop output and soil fertility. Today's soil management approaches rely mostly on inorganic chemical fertilizers (Figure 1 C), which pose a significant risk to both human health and the environment [9]. The benefits of using compost in maintaining soil quality have been increasingly recognized [10,11]. The chemical, physical and biological fertility of a plant growth medium as suggested by the authors in [12] are controlled by the organic matter found in the growth medium and thus should be supplied through the application of manure and crop residues, to either maintain or elevate the organic matter content in the growth medium. False yam (Icacina oliviformis) [13] is a small, drought-resistant shrub forming dense stands in the West African and Central African savannas [14]. It belongs to the family Icacinaceae [15] and indigenous to the west and central Africa [16]. The tuber is said to possess advantageous agronomic and nutritional features that are similar when compared to soil [17]. The usage of animal manure [18] in organic farming [19–21] is geared towards improved crop yields, improved soil fertility, and water holding capacity to optimum levels [22]. The problem of poor soils contribute to a drop in crop productivity in Northern Ghana [23], which is negatively affecting the development of agriculture [24] . Using cucumber as a test crop, this study aims to assess the performance of compost made from false yam (Icacina oliviformis) tubers on crop growth performance alongside animal manure.

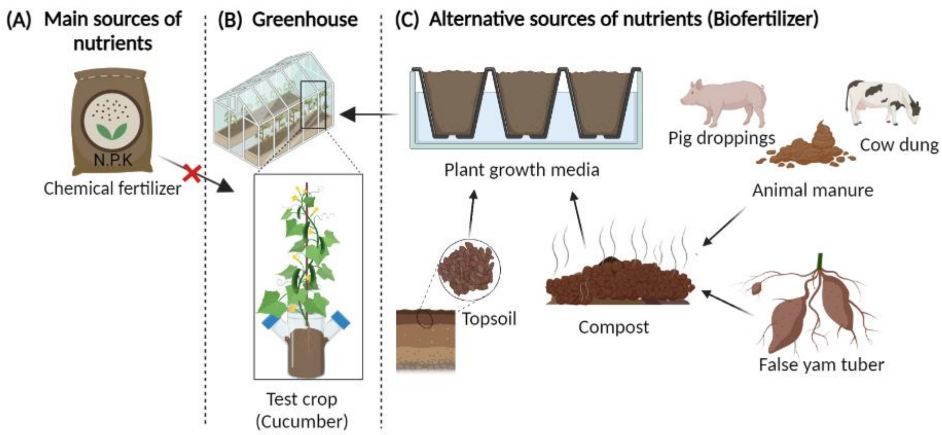

Figure 1. Sources of plant nutrients in Ghana. (A) Chemical fertilizers. Although quick and simple to use, it poses significant environmental risks and raises production costs. (B) Greenhouse. Trials of organic fertilizers are easily evaluated in these controlled environments. (C) Biofertilizer. Utilizing organic fertilizers is challenging. But it is affordable, eco-friendly, and sustainable.

2. Materials and Methods

2.1. Experimental Area

The experiment was conducted in the farm for the future field and plant house of the University for Development Studies' Nyankpala campus in Tamale, Ghana. According to the Savanna Agricultural Research Institute's (SARI) report in 2001, the location lies on latitude 9^0 25^1 45^1N and longitude 0^0 58^1 42^1 N at latitude 182m above sea level characterized as a hot dry savannah zone. The pattern of rainfall in this area is a unimodal which occurs in April to October followed by the dry season which sets in from November to March [17]. The temperature of the area ranges between 19^0C (minimum) and 42^0C (maximum). A report by SARI in 1998 stated that the average annual rainfall is 1060mm.

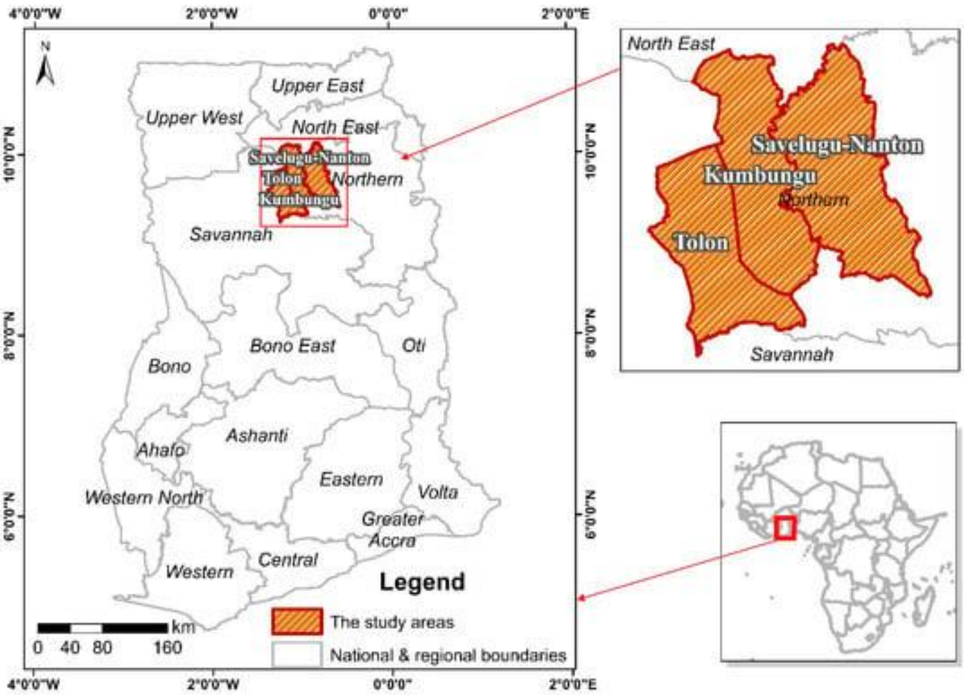

Figure 2. Description of study area. The location lies on latitude $9^0 25^1 45^1$N and longitude $0^0 58^1 42^1$ N at latitude 182m above sea level characterized as a hot dry savannah zone. A report by SARI in 1998. The image was taken from MacCarthy et al., 2022 [25].

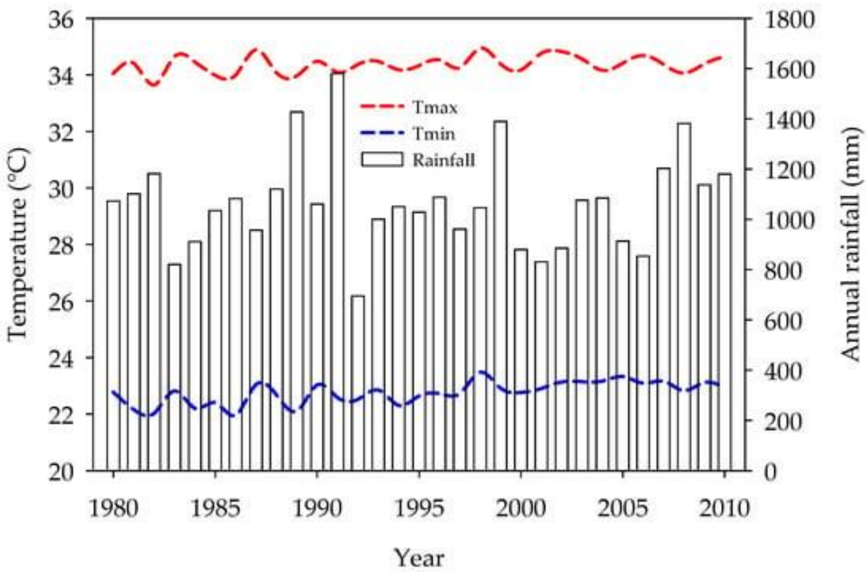

Figure 3. The research site's historical (1980–2010) annual average maximum and lowest temperatures and total annual rainfall. The pattern of rainfall in this area is unimodal, temperature ranges between 19^0C (minimum) and 42^0C (maximum) and average annual rainfall is 1060mm. The image was taken from MacCarthy et al., 2022 [25].

2.2. Experimental design and analysis

For two sets of experiments, four treatment levels were used. The first batch consisted of false yam compost mixed with topsoil in ratios of 1:1, 1:2, and 2:1 (false yam: topsoil) at 12 weeks, 14 weeks, and 16 weeks after composting and topsoil served as control laid in a Randomized Complete Block Design (RCBD).

The second set of experiments was composed of false yam compost at week 12 and topsoil mixed with animal manure in a 1:2 ratio in a completely randomized design. Both sets were replicated three times. The false yam compost was combined with the following animal manure; false yam tuber compost and cow dung (FYCD), false yam tuber compost and pig dropping (FYPD) decomposed false yam plus cow dung and pig dropping (FYCDPD), and false yam tuber compost only (control).

Table 1. Treatment combinations of false yam compost and topsoil at 12 weeks, 14 weeks, and 16 weeks after decomposition (Experiment 1).

Treatment		Ratio	
Weeks of decomposition	**Treatment level**	**False Yam Compost**	**Topsoil**
12W	T1	1	1
	T2	2	1
	T3	1	2
	T4	0	1
14W	T1	1	1
	T2	2	1
	T3	1	2
	T4	0	1
16W	T1	1	1
	T2	2	1
	T3	1	2
	T4	0	1

Table 2. Treatment combinations of false yam compost and animal manure (Experiment 2).

Treatments	Composition Ratio			
	False yam	**Topsoil**	**Cow dung**	**Pig dropping**
FYCD	1	2	1	-
FYPD	1	2	-	1
FYCDPD	1	2	1/2	1/2
FY	1	2	-	-

At a significance level of (P0.05), the collected data were subjected to an analysis of variance (ANOVA) using the Genstat statistical program, 4th edition. Except for pH, which was measured in the second experiment, data were collected on plant girth, the number of leaves per plant, plant height, and leaf area for the two sets of experiments.

2.3. Test Crop

The experiment used cucumber (Cucumis sativa), the poinsett variety as a test crop.

2.4. Preparation of false yam tuber and animal manure to serve as a substrate

Fresh false yam (*Icacina oliviformis*) tubers were harvested within the Nyankpala Campus of the University for Development Studies, Tamale - Ghana. Harvested false yam tubers were chopped into pieces about 2cm and buried in compost pits of dimensions 152cm×61cm×91cm and covered with black polythene bags (figure 4). Every week, proper aeration was achieved by rotating and watering to a wet condition. The composting process lasted for twelve, fourteen, and sixteen weeks. Planting began in October, and data collecting was completed in December 2015. The experimental plastic plant pots used had perforations at the bottom and a volume of roughly 7067 cm3. The experiment was set up in a plant house.

Figure 4. Experimental set-up. (1-3) Harvesting and chopping false yam into smaller size for decomposition. (4-5) Chopped false yam buried in pit and covered to keep required temperature for microbial decomposition of false yam tuber. (6) matured false yam compose. (7-9) Establishment of test crop and growth parameters evaluation.

3. Results

3.1. Substrate pH

Table 3 indicates highly significant differences in substrate pH values for all treatments resulting in the different performances of the test crops subjected to the different treatments.

Table 3. Substrate pH of the treatment.

Treatment	pH
FYCD	5.57
FYPD	5.36
FYCDPD	4.69
FY	5.61
P-Value	<0.001

This may be owing to the difference in resident ions and/or microbial metabolites in the treatments resulting in dissimilar nutrient and water uptake among the test crops. Cucumbers are sensitive to acidic soils hence a pH of 5.5 to 6.7 is optimum [26]. According to a study [27], plants grew on agar media with a pH range of 4 to 8. Additional research by the author demonstrating how varying soil pH values affect plant growth in natural soils suggests that soil pH has a significant impact on the growth and development of *A. artemisiifolia* [27]. Organic fertilizer improves the capacity of growth medium to buffer changes in pH and cation exchange capacity and serves as a reservoir of elemental constituents such as N, S, P, and many minor elements [28–33]. In a natural setting, soil pH has an impact on the biological, chemical, and physical characteristics of the soil, which impacts translocation, plant growth and biomass production [34]. Because it readily provides an indication of the soil condition and the expected direction of many soil activities, soil pH is compared to a patient's temperature when making medical diagnoses. Thus, the pH regulates both soil biology and biological activities that have an impact on plant performance [34].

Experiment 1 (set-up 1)

3.2. Plant Girth

Results in Set-up 1 there was significant difference among treatments ($P<0.05$) for all the weeks of decomposition (figure 5). This may be attributed to the fact that nutrients were released variedly from decomposed false yam into the growth media. Also, the information revealed that 12W and 14W were not different from each other at T1 and T2 but differed at 16W. It may be that enough nutrients were released at 12W and 14W hence an increase in performance than 16W; and at 16 the available nutrients were reused by the microbial community in succession. Notably, 12W was not different from 14W.

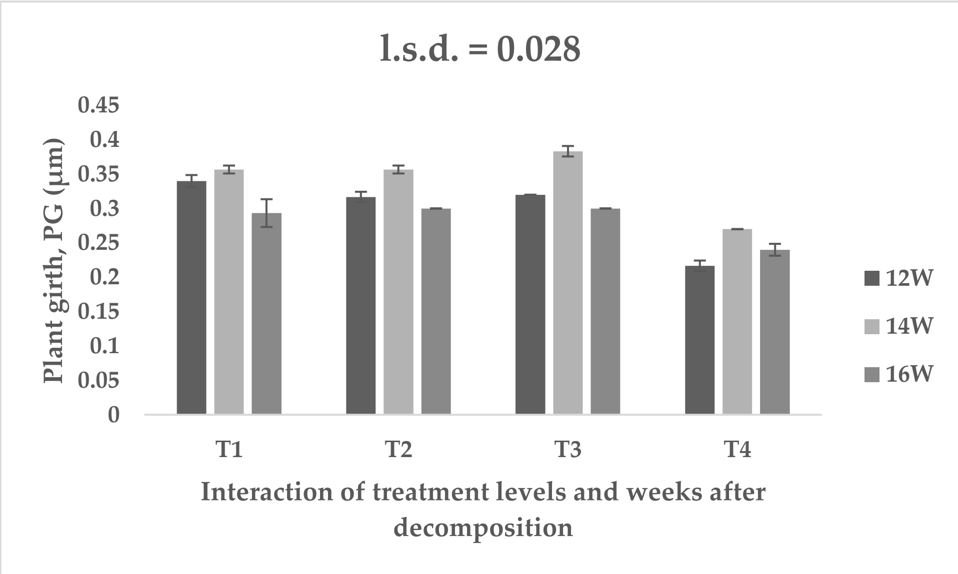

Figure 5. Plant girth of test crop (Set-up 1).

3.3. Leaf Area

The result indicates significant differences among the individual treatments (Figure 6). As reported by authors in [35] organic manure had a profound effect on the vegetative growth of the cucumber plant. The study revealed that 16W compost recorded the least performance in terms of leaf area for all treatments. This may be ascribed to the fact that nutrients which were produced started to diminish as the weeks of decomposition increased to 16W. This confirms the finding of the author in [36], who reported that the duration of decomposition influenced the nutrient released from the composting material. However, 12W recorded the highest performance at T2. This indicated that treatments with the least amount of false yam compost had better performance in terms of leaves than those with high levels of false yam compost. This may explain the fact that false yam compost provided nutrients for plant growth when added to certain levels. Thus, decreasing the quantity of false yam compost to soil ratio increased performance. The authors in [35] also made a similar observation in the weight of fruit yield of cucumber increased significantly with the application of treatments of poultry manure.

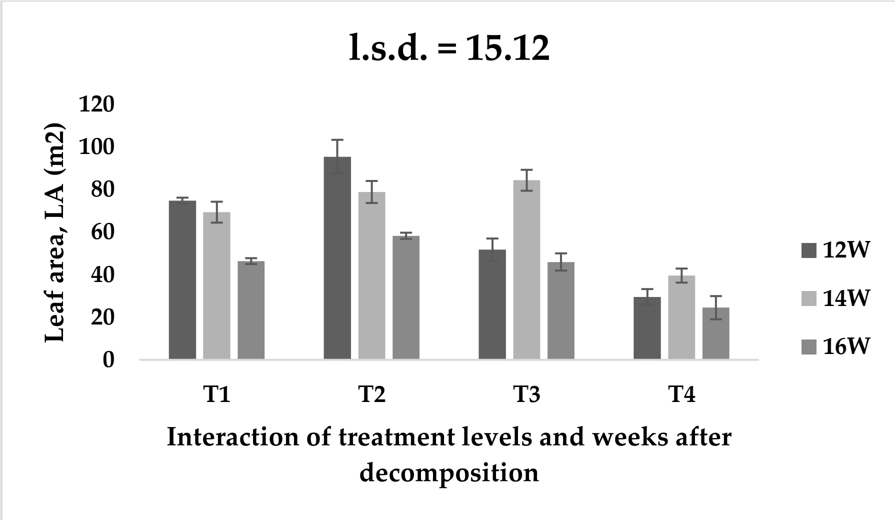

Figure 6. Leaf Area of the test crop (Set-up 1).

3.4. Number of leaves per plant

In set-up 1 (Figure 7), there was a significant difference (P<0.05) between the treatments applied and the control. Figure 7 indicated that T1, T2, and T3 were not significantly different but were different from T4. This may be associated with the fact that decomposed false yam added nutrients to the soil since all the treatments with decomposed false yam mixed with topsoil performed better than the control T4. This agrees with the finding of the author in [37] who report that the incorporation of manure into soil stimulated transformation and mineralization and increase Phosphorus uptake by the plant. However, T1, T2, and T3 were not significantly different from each other. The indication revealed that the treatment levels applied had no effect on the number of leaves a plant produced for all the weeks after decomposition. This may be that decomposed false yam in the various media supplied a similar amount of nutrients to the crop. This agrees with the finding of the authors in [17] who reported that plants on diverse media parade resemblances in growth and development when nutrients available to them are the same. Also, 12W, 14W, and 16W decomposition differed significantly from each other with 14W recording the highest performance in terms of leaves. This may be attributed to the fact that enough nutrients required for leaves to develop were released from decomposed false yam into the media at 14W.

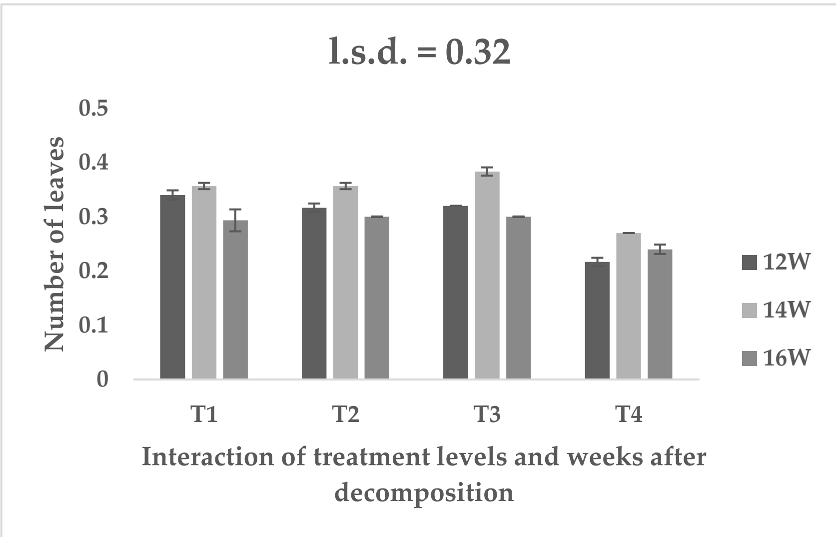

Figure 7. Number of leaves per plant (Set-up 1).

3.5. Plant height

In set-up 1 (figure 8), there were significant differences (P<0.05) between all treatments. Generally, T1, T2, and T3 were not significantly different from each other but were different from control (T4). This may be attributed to the fact that decomposed false yam added nutrients to the soil since all the treatments with decomposed false yam mixed with topsoil performed better than the control. The authors in [38] reported that manure is a source of nutrients, which are released through mineralization, thus supplying the necessary elements for plant growth. However, T1, T2, and T3 were not significantly different from each other. This may be that the nutrients released from decomposed false yam into the media were perhaps enough for growth at the treatment levels as indicated in height.

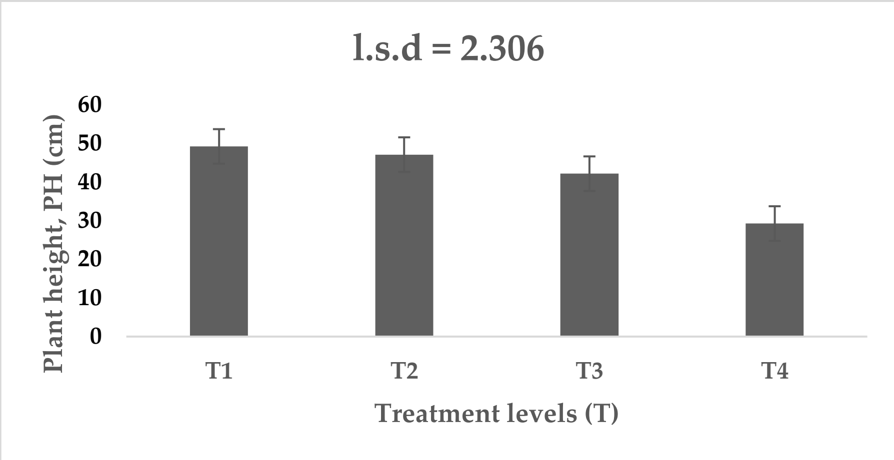

Figure 8. Plant height of test crop (Set-up 1).

Experiment 2 (set-up 2)

3.6. Plant Girth

Figure 9 reveals that there was a significant difference (P<0.05) in the four treatments for two (P=0.008) and four (P=0.019) weeks after planting. These exist between, FY and FYPD; FY and FYCDPD; FYCD and FYPD for two weeks after planting and FYCD and FYPD; FY and FYPD for four weeks after planting. However, at six weeks after planting (P=0.177), there was no significant difference in plant girth for all the treatments. This may be attributed to the differences in nutrient content and supply by treatments to the test crop at the earlier stages of the experiment. This finding is in line with the findings of the authors in [39] who stated that crop development generally, is wholly determined by the nutrients present in the medium. Authors in [40–42], reported that organic manure inputs improve the vegetative development of vegetables, attributing it to an increase in soil nutrients and microbial biomass associated with the use of organic matter.

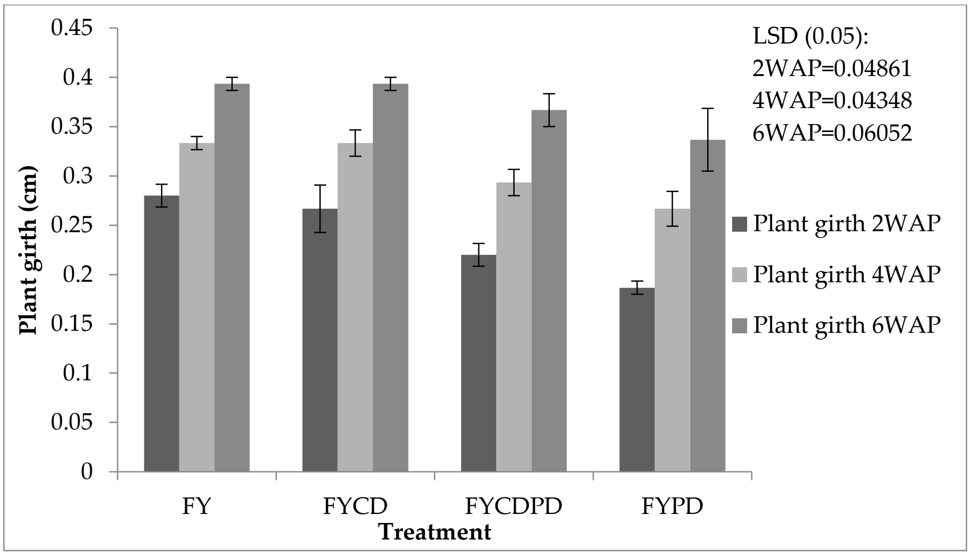

Figure 9. Plant girth of test crop (Set-up 2)**.**

However, no significant difference existed between FY and FYCD and may be said that FY and FYCD supplied similar nutrient elements essential for plant girth development. At 6 WAP, no significant difference existed in plant girth measurements for all treatments, and this may be an indication of the depletion of plant nutrient sources essential for vegetative growth and as well the inherent decrease in vegetative growth of crops near maturity.

3.7. Leaf Area

Figure 10 indicated no statistical differences in measurements for the various treatments. These indications may be associated with the physical conditions such as porosity of the media being similar. Similarly, authors in [43] verified that the leaves of cucumber grown in hydroponic sand culture were larger in total area and had different geometry in relation to plants grown in soil, thus changing the relationship between its length and width, and hence showing that environmental conditions change leaf geometry of plants of the Cucurbitaceae family. Excessive moisture resulting from poor drainage results in a reduced availability of oxygen which affects plant growth and eventually affects leaf development [44]. Authors in [45] agreed that water tension decreases the leaf area index (LAI) in greenhouse cucumber supporting the suggestion that, such difference could have resulted from poor water holding capacity which resulted in water stress.

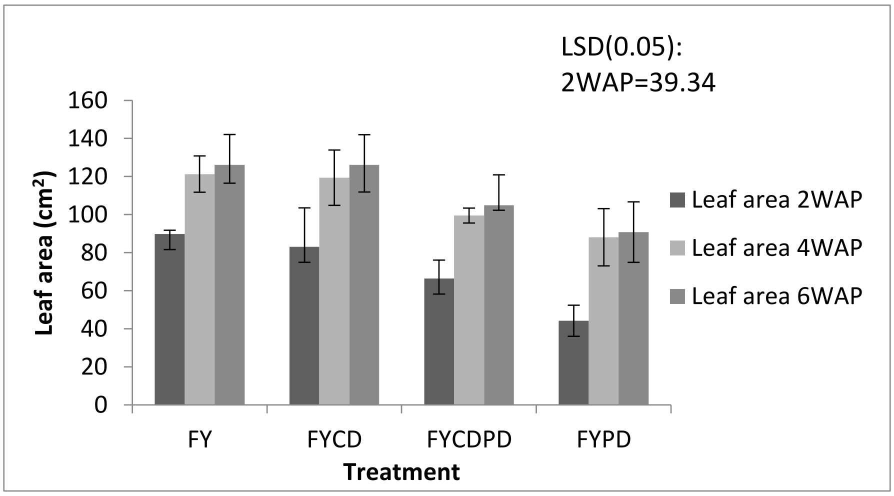

Figure 10. Shows leaf area index of test crop (Set-up 2)**.**

3.8. Number of leaves per plant

Figure 11 shows no significant difference (P>0.05) in the number of leaves measured in all the treatments at two (P=0.055) and four (P=0.097) weeks after planting. However, there is a significant difference at six weeks after planting (P=0.010). Significant differences exist between FYCD and FYCDPD; FYCD and FYPD; FY and FYCDPD.

Figure 7 illustrates no significant differences in the number of leaves per plant at two and four after planting but however, at 6WAP significant differences exist between treatments. This may be attributed to the supply of similar amounts of elemental nitrogen as plant nutrients by treatments required for leaf development during the early stages of the experiment. In accordance with this, it has been reported by literature that plants on varied substrates exhibit similarities in organ and general development of plants when nutrients are similar and functions in a sterile condition.

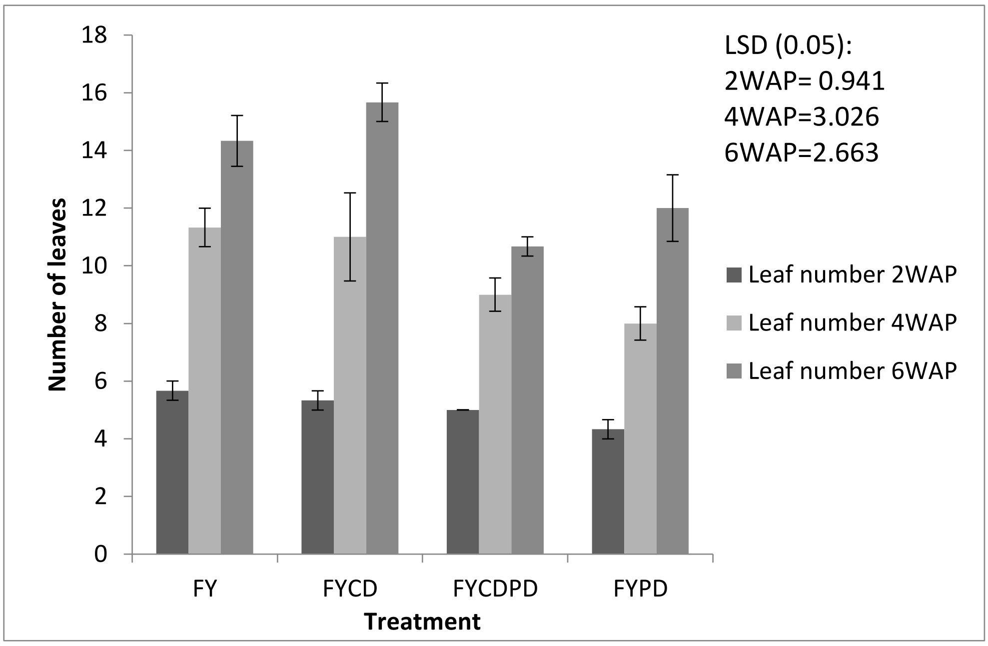

Figure 11. Number of leaves per plant for test crop (Set-up 2).

The difference may be associated with the presence of large amounts of nitrogen in FYCD as well as a resulting availability and supply of the nitrogen to the test crop. A report by the authors in [46] indicated that as the nutrient particularly nitrogen increases, leaf number per plant also tends to increase. The authors in [47] also stated that cattle manure when mixed with another nitrogen source increased the leaf number per plant in maize.

3.9. Plant height

There were significant differences (P<0.05) in plant height for all the treatments at two (P=0.015), four (P=0.014) and six (P=0.010) weeks after planting, which exist between FYCD and FYCDPD; FY and FYPD at two weeks after planting, FYCD and FYPD; FYCD and FYCDPD; FY and FYPD at four weeks after planting and FYCD and FYPD; FYCD and FYCDPD; FY and FYPD at six weeks after planting (Figure 12).

Figure 12 depicts significant differences in plant height measurements at the different weeks after planting between treatments. These differences in plant height may be associated with the difference in nutrient supply by manure inclusions specifically phosphorus and nitrogen which stimulate vegetative growth in plants or the enrichment of growth media to different degrees. Organic manure is a reservoir of nutrients, and these nutrients are released during humification, thus supplying the necessary elements for plant growth.

The differences may be attributed to the differences in the water holding capacity exhibited by the treatment and this resulting in differences in the availability of nutrients.

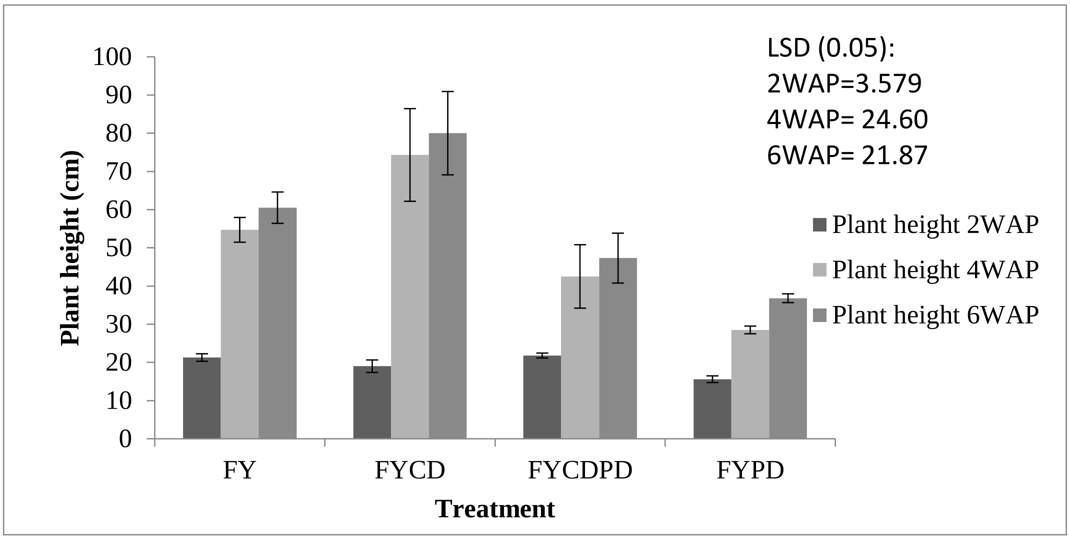

Figure 12. Shows plant height of test crop (Set-up 2)**.**

It was observed that the inclusion of manure increased the soil water holding capacity and this meant that nutrients would be made more available to crops. The cucumber plant, therefore, had enough nutrients for rapid growth and development considering the composition of the farmyard manure which was incorporated into the soil during land preparation [48,49]. It was further observed that the higher the nutrients available, the higher the values of the vine length and number of leaves produced per plant [50].

Poor water holding capacity resulting in water stress may be a reason for the differences in plant height, which is in line with [51], stating that cucumber (*Cucumis sativus* L.) is extremely sensitive to adverse conditions particularly water stress.

4. Discussion

The result of the study showed the potential of false yam tuber compost incorporation in soil as an organic source of soil amendment to improve not only soil nutrients but also phyco-chemical properties of the soil. First, our research was able to affirm the effect of soil pH on seed germination of test crop. Other studies have indicated that some crops perform in certain optimal pH range whereas our test crop performed within a pH of 5.5 to 6.7. This was in range of the optimal pH necessary for cucumber development as reported by Robert R. Westerfield, Extension Horticulturist. The period of decomposition influenced the performance of the amendment and consequently, the test crop. Composted organic materials release nutrients at rates that are regarded as sluggish (1-3 % of total nitrogen per year), and the leaching process can last for several years, according to the author's study in [52]. We observed that as the weeks of planting progresses, the performance of the test crop increases indicating the slow release of nutrients into the plant growth medium.

Composts older than 12 weeks, showed signs of nutrient deficiency on the leaves of the test crop. This informed us that the best optimal period to compost false yam tuber for biofertilizer should not exceed 12 weeks since this could lead to loss of nutrients in the biofertilizers. To enhance the retention of nutrients in the growing medium, we postulate that the time of decomposing biomaterials to be utilized as biofertilizer should be carefully taken into consideration. Again, incorporating animal manure in the false yam-topsoil medium improved the water holding capacity and increases the growth performance of the test crop. This indicates that the additions of animal manure were able to improve both the nutrient content and the physical properties of the growth medium. Therefore, we have found that adding false yam tuber compost to topsoil has the potential to increase crop yield and enhance the physico-chemical characteristics of the soil. This discovery was made while trying to develop an alternative, affordable, sustainable, and eco-friendly biofertilizer for the small-scale farmers in northern Ghana. However, this investigation was carried out in the plant house, a controlled environment. Therefore, to determine its viability, additional research must be conducted on a trial field to evaluate the effectiveness of these plant growth media in the harsh climatic conditions of Ghana's northern region.

5. Conclusions

The study revealed that growth performance increased when 12 weeks old false yam tuber compost was added to topsoil. FYCD and FY performed better than FYCDPD and FYPD after animal manure was added to twelve weeks old compost in a 1:2 ratio with topsoil. It was noticed that false yam compost integrated with cow dung enhanced crop performance with better physical medium characteristics as well as pH. In summary, the study showed that 12W old false yam compost may be preferred at 1:2 ratio with topsoil. Combining with cow dung manure will positively support crops with better soil properties that will maximize crop performance and thus serving as a good soil amendment which is cost-effective.

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