Turkish Journal of Agriculture - Food Science and Technology, 11(4): 811-822, 2023
DOI: https://doi.org/10.24925/turjaf.v11i4.811-822.5520

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effects of Compost and Nano-Gel Water Accumulator Applications on Soil Properties and on the Early Growth of *Amaranthus Spinosus*

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ARTICLE INFO

Research Article

Received : 20-09-2022
Accepted : 16-12-2022

Keywords:
Alfisols
Amended soil
Compost
Food security
Nano-gel water accumulator

ABSTRACT

The depletion of minerals in agricultural soils has been a major food security challenge in many parts of the world. To curtail this problem, farmers use inorganic fertilizer to boost soil fertility even though it poses a lot of environmental challenges. In this research, an alternative route to soil nutrient amendment was explored via the use of compost and nano-gel water accumulator. The rock side soils and cultivated soils were mixed respectively with compost and nano-gel water accumulator in ratios of 1:0, 1:1, 1:2, and 2:1 using a suitable potting media for the greenhouse production of *A. spinosus L*. Physicochemical values, mineral, and heavy metals concentration were evaluated in the soil and compost samples while mineral, proximate, anti-nutrients and vitamins compositions were analyzed in *A. spinosus L.* grown on the soils. Data obtained were analyzed using analysis of variance (ANOVA) at a 95% confidence limit using SPSS 20.0 software. The properties of self-prepared compost (PC) and commercial compost (CC) were evaluated and compared. Both composts have appreciable nutrients for soil amendation. The experimental results obtained from the use of CC showed that nano-gel water accumulator and compost on one hand significantly improved the soil fertility and produced higher nutritional values on *A. spinosus L.* when compared with when compost is used alone or when they are not used at all.

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Introduction

Soil is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. Low soil fertility is one of the main factors responsible for the low productivity of vegetable crops in some parts of the world, but productivity can be enhanced by the use of compost. Alfisols are moderately weathered and are less acidic soils with a clay-enriched subsoil, relatively moderate inherent fertility, and a base saturation >50%, formed in semiarid to humid areas, typically under forested vegetation (Bekele and Birhan, 2021; Miguel, 2004). Due to soil fertility problems, crop returns from soils cultivated over many years (cultivated soils) often decrease and the crops are now more susceptible to pests and diseases because they are in bad condition (Yang et al., 2006). To increase soil fertility for plant growth and production on such soils, nutrients such as C, H, O, N, P, K, S, Ca, Mg, Fe, B, Mn, Cu, Zn, Mo, Ni, and Cl have to be added and this is often done by applying inorganic fertilizers (Pagani et al., 2010; White and Brown, 2010). More so, small-scale farmers are often faced with the challenges of the high cost of inorganic fertilizers, which can worsen food security issues. Combating this menace, there is therefore the need to seek for improved ways of boosting food crop production through the use of cheap, natural, biocompatible, and biodegradable organic fertilizer, such as compost applications (Mark Risse, 2017).

Composting is a biological process by which micro-organisms convert organic materials such as crop residues and/or animal manure into a dark humus-rich soil-like material called compost. It can be made on the farm at a very low cost; the most important input is the farmer's labour (Eleroğlu and Korkmaz, 2016). In order to improve soil fertility in the long term, it is necessary to amend the cultivated soil with compost to improve the soil structure and organic matter content (Cooperband, 2000). Nitrogen losses do occur by the downward movement of water through the soil profile (Ibrikci et al., 2012). Amongst the various forms of N, only nitrate is leached out more from the soil in considerable amounts by the percolating water (Adeniyan et al., 2011). This nitrate leaching constitutes a major N loss mechanism from field soils with humid climates supported by irrigated cropping systems (Mba, 2006). This mechanism is however slowed down when compost is used instead of inorganic fertilizer (Annabi et al., 2007).

Nano-gel water accumulator is made of copolymer granules based on potassium salt which provides an increased utilizable reservoir capacity for soils and bedrock. In contact with water, the granules swell up into gel particles. The roots grow straight through the gel particles and absorb water and nutrients from soils (SHEPROS, 2021). However, to reduce the depletion of soil nutrient content through leaching, it is necessary to conserve water with the use of a nano-gel water accumulator. This will reduce the frequency of plant watering during the dry season and thus enable growing of plants in dry locations. Moreover, its usage is environmentally friendly with inherent highly effective natural minerals that improve the ion exchange between the water, soil, and plants (Akhtar et al., 2022; Bhat et al., 2021).

Amaranthus spinosus L. (Family Amaranthaceae) is an annual vegetable that is widely available in the humid zone of the tropics. *Amaranthus spinosus (A. spinosus)* is eaten as a vegetable in many parts of Africa. It is reported that most amaranth cultivars grow rapidly and could be harvested from 30 to 55 days from sowing when they would have reached a height of 0.6m (Mofunanya et al., 2015). The timing of harvest is not as straightforward as with other commodity crops. Management during harvest is highly critical in the production of grain amaranth. Without careful harvest techniques, most of the seed would be lost. *A. spinosus* is also a very good source of fodder for cattle and goats (Alegbejo, 2014). The *A. spinosus* has been reported to possess nutritional and pharmacological properties (Assiak et al., 2001).

The objective of the present study is to investigate the effectiveness of compost and nano-gel water accumulator applications on soil properties and on the early growth of *Amaranthus Spinosus. This is* expected to give clue to the impact on the soil quality, on the nutrients in the *A. Spinosus*, and thus project some lasting solution to challenges in cultivating nutritious food.

Materials and Methods

Nano-gel Water Accumulator Origin

The nano-gel water accumulator used was bought from Nano land South Africa. Nano-gel water accumulator was used in this study to increase the water retention capacity of soils and substrates and to improve the ion exchange capacity in the water, soil, and plants.

Compost Sampling and Preparation

The commercial compost (CC) sample was collected from the National Environmental Standards and Regulations Enforcement Agency (NESREA), Ilokun, Ado-Ekiti, Nigeria, and packed in a sterile sample bag for analysis. For proper analytical comparison with the compost sample collected from NESREA, freshly prepared compost (PC) was generated in the laboratory using the method invented by a farmer in India, Narayan Deotao Pandharipande, popularly called the 'NADEP' composting method.

The prepared compost (PC) was obtained by mixing (w/w) 50% sawdust and 50% cow dung and was prepared for a period of 10 weeks to achieve a complete composting process and quality compost production through a perfect decomposition of the ingredients, from the raw materials to form dark-colored compost. The preparation also involved frequent watering of the prepared compost at an interval of 11 h daily to aid the growth of microorganisms. During moistening, over wetting was avoided to avoid leaching of the nutrients. The compost temperature was also taken and recorded at intervals before wetting. After the mixture has been completely composted, the compost was air dried under atmospheric temperature, crushed to reduce the surface area of the compost using mortar and pestle, and sieved through a 2 mm mesh size. The sieved sample was collected and stored for laboratory analysis.

After preliminary comparative analysis (physicochemical properties and mineral composition) had been carried out on samples of the commercial compost (CC) and prepared compost (PC) and verified to be fairly comparable, only CC was used to treat the soils by blending with different ratios of the over-used soils. The different blends were UACS: Un-amended cultivated soil, ACS1:1: Amended cultivated soil 1:1, ACS1:2: Amended cultivated soil 1:2, ACS2:1: Amended cultivated soil 2:1, ACS1:1N: Amended cultivated soil 1:1 with nano-gel water accumulator. Others were UACRS: Un-amended cultivated rock soil (i.e. degraded soil called rock soil), UACRSN: Un-amended cultivated rock soil with nano-gel water accumulator, and ACRS1:1: Amended cultivated rock soil 1:1 with compost without a nano-gel water accumulator.

Soil Sampling and Preparation

Over-used soil (cultivated soil) and degraded soil (cultivated rock soil) were collected from a farm settlement opposite Pathfinder Hotel along Ekiti State University Road and at Omojola Layout in Government Reserved Area (GRA), Nigeria, via Immigration Office along with Ado – Ijan road respectively. Dominant soil types in the study region have generally been classified as alfisols (Fasina, 2004). Digging for soil samples was done on the field to a depth of 30 cm and bulked for routine analysis. The samples were then air-dried, crushed, and sieved using a 2 mm mesh sizes sieve for laboratory analysis.

Planting Procedure

Eight pots (a) UACS: Un-amended cultivated soil, (b) ACS1:1: Amended cultivated soil 1:1, (c) ACS1:2: Amended cultivated soil 1:2, (d) ACS2:1: Amended cultivated soil 2:1, (e) ACS1:1N: Amended cultivated soil 1:1 with nano-gel water accumulator, (f) UACRS: Un-amended cultivated rock soil, (g) UACRSN: Un-amended cultivated rock soil with nano-gel water accumulator, and (h) ACRS1:1: Amended cultivated rock soil 1:1) were duplicated with a space of 20 cm between pots and filled up with treated soils of different ratios (soil, compost, and nano-gel water accumulator). The treated soil samples were mixed thoroughly and wet with water by hand as required for two weeks before seedlings were planted. On the other hand, a nano-gel water accumulator was applied immediately after planting the seeds of *A. spinosus*. Fifteen pieces of *A. spinosus* seeds were planted in each pot, maintaining a planting distance of 2 cm in a circular arrangement. The seeds of *A. spinosus* were collected from the Ministry of Agriculture and Food Security, Osun State, Osogbo, Nigeria. The seedlings were allowed to grow to the maturity stage for a period of 8 weeks in a greenhouse at 15±2°C minimum night temperature and 28±2°C maximum day temperature before harvesting. During this period the growth pattern of all the cultivated *A. spinosus* was determined and pictured. The plant heights were determined with the use of a tape rule, measured from the base of the plant above the ground to the last expanded leaf of the growing tip. At the end of the experiment, the plant grown is plucked and then the leaf, stem, and root were crushed together and dried at a temperature of 70°C for 24 h and milled into powder in an electric mill. Furthermore, 20 g were taken from each grinded sample for the determination of proximate, minerals, anti-nutrients, and vitamins A and C contents.

Determination of the Physicochemical Properties

The physical and chemical properties were determined on the soil samples and compost samples, the parameters include pH, percentage moisture content (%MC), percentage nitrogen, percentage organic carbon, percentage organic matter, percentage exchangeable hydrogen ion (%E_{H^+}), percentage exchangeable aluminum ion (%$E_{Al^{3+}}$), cation exchange capacity (CEC) (meg/100g), and bulk density (g/cm^3).

A suspension of 20 g fresh sample and 50 ml distilled water was stirred for 30 min, at 25°C for measuring pH. Nitrogen was determined by the modified Kjeldahl's method (Licon, 2022). Organic carbon and organic matter were determined by the Walkley and Black method (Walkley and Black, 1934). Bulk density and particle density were measured according to Blake's procedure (Blake, 1965). Exchangeable acidity was determined by the KCl extraction method (Mclean, 1965). Moisture content was determined using 3 g samples dried in the oven at 103±2°C for three hours and continued until a constant weight was attained. Cation exchange capacity was determined using the procedure outlined by Olaitan et al. (1988). The particle size distribution was determined with the hydrometer method (Day, 2015), and the percent (%) clay, silt, and sand in the soils were determined using the typical texture triangle diagram (SHEPROS, 2021).

Determination of the Proximate Chemical Composition of Some Nutrients

The proximate composition of the nutrient were determined by existing methods (International, 2019; Pearson, 1976). Carbohydrate was determined by difference: 100 – (% moisture +% proteins +% lipids +% ash +% fibres). The calorific value was estimated using the equation: (% proteins x 2.44) + (% carbohydrates x 3.57) + (% lipids x 8.37) (Patricia Oulai et al., 2015). Vitamin A was determined spectrophotometrically at a wavelength of 440 nm according to the established methods; while Vitamin C (ascorbic acid) content determination was conducted by titration method according to the method of Barakat et al. (1973).

Determination of Minerals and Anti-nutrients

The concentration of Na, K, P, Mg, Ca, Cu, Zn, Co, Cd, Pb, and Cr minerals were determined in the soil samples and vegetable samples using an atomic absorption spectrophotometer Buck 210 model (International, 2019). Sodium and potassium levels were estimated using flame photometry (Jenway PFP7 Clinical Flame Photometer, UK). Phosphorus was determined as described by the vanado-molybdate yellow colorimetric technique (Pearson, 1976). Alkaloids and reducing compounds by the Harborne method (Harborne, 1998), tannins by Van Buren and Robinson method (Van Buren and Robinson, 1969), saponins by the Obdoni procedure (Obdoni, 2002), flavonoids by Bohm and Koupai-Abyazani, (1994), while the total phenol, phytate, and oxalate were determined as described by Abara et al. (2000).

Results and Discussion

Temperature Examination During Compost Preparation

The temperature readings during compost preparation of Prepared Compost (PC) are shown in Table 1. The composting was done for a period of 10 weeks. The graph of percentage (%) change in temperature against time (Figure 1) during composting peaked at week 4 which is indicative of the time that the composting process has the highest microbiological activity.

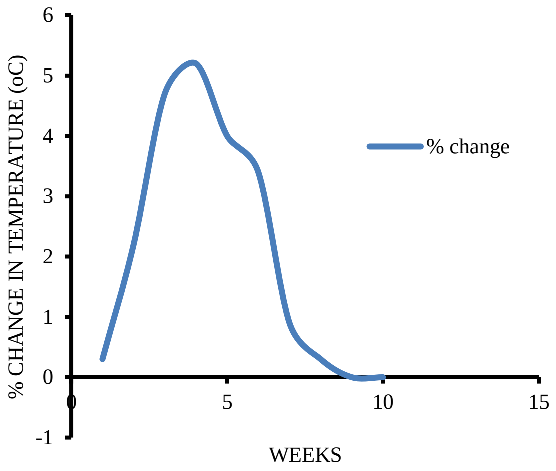

Figure 1. Graph of% change in Temperature against Time (Weeks) during composting.

The highest temperature (°C) reached during the composting process in week 4 (34.2±0.8) was attributed to the activities of microorganisms as shown in Table 1 and Figure 1. Temperature increased gradually from week 1 to week 4 with mean values of 32.2±1.7, 32.5±0.6, 33.5±0.6, and 34.2±0.8 progressively. This could be attributed to strong heat accompanying the exothermic microbial activities which dropped slightly from week 5 to week 8 with mean values of 33.4±0.6, 33.2±0.6, 32.6±0.3, and 32.5±0.2 for weeks 5, 6, 7 and 8 respectively. The temperature stabilized at room temperature of about 33.3°C (constant value) for weeks 9 and 10 with the percentage change in temperature (%) being 0.0. This affirms the attainment of complete composting for the prepared compost.

Table 1. Temperature (°C) variation and observations made during composting

Weeks	Ambient °C (1)	°C in Compost (2)	°C for Difference (2-1)	%Change in °C	Remark
Week 1	32.1±1.1	32.2±1.7	0.1±0.6	0.3	Exothermic
Week 2	31.8±1.1	32.5±0.6	0.7±0.5	2.2	Increasing
Week 3	32±0.5	33.5±0.6	1.5±0.1	4.7	Increasing
Week 4	32.5±0.5	34.2±0.8	1.7±0.3	5.2	Highest microbial and respiratory activity
Week 5	32.1±0.4	33.4±0.6	1.3±0.2	4.0	Decreasing
Week 6	32±0.3	33.2±0.6	1.2±0.3	3.4	Decreasing
Week 7	32.3±0.2	32.6±0.3	0.3±0.1	0.9	Decreasing
Week 8	32.4±0.1	32.5±0.2	0.1±0.1	0.3	Decreasing
Week 9	32.3±0.2	32.3±0.2	0.0±0.0	0.0	Matured and stable
Week 10	32.4±0.1	32.4±0.1	0.0±0.0	0.0	Matured and stable

Results are expressed as the mean±SD.

Physicochemical Properties of Prepared Compost and Commercial Compost

Table 2 presents a comparative analysis result of the physicochemical parameters of prepared compost (PC) and commercial compost (CC). It revealed that the mean pH values of the PC and CC samples varied significantly (P<0.05) with mean values of 9.3±0.2, and 9.0±0.2 respectively. This indicates that the compost samples were alkaline showing typical mineral compost behaviour. Our prepared compost was slightly more alkaline. According to the results presented in Table 2, the mean values of moisture content for the compost samples (CC and PC) were found to be low but no significant (P<0.05) difference exists between them. The mean moisture content of the PC and CC samples were: 1.3±0.01% and 1.2±0.01% respectively as shown in Table 2. The lower moisture content of the commercial compost samples was due to its lower density occasioned by a longer drying period and storage time at the ambient temperature of the samples. The mean nitrogen values of all the compost samples varied significantly (P<0.05). The percentage nitrogen content in the prepared compost (PC) was 3.15±0.01% while that in the commercial compost (CC) was 3.20±0.005%. According to Eghball (2002), the extent of nitrogen mineralization is controlled by compost properties of its organic carbon content, soil moisture, soil texture, and microbial activity.

The mean values of the % organic carbon for PC (6.3±0.2%) were significantly higher than for CC (6.2±0.007%) at P<0.05level. The result obtained for the organic matter of the compost samples is the same trend as that for organic carbon. The mean value ranged from 10.8±0.1 to 11.0±0.2%. The result for the mean values of exchangeable hydrogen ion,%E_{H}^{+} was (5.04±0.01, 5.11±0.01%) for PC and CC which were significantly (P<0.05) different compared to exchangeable aluminium ion,%E_{Al}^{3+} that had mean values (2.22±0.01, 2.19±0.01) which were not significantly (P<0.05) different. The cation exchange capacity (CEC) of CC was significantly (P<0.05) higher than PC. The mean value of CEC for CC was 7.3±0.01 c.mol/kg while that for PC was 7.2±0.01.c.mol/kg However, the level of CEC observed in the compost samples is indicative of their efficiency as cationic exchangers in amending soil nutrients (Table 4 and Table 5). While the mean values of bulk density (1.07±0.01, 1.04±0.005 g/cm^3) and particle density (2.32±0.01, 2.29±0.01%) for PC and CC respectively were not significantly different, the mean particle size values of all the compost samples varied significantly (P<0.05).

These results reveal that PC contained slightly less of % N, % E_{H}^{+} and CEC while results for pH, organic carbon, organic matter, E_{Al}^{3+}, and particle density, were slightly higher compared with the CC. The variation in the level of physicochemical properties between commercial and prepared compost could be due to the nature of compost preparation, but the trends are practically similar.

The Mineral Composition of Prepared Compost and Commercial Compost

Table 3 below shows that the mineral composition of PC and CC resulted in close mean values justifying that the composts are both good for soil amendment. The mean values of mineral compositions of CC and PC were slightly close. The results show that PC and CC have a high content of the macronutrients, K, Ca, and Mg. The values obtained for Ca (65.44±1.4, 66.43±1.4) and Mg (5.39±1.1, 4.78±0.5 mg/100g) were slightly lower compared to K (74.88±0.5, 81.23±1.1) mg/100 g respectively for PC and CC. This observation supports the statement that organic manure even though it has the ability to supply the required macro and micro plant nutrients, the kinetics involved makes releases in low quantities over time. The mean values for K, Ca, and Mg in all the samples varied significantly (P<0.05) between both compost samples. The mean value obtained for the heavy metals in PC and CC showed Pb (0.03±0.05, 0.01±0.05 mg/100 g) and Zn (1.46±1.1, 1.49±1.1 mg/100 g) were observed in low quantities likewise Cr (0.05±0.00, 0.02±0.00 mg/100 g), Co (0.02±0.00, 0.03±0.00 mg/100 g) and Cd (0.06±0.00, 0.03±0.01 mg/100 g) were fairly low in both compost samples. However, Cu (10.2±0.01, 11.5±0.01 mg/ 100 g) concentrations were high in both samples. The mean value of phosphorus in PC (81.6±0.01 mg/ 100 g) was significantly (P<0.05) higher compared to that in CC (78.5±0.03 mg/100 g). This difference in the mean was caused by the variations in the efficiency of the composting process.

Physicochemical Properties of Soil Samples before Planting in Different Ratios

The physico-chemical properties of soil samples (cultivated soil and degraded soil/rock soil) in different ratios (UACS: Un-amended cultivated soil, ACS1:1: Amended cultivated soil 1:1, ACS1:2: Amended cultivated soil 1:2, ACS2:1: Amended cultivated soil 2:1, ACS1:1N: Amended cultivated soil 1:1 with nano-gel water accumulator, UACRS: Un-amended cultivated rock soil, UACRSN: Un-amended cultivated rock soil with nano-gel water accumulator, ACRS1:1: Amended cultivated rock soil 1:1) are shown in Table 4.

Table 2. Comparative data of the physicochemical parameters of prepared compost (PC) and commercial compost (CC).

Parameters	Samples PC	CC
Chemical properties		
pH	9.33±0.01^b	9.06±0.01^a
% MC	1.26±0.01	1.22±0.01
% Nitrogen	3.15±0.01^a	3.20±0.005^b
% Organic carbon	6.34±0.01^b	6.29±0.005^a
% Organic matter	10.96±0.02 ^{b}	10.78±0.01 ^{a}
% E_H^+	5.04±0.01^a	5.11±0.01^b
% E_{Al}^{3+}	2.22±0.01	2.19±0.01
CEC (c.mol/kg)	7.17±0.01^a	7.33±0.01^b
Physical properties		
Bulk density (g/cm^3)	1.07±0.01^a	1.04±0.005^a
% Particle density	2.32±0.01	2.29±0.01

Results are expressed as the mean±SD.; PC: Prepared Compost, CC: Commercial Compost, MC: Moisture Content, CEC: Cation Exchange Capacity, E_H^+: Exchangeable hydrogen ion, E_{Al}^{3+}: Exchangeable aluminium ion, and SD= Standard Deviation. Means are coded a-b, and codes of the same letter on the same row are not significantly different at P<0.05. n=4.

Table 3. Comparative data of the mineral composition of prepared compost (PC) and commercial compost (CC).

Parameters (mg/100g)	PC	Samples CC
P	81.6±0.01 ^{b}	78.5±0.03 ^{a}
K	74.88±0.5^a	81.23±1.1^b
Mg	5.39±1.1^b	4.78±0.5^a
Na	67.40±0.5^a	69.31±1.7^b
Ca	65.44±1.4 ^{a}	66.43±1.4 ^{b}
Cu	10.2±0.01^a	11.5±0.01^b
Pb	0.03±0.05	0.01±0.05
Zn	1.46±1.1	1.49±1.1
Cd	0.06±0.00^b	0.03±0.01 ^{a}
Cr	0.05±0.00^b	0.02±0.00^a
Co	0.02±0.00	0.03±0.00

NB: Results are expressed as the mean±SD; PC: Prepared compost, CC: Commercial compost, and SD= Standard Deviation; Means are coded a-b, and codes of the same letter on the same row are not significantly different at P<0.05. n=4.

The soil pH indicates the acidic or alkaline nature of the soil. The pH level of the soil samples ranged from 7.39-11.12 which indicated the alkaline nature of the soil samples. This study revealed that the highest value of pH was recorded in un-amended spent rock soil with nano-gel water accumulator (UACRSN) being 11.12 and the lowest value of pH was observed in un-amended spent rock soil (UACRS) with a value of 7.39. According to Adeyeye (2005), soil pH may influence nutrient absorption and plant growth either through the direct effect of the hydrogen ion levels (pH) or indirectly, through its influence on making nutrients and toxic ions available at that particular pH. In most soils, the latter effect is of great significance. Several essential elements such as Fe, Mn, and Zn tend to become less available as the pH is raised from 5.0 to 7.5 or 8.0. At pH values below 5.0, Al, Fe, and Mn are often soluble in sufficient quantities to be toxic to the growth of some plants.

This study has revealed that the application of compost and nano-gel water accumulator on soils has a greater potential on soil pH. This implies that the application of compost and nano-gel water accumulator could serve as a good route to amending soils that are acidic in nature. It was also observed that the application of compost increased the soil moisture in the different soil samples. The soil with nano-gel water accumulator (UACRSN, ACS1:1N) was found to be significantly higher in mean percentage moisture than soils amended with only compost (ACS1:1, ACS1:2, ACS2:1, ACRS1:1) and soil without compost and nano-gel water accumulator (UACRS, UACS).

Nitrogen is the most important nutrient stored in soil organic matter from which it is mineralized into ammonium-N by the action of soil organisms. The present study revealed significant differences in the nitrogen percentage of the different soil samples which ranged between 0.81 to 2.71%. The highest value of % nitrogen was recorded in UACRSN (2.71%), and the lowest value was observed in ASS1:2 (0.81%). The % organic carbon ranged from 4.48 % (UACRS) to 8.36% (ACRS1:1). This study showed that the application of compost and nano-gel water accumulator increased the proportion of organic carbon on the soil surface; this indicated an increase in the level of organic matter, which has a significant impact on plant nutrition. Thus, all the amended soil samples had an appreciable level of organic carbon that can enhance the soil nutrients.

The highest value of exchangeable hydrogen ion (E_H^+) was recorded in ACRS1:1 (5.56%) and the lowest value was recorded in UACRS (4.21%). The values of E_H^+ were significantly different across all the soil samples. It was also found that the E_H^+ value of all the soil samples increased significantly after planting. The mean value of exchangeable aluminum ion (E_{Al}^{3+}) of all the soil samples varied significantly (P<0.05). It ranged from 0.93 to 2.9%. The highest value of E_{Al}^{3+} was found in ASRS1:1 while the lowest mean value was found in UACRS.

Cation exchange capacity (CEC) is determined by the level of clay and organic content. The mean CEC value of UACRS was significantly higher (P<0.05) than other soil samples. The values of CEC ranged from UACRS (5.77meq/100kg) to ASS2:1 (6.32 meq/100kg). However, the mean value of CEC observed in the soil samples will influence the soil's ability to retain essential nutrients and provides the needed buffer against soil acidification. Sneh et al. (2005) confirmed that compost act as a reservoir of plant nutrients and prevent leaching of the plant nutrients by retaining a high cation exchange capacity, as well as protecting growing plants against unexpected changes in their chemical environment.

The particle density significantly varied (P<0.05) across all the soil samples. The particle density in UACRS had a higher mean value of 3.25% while UACRS had the lowest mean value of 1.85%. In comparing the particle density mean value of soil samples without compost and nano-gel water accumulator, it was found that the mean value of rock soil sample UACRS (3.25%) was higher than spent soil samples UASS (2.61%). The highest value of bulk density was recorded in the ACRS1:1 (1.71 g/cm^3) while UASS gave the lowest value (1.16 g/cm^3).

Table 4. Comparative data of the physicochemical parameters of soil samples in different ratios before planting.

Parameters	Samples,							
	UACRS	UACS	UACRSN	ACS1:1	ACRS1:1	ACS1:2	ACS2:1	ACS1:1N
pH	7.39±0.01^{a}	8.83±0.07^{c}	11.12±0.07^{o}	9.06±0.02^{e}	9.19±0.00^{f}	9.89±0.01^{i}	9.03±0.02^{d}	9.42±0.02^{g}
% MC	1.54±0.01^{d,e}	1.52±0.07^{c,d}	1.62±0.02^{h,i}	1.52±0.03^{c,d}	1.54±0.01^{d,e}	1.46±0.02^{a}	1.51±0.00^{b,c}	1.61±0.02^{g}
% Nitrogen	0.95±0.01^{d}	0.82±0.02^{b,c}	2.71±0.07^{g}	0.82±0.03^{b,c}	0.83±0.01^{b,c}	0.81±0.00^{b,c}	0.82±0.00^{b}	0.84±0.02^{c}
% OC	4.48±0.02^{a}	4.85±0.07^{b}	8.15±0.07^{j}	7.76±0.02^{e}	8.36±0.02^{l}	7.81±0.00^{f}	7.89±0.007^{g}	7.84±0.00^{g}
% OM	7.75±0.03^{a}	8.35±0.06^{b}	14.1±0.07^{i}	12.57±0.01^{d}	15.06±0.02^{l}	13.48±0.02^{f}	13.58±0.00^{g}	13.53±0.00^{g}
% E_{H}^{+}	4.21±0.01^{a}	4.56±0.02^{b}	5.53±0.07^{d}	5.21±0.01^{c}	5.56±0.02^{j}	5.37±0.01^{e}	5.42±0.02^{f}	5.31±0.00^{d}
% E_{Al}^{3+}	0.93±0.04^{a}	0.98±0.07^{b}	2.82±0.07^{f}	2.72±0.02^{c}	2.9±0.02^{h}	2.76±0.01^{e}	2.80±0.02^{e}	2.70±0.00^{c}
CEC	5.77±0.01^{a}	5.9±0.02^{b}	6.06±0.02^{c}	6.11±0.01^{d}	6.07±0.03^{c}	6.27±0.01^{f}	6.32±0.02^{i}	6.20±0.00^{e}
BD	1.64±0.01^{h}	1.43±0.01^{f}	1.63±0.07^{h}	1.32±0.03^{b}	1.71±0.02^{i,j}	1.56±0.02^{g}	1.62±0.02^{g}	1.44±0.00^{c,d}
% PD	3.25±0.07^{m}	2.61±0.01^{f}	1.85±0.07^{c}	2.62±0.07^{f}	2.86±0.02^{k}	2.72±0.00^{h,i}	2.77±0.01^{c,h}	2.65±0.00^{g}
% Sand	33.45±0.07^{f}	32.2±0.01^{a}	33.4±0.07^{f}	33.08±0.01^{c,d}	33.48±0.02^{g}	32.91±0.00^{b}	33.06±0.02^{c}	33.11±0.00^{d}
Silt (%)	44.23±0.02^{f}	41.3±0.07^{c}	44.2±0.02^{f}	43.29±0.01^{e}	44.26±0.02^{f}	43.38±0.01^{e}	42.23±1.71^{c,}	43.24±0.00 ^{e}
Clay (%)	22.31±0.09^{h}	26.3±0.08^{m}	22.3±0.01^{h}	23.66±0.01^{j,k}	22.31±0.03^{h}	23.71±0.00^{l}	23.53±0.02^{i}	23.64±0.00^{k}
STC	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam

%OC: Organic Carbon;%OM: Organic Matter; CEC: CEC (meg/100g); BD: Bulk density (g/cm3);%PD: Particle density; STC: Soil Textural Classes; NB: Results are expressed as the mean±SD; UACRS: Un-amended cultivated rock soil, UACS: Un-amended cultivated soil, UACRSN: Un-amended cultivated rock soil with nano-gel water accumulator, ACS1:1: Amended cultivated soil 1:1, ACRS1:1: Amended cultivated rock soil 1:1, ACS1:2: Amended cultivated soil 1:2, ACS2:1: Amended cultivated soil 2:1, ACS1:1N: Amended cultivated soil 1:1 with nano-gel water accumulator, ND = Not Detected, SD= Standard Deviation; Means are coded a-o, and codes of the same letter on the same row are not significantly different at $P<0.05$. n=4. Variations are indicated by the disparity in codes.

Table 5. Comparative data of mineral composition of soil samples in different ratios before planting.

Parameters (mg/100g)	Samples							
	UACRS	UACS	UACRSN	ACS1:1	ACRS1:1	ACS1:2	ACS2:1	ACS1:1N
Na	32.54±0.07^{i}	28.9±0.07^{g}	69.8±0.3$^{r, s}$	63.5±0.01^{0}	66.86±0.02^{p}	32.60±0.00^{i}	62.5±0.07^{m}	68.5±0.007^{q}
K	13.25±0.07^{i}	10.3±0.07^{h}	81.1±0.02^{s}	71.7.01^{n}	83.47±0.71^{t}	32.64±0.00^{j}	70.7±0.02^{m}	76.7±0.007^{o}
Ca	50.1±0.07^{h}	50.8±0.07^{i}	68.9±0.49^{k}	86.7±0.03^{l}	90.46±0.72^{p}	90.18±0.00^{p}	84.7±0.03^{l}	87.7±0.02^{o}
Mg	7.85±0.07^{i}	5.71±0.07^{g}	60.1±0.02^{q}	55.5±0.02^{j}	77.81±0.01^{u}	57.81±0.02^{l}	56.6±0.01^{k}	58.5±0.007^{p}
Zn	1.31±0.07^{a,b,c}	1.21±0.07^{a,b}	1.36±0.02^{b,c,d}	1.25±0.00^{a,b}	1.46±0.02^{c,d,e,}	1.20±0.00^{a,b}	1.3±0.07^{a,b,c}	1.20±0.007^{a,b}
Cr	ND	ND	0.01±0.0^{a}	0.01±0.0^{a}	0.02±0.00^{a}	ND	0.01±0.00^{a}	0.01±0.00^{a}
Cu	10.23±0.07^{k}	6.71±0.07^{f}	11.2±0.02^{o}	10.23±0.02^{k}	13.12±0.17^{p}	11.01±0.0^{m}	10.29±0.02^{k}	9.24±0.007^{i}
Co	ND	ND	0.01±0.0a	ND	0.01±0.0^{a}	ND	ND	ND
Cd	ND	ND	0.01±0.0a	ND	0.01±0.0^{a}	ND	ND	ND
Pb	ND	ND	0.05±0.01$^{a, b}$	0.02±0.0^{c}	1.04±0.01^{h}	0.01±0.0^{b}	0.02±0.0^{c}	0.02±0.00^{c}
P	69.23±0.0^{m}	50.61±0.0^{h}	70.5±0.72^{p}	65.3±0.01^{j}	68.96±0.02^{m}	67.6±0.00^{k}	65.3±0.01^{j}	65.3±0.007^{j}

Results are expressed as the mean±SD.; UACRS: Un-amended cultivated rock soil, UACS: Un-amended cultivated soil, UACRSN: Un-amended cultivated rock soil with nano-gel water accumulator, ACS1:1: Amended cultivated soil 1:1, ACRS1:1: Amended cultivated rock soil 1:1, ACS1:2: Amended cultivated soil 1:2, ACS2:1: Amended cultivated soil 2:1, ACS1:1N: Amended cultivated soil 1:1 with nano-gel water accumulator, ND = Not Detected, SD= Standard Deviation; Means are coded a-u, and codes of the same letter on the same row are not significantly different at $P<0.05$. n=4. Variations are indicated by the disparity in codes.

Table 6. Comparative data of mineral composition values obtained on the cultivated *Amaranthus spinosus* from the different soil blends.

Parameters (mg/100g)	Samples							
	PUACRS	PUACS	PUACRSN	PACS1:1	PACRS1:1	PACS1:2	PACS2:1	PACS1:1N
Na	10.08±0.04^{b}	9.87±0.04^{a}	10.81±0.33^{b}	11.39±0.09^{c}	11.44±0.05^{c}	13.15±0.03^{d}	10.84±0.38^{b}	11.81±0.3^{d}
K	4.27±0.03^{a}	4.24±0.01^{a}	5.17±0.03^{b}	5.53±0.0^{c}	5.83±0.4^{d}	8.56±0.06^{g}	5.23±0.12^{b}	6.32±0.04^{e}
Ca	5.38±0.02^{a}	5.35±0.04^{a}	6.92±0.04$^{b, c}$	7.35±0.2^{d}	7.34±0.24^{d}	6.72±0.07^{b}	6.99±0.17^{c}	7.90±0.12^{e}
Mg	1.92±0.04^{a}	1.85±0.04^{a}	2.29±0.08$^{c, d}$	2.36±0.03^{d}	2.36±0.08^{d}	2.15±0.2^{b}	2.25±0.09^{c}	2.46±0.08^{e}
Zn	1.59±0.02^{e}	1.48±0.04^{d,e}	2.50±0.1^{f}	2.82±0.33^{g}	3.13±0.14^{h}	3.82±0.42^{j}	2.48±0.1^{f}	3.30±0.07^{i}
Cr	0.02±0.00^{a}	0.01±0.0^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.02±0.00^{a}	0.02±0.00^{a}	0.01± 0.00^{a}	0.01±0.00^{a}
Cu	1.07±0.03^{c}	1±0.07^{b}	1.06±0.04^{c}	1.11±0.02^{c}	1.3±0.11^{d}	1.35±0.05^{d}	0.64±0.61^{c}	1.05±0.04^{b}
Co	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND	ND	ND	ND
P	9.83±0.35^{b}	9.58±0.70a	10.24±0.09^{c}	10.26±0.0^{c}	15.67±0.62^{e}	1.35±0.05^{d}	10.36±0.17^{c}	16.82±0.37^{f}
Ca/P	0.54$^{a, b}$	0.56$^{a, b}$	0.67$^{b, c}$	0.71^{c}	0.46^{a}	0.44^{a}	0.68$^{b, c}$	0.47^{a}
Na/K	2.35$^{d, e, f}$	2.33$^{d, e}$	2.08$^{c, d, e}$	2.05$^{c, d, e}$	1.96$^{c, d}$	1.53^{b}	2.07$^{c, d, e}$	1.87^{a}

Results are expressed as the mean±SD.PACS1:2: Plant from amended cultivated soil 1:2, PACS1:1N: Plant from amended cultivated soil 1:1, PUACRS: Plant from un-amended cultivated rock soil, PUACS: Plant from un-amended cultivated soil, PUACRSN: Plant from amended cultivated rock soil with nano-gel water accumulator, PACS1:1: Plant from amended cultivated soil 1:1, PASRS1:1: Plant from amended cultivated rock soil 1:1, PASS2:1: Plant from amended cultivated soil 2:1, ND = Not Detected, SD= Standard Deviation. Means are coded a-h, and codes of the same letter on the same row are not significantly different at $P<0.05$. n=4. Variations are indicated by the disparity in codes.

The soil samples (CC and PC) contain various levels of sand, silt, and clay particles which exhibit light and heavy properties in about equal proportions. According to Mohammed et al. (2004), application of compost to soil generally influences soil structure in a favourable way by lowering soil density due to the mixture of low-density organic matter into the mineral soil fraction. The highest value of sand was found in ACRS1:1 (33.48%) while the lowest value was UACS (32.2%). The mean silt percentage of the soil samples ranged between UACS (41.3%) to ACRS1:1 (44.29%). All the soil samples showed a high mean value of silt, their silt means values were all between 40% and 44%. However, the mean clay percentage of the soil samples ranged between UACRN (22.3%) to ACS1:2 (23.7%).

This study revealed that with the application of compost and nano-gel water accumulator to the soil samples; there was a significant positive change in the soil's physical parameters. This report is in accordance with Bouajila and Sanaa (2011), who reported that application of compost improved soil’s physical proprieties when compared with control.

Comparative Mineral Concentrations

Results of physicochemical parameters for the soils samples (UACRS: Un-amended cultivated rock soil, UACS: Un-amended cultivated soil, UACRSN: Un-amended cultivated rock soil with nano-gel water accumulator, ACS1:1: Amended cultivated soil 1:1, ACRS1:1: Amended cultivated rock soil 1:1, ACS1:2: Amended cultivated soil 1:2, ACS2:1: Amended cultivated soil 2:1, ACS1:1N: Amended cultivated soil 1:1 with nano-gel water accumulator) are presented in Table 5.

Mineral contents such as sodium, potassium, calcium, magnesium, and phosphorus varied significantly. It can be seen that the mineral composition of the soil sample and plant sample resulted in a difference (P<0.05) mean value. The effects of compost on the soil sample were found to be significantly different (P<0.05). However, it was shown that the incorporation of an increased amount of soil: compost resulted in a significantly higher mean value (P<0.05) in the soil sample and on the *A. spinosus.*

Results revealed that the soil samples showed the highest value for sodium (69.8±0.3 mg/100g), potassium (83.47±0.71 mg/100g), calcium (90.46±0.72 mg/100g), magnesium (77.81±0.01 mg/100g), and phosphorus (70.5±0.72 mg/100g) in UACRSN, ACRS1:1, ACRS1:1, ACRS1:1, and UACRSN respectively. It was observed that the majority of the minerals considered were more reduced after planting which could be due to leaching or the minerals were used up by the plants.

In addition, the results presented in Table 6 showed that Na, K, Ca, Mg, Zn, and P were significantly higher (P<0.05) in plants cultivated on amended cultivated soils 1:2 (PACS1:2) and 1:1 embellished with nano-gel water accumulator (PACS1:1N) than in plants cultivated on un-amended cultivated rock soils PUACRS, PUACS, plant cultivated on amended cultivated rock soil with nano-gel water accumulator (PUACRSN), plant cultivated on amended cultivated soil 1:1 (PACS1:1), plant cultivated on amended cultivated rock soil 1:1 (PACRS1:1) and plant cultivated on amended cultivated soil 2:1 (PASS2:1).The observation showed that PUACS had the lowest minerals values in all the plant samples which justified the need for mineralization and basis for this research. Mean values obtained for PACS1:2 in the above minerals were13.15 ± 0.08, 8.56 ± 0.06, 6.72 ± 0.07, 2.15 ± 0.2, 3.82 ± 0.42 and 15.26 ± 0.07 mg/100g while minerals values for PACS1:1N were 11.81 ± 0.3, 6.32 ± 0.04, 7.90 ± 0.12, 2.46 ± 0.08, 3.30 ± 0.07 and 16.82±0.37 mg/100 respectively. Corresponding mean values obtained for PUACS were 9.87±0.04, 4.24±0.01, 5.35 ± 0.04, 1.85±0.04, 1.84±0.04 and 9.58±0.70 mg/100g.

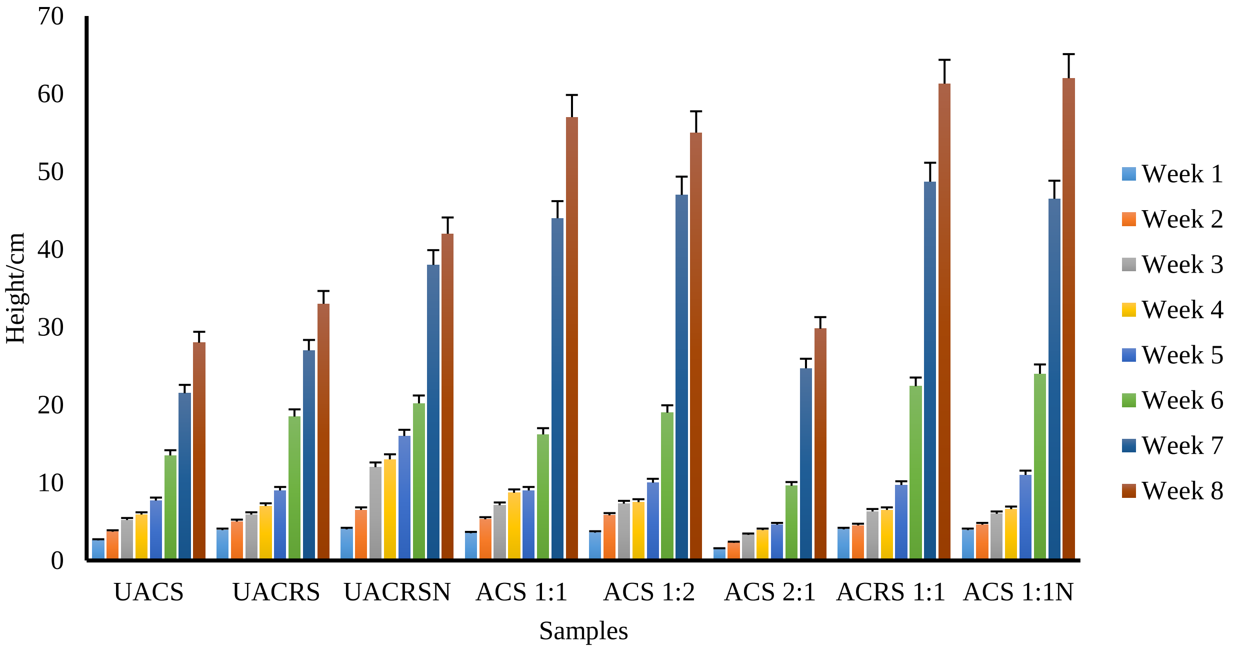

Figure 2. Growth patterns of cultivated *Amaranthus spinosus* on the different blends of soil samples from Week 1 to Week 8.

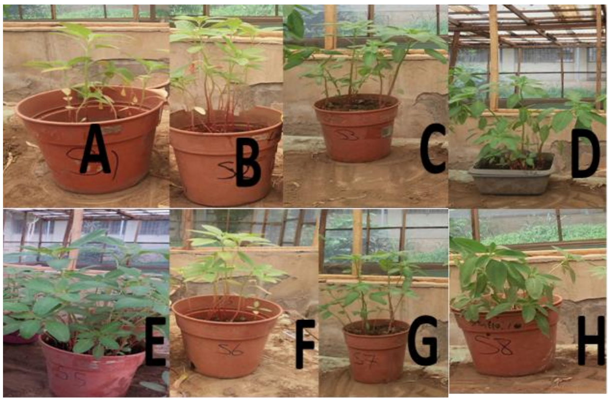

Figure 3. Pictorial view of growth pattern of cultivated *Amaranthus Spinosus L.*on all the soil samples; (A) UACS, (B) UACRS, (C) ACS 1:1, (D) ACS 1:2, (E) ACS 1:1N, (F) ACS 2:1, (G) ACRS 1:1 and (H) UACRSN.

The heavy metals Co, Cd, Pb Cr, and Cu were either in low quantities or not detected in the plant and soil samples which affirmed that the soil samples and compost used were not laden with heavy metal pollution. Also shown in Table 6 are the ratios of sodium to potassium (Na/K) in the plant samples which ranged from 1.53 ± 0.07 (in PACS1:2) to2.35 ± 0.07 (in PUACRS) mg/100g and for ratios of calcium to phosphorus (Ca/P), it ranged from 0.44 ± 0.002 (in PASS1:2) to 0.71 ± 0.01 (in PACS1:1) mg/100g respectively. The Na/K ratio in the body is of great concern for the prevention of high blood pressure. Calcium and phosphorus are associated with each other for the growth and maintenance of bones, teeth, and muscles (Dosunmu, 1997). The calcium level in the *A. Spinosus* studied compared favorably with the value reported for some green leafy vegetables consumed in Nigeria (Ladan et al., 1996). For good intestinal absorption, the Ca/P ratio should be close to unity for humans and higher for ruminants (Guil-Guerrero et al., 1998). The ratio in this sample meets this requirement and as such predicates a good Ca/P intestinal absorption. The magnesium content in all the plant samples is within the range reported for some green vegetables. Mg is a component of chlorophyll (Akwaowo et al., 2000). It is an important mineral element for the management of ischemic heart disease and calcium metabolism in bones(Ishida et al., 2000).

The Growth Pattern of Amaranthus Spinosus

The growth pattern of *A. spinosus* is shown in Figure 2 over a period of seven weeks. The highest growth was observed in *A. spinosus* cultivated on amended cultivated soil 1:1 with nano-gel water accumulator (ACS1:1N) while the shortest and poorest growth was observed in un-amended soil samples (UACS and UACRS). Figure 3 shows the pictorial view of the growth patterns observed in the different pots A – G. However, a better growth pattern was seen in all amended soil samples having the application of compost with or without the use of a nano-gel water accumulator. This indicates that the application of compost with the use of an environmentally friendly co-polymer (nano-gel water accumulator) for agriculture could provide a route to sustainable agriculture in Nigeria.

Proximate Composition of Amaranthus spinosus cultivated on different soil samples

From the results presented in Table 7, the ash content in the samples ranged from 7.04±0.01% (PUACS) to 10.41±0.01% (ACS1:2). These values indicate that the vegetable samples will serve as a good source of minerals when compared to cereals and tubers with values ranging from 2–10% (Kwenin et al., 2011).

The crude fibre of PACS1:1N was found to be significantly (P<0.05) higher with mean value of 23.48±0.01 g/100g than PACS1:1, PACRS1:1, PACS1:2, PACS2:1, PUACRS, PUACS and PUACRSN with values of 23.44±0.01, 21.37±0.01, 21.49±0.01, 21.44±0.01, 20.43±0.01, 21.39±0.01 and 20.39±0.01 g/100g respectively. The mean values are relatively close and affirm that *A. Spinosus* is a rich source of dietary fibre. A high level of crude fibre in vegetables is advantageous for the regulation of intestinal movement, increasing dietary bulk based on the ability to absorb water (Patricia Oulai et al., 2015). It has been posited that intake of adequate dietary fibre can lower the serum cholesterol level and thus lower the risk of coronary heart diseases, hypertension, colon and breast cancer, constipation, and diabetes (Anderson et al., 2009).

However, fat content of 7.26±0.01 g/100g obtained for PASS1:1 is significantly (P<0.05) higher compared to mean value of PACS1:1N (7.24±0.01), PACRS1:1 (6.83±0.02), PACS1:2 (6.86±0.01), PACS2:1 (6.87±0.05), PUACRS (7.16±0.007), PUACS (7.21±0.07) and PUACRSN (7.1±0.01) g/100g. Thus, fat content in the plant samples showed justification for their essential diet intake.

PACRS1:1 had the highest mean value of protein content (17.24±0.01) g/100 g and followed by 16.36±0.02 g/100g for PASS1:1N while the least mean value was 15.19±0.01 g/100g (PACS2:1). The mean value of protein content of *A. spinosus* was found to be within the range reported for some leafy vegetables; *Momordica balsamina* (11.29%) and *Moringa oleifera* (20.72%) (Asaolu et al., 2012). Studies have shown that plant food that provides more than 12% of its calorific value from protein is considered a good source of protein (Aberoumand, 2009). Therefore, the result obtained from this study on *A. spinosus* meets this requirement. Adults, children, and pregnant and lactating mothers require 34 - 56, 13 - 19, and 17 and 71 g of protein daily, respectively. This suggests that the vegetable investigated in this study is a good source of proteins and could play a significant role in providing cheap, affordable, and available proteins for rural dwellers. However, protein is the major source of building material for the body. It may be used as a source of heat and energy. Excess protein that is not used for building tissue or energy can be converted by the liver and stored as fat in the body tissues (Akinyeye et al., 2011).

The mean value of carbohydrate content of PUACRS (39.26 ± 0.04) g/100g is significantly (P<0.05) higher than mean value of PACS1:1 (34.79 ± 0.07) g/100g, PACRS1:1 (36.38 ± 0.02) g/100g, PACS1:2 (36.24 ± 0.03) g/100g, PACS2:1 (36.59 ± 0.05) g/100g, PUACS (38.57 ± 0.03) g/100g,PACS1:1N (34.32 ± 0.01) g/100g and PUACRSN (38.33 ± 0.0) g/100g. The carbohydrate content of all the plant samples was comparable with the values of 20, 23.7 and 39.05% reported for *Senna obtusfolia*, *Amaranthus incurvatus* and *Momordica balsamina* leaves respectively (Hassan and Umar, 2006). These values were however lower than those reported for *Corchorus tridens* (75%) and sweet potato leaves (82.8%) (Asibey-Berko and Tayie, 1999). Carbohydrate helps to regulate protein and fat metabolism; fat requires carbohydrates for its breakdown within the liver (Mul et al., 2015).

The estimated calorific values obtained for *A. Spinosus* ranged from 223 – 234 kcal/100 g. The different values are PACS1:1 (224.4 kcal/100 g), PACRS1:1 (229.1 kcal/100 g), PACS1:2 (223.9 kcal/100 g), PACS2:1 (225.1 kcal/100 g), PUACRS (237.7 kcal/100 g), PUACS (235.2 kcal/100 g), PACS1:1N (223.06 kcal/100 g) and PUACRSN (233.9 kcal/100 g) respectively. These values are low when compared to 248.8–307.1 kcal/100 g reported in some Nigerian food crops and vegetables (McDonald et al., 1995). Thus, the low calorific values agree with the general observation that vegetables have low energy values (Lintas, 1992).

Profiles of Anti-Nutrients of Amaranthus spinosus Cultivated on Different Soil Samples

The results in Table 8 show that among the anti-nutrient parameters, phytate had the highest mean value (35.39 mg/100g) while the lowest anti-nutrient parameter was alkaloid (0.46 mg/100g), both the mean values of (phytate and alkaloid) were found in plant cultivated on amended spent soil 1:2 (PACS1:2).

Across the plant samples, anti-nutrient contents such as tannins, total phenol, phytate, oxalate, alkaloids, saponins, and flavonoids varied significantly. Results revealed that tannin was significantly (P<0.05) higher in PACRS1:1 with a mean value of 4.22±0.01 mg/100g. A similar observation was recorded in the quantities of total phenol, phytate, oxalate, alkaloids, saponins, and flavonoids which were significantly (P<0.05) higher in PACRS1:1 (3.36±0.02), PACS1:2 (35.39±0.01), PACS1:1N (3.14±0.01), PACRS1:1 (0.83±0.007), PACS1:1N (2.61±0.02) and PACS1:1 (1.09±0.01) mg/100g respectively. It was observed that the majority of the parameters that had higher mean value in the plants were the plants cultivated on the soils amended with compost and the soil amended with compost and nano-gel water accumulator. The high value of anti-nutrients recorded in this study agrees with the observation of Katherine, (2007) that organic foods contain higher levels of anti-nutrients and that they may reduce heart disease and cancer.

Table 7. Comparative data of the proximate composition of *Amaranthus spinosus* cultivated on different soil samples.

Parameters	Samples (g/100 g)							
	PACS1:1	PACRS1:1	PACS1:2	PACS2:1	PUACRS	PUACS	PACS1:1N	PUACRSN
%Ash	8.04±0.01^{c}	8.45±0.007^{e}	10.41±0.01^{g}	10.23±0.01^{f}	7.09±0.01^{b}	7.04±0.01^{a}	8.25±0.02^{d}	7.07±0.03^{b}
%Mc	10.29±0.01^{d}	9.74±0.01^{b}	9.78±0.02^{c}	9.68±0.01^{a}	10.65±0.02^{g}	10.57±0.01^{f}	10.34±0.01^{e}	11.65±0.02^{h}
%CP	16.18±0.01^{d}	17.24±0.01^{g}	15.21±0.007^{b}	15.19±0.01^{a}	15.4±0.02^{c}	15.21±0.01^{b}	16.36±0.02^{f}	15.46±0.007^{d}
%Fat	7.26±0.01^{f}	6.83±0.02^{a}	6.86±0.01^{a,b}	6.87±0.05^{b}	7.16±0.007^{d}	7.21±0.007^{e}	7.24±0.01^{f}	7.1±0.01^{c}
%Fibre	23.44±0.01^{g}	21.37±0.01^{d}	21.49±0.01^{f}	21.44±0.01^{e}	20.43±0.01^{b}	21.39±0.01^{d}	23.48±0.01^{h}	20.39±0.01^{a}
%CHO	34.79±0.07^{b}	36.38±0.02^{d}	36.24±0.03^{c}	36.59±0.05^{e}	39.26±0.042^{h}	38.57±0.03^{g}	34.32±0.01^{a}	38.33±0.0^{f}
CV)	224.4±0.41	229.1±0.31	223.9±0.26	225.1±0.71	237.7±0.28	235.2±0.22	223.06±0.33	233.9±0.1

CV: Calorific value (Kcal/100g; Results are expressed as the mean±SD; PUACRS: Plant from un-amended cultivated rock soil, PUACS: Plant from un-amended cultivated soil, PUACRSN: Plant from un-amended cultivated rock soil with nano-gel water accumulator, PACS1:1: Plant from amended cultivated soil 1:1, PACRS1:1: Plant from amended cultivated rock soil 1:1, PACS1:2: Plant from amended cultivated soil 1:2, PACS2:1: Plant from amended cultivated soil 2:1, PAS1:1: Plant from amended cultivated soil 1:1, SD= Standard Deviation; Means are coded a-h, and codes of the same letter on the same row are not significantly different at P<0.05. n=4.Variations are indicated by the disparity in codes.

Table 8. Comparative data of anti-nutrients values of *Amaranthus spinosus* cultivated on different soil samples.

Parameters (mg/100 g)	Samples							
	PACS1:1	PACRS1:1	PACS1:2	PACS2:1	PACS1:1N	PUACRS	PUACS	PUACRSN
Tannin	3.55±0.02^{f}	4.22±0.01^{g}	2.99±0.02^{b}	3.54±0.01^{f}	3.39±0.01^{d}	3.23±0.01^{c}	2.55±0.02^{a}	3.45±0.1^{e}
Total Phenol	2.99±0.04$^{d, e}$	3.36±0.02^{g}	2.55±0.02^{b}	2.93±0.02^{c}	3.06±0.01^{f}	2.97±0.03^{d}	2.49±0.01^{a}	3.03±0.07^{f}
Phytate	31.68±0.02^{c}	29.69±0.02^{b}	35.39±0.01^{e}	31.65±0.03^{c}	34.69±0.02^{d}	29.17±0.7^{a}	29.1±0.7^{a}	29.69±0.01^{b}
Oxalate	2.46±0.02^{a}	3.12±0.02^{e}	2.66±0.01^{c}	2.48±0.01$^{a, b}$	3.14±0.03^{e}	2.51±0.01^{b}	2.44±0.03^{a}	3.01±0.04^{d}
Alkaloids	0.58±0.02^{c}	0.83±0.007^{f}	0.46±0.01^{a}	0.59±0.02^{c}	0.67±0.01^{d}	0.58±0.01^{c}	0.50±0.02^{a}	0.71±0.042^{e}
Saponin	2.05±0.07^{d}	1.86±0.1^{c}	2.32±0.01^{e}	2.01±0.05^{d}	2.61±0.02^{f}	1.77±0.02^{b}	1.66±0.08^{a}	1.80±0.02^{b,c}
Flavonoids	1.09±0.01^{e}	0.63±0.007^{b}	0.86±0.01^{c}	1.07±0.02^{e}	0.56±0.01^{a}	1.00±0.10^{d}	0.58±0.01^{a}	0.59±0.01^{a,b}

Results are expressed as the mean±SD; PUACRS: Plant from un-amended cultivated rock soil, PUACSAP: Plant from un-amended cultivated soil, PUACRSN: Plant from un-amended cultivated rock soil with nano-gel water accumulator, PACS1:1: Plant from amended cultivated soil 1:1, PACRS1:1: Plant from amended cultivated rock soil 1:1, PACS1:2AP: Plant from amended cultivated soil 1:2, PACS2:1AP: Plant from amended cultivated soil 2:1, PACS1:1NBP: Plant from amended cultivated soil 1:1, SD= Standard Deviation; Means are coded a-g, and codes of the same letter on the same row are not significantly different at P<0.05. n=4.Variations are indicated by the disparity in codes.

Table 9. Comparative data of vitamins concentrations of *Amaranthus spinosus* cultivated on different soil samples.

Parameters (mg/100 g)	Samples							
	PACS1:1	PACRS1:1	PACS1:2	PACS2:1	PACS1:1N	PUACRS	PUACS	PUACRSN
VITAMIN A	2.13±0.01^{d}	3.32±0.02^{g}	1.24±0.007^{a}	2.08±0.007^{c}	3.53±0.01^{h}	2.32±0.007^{e}	1.69±0.01^{b}	3.02±0.007^{f}
VITAMIN C	38.32±0.01^{c}	40.24±0.01^{d}	42.19±0.02^{e}	38.26±0.02^{c}	63.58±0.02^{g}	35.19±0.05^{b}	32.81±0.70^{a}	53.56±0.01^{f}

Results are expressed as the mean±SD; PUACRS: Plant from un-amended cultivated rock soil, PUACS: Plant from un-amended cultivated soil, PUACRSN: Plant from un-amended cultivated rock soil with nano-gel water accumulator, PACS1:1: Plant from amended cultivated soil 1:1, PACRS1:1: Plant from amended cultivated rock soil 1:1, PACS1:2: Plant from amended cultivated soil 1:2, PACS2:1: Plant from amended cultivated soil 2:1, PACS1:1N: Plant from amended cultivated soil 1:1, SD= Standard Deviation; Means are coded a-h, and codes of the same letter on the same row are not significantly different at P<0.05. n=4.Variations are indicated by the disparity in codes.

Profiles of Vitamins concentrations in Amaranthus spinosus Cultivated on Different Soil Samples

Vitamin A and C concentrations varied significantly ($P<0.05$) in all the plant samples as shown in Table 9 above. The result showed that vitamin C had the highest mean value in all plant samples compared to vitamin A. The plant cultivated on the amended cultivated soil 1:1 with nano-gel water accumulator (PACS1:1N) had the highest mean value of Vitamin A and C content. This indicates that the application of compost with a nano-gel water accumulator significantly affected the production of vitamin A and C contents in the vegetables. Among the plant samples examined, the highest amount of vitamin A and C contents were 3.53 mg/100g and 63.58 mg/100g respectively.

It is true that vitamin A and C are important for food metabolism and cellular functions, prevents oxidative damage, important for proper lung function and immunity. Thus, this observation is similar to the study of Shade et al. (2007) who ascertained that vegetables are important sources of protective foods that is highly beneficial for the maintenance of good health and prevention of diseases.

Therefore, the consumption of adequate quantities of this plant will help meet the daily requirements for both adult males and females (Mie et al., 2017). Vitamin A is needed for the maintenance of skin, mucous membranes, bones, teeth, hair, vision, and reproduction.

Conclusion

This study investigated the analytical profiles of the soil nutrients blended in different ratios and the nutritional value of *Amaranthus spinosus* cultivated on the soil samples. The various soils investigated were blendedwith compost of different ratios. The work further explored gaining expertise in compost production for commercial agriculture. The obtained results showed that the blended soil samples (compost + soil sample), (compost + soil sample + nano-gel water accumulator), (soil sample + nano-gel water accumulator) enhanced the growth of the vegetable. The various findings in this research work have provided new information to the current knowledge regarding soil nutrient availability following the use of compost for soil amendment. It further demonstrated that properly managed agricultural wastes could be combined and employed as compost to boost the nutrient status and thus employed in agriculture leading to both agronomic and environmental benefits. We also affirmed that the application of the combination of compost and nano-gel water accumulator significantly enhanced soil quality, and consequently improved crop yield.

The results of this research also affirmed the reports from the Nano-land South Africa and SHEPROS that nano-gel water accumulator improves soil nutrients and enhances the yield of plants crops that can be harvested from the soil. The observed increase in the compositions of minerals, proximate, and anti-nutrients of the cultivated vegetable that was treated with nano-gel powder in this research gives credence to the use of nano-gel water accumulator (with or without compost) than using only compost. The results of this study, therefore, encourage the application of nano-gel water accumulators for agricultural practices for better nutritional quality. The use of compost coupled with the application of nano-gel water accumulator for commercial agricultural practice produces a better and high yield of quality vegetables.

Given these encouraging results, further experiments are in progress to evaluate the material balance of the blended soil samples and mineral composition of root, stem, and leaf of the *A. spinosus* planted on the different soil ratios.

Acknowledgments

The authors would like to acknowledge the Department of Plant Science and Biotechnology, Ekiti State University, Ado-Ekiti, Nigeria for making their Greenhouse facility available for this research. We specially thank National Environmental Standards and Regulations Enforcement Agency (NESREA), Ilokun in Ado-Ekiti, Nigeria for making their commercial compost and facilities available for this study.

Conflict of Interest

The authors declare no competing conflict of interest.

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