

Growth, yield attributes and metabolite components of Thickhead (Ebolo) (CrassocephalumcrepidioidesBenth.) as affected by soil amendment

Abstract

A screenhouse experiment was conducted to determine the growth, yield attributes and bioactive components of thickhead (ebolo) as affected by soil amendments. Treatments were soil type (fertile soil and degraded land respectively amended with NPK @300kg/ha (F₁), NPK@150kg/ha (F₂), Poultry Manure@10,000t/ha (F₃), Poultry Manure @5000t/ha (F₄), NPK @ 150kg/ha + Poultry Manure @5000t/ha, (F₅), NPK @ 75kg/ha + Poultry Manure @ 2500t/ha (F₆) and unamended control. Data were collected on soil properties, growth and biomass yields of thickhead and chemical, proximate and bioactive components of leaves. Results showed that soil type and amendment significantly affected growth, yield and bioactive components of thickhead. Growth of thickhead improved significantly for soil collected under fallow vegetation (S₁) while application of NPK and poultry manure combination at 0.375g + 12.5g per plant significantly enhanced most of the measured variables of thickhead. Fertilizer amendment of soils enhanced leaf sodium, potassium, calcium and magnesium contents, poultry manure amendment improved moisture content and crude protein, while NPK increased significantly leaf ash and fat contents. Post-cropping chemical analysis of treated soils showed increases in pH, organic carbon, nitrogen, organic matter, available P, K, Na, Ca, and Mg of fertilizer-amended soils compare with the unamended. Thickhead (ebolo) can be grown both on fertile and degraded soils, soil amendment using NPK-poultry manure combinations enhanced the growth, yield and nutrition of thickhead and is recommended for its production.

Keywords: *Ebolo, thickhead, soil amendment, growth, phytochemicals, nutrition*

Introduction

Crassocephalumcrepidioides(Benth.) S. Moore, has various common names such as Thickhead, fireweed or ragleaf, is an African leafy vegetable that belongs to the family Asteraceae (Compositae). Locally it is called “Ebolo” by the Yoruba people of Southern Nigeria (Adams, 1963). It is an annual edible plant that is wide spread in tropical and sub-tropical regions (Rajesh, 2011). Thickhead is an erect, slightly succulent, annual herb up to 100-180 cm tall, stem rather stout, soft and ribbed pubescent. Leaves are arranged spirally, simple lobed or pinnatifid, stipules absent, lower leaves with short petiole, upper ones sessile, blade elliptical to obvate-elliptical in outline, usually lobed, irregularly serrated. Inflorescence is cylindrical head 13-16 mm × 5- 6 mm arranged in a terminal corymb, many flowered, outer involucre bracts unequal, 1-4 long. Flower is bisexual, equal corolla tubular, 9-11 mm long, yellow or orange with anthers united into tube, purple and inferior ovary. Fruits are ribbed achene 2 cm long, hairy, dark purplish crowned by white caduceus hairs, 9-12 mm long seed with epigeal germination (Kostermans et al., 1996).

The seedling of thickhead appears 8 to 10 days after sowing. Growth of seedlings is fast within 40-45 days after sowing, the plants are reaped for the first harvest by uprooting, and harvesting for seed can start on 15 to 17 weeks after sowing (Okigbo, 1999). Tannin found in the roots of the

plant is used to treat swollen lips and according to Dairo and Adanlawo (2007), it is a good source of protein in human and animal nutrition. It also possesses antioxidant and cytoprotective properties (Wijaya et al, 2011).

Thickhead germinates at temperature between 10°C and 40°C, the power limit of germinated temperature explains the incidence at high altitudes. Nakamura and Hossain (2009) reported a germination range of 10-30°C with an optimum of 15-20°C. Seeds germinate over a wide pH range (2 to 12) with highest germination rate between pH 4 and 10. Germination rate may be drastically reduced after one year and emergence is high on the soil surface while no seedling emerged from a depth of above 1cm and seeds have no apparent dormancy and retain high viability after room temperature for 10 months (Nakamura and Hossain, 2009). Thickhead produce seeds with silky pappus hairs (plumed seeds) that can be easily dispersed by wind and or water, (Denton, 2004). The nutritional composition of “Ebolo” leaves per 100 g portion is water (79.9%), energy (268 kj), protein (3.2 g), fat (0.7 g) and Phosphorus (52 mg). Thickhead is eaten by human in many countries in Africa. Succulent leaves and stems are used as a vegetable in soups and stews, especially in West and Central Africa. In Sierra Leone they are popular and are made into a sauce with groundnut paste. In Australia, this species is eaten as a salad green, either cooked or raw. It is also used in traditional African medicine to treat indigestion, stomach ache, epilepsy, sleeping sickness and swollen lips. Tomimori et al., (2012) reported antitumor activity associated with nitric oxide production. It is also used as green fodder for poultry and livestock (Denton,2004).

The annual production of thickhead is about 25-27 t/ha of leaves and shoots from repeated harvesting (Bolade 2019). Thickhead is an annual weed that flowers all year round with a high seed production capacity, it is able to produce 29 flowers with approximately 4379 seeds per plant, reaching a plant density of 70.5 individuals per square meter in tea plantations (Kadereit, 2009). The wide genetic variation is yet to be exploited and there are no records of germplasm collections in Africa. Breeding of improved cultivars is needed, as well as research to solve the problem of seed availability that has hitherto limited cultivation (Denton, 2004). Information about its germination and seed production is scanty in literature. According to Sakpere et al., (2013) thickhead produced up to 768-1152 seeds per plant indicating that the seed production potential of the plant is very high. Germination percentage was not consistent with age and may be influenced by seed maturity, thickhead produced an average of 96 seeds per inflorescence and there were 8 to 12 inflorescences per plant. The average weight of 1000 seeds was 0.176 g.

Thickhead is used traditionally in the treatment of wounds, boils, burns, indigestion, stomach ulcer, nose bleeding, fever and inflammation and edema (Ajibesin, 2012; Aniya et al., 2005; Oyelakin and Ayodele, 2013; Chaitanya et al., 2013; Sakpere et al.,2013).Scientific investigations have shown *thickhead* a useful source of protein in both human and animal diet (Dairo and Adanlawo, 2007). The plant has also been reported to be a good source of vitamins and minerals (Smith and Eyzaguirre, 2007), therefore making it a good source of nutraceuticals in prevention and management in prevention and management of diseases (Adjatin et al., 2013). Further review of Ethnopharmacological reports on thickhead showed that the plant possesses anti-helminthic, antibacterial, anti-inflammatory, antidiabetic, and acetyl cholinesterase inhibitory properties (Baharetal., 2017; Bogning et al., 2016; Joshi, 2014;; Tomimori et al.,2012). The antioxidant, cytoprotective (Odukoya et al.,2007; Wijaya et al., 2011), cancer chemoprotective and anti-tumor activities (Chia-chunget al., 2007; Chaitanya et al., 2013) of the plant have also been demonstrated.

Comment [MK1]: Include “and”

The *in vitro* anticoagulant activity of the plant leaf methanol extract and fractions was recently reported (Ayodele et al., 2019). Therefore, with such great medicinal value being suggested, a detailed analysis to identify and characterize the phytochemical compounds in the plant is very much needed. However, few reports are available on the bioactive compounds present in the plant. Reports on preliminary phytochemical screening of *thickhead* methanol extract have revealed the presence of alkaloids, glycosides, tannins, flavonoids, phenolics, saponins and ascorbic acid (Arawande, 2013; Bahar et al., 2017). The essential oils of thickhead from south western Nigeria and western Ghats region of India were found to mainly consist of α -caryophyllene, thymol, α -farnesene, β -cubebene and 4-cyclohexybutyramide, thus concluding that *C. crepidioides* may be a natural source of thymol, with established antimicrobial activity (Owokomoto et al., 2012; Rajesh, 2011).

Over the years, the thickhead (ebolo) has been described as under exploited and underutilized in both cultivation and consumption, biology, agronomy and phytochemistry. According to Lowe and Soladoye (1990), it is a low priority vegetable for researchers in Africa. Increased effort is required to solve the problem of its seed availability and other agronomic practices which have limited the cultivation and consumption of thickhead (Ebolo). Knowledge gap also exists with respect to the effects of agronomic management practice on the growth, yield, chemical and nutritional qualities and bioactive compounds of indigenous vegetables including ebolo. Horticultural management practices especially soil conditions (physical and chemical properties) are known to influence chemical and proximate composition as well as phytochemistry of plants especially vegetables.

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Comment [MK2]: Repeated content.

The aim of the study is to evaluate the growth, yield components and bioactive compounds of thickhead (ebolo) as affected by amendment of two soil types (degraded and fertile soil).

The specific objectives are to determine the effects of soil types and amendment on the growth and yield of thickhead (ebolo), chemical and proximate composition as well as components of bioactive compounds and the interactions of soil type and fertilizers on the growth, yield and nutritional quality of thickhead (ebolo).

MATERIALS AND METHODS.

Experimental site

The experiment was carried out in the screenhouse of Federal College of Agriculture, Akure, Nigeria.

Comment [MK3]: Mention the year of experiment

Sources of planting materials

Stem cuttings of thickhead (ebolo) was obtained at ojaobaAkure, Ondo State, Nigeria. The stem was cut into 0 to 10cm and was raised in polythene bags to propagate new plantlets.

Sources of experimental soils Soil type one (S_1) was collected from fallow vegetation and soil type two (S_2) from field of over 10 year which has also been recently subjected to top soil removal via heavy machinery excavation. Perforated pots were filled with 5kg of each soil types and were arranged accordingly in a **Completely Randomized Design (CRD)** in the screen-house.

Treatments and experimental design

The experiment consist of 2 by 7 factorial combinations of soil types, and poultry manure-NPK ratios arranged in Completely Randomized Design (CRD) with 5 replications. Treatment are two soil types which differed in physical and chemical properties which were obtained from fallow vegetation (S_1) and degraded land (S_2) were amended with organic and inorganic fertilizers (NPK and poultry manure). The experiment consists of 2x7 factorial combinations of soil types, and poultry manure-NPK ratios arranged in Completely Randomized Design (CRD) with 5 replicates.

The soil types differed in physical and chemical properties and were obtained from fallow vegetation (S_1) and degraded land (S_2). The soils were amended with organic and inorganic fertilizers (NPK and poultry manure). Thus, there was the control (unamended), NPK @ 300kg/ha (0.8g/pot), NPK @ 150kg/ha (0.38g/pot), poultry manure @ 10000t/ha (25g/pot), poultry manure @ 5000t/ha (12.5g/pot), NPK + P.M (0.38 + 12.5g/pot) and NPK + P.M (0.19g + 6.25g/pot)

Data was collected on pre and post soil chemical analysis. Plants were sampled for determination of the number of leaves and branches, stem height, fresh root and shoot biomass yield leaf samples were also subjected to analysis of chemical composition, proximate contents and bioactive compound using standard laboratory procedures and methods.

Data collected were subjected to analysis of variance and means were separated using Turkey's test at 5% probability level.

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Comment [MK5]: Mention the Software used for statistical analysis

Comment [MK6]: Tukey's test

RESULTS AND DISCUSSION

Chemical and physical properties of experimental soils before treatment importation

Table 1 shows the results of the chemical and physical analysis of the experimental soils before treatment application. The pH obtained from S_1 (fallow vegetation) is around 4.31 with the following chemical properties: organic carbon 1.92%, organic matter 3.31%, nitrogen 0.14%, potassium 0.62cmol/100g, sodium 0.31cmol/100g, magnesium 1.2cmol/100g, and calcium of 7.0cmol/100g. For soil S_2 (degraded soil) have considerably lower values of chemical elements measured. Soil S_2 textural class is sandy clay loam.

Treatment effects on growth variables of Ebolo

The result of effects of soil type, fertilizers and their interactions on biomass yield of ebolo is presented in Table 2. For soil type treatment S_1 (fallow vegetation) had significantly higher leaf fresh weight, root fresh weight, stem fresh weight, leaf dry weight, root dry weight and stem dry weight respectively. For fertilizers, F_5 had significantly higher for leaf, root and stem fresh weight, while treatment F_5 and F_6 were significantly higher for leaf and stem dry weight.

Treatment F₅ recorded (4.26a) significantly higher root dry weight and also proof to be the best among other treatments for the biomass yield. Treatment S₁F₅ had significantly higher leaf fresh weight, while ~~not significant~~ different were recorded for all treatment for root and stem fresh weight, leaf dry weight, root dry weight and stem dry weight for the interactions between soil type and fertilizers.

Comment [MK7]: Non-significant

Fallow vegetation (S₁) significantly improved the growth of thick compared with degraded soil, NPK 0.38g + 12.5g poultry manure had significant effect on the growth and yield of thickhead. Biomass yield of thickhead (ebolo) was significantly increased upon treatment S₁, F₅ and S₁F₅.

Treatment effects on chemical and proximate composition and bioactive compounds of Ebolo.

Soil types, fertilizers and their interactions significantly affected the chemical composition of ebolo (Table 3). The nitrogen, sodium and potassium of treatment S₁ were completely significantly higher while, treatment S₂ had significantly higher for calcium, magnesium and phosphorus. For the fertilizers, treatment F₀ (control) significantly higher for Na, K, Ca, and mg, while F₄ recorded significantly higher P, and F₂, F₃, and F₅ were significant for N. Among the interactions treatment S₁F₀ had significantly higher for Ca, P, Na, and mg. Treatment S₂F₆ recorded significantly higher for P and S₁F₃ had significantly higher for N. The control treatment proof to have higher amount of chemical composition than other treatment with different fertilizer rates.

Table 4 shows the result of effects of soil types, fertilizer rates and interactions on the proximate composition of ebolo. Thickhead raised on degraded soil (S₂) had significantly higher for moisture content, ash and fat while those grown on fallow vegetation (S₁) had higher crude fiber, crude protein and carbohydrate. For the fertilizer rates, treatment F₃ (25g poultry manure) had significantly higher moisture content; F₁ for ash, F₂ recorded significantly higher fat and F₄ for carbohydrate. The control had significantly higher crude fibre and F₅ recorded higher protein content which differed significantly from others treatments. Fat contents were significantly higher for treatment S₂F₂, crude fibre content was significantly higher for S₂F₀ while carbohydrate were significantly higher for S₁F₅ and crude protein for S₁F₃.

The bioactive compounds of ebolo grown on two soil types and fertilizers showed that the chlorophyll and phenolics content for treatment S₂ (323.48a and 2.25a) were significantly different, while S₁ had higher flavonoids and terpenoids content (Table 5) The control (F₀) had the highest chlorophyll content compare with other treatment, F₁ had significantly higher flavonoids, higher phenolics for F₆, and higher terpenoids for F₂ for terpenoids. With respect to interactions, treatment S₂F₀ had significantly higher chlorophyll, S₂F₁ had higher flavonoids, S₂F₄ for phenolics and S₁F₅ for terpenoids. The growth and yield of thickhead (ebolo) was best with fallow vegetation soil. Fertilizer amendment of soils improved mineral, nutrition quality, proximate and bioactive components of thickhead (ebolo).

Treatment effects on post cropping chemical properties of experimental soils

Table 6a shows the result of post cropping chemical properties of experimental soils. The soil pH for both fallow vegetation (S₁) and degraded soil (S₂) increased expect for treatment S₁F₃ which the soil pH reduce from (4.31 to 4.05) and S₂F₁ reduce from (4.51 to 4.24). The organic carbon content increase for most of the treatment except for the controls S₁F₀ (1.92% to 0.19%), S₂F₀

(0.84% to 0.16%) and S₂F₆ which had the lowest value for organic carbon. This implies that the plant really utilize the available organic carbon in the control soils. The organic matter also reduce for control treatments S₁F₀, S₂F₀ and treatment S₂F₆ and S₁F₅ while other treatments increase in organic matter content. The percent nitrogen increased for all other treatment except for the control treatments which reduced S₁F₀, S₂F₀ and treatment S₁F₅. Table 6b also shows the result of post cropping soil chemical properties. For phosphorus, potassium, sodium, calcium and magnesium increase in value than the pre cropping soil analysis except for the unamended control which reduced in value.

The results of this study showed that growth parameters: number of leaves, plant height, stems girth, and numbers of branches were significantly and positively influenced by soil type and NPK and poultry manure amendments. Significant increases were observed in growth parameters at 2, 4, 6, and 8 weeks after treatment application respectively. Soil type S₁ (fallow vegetation) produce significant growth parameters of thickhead (ebolo). S₁ produce more significant leaves at 4, 6, and 8 weeks after treatment application than S₂ (degraded soil) also, S₁ produce significant number of branches and stem girth across the weeks of treatment of application.

This observation is due to differences in soil physical and chemical status. S₁ is soil obtained under fallow vegetation which has more nutrient content than the degraded soil. S₂ (degraded soil) recorded significant increase in root length and number of roots. The biomass yield of thickhead (ebolo) grown on fallow vegetation (S₁) produce heavier biomass yield than those planted on degraded soil (S₂). In terms of bioactive compounds, thickhead (ebolo) grown on degraded soil (S₂) has more chlorophyll and phenolics content than fallow vegetation (S₁), flavonoids and terpenoids were significant for fallow vegetation. Moisture content, ash and fat content S₂ recorded significant higher values, while S₁ were higher for crude fibre and crude protein. For the chemical compositions of thickhead (ebolo) S₁ recorded significantly highest value for sodium, potassium, and nitrogen while for phosphorus, calcium and magnesium were significantly higher for treatment S₂.

NPK-poultry manure (PM) amendment at 0.38g NPK +12.5g poultry manure : F₅ out-perform other treatments. This treatment F₅ produced significant higher number of leaves and taller plants and heavier biomass yield compare with other NPK-PM combinations. The combined application of NPK and PM (inorganic and organic sources of nutrients to the soil which are translocated to the aerial parts for the synthesis of protoplasmic proteins and other metabolites enabling the expansion of photosynthetic area and thus spread. Similar findings were reported by Adekaode&Ogunkoya (2011).

The unamended control (F₀) had significantly higher chlorophyll, F₁ for flavonoids, F₂ for terpenoids and F₆ were significant for phenolics. Treatments with NPK fertilizer greatly influence the flavonoids and terpenoids content. The chemical composition of thickhead (ebolo) was significantly better for poultry manure amended soil compare with NPK fertilizer amendments especially for moisture content, crude protein and carbohydrate, Devkota et al. (2021) reported that phytochemicals of organic fertilizers treated plant had higher concentration of Alkaloid, flavonoid, tannin, saponin, ash, moisture and protein in addition to minerals (Fe, Zn, Cu, Ca and Mg) compared to other fertilizer treatments. Talib *et al.*, (1994) suggested that the poultry manure and NPK-PM combinations improved the leaf contents of protein, carbohydrate and crude fibre while NPK treatment increased ash and fat contents. Michael *et al.*, (2010)

reported increases in contents of phytochemicals under livestock manure treatment. Also, Oyedeji et al. (2014) recorded highest protein content for NPK and highest ash content for poultry manure.

Improvements in growth parameters (number of branches and leaves) were significant for thickhead (ebolo) where NPK and poultry manure combinations were applied. The growth parameters measured were greatly influenced by (0.375g NPK +12.5g PM) which was significantly better. The biomass yield of thickhead grown on S₁F₅ (fallow+ NPK 0.375g + P.M 12.5g) produce heavier biomass than other treatment. Treatment S₂F₀ (degraded soil with no amendment) recorded highest chlorophyll content which were significantly different from other soil type-amendment. S₂F₁ for flavonoids, S₂F₄ for phenolics and treatment S₁F₅ were significantly different for terpenoids for the bioactive compounds. Chemical composition of thickhead (ebolo) were significantly influence by treatment S₁F₀ (fallow vegetation with no amendment) for potassium, calcium, sodium and magnesium, while for phosphorus, S₂F₆ (Degraded soil + NPK 0.19g + P.M 6.25g) were significantly higher to other treatments. Moisture content, ash and fat content recorded significantly higher values for treatment degraded soil with amendment, Crude fibre was higher for S₂F₀; crude protein was significantly higher for S₁F₃(fallow + P.M 25g) and carbohydrate for S₁F₅.

This result also showed an increase in soil pH of crop maturity for all the treatments except S₁F₃ (fallow + P.M 25g) and S₂F₁ (Degraded soil + NPK 0.75g) which had reduced soil pH. Agbede(2021) reported that mixture of NPK fertilizer, biochar and poultry manure significantly increased soil total N, available P, exchangeable K, Ca and Mg concentrations after 2 years of cultivation compared with biochar, poultry manure or NPK fertilizer alone. The increased in soil pH might be due to activities that have taken place on the soil such as planting and addition of fertilizer. Organic carbon increased for all treatments except the unamended control for degraded and fallow vegetation soils. Organic matter reduced for S₁F₅ (fallow+ NPK 0.375g + P.M 12.5g) and S₂F₆ (Degraded soil + NPK 0.19g + P.M 6.25g). The reduction in organic matter of S₁F₅ (fallow+ NPK 0.375g + P.M 12.5g) might be due to heavy biomass yield, the plant really exhausted all the organic matter in the treatment. The nitrogen content increased for all treatments except the control in addition to other chemical properties such as sodium, potassium, calcium, phosphorus and magnesium

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Conclusions

The growth, yield and bioactive phytochemicals of thickhead (ebolo) were evaluated on fertile and degraded soils amended with poultry manure –NPK combinations. Soil type (fallow vegetation and degraded) and fertilizer (poultry manure –NPK combinations: F₀ =control, F₁ =0.75g NPK, F₂ =0.375g NPK, F₃ =25g PM, F₄ =12.5g PM, F₅ =0.375g NPK +12.5g PM, F₆ =0.186g NPK + 6.25g PM) affected the growth, yield, bioactive compounds, chemical and proximate compositions of thickhead (ebolo). Fallow vegetation (S₁) significantly improved the growth of thickhead compared with degraded soil, NPK 0.38g + 12.5g poultry manure had significant effect on the growth and yield of thickhead. Biomass yield of thickhead (ebolo) was significantly increased upon treatment S₁, F₅ and S₁F₅. The growth and yield of thickhead (ebolo) was best with fallow vegetation soil. Fertilizer amendment of soils improved mineral, nutrition quality, proximate and bioactive components of thickhead (ebolo). The post cropping chemical analysis of the experimental soils showed that soil pH, organic carbon, nitrogen, organic matter,

available P, K, Na, Ca, and Mg increased for all treatments except for the control (soils without fertilizer) which recorded lower values of chemical elements.

Thickhead (ebolo) can be grown both on fertile and degraded soils, fertilizer amendment of soils is recommended for thickhead (ebolo) production for enhancing its growth, yield and nutrition. In particular NPK – poultry manure (0.375g + 12.5g) experiment performed best under the tested soils

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Table 1: results of chemical and physical analysis of the experimental soils before treatment was imposed

Parameters	S ₁ (fallow vegetation)	S ₂ (degraded soil)
pH	4.31	4.51
Mg/kg - P	1.95	0.23
Ca	7.0	1.4
Mg	1.2	1.2
Na	0.31	0.09
K	0.62	0.17
N (%)	0.14	0.06
Organic carbon (%)	1.92	0.84
Organic matter (%)	3.31	1.45
Particle size		
Silt and clay (%)	51.2	39.2
Clay (%)	35.2	27.2

Silt (%)	16.00	12.00
Sand (%)	48.8	60.8
Textural class	Sandy clay	Sandy clay loam
g/cm ³ Bulk density	1.300	1.430

Table 2: Effects of soil type, fertilizers and interactions on root and shoot biomass of Ebolo.

	Treatment	Leaf Fresh Weight(g)	Root Fresh Weight(g)	Stem Fresh Weight(g)	Leaf Dry Weight(g)	Root Dry Weight (g)	Stem Dry Weight (g)	
Soil type	S ₁	54.93a	15.59a	116.13a	3.93a	4.01a	18.24a	
	S ₂	37.66b	9.81b	81.80b	3.39b	2.18b	14.58b	
Amendment	F ₀	36.44e	8.03d	73.09g	2.94d	2.01e	10.37d	
	F ₁	45.83c	14.59b	110.80b	3.09cd	2.46d	15.44c	
	F ₂	47.85b	15.07b	97.67e	3.27c	3.29c	17.38b	
	F ₃	42.92d	9.14d	101.22d	3.69b	2.58d	16.16c	
	F ₄	41.52d	11.33c	89.23f	3.77b	3.58b	17.56b	
	F ₅	60.99a	18.44a	117.15a	4.46a	4.26a	18.98a	
	F ₆	48.55b	12.32c	103.59b	4.39a	3.50bc	18.97a	
Soil by Amendment	S ₁	F ₀	41.49e	10.93d	96.53f	3.39efg	2.57def	11.98f
		F ₁	52.56d	19.38ab	116.41c	3.09h	2.97d	16.85c
		F ₂	61.24b	19.81a	121.31b	3.41ef	3.79c	19.95ab
		F ₃	51.36d	8.36de	123.55ab	3.82bcd	2.46ef	17.02c
		F ₄	51.82d	16.73bc	102.57e	3.86bc	5.77a	19.13b
		F ₅	64.59a	19.29ab	125.45a	4.86a	5.71a	21.16a
	S ₂	F ₆	61.47b	14.65c	127.06a	5.05a	4.79b	21.63a
		F ₀	31.39g	5.12f	49.64j	2.49i	1.44gh	8.76g
		F ₁	39.11e	9.81d	105.18de	3.09gh	1.95g	14.03e
		F ₂	34.46f	10.33d	74.03i	3.13fgh	2.78de	14.83de
		F ₃	34.47f	9.92d	78.89gh	3.55de	2.70de	15.29cde
		F ₄	31.22g	5.93ef	75.89hi	3.67cde	1.38h	15.99cd
		F ₅	57.38c	17.59ab	108.85d	4.05b	2.81de	16.81c
		F ₆	35.47f	9.99d	80.13g	3.72cd	2.19f	16.31cd

Means along column with different alphabets differed significantly at 5% level of probability according to Tukey HSD. S₁ =Fallow Vegetation, S₂ =Degraded Soil, F₀ =control, F₁ =0.75g NPK, F₂ =0.375g NPK, F₃ =25g PM, F₄ =12.5g PM, F₅ =0.375g NPK +12.5g PM, F₆ =0.186g NPK + 6.25g PM, S₁F₀ = fallow with No fertilizer application, S₁F₁ = fallow + NPK 0.75g, S₁F₂ = fallow + NPK 0.375g, S₁F₃ = fallow + P.M 25g, S₁F₄ = fallow + P.M 12.5g, S₁F₅ = fallow + NPK 0.375g + P.M 12.5g, S₁F₆ = fallow + NPK 0.19g + P.M 6.25g, S₂F₀ = Degraded soil with No fertilizer application, S₂F₁ = Degraded soil + NPK 0.75g, S₂F₂ = Degraded soil + NPK 0.375g, S₂F₃ = Degraded soil + P.M 25g, S₂F₄ = Degraded soil + P.M 12.5g, S₂F₅ = Degraded soil + NPK 0.375g + P.M 12.5g, S₂F₆ = Degraded soil + NPK 0.19g + P.M 6.25g

Table 3: Effects of soil types, fertilizers and interactions on chemical compositions of Ebolo

	Treatment	N (%)	P (P ₂ O ₅)mg/ 100g	K (K ₂ O)mg/ 100g	Ca (mg/100g)	Na (mg/100g)	Mg (mg/100g)
Soil type	S₁	0.59a	24.03b	6.19a	5.04b	3.91a	2.81b
	S₂	0.57b	24.60a	5.86b	5.74a	3.62b	2.91a
	F₀	0.55bc	10.46g	6.96a	6.31a	4.40a	3.29a
	F₁	0.57b	20.56e	5.46f	4.81f	3.45f	2.72f
	F₂	0.60a	29.40c	6.12c	4.57g	3.82c	2.07g
	F₃	0.61a	21.30d	6.07d	6.01b	3.73d	3.09c
	F₄	0.56b	38.39a	5.29g	5.51c	3.32g	3.16b
	F₅	0.61a	17.97f	5.76e	5.31d	3.59e	2.81e
	F₆	0.54c	32.11b	6.52b	5.22e	4.06b	2.93d
S₁	F₀	0.54	11.44l	7.40a	6.92a	5.13a	3.44a
	F₁	0.58bc	17.23j	5.56h	4.46hi	3.55efg	2.86f
	F₂	0.61b	26.53f	5.97e	4.38i	3.79de	1.97j
	F₃	0.66a	34.53d	6.86b	5.78de	4.15c	2.99d
	F₄	0.55d	37.89c	4.95k	4.45hi	3.18j	3.16c
	F₅	0.64b	19.39i	5.87f	4.73g	3.75de	2.36h
	F₆	0.51e	21.17h	6.18d	4.57h	3.79de	2.89ef
S₂	F₀	0.59bc	9.48m	5.97e	5.69e	3.66ef	3.10c
	F₁	0.52e	23.89g	5.35i	5.16f	3.34hi	2.57g
	F₂	0.58bc	32.27e	6.28c	4.76g	3.85d	2.16i
	F₃	0.56c	8.06n	5.28j	6.24c	3.30ij	3.18c
	F₄	0.57c	38.89b	5.63g	6.56b	3.45gh	3.16c
	F₅	0.57c	16.55k	5.65g	5.88d	3.43gh	3.26b
	F₆	0.58bc	43.05a	6.85b	5.86d	4.34b	2.97d

Means along column with different alphabets differed significantly at 5% level of probability according to Tukey HSD. S₁ =Fallow Vegetation, S₂ =Degraded Soil, F₀ =control, F₁ =0.75g NPK, F₂ =0.375g NPK, F₃ =25g PM, F₄ =12.5g PM, F₅ =0.375g NPK +12.5g PM, F₆ =0.186g NPK + 6.25g PM, S₁F₀= fallow with No fertilizer application, S₁F₁= fallow + NPK 0.75g, S₁F₂: fallow + NPK 0.375g, S₁F₃= fallow + P.M 25g, S₁F₄= fallow + P.M 12.5g, S₁F₅ =fallow+ NPK 0.375g + P.M 12.5g, S₁F₆= fallow + NPK 0.19g + P.M 6.25g, S₂F₀= Degraded soil with No fertilizer application, S₂F₁= Degraded soil + NPK 0.75g, S₂F₂= Degraded soil + NPK 0.375g, S₂F₃= Degraded soil + P.M 25g, S₂F₄= Degraded soil + P.M 12.5g, S₂F₅= Degraded soil + NPK 0.375g + P.M 12.5g, S₂F₆= Degraded soil + NPK 0.19g + P.M 6.25g

Table 4: Effects of soil type, fertilizers and their interactions on proximate composition of Ebolo

	Treatment	Moisture Content (%)	Ash (%)	Fat (%)	Crude Fibre (%)	Crude Protein (%)	Carbohydrate (%)	
Soil Type	S ₁	88.29b	3.03b	1.06b	2.19a	3.66a	1.77a	
	S ₂	89.32a	3.50a	1.16a	2.16b	3.54b	0.32b	
Amendment	F ₀	88.64c	3.64b	1.18b	2.69a	3.53c	0.32e	
	F ₁	89.36b	3.67a	1.17c	2.15b	3.42d	0.23f	
	F ₂	88.68c	2.77f	1.20a	2.06c	3.72b	1.57c	
	F ₃	89.52a	3.38d	1.07e	2.15b	3.82a	0.06g	
	F ₄	88.52d	2.68g	1.12d	2.14b	3.52c	2.02a	
	F ₅	88.27f	3.57c	1.00g	1.88d	3.80a	1.48d	
	F ₆	88.36e	3.15e	1.03f	2.14b	3.40e	1.92b	
Soil by Amendment	S ₁	F ₀	89.19g	3.56d	1.13e	2.15def	3.39i	0.58h
		F ₁	89.83c	3.02g	1.12e	2.14efg	3.61e	0.28i
		F ₂	87.70j	2.73j	1.12e	2.23c	3.82c	2.40d
		F ₃	89.87b	2.81i	0.92j	2.13fg	4.12a	0.15k
		F ₄	87.76j	2.41k	1.18d	2.16de	3.45h	3.04b
		F ₅	86.35l	3.21f	0.98i	2.15def	4.02b	3.29a
		F ₆	87.29k	3.48e	0.98i	2.34b	3.18k	2.73c
	S ₂	F ₀	88.08i	3.72c	1.24b	3.23a	3.67d	0.06m
		F ₁	88.88h	4.31a	1.22c	2.15def	3.23j	0.21j
		F ₂	89.65d	2.82i	1.28a	1.89i	3.61e	0.75g
		F ₃	89.60d	3.59c	1.16d	2.17d	3.46g	0.02l
		F ₄	89.28f	2.94h	1.05g	2.12g	3.58f	1.03f
		F ₅	90.18a	3.92b	1.00h	1.31j	3.56f	0.03l
		F ₆	89.43e	2.83i	1.07f	1.94h	3.61e	1.12e

Means along column with different alphabets differed significantly at 5% level of probability according to Tukey HSD. S₁ =Fallow Vegetation, S₂ =Degraded Soil, F₀ =control, F₁ =0.75g NPK, F₂ =0.375g NPK, F₃ =25g PM, F₄ =12.5g PM, F₅ =0.375g NPK +12.5g PM, F₆ =0.186g NPK + 6.25g PM, S₁F₀= fallow with No fertilizer

application, S₁F₁= fallow + NPK 0.75g, S₁F₂: fallow + NPK 0.375g, S₁F₃= fallow + P.M 25g, S₁F₄= fallow + P.M 12.5g, S₁F₅=fallow+ NPK 0.375g + P.M 12.5g, S₁F₆= fallow + NPK 0.19g + P.M 6.25g, S₂F₀= Degraded soil with No fertilizer application, S₂F₁= Degraded soil + NPK 0.75g, S₂F₂= Degraded soil + NPK 0.375g, S₂F₃= Degraded soil + P.M 25g, S₂F₄= Degraded soil + P.M 12.5g, S₂F₅= Degraded soil + NPK 0.375g + P.M 12.5g, S₂F₆= Degraded soil + NPK 0.19g + P.M 6.25g

Table 5: Effects of soil type, fertilizers and interactions on the bioactive compounds of Ebolo

	Treatment	Chlorophyll (mg/100g)	Flavonoids (%)	Phenolics (mg/100g)	Terpenoids	
Soil Type	S ₁	204.61b	2.10a	1.92b	175.87a	
	S ₂	323.48a	2.07b	2.25a	63.47b	
Amendment	F ₀	343.11a	1.85f	1.71f	95.22e	
	F ₁	133.02g	2.74a	2.15c	80.57f	
	F ₂	262.69e	1.90e	2.09d	187.09a	
	F ₃	285.25c	1.78g	1.88e	99.21d	
	F ₄	264.53d	2.18c	2.09d	77.37g	
	F ₅	300.55b	2.23b	2.33b	180.04b	
	F ₆	259.17f	1.93d	2.34a	118.22c	
Soil by Amendment	S ₁	F ₀	254.84g	1.80j	1.62k	102.12e
		F ₁	25.12m	2.73b	1.87h	111.27d
		F ₂	271.52f	1.91g	2.02g	306.11b
		F ₃	189.82l	1.94e	1.72j	97.26h
		F ₄	218.92j	2.52d	1.55l	98.28g
		F ₅	271.52f	1.89h	2.33d	324.81a
		F ₆	200.52k	1.92f	2.35c	191.21c
	S ₂	F ₀	431.37a	1.91g	1.81i	88.31i
		F ₁	240.91i	2.75a	2.44b	49.86l
		F ₂	253.86h	1.89h	2.16e	68.07j
		F ₃	380.67b	1.61k	2.04f	101.15f
		F ₄	310.13e	1.84i	2.63a	56.45k
		F ₅	329.58c	2.56c	2.33d	35.26n
		F ₆	317.81d	1.94e	2.33d	45.22m

Means along column with different alphabets differed significantly at 5% level of probability according to Tukey HSD. S₁ =Fallow Vegetation, S₂ =Degraded Soil, F₀ =control, F₁ =0.75g NPK, F₂ =0.375g NPK, F₃ =25g PM, F₄ =12.5g PM, F₅ =0.375g NPK +12.5g PM, F₆ =0.186g NPK + 6.25g PM, S₁F₀= fallow with No fertilizer application, S₁F₁= fallow + NPK 0.75g, S₁F₂: fallow + NPK 0.375g, S₁F₃= fallow + P.M 25g, S₁F₄= fallow + P.M 12.5g, S₁F₅=fallow+ NPK 0.375g + P.M 12.5g,

S₁F₆= fallow + NPK 0.19g + P.M 6.25g , S₂F₀= Degraded soil with No fertilizer application, S₂F₁= Degraded soil + NPK 0.75g, S₂F₂= Degraded soil + NPK 0.375g, S₂F₃= Degraded soil + P.M 25g , S₂F₄= Degraded soil + P.M 12.5g, S₂F₅= Degraded soil + NPK 0.375g + P.M 12.5g, S₂F₆= Degraded soil + NPK 0.19g + P.M 6.25g

Table 6a: Results of Post-cropping laboratory analysis of experimental soils

	Soil types	Soil pH	Organic Carbon %	Organic Matter %	Nitrogen %
S ₁	F ₀	5.22	0.19	0.33	0.08
	F ₁	5.14	2.78	4.79	0.39
	F ₂	5.06	3.06	5.28	0.46
	F ₃	4.05	2.39	4.13	0.38
	F ₄	4.96	2.87	4.95	0.36
	F ₅	4.64	2.57	0.99	0.14
	F ₆	5.04	2.59	4.46	0.32
S ₂	F ₀	5.19	0.16	0.23	0.04
	F ₁	4.24	3.2	5.51	0.52
	F ₂	4.96	1.11	1.92	0.19
	F ₃	5.3	1.82	3.14	0.22
	F ₄	5.08	2.39	4.13	0.36
	F ₅	4.96	1.97	3.4	0.26
	F ₆	5.02	0.46	0.79	0.1

S₁ =Fallow Vegetation, S₂=Degraded Soil, F₀=control, F₁=0.75g NPK, F₂=0.375g NPK, F₃=25g PM, F₄=12.5g PM, F₅=0.375g NPK +12.5g PM, F₆=0.186g NPK + 6.25g PM, S₁F₀= fallow with No fertilizer application, S₁F₁= fallow + NPK 0.75g, S₁F₂: fallow + NPK 0.375g, S₁F₃= fallow + P.M 25g, S₁F₄= fallow + P.M 12.5g, S₁F₅=fallow+ NPK 0.375g + P.M 12.5g, S₁F₆= fallow + NPK 0.19g + P.M 6.25g , S₂F₀= Degraded soil with No fertilizer application, S₂F₁= Degraded soil + NPK 0.75g, S₂F₂= Degraded soil + NPK 0.375g, S₂F₃= Degraded soil + P.M 25g , S₂F₄= Degraded soil + P.M 12.5g, S₂F₅= Degraded soil + NPK 0.375g + P.M 12.5g, S₂F₆ = Degraded soil + NPK 0.19g + P.M 6.25g

Table 6b: Results of post-cropping laboratory analysis of experimental soils

Soil types	Phosphorus	Potassium	Sodium	Calcium	Magnesium
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		(mg/kg)	(cmol/100g)	(cmol/100g)	(cmol/100g)	(cmol/100g)
S₁	F₀	1.56	0.49	0.67	1.0	0.5
	F₁	42.39	0.59	0.73	4.0	1.9
	F₂	13.84	0.46	0.56	3.2	1.4
	F₃	7.31	0.91	1.15	3.6	1.5
	F₄	48.46	0.21	0.31	8.0	3.8
	F₅	5.76	0.67	0.86	1.7	0.8
	F₆	28.86	0.60	0.70	0.9	1.2
S₂	F₀	0.12	0.13	0.06	1.1	1.0
	F₁	1.63	0.15	0.67	5.0	2.4
	F₂	1.17	0.21	0.82	1.8	0.8
	F₃	63.08	0.34	0.95	2.6	1.2
	F₄	56.23	0.44	0.89	2.8	1.4
	F₅	18.98	0.38	1.18	2.0	0.9
	F₆	51.18	0.26	1.09	3.9	1.7

S₁ =Fallow Vegetation, S₂ =Degraded Soil, F₀ =control, F₁ =0.75g NPK, F₂ =0.375g NPK, F₃ =25g PM, F₄ =12.5g PM, F₅ =0.375g NPK +12.5g PM, F₆ =0.186g NPK + 6.25g PM, S₁F₀= fallow with No fertilizer application, S₁F₁= fallow + NPK 0.75g, S₁F₂: fallow + NPK 0.375g, S₁F₃= fallow + P.M 25g, S₁F₄= fallow + P.M 12.5g, S₁F₅ =fallow+ NPK 0.375g + P.M 12.5g, S₁F₆= fallow + NPK 0.19g + P.M 6.25g , S₂F₀= Degraded soil with No fertilizer application, S₂F₁= Degraded soil + NPK 0.75g, S₂F₂= Degraded soil + NPK 0.375g, S₂F₃= Degraded soil + P.M 25g , S₂F₄= Degraded soil + P.M 12.5g, S₂F₅= Degraded soil + NPK 0.375g + P.M 12.5g, S₂F₆ = Degraded soil + NPK 0.19g + P.M 6.25g