# *Growth, yield attributes and metabolite components of Thickhead (Ebolo) (Crassocephalum crepidioides Benth.) 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 ($F_1$), NPK@150kg/ha ($F_2$), Poultry Manure@10t/ha ($F_3$), Poultry Manure @5t/ha ($F_4$), NPK @ 150kg/ha + Poultry Manure @5000t/ha, ($F_5$), NPK @ 75kg/ha + Poultry Manure @ 2500t/ha ($F_6$) 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 ($S_1$) 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

*Crassocephalum crepidioides* (Benth.) S. Moore, has various common names such as Thickhead, fireweed or rag leaf, 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 involucral 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 reap for the first harvest by uprooting, and harvesting for seed can start on 15 to17 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, inflammation andedema (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-chung et al., 2007; Chaitanya et al., 2013) of the plant have also been demonstrated.

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-farnasene, 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.

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 thickhead (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.

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.

**Sources of planting materials**

**S**tem 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 typeone($S_1$)was collected from fallow vegetation and soil type two ($S_2$) from field of over 10year 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.

## 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 0.62 cmol/100g, sodium 0.31cmol/100g, magnesium 1.2cmol/100g, and calcium of 7.0 cmol/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 $F_5$ recorded (4.26a) significantly higher root dry weight and also proof to be the best among other treatments for the biomass yield. Treatment $S_1F_5$ 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.

Fallow vegetation ($S_1$) 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 $S_1$, $F_5$ and $S_1F_5$.

**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 $S_1$ were completely significantly higher while, treatment $S_2$had significantly higher for calcium, magnesium and phosphorus. For the fertilizers, treatment $F_0$ (control) significantly higher for Na, K, Ca, and mg, while $F_4$ recorded significantly higher P, and $F_2$, $F_3$, and $F_5$ were significant for N. Among the interactions treatment $S_1F_0$ had significantly higher for Ca, P, Na, and mg. Treatment $S_2F_6$ recorded significantly higher for P and $S_1F_3$ 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 ($S_2$) had significantly higher for moisture content, ash and fat while those grown on fallow vegetation ($S_1$) had higher crude fiber, crude protein and carbohydrate. For the fertilizer rates, treatment $F_3$ (25g poultry manure) had significantly higher moisture content; $F_1$ for ash, $F_2$ recorded significantly higher fat and $F_4$ for carbohydrate. The control had significantly higher crude fibre and $F_5$ recorded higher protein content which differed significantly from others treatments. Fat contents were significantly higher for treatment $S_2F_2$, crude fibre content was significantly higher for $S_2F_0$ while carbohydrate were significantly higher for $S_1F_5$and crude protein for $S_1F_3$.

The bioactive compounds of ebolo grown on two soil types and fertilizers showed that the chlorophyll and phenolics content for treatment $S_2$(323.48a and 2.25a) were significantly different, while $S_1$ had higher flavonoids and terpenoids content (Table 5) The control ($F_0$) had the highest chlorophyll content compare with other treatment, $F_1$ had significantly higher flavonoids, higher phenolics for $F_6$, and higher terpenoids for $F_2$ for terpenoids. With respect to interactions, treatment $S_2F_0$ had significantly higher chlorophyll, $S_2F_1$ had higher flavonoids, $S_2F_4$ for phenolics and $S_1F_5$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 ($S_1$) and degraded soil ($S_2$) increased expect for treatment $S_1F_3$ which the soil pH reduce from (4.31 to 4.05) and $S_2F_1$ reduce from (4.51 to 4.24). The organic carbon content increase for most of the treatment except for the controls $S_1F_0$ (1.92% to o.19%), $S_2F_0$ (0.84% to 0.16%) and $S_2F_6$ 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 $S_1F_{0,}$ $S_2F_0$ and treatment $S_2F_6$ and $S_1F_5$ while other treatments increase in organic matter content. The percent nitrogen increased for all other treatment except for the control treatments which reduced $S_1F_{0,}$ $S_2F_0$ and treatment $S_1F_{5.}$ 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 8weeks after treatment application respectively. Soil type $S_1$ (fallow vegetation) produce significant growth parameters of thickhead (ebolo). $S_1$produce more significant leaves at 4, 6, and 8weeks after treatment application than $S_2$ (degraded soil) also, $S_1$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. $S_1$ is soil obtained under fallow vegetation which has more nutrient content than the degraded soil.$S_2$ (degraded soil) recorded significant increase in root length and number of roots. The biomass yield of thickhead (ebolo) grown on fallow vegetation ($S_1$)produce heavier biomass yield than those planted on degraded soil ($S_2$).In terms of bioactive compounds, thickhead (ebolo) grown on degraded soil ($S_2$) has more chlorophyll and phenolics content than fallow vegetation ($S_1$), flavonoids and terpenoids were significant for fallow vegetation. Moisture content, ash and fat content $S_2$ recorded significant higher values, while $S_1$ were higher for crude fibre and crude protein. For the chemical compositions of thickhead (ebolo) $S_1$ recorded significantly highest value for sodium, potassium, and nitrogen while for phosphorus, calcium and magnesium were significantly higher for treatment $S_2$.

NPK-poultry manure (PM) amendment at 0.38g NPK +12.5g poultry manure : $F_5$ out-perform other treatments. This treatment $F_5$ 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 ($F_0$) had significantly higher chlorophyll, $F_1$ for flavonoids, $F_2$ for terpenoids and $F_6$ 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 $S_1F_5$ (fallow+ NPK 0.375g + P.M 12.5g) produce heavier biomass than other treatment. Treatment $S_2F_0$ (degraded soil with no amendment) recorded highest chlorophyll content which were significantly different from other soil type-amendment. $S_2F_1$ for flavonoids, $S_2F_4$ for phenolics and treatment $S_1F_5$ were significantly different for terpenoids for the bioactive compounds. Chemical composition of thickhead (ebolo) were significantly influence by treatment $S_1F_0$ (fallow vegetation with no amendment) for potassium, calcium, sodium and magnesium, while for phosphorus, $S_2F_6$ (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 $S_2F_0$; crude protein was significantly higher for $S_1F_3$(fallow + P.M 25g) and carbohydrate for $S_1F_{5.}$

This result also showed an increase in soil pH of crop maturity for all the treatments expect $S_1F_3$ (fallow + P.M 25g) and $S_2F_1$ (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 $S_1F_5$ (fallow+ NPK 0.375g + P.M 12.5g) and $S_2F_6$ (Degraded soil + NPK 0.19g + P.M 6.25g). The reduction in organic matter of $S_1F_5$ (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 expect the control in addition toother chemical properties such as sodium, potassium, calcium, phosphorus and magnesium

## 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: $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM) affected the growth, yield, bioactive compounds, chemical and proximate compositions of thickhead (ebolo). Fallow vegetation ($S_1$) 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 $S_1$, $F_5$ and $S_1F_5$. 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

**References**

Adekayode, F.O. and Ogunkoya, M.O. (2011). Comparative effects of organic compost and NPK fertilizer on soil fertility, yield and quality of amaranth in southwest Nigeria. International journal of biological chemistry science. 5(2): 490-499

Agbede, T. M. (2021). Effect of tillage, biochar, poultry manure and NPK 15-15-15 fertilizer, and their mixture on soil properties, growth and carrot (Daucuscarota L.) yield under tropical conditions. *Heliyon*, *7*(6), e07391.

Ajibesin, Danladi N. Bala & Uwemedimo F. Umoh (2012) Ethno- medicinal survey of plants used by the indigenes of Rivers State of Nigeria, Pharmaceutical. Biology. 50:9,1123-1143,DOI:10.3109/13880209.2012.661740.

Arawande, J. O., Komolafe, E. A., &Imokhuede, B. (2013). Nutritional and phytochemical compositions of fireweed (Crassocephalum crepidioides). *Journal of Agricultural Technology*, *9*(2), 439-449.

Ayodele, O. O., Onajobi, F. D., &Osoniyi, O. R. (2020). Phytochemical Profiling of the Hexane fraction of Crassocephalum crepidioidesBenth S. Moore leaves by GC-MS.

Bahara, Y. N., & Nicolle, C. (2017). Building Energy Optimization through Thermal Efficiency Determination using Digital Mock-up Simulation for Heritage Building of Cluny Abbey. *Journal of Buildings and Sustainability*, *2*(1).

Devkota, S., Rayamajhi, K., Yadav, D.R., & Shrestha, J. (2021). Effects of different doses of organic and inorganic fertilizers on cauliflower yield and soil properties.*Journal of Agriculture and Natural Resources*, *4*(2), 11-20. DOI: https://doi.org/10.3126/janr.v4i2.33647

Joshi, R. K. (2011). Terpene composition of *Crassocephalum crepidioids* from Western Ghats region of India. *Int. J. Nat. Prod. Res.* 1, 19–22.

Oyebode, O. A., Erukainure, O. L., Ibeji, C., Koorbanally, N. A., and Islam, M. S. (2019). *Crassocephalum rubens*, a leafy vegetable, suppresses oxidative pancreatic and hepatic injury and inhibits key enzymes linked to type 2 diabetes: an ex vivo and in silico study. *J. Food Biochem.* 43:e12930. doi: 10.1111/jfbc.12930

Oyedeji, S., Animasaun, D. A., Bello, A. A., &Agboola, O. O. (2014). Effect of NPK and poultry manure on growth, yield, and proximate composition of three Amaranths. *Journal of Botany*.s

Okigbo, R. N., Anuagasi, C. L., &Amadi, J. E. (2009). Advances in selected medicinal and aromatic plants indigenous to Africa. *Journal of medicinal plants Research*, *3*(2), 86-95.

Oyebode, O. A., Erukainure, O. L., Ibeji, C., Koorbanally, N. A., and Islam, M. S. (2019). *Crassocephalum rubens*, a leafy vegetable, suppresses oxidative pancreatic and hepatic injury and inhibits key enzymes linked to type 2 diabetes: an ex vivo and in silico study. *J. Food Biochem.* 43:e12930. doi: 10.1111/jfbc.12930

Raman, D., Joshi, N., &Rana, P. S. (2022). Effect of Organic and Chemical Fertilizers on the Nutritional Composition of Amaranthusspinosus. *bioRxiv*, 2022-06.

**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 | cmol/kg | 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. $S_1$ =Fallow Vegetation, $S_2$ =Degraded Soil, $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM, $S_1F_0$= fallow with No fertilizer application,$S_1F_1$= fallow + NPK 0.75g, $S_1F_2$: fallow + NPK 0.375g, $S_1F_3$= fallow + P.M 25g, $S_1F_4$= fallow + P.M 12.5g, $S_1F_5$ =fallow+ NPK 0.375g + P.M 12.5g, $S_1F_6$= fallow + NPK 0.19g + P.M 6.25g , $S_2F_0$= Degraded soil with No fertilizer application, $S_2F_1$= Degraded soil + NPK 0.75g, $S_2F_2$= Degraded soil + NPK 0.375g, $S_2F_3$= Degraded soil + P.M 25g , $S_2F_4$= Degraded soil + P.M 12.5g, $S_2F_5$= Degraded soil + NPK 0.375g + P.M 12.5g, $S_2F_6$ = 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 ($P_2O_5$)mg/ 100g** | **K ($K_2O$)mg/ 100g** | **Ca (mg/100g)** | **Na (mg/100g)** | **Mg (mg/100g)** |
|---|---|---|---|---|---|---|---|
| **Soil type** | **$S_1$** | 0.59a | 24.03b | 6.19a | 5.04b | 3.91a | 2.81b |
| | **$S_2$** | 0.57b | 24.60a | 5.86b | 5.74a | 3.62b | 2.91a |
| | **$F_0$** | 0.55bc | 10.46g | 6.96a | 6.31a | 4.40a | 3.29a |
| | **$F_1$** | 0.57b | 20.56e | 5.46f | 4.81f | 3.45f | 2.72f |
| | **$F_2$** | 0.60a | 29.40c | 6.12c | 4.57g | 3.82c | 2.07g |
| | **$F_3$** | 0.61a | 21.30d | 6.07d | 6.01b | 3.73d | 3.09c |
| | **$F_4$** | 0.56b | 38.39a | 5.29g | 5.51c | 3.32g | 3.16b |
| | **$F_5$** | 0.61a | 17.97f | 5.76e | 5.31d | 3.59e | 2.81e |
| | **$F_6$** | 0.54c | 32.11b | 6.52b | 5.22e | 4.06b | 2.93d |
| **$S_1$** | **$F_0$** | 0.54 | 11.44l | 7.40a | 6.92a | 5.13a | 3.44a |
| | **$F_1$** | 0.58bc | 17.23j | 5.56h | 4.46hi | 3.55efg | 2.86f |
| | **$F_2$** | 0.61b | 26.53f | 5.97e | 4.38i | 3.79de | 1.97j |
| | **$F_3$** | 0.66a | 34.53d | 6.86b | 5.78de | 4.15c | 2.99d |
| | **$F_4$** | 0.55d | 37.89c | 4.95k | 4.45hi | 3.18j | 3.16c |
| | **$F_5$** | 0.64b | 19.39i | 5.87f | 4.73g | 3.75de | 2.36h |
| | **$F_6$** | 0.51e | 21.17h | 6.18d | 4.57h | 3.79de | 2.89ef |
| **$S_2$** | **$F_0$** | 0.59bc | 9.48m | 5.97e | 5.69e | 3.66ef | 3.10c |
| | **$F_1$** | 0.52e | 23.89g | 5.35i | 5.16f | 3.34hi | 2.57g |
| | **$F_2$** | 0.58bc | 32.27e | 6.28c | 4.76g | 3.85d | 2.16i |
| | **$F_3$** | 0.56c | 8.06n | 5.28j | 6.24c | 3.30ij | 3.18c |
| | **$F_4$** | 0.57c | 38.89b | 5.63g | 6.56b | 3.45gh | 3.16c |
| | **$F_5$** | 0.57c | 16.55k | 5.65g | 5.88d | 3.43gh | 3.26b |

| | | | | | | |
|---|---|---|---|---|---|---|
| **$F_6$** | 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. $S_1$ =Fallow Vegetation, $S_2$ =Degraded Soil, $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM, $S_1F_0$= fallow with No fertilizer application,$S_1F_1$= fallow + NPK 0.75g, $S_1F_2$: fallow + NPK 0.375g, $S_1F_3$= fallow + P.M 25g, $S_1F_4$= fallow + P.M 12.5g, $S_1F_5$ =fallow+ NPK 0.375g + P.M 12.5g, $S_1F_6$= fallow + NPK 0.19g + P.M 6.25g , $S_2F_0$= Degraded soil with No fertilizer application, $S_2F_1$= Degraded soil + NPK 0.75g, $S_2F_2$= Degraded soil + NPK 0.375g, $S_2F_3$= Degraded soil + P.M 25g , $S_2F_4$= Degraded soil + P.M 12.5g, $S_2F_5$= Degraded soil + NPK 0.375g + P.M 12.5g, $S_2F_6$ = 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. $S_1$ =Fallow Vegetation, $S_2$ =Degraded Soil, $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM, $S_1F_0$= fallow with No fertilizer application,$S_1F_1$= fallow + NPK 0.75g, $S_1F_2$: fallow + NPK 0.375g, $S_1F_3$= fallow + P.M 25g, $S_1F_4$= fallow + P.M 12.5g, $S_1F_5$ =fallow+ NPK 0.375g + P.M 12.5g, $S_1F_6$= fallow + NPK 0.19g + P.M 6.25g , $S_2F_0$= Degraded soil with No fertilizer application, $S_2F_1$= Degraded soil + NPK 0.75g, $S_2F_2$= Degraded soil + NPK 0.375g, $S_2F_3$= Degraded soil + P.M 25g , $S_2F_4$= Degraded soil + P.M 12.5g, $S_2F_5$= Degraded soil + NPK 0.375g + P.M 12.5g, $S_2F_6$ = 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. $S_1$ =Fallow Vegetation, $S_2$ =Degraded Soil, $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM, $S_1F_0$= fallow with No fertilizer application,$S_1F_1$= fallow + NPK 0.75g, $S_1F_2$: fallow + NPK 0.375g, $S_1F_3$= fallow + P.M 25g, $S_1F_4$= fallow + P.M 12.5g, $S_1F_5$ =fallow+ NPK 0.375g + P.M 12.5g, $S_1F_6$= fallow + NPK 0.19g + P.M 6.25g , $S_2F_0$= Degraded soil with No fertilizer application, $S_2F_1$= Degraded soil + NPK 0.75g, $S_2F_2$= Degraded soil + NPK 0.375g, $S_2F_3$= Degraded soil + P.M 25g , $S_2F_4$= Degraded soil + P.M 12.5g, $S_2F_5$= Degraded soil + NPK 0.375g + P.M 12.5g, $S_2F_6$ = 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 |

$S_1$ =Fallow Vegetation, $S_2$ =Degraded Soil, $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM, $S_1F_0$= fallow with No fertilizer application,$S_1F_1$= fallow + NPK 0.75g, $S_1F_2$: fallow + NPK 0.375g, $S_1F_3$= fallow + P.M 25g, $S_1F_4$= fallow + P.M 12.5g, $S_1F_5$ =fallow+ NPK 0.375g + P.M 12.5g, $S_1F_6$= fallow + NPK 0.19g + P.M 6.25g , $S_2F_0$= Degraded soil with No fertilizer application, $S_2F_1$= Degraded soil + NPK 0.75g, $S_2F_2$= Degraded soil + NPK 0.375g, $S_2F_3$= Degraded soil + P.M 25g , $S_2F_4$= Degraded soil + P.M 12.5g, $S_2F_5$= Degraded soil + NPK 0.375g + P.M 12.5g, $S_2F_6$ = Degraded soil + NPK 0.19g + P.M 6.25g



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

| | Soil types | Phosphorus (mg/kg) | Potassium (cmol/100g) | Sodium (cmol/100g) | Calcium (cmol/100g) | Magnesium (cmol/100g) |
|---|---|---|---|---|---|---|
| **$S_1$** | **$F_0$** | 1.56 | 0.49 | 0.67 | 1.0 | 0.5 |
| | **$F_1$** | 42.39 | 0.59 | 0.73 | 4.0 | 1.9 |
| | **$F_2$** | 13.84 | 0.46 | 0.56 | 3.2 | 1.4 |
| | **$F_3$** | 7.31 | 0.91 | 1.15 | 3.6 | 1.5 |
| | **$F_4$** | 48.46 | 0.21 | 0.31 | 8.0 | 3.8 |
| | **$F_5$** | 5.76 | 0.67 | 0.86 | 1.7 | 0.8 |
| | **$F_6$** | 28.86 | 0.60 | 0.70 | 0.9 | 1.2 |
| **$S_2$** | **$F_0$** | 0.12 | 0.13 | 0.06 | 1.1 | 1.0 |
| | **$F_1$** | 1.63 | 0.15 | 0.67 | 5.0 | 2.4 |
| | **$F_2$** | 1.17 | 0.21 | 0.82 | 1.8 | 0.8 |
| | **$F_3$** | 63.08 | 0.34 | 0.95 | 2.6 | 1.2 |
| | **$F_4$** | 56.23 | 0.44 | 0.89 | 2.8 | 1.4 |
| | **$F_5$** | 18.98 | 0.38 | 1.18 | 2.0 | 0.9 |
| | **$F_6$** | 51.18 | 0.26 | 1.09 | 3.9 | 1.7 |

$S_1$ =Fallow Vegetation, $S_2$ =Degraded Soil, $F_0$ =control, $F_1$ =0.75g NPK, $F_2$ =0.375g NPK, $F_3$ =25g PM, $F_4$ =12.5g PM, $F_5$ =0.375g NPK +12.5g PM, $F_6$ =0.186g NPK + 6.25g PM, $S_1F_0$= fallow with No fertilizer application,$S_1F_1$= fallow + NPK 0.75g, $S_1F_2$: fallow + NPK 0.375g, $S_1F_3$= fallow + P.M 25g, $S_1F_4$= fallow + P.M 12.5g, $S_1F_5$ =fallow+ NPK 0.375g + P.M 12.5g, $S_1F_6$= fallow + NPK 0.19g + P.M 6.25g , $S_2F_0$= Degraded soil with No fertilizer application, $S_2F_1$= Degraded soil + NPK 0.75g, $S_2F_2$= Degraded soil + NPK 0.375g, $S_2F_3$= Degraded soil + P.M 25g , $S_2F_4$= Degraded soil + P.M 12.5g, $S_2F_5$= Degraded soil + NPK 0.375g + P.M 12.5g, $S_2F_6$ = Degraded soil + NPK 0.19g + P.M 6.25g