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Biorational Preservation of Rose (*Rosa hybrida* L.) Cut-Flower Using Stevia (*Stevia rebaudiana* B.) and Thyme (*Thymus vulgaris* L.) Extracts

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Keywords: Floral quality, rose cut flower, stevia extracts, thyme extracts, vase life,

Abstract. Rose cut flower is one of the widely grown cut flowers in Kenya. However, most roses have a challenge of short vase life. This study aimed at determining the efficacy of plant extracts from thyme and stevia in preservation of rose cut-flowers. Two rose cut-flower cultivars; 'radiance and 'high & sparkling' were subjected to stevia and thyme extracts each at three levels (0.2, 0.4, and 0.6gL^{-1}). Thyme extracts at a concentration of 0.2 gL^{-1} significantly (p≤001) extended the vase life of rose cut flower by 3.5 days and floral absorption rates by 10.4% compared to the commercial preservative (chrysal) at the same concentration rates. Application of higher doses (0.4gL^{-1} and 0.6gL^{-1}) of plant extracts led to shorter vase life (6 days) of rose cut flower and maximum bent neck records at day 8. The response of rose cut flower to the treatments did not vary between cultivars. The results from this study indicate that thyme extracts offer an attractive alternative to the use of chemical floral preservatives for prolonging the vase life and enhancing quality of rose cut flower. The efficacy of extracts is however depended on the concentration level with 0.2gL^{-1} dosage recording the best results.

Introduction

Postharvest life is a major concern in rose cut flowers especially due to their ethylene production property. Chemical floral preservatives mainly containing sugars and germicides are used to improve postharvest life of rose flowers. However, most of the chemical floral preservatives contain either aluminium sulphate, silver nitrate, silver thiosulphate, calcium chloride which have negative effects on the environment [1]. This study used extracts from stevia and thyme to preserve rose cut flowers. *Stevia rebaudiana* is an herbaceous plant grown for its leaves. The plant has high levels of sugar relating to stevioside and rebaudioside concentrations [2]. The extracts from stevia have been tested for their ability to preserve cut flowers especially in improving fresh weight and extending diameter [3]; in preventing chlorophyll degradation during postharvest handling [4] and in preventing bent neck development [5]. There is however, limited research on applicability of stevia extracts as flower food. There is a need therefore to explore its potential since stevia extracts have been reported to contain natural stevioside [2] which could substitute chemical preservatives.

Thyme herb (*Thymus vulgaris*) is an evergreen herb with culinary, medicinal and ornamental value. Essential oil from thyme contains thymol and carvacrol which exhibit anti-microbial properties [6-9]; hence improving relative fresh weight and solution uptake of cut flower. Thyme monoterpens have been found to inhibit ethylene production [10] hence improve floral quality [3] and vase life. Whereas many studies have been done on potential use of thyme extracts in preservation of cut flowers, differing results have been reported on the best application rate of thyme extracts for improving floral quality. Furthermore, most of the studies on thyme extracts have been done on carnations and gerbera flowers and very few studies have focused on roses especially radiance and high and sparkling cultivars. This study therefore aimed at determining the best application rates of thyme and stevia extracts and their efficacy on improving the postharvest life and quality of two rose cultivars.

Materials and Methods

Production of Stevia and Thyme Plants

A field experiment was established at Karatina University agricultural farm. The region lies at an altitude of 1980m above sea level with annual rainfall of 1200mm. The soil is mainly red volcanic soil. The average temperature ranges from 15^0C -18^0C. The field experiments were set up following a randomized complete block design. Beds measuring 1.35m width on top and 1.55 m at the base and 25m length were prepared. Each bed had 4 rows at a spacing of 35cm. Plant to plant spacing was 16 cm. A total of 20 beds were prepared. The plants were planted and all agronomic practices carried out.

Harvesting of Stevia and Thyme Leaves

Initial harvesting was done at four months after transplanting. Leaves were harvested by plucking. The leaves were harvested during the vegetative stage prior to flowering and the plants were trimmed completely leaving 4 inches from the ground. New plants were harvested again one month after a new flush of leaves sprouted.

Postharvest handling and storage of stevia and thyme Leaves

After harvesting, the leaves were shade dried under a net to prevent volatilization of plant chemical compounds due to strong sun light effect. The dried leaves were then crushed using a grinding machine to form powder. The powder obtained was stored in polythene bags at room temperature.

Preparation of stevia and thyme Extracts

Shade dried stevia powder was mixed with 0.5L of 100% pure acetone and 0.5L pure water. A mechanical shaker was used to shake the mixture for seventy two hours. The mixture was then sieved using filter paper and then transferred to an oven at 70°C temperature for seventy two hours to obtain uniform powders [11]. Thyme extracts was prepared by mixing dried leaves with 1L of 85% ethanol and shaken for seventy two hours. The resulting mixture was then sieved with a filter paper. The extract was transferred into a vacuum distillation unit at 80°C temperature. The solvent was evaporated and condensed. The extract was concentrated in the oven at 70 °C for seventy two hours [11].

Phytochemical analysis of thyme and stevia extracts

Dried parts of stevia and thyme plants (about 100g) were cut into small pieces and subjected to hydrodistillation (HD) for 3hrs using a Clevenger type apparatus. Oils obtained from the dried plant parts were dried using anhydrous sodium sulphate. The volatile compounds isolated by hydrodistillation were analysed by GC/MS, using an Agilent Technologies 6890N GC. The fused HP-5MS capillary column was coupled to an Agilent Technologies 5973B MS (Hewlett-Packard, Palo Alto, CA, USA). The oven temperature was programmed at 50°C for 1 min, then 7°C/min to 250°C, and then left at 250°C for 5 min. The injection port temperature was 250°C while that of the detector was 280°C (split ratio: 1/100). Helium gas (99.995% purity) was used as a carrier gas at a flow rate of 1.2 ml/min. The MS conditions were as follow: ionization voltage, 70 eV; ion source temperature, 150°C; electron ionization mass spectra were acquired over the mass range 50 to 550 m/z. The percent phytochemical composition of thyme and stevia are shown in Table 1 and 2.

Table 1. Percent (%) phytochemical composition of thyme extracts

Components	Concentration (%)
Thymol	46.21
Carvacrol	2.44

Table 2. Percent (%) phytochemical composition of stevia extracts

Compound	Concentration (%)
Stevioside	10
Rebaudioside	2
Pulcoside	0.7

Production and management of rose cut-flower cultivars

Two rose flower cultivars (radiance and high and sparkling) were hydroponically raised in a greenhouse at Zena roses, Thika.Temperature and relative humidity were controlled at 17-18^{0}c and 65-80% respectively. The flowers were fertigated twice per week. Pest and disease control was done based on daily scouting reports. The flowers (1st bloom) were harvested at bud stage 12 weeks after planting by cutting slightly above the second five leaflet leaf using a secateur.

Post-harvest Handling of Rose Cut Flowers

The flowers were immediately placed in buckets half filled with water [12] after harvesting, then transported to a pack house. Flowers were pre-cooled for two hours to remove field heat in a pack house, graded in a grading room and then trimmed to a length of 35cm using a sterilized scalpel and immediately taken to a post-harvest laboratory.

Determination of the efficacy of thyme and stevia extracts on vase-life and quality of rose cut-flower

Experimental design

The experiment followed a randomized complete block design in a factorial arrangement with three replications. The two rose cultivars were the main treatments while the various levels of thyme and stevia extracts formed the sub-treatments.

Preparation of stock solutions

Thyme and stevia extracts were prepared separately by addingone gram of dried plant material to five litres of sterile distilled water to make a 5litre stock solution of 0.2gL^{-1} concentration. Higher concentrations of stevia and thyme (0.4 and 0.6g/L) were prepared by adding 2grams and 3grams respectively to 5 litres of sterile distilled water.

The cut flowers were cut to a length of 35cm. The one litre volume vases were cleaned and the prepared solutions added. A total of thirty six bunches of 6 rose stems each were separately placed in one litre of each stock solution with the respective amount of each of the three treatments each at three concentration levels (0.2, 0.4 and 0.6gL^{-1}).

Floral arrangement

Six rose flower stems were placed in each flower vase (three stems for each cultivar). The cultivars were placed in one vase since most of rose flowers are sold in mixed bouquets. The vases were sealed in the neck using water proof polythene seal to prevent evaporation of vase solution. Observations were done on daily basis. The temperature of the testing room was maintained at 22^{0}c with 12 hours of photoperiod.

Data collection

Data was collected on the following parameters:

Vase Life (day(s): This is a parameter used to show post-harvest longevity of cut flower [13]. It is defined as the post-harvest period a cut flower retains its aesthetic value until the end of consumer utility [14]. Severe petal discolouration, tips blackening, petal browning and bent neck of flowers was deemed as the end of cut flower life.

Solution absorption rate (%): This was assessed based on the formula described below.

$$\text{Solution absorption rate (\%)} = \frac{\text{Initial solution level-Final solution level} * 100}{\text{Initial solution level}}$$

Physical Quality; Bent Neck

The physical quality of harvested flowers is among the major factors in the market value of cut flowers. In this study, flower physical qualities were determined using a modified physical quality and vase life termination rating scale as described by [15] & [16; 0: bending 0 - 15°, 1: bending between 16°- 25°, 2: bending between 26°- 65°, 3: bending between 66°- 90°, 4: bending more than 90°.

Statistical Analysis

All collected data was subjected to analysis of variance (ANOVA) using GenStat 12.1 version. Means were separated using the Least Significant Difference at 99% level of confidence.

Results and Discussion

Effects of Stevia and Thyme Extracts on vase life

The results indicated that the efficacy of stevia and thyme extracts on the vase-life and quality of the selected rose cut flower cultivars (high and sparkling and Radiance cultivars) was depended ($p=0.001$) on the concentration level of the extract but independent ($p=0.080$) of the cultivar used.

Treatment of radiance cultivar with stevia and thyme extracts enhanced vase life by 0.6% and 16% respectively compared to the control. The vase life of high and sparkling cultivar was enhanced by 11.1% and 3.2% when treated with thyme and stevia extracts respectively Treatment of compared to the non-treated control. The highest vase life extension was observed on cut flower treated with the commercial floral preservative (Chrysal) enhancing the vaselife of radiance and high and sparkling cultivars by 18.3% and 17.1% respectively compared to the control.

Table 3. Effect of thyme extracts, stevia extracts and chrysal on vase of radiance & high and sparkling rose cultivars

Treatment	Cultivar	Mean vase life (days)
Control	Radiance	8.033a
Control	High & sparkling	8.147a
Stevia extracts	Radiance	8.083a
Stevia extracts	High & sparkling	8.417a
Thyme extracts	High & sparkling	9.167b
Thyme extracts	Radiance	9.583bc
Chrysal	Radiance	9.833c
Chrysal	High & sparkling	9.833c

Means followed by the same letter are not significantly different at 1% LSD

Plant extract type and treatment level significantly ($p\leq001$) affected the vaselife of rose cut-flower cultivars. Thyme extracts, chrysal and stevia extracts at applied to rose cut flower at the rate of $0.2gL^{-1}$ enhanced vase life by 44.1%, 30.7% and 8.4% respectively compared to the control.

Thyme extracts, stevia extracts and chrysal applied at c had varying effects on extending the vase life of rose cut flower compared to the control. The highest vase life enhancement (16.3%) was observed on chrysal treated flowers followed by stevia (0.9%). Thyme at $0.4gL^{-1}$ had no effect on vase life enhancement (0 % extension) compared to the control. Thyme and stevia extracts applied at $0.6gL^{-1}$ decreased the vase life of rose cut flowers by -15.6% and -1.1% compared to the control while treatment with chrysal at $0.6gL^{-1}$ increased vase life of rose cutflower by 19.1% compared to control. (Fig. 1).

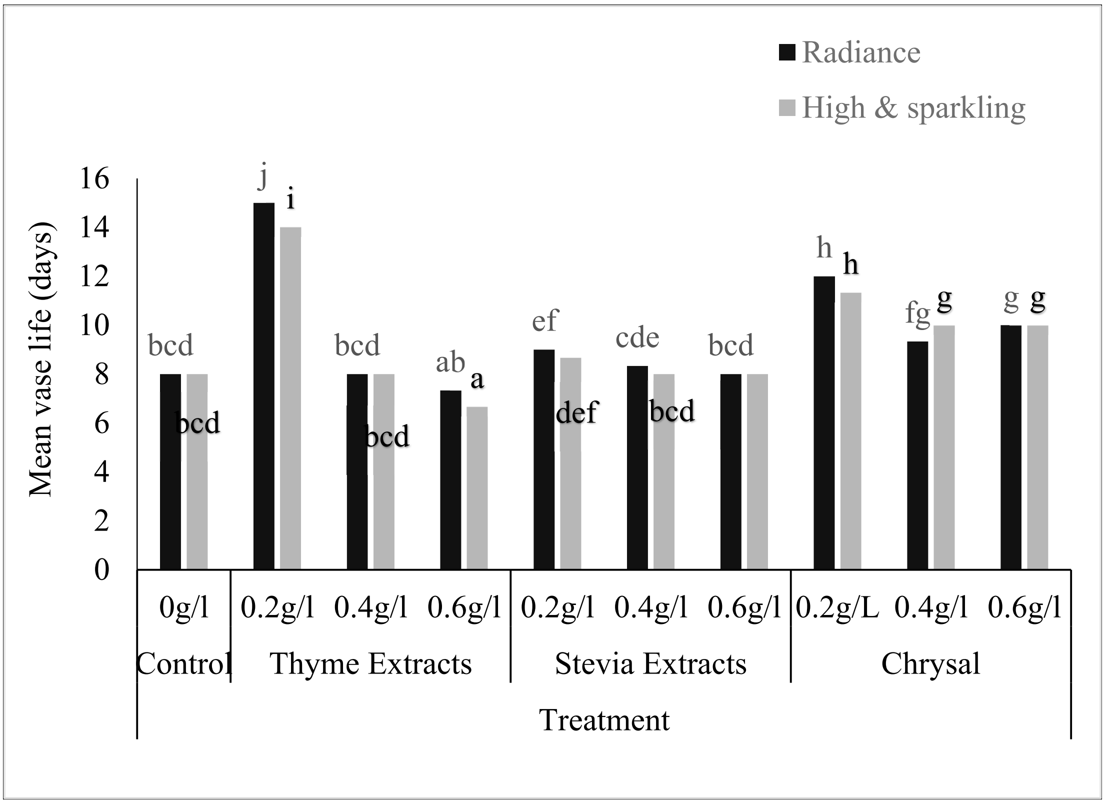

Figure 1. Effect of chrysal, stevia extracts and thyme extracts application dosages on vase life of radiance and high and sparkling rose cultivar. Bars followed by the same letter are not significantly different at LSD= 0.01

This indicates that the efficacy of plant extracts (thyme and stevia) decreases with increasing concentration level. Thyme extracts at $0.2gL^{-1}$ concentration were most efficacious extending vase life of rose cut-flower by 2.833 and 5 days compared to chrysal at $0.2gL^{-1}$ concentration and stevia at $0.2gL^{-1}$ concentration respectively. This result agrees with [17] who found that application of 200ppm of thyme essential oil significantly lengthened vase life in carnation, 'sensi cultivar' by 2 days. Similar findings were obtained by [4] indicating that flower senescence of cut roses 'dolce vita' decreased when treated with thyme extracts at 0.2ppm along with pulse treatment of sucrose and calcium chloride. The result is also in agreement with [6] who proved that $100mgL^{-1}$ thymol and $50mgL^{-1}$ carvacrol compared to the control was most effective in prolonging the vase life of cut gerbera. This result however differs with [18] who reported that thyme extracts at $900mgL^{-1}$ concentration was most effective in prolonging the vase life of *lilium santander* cut flower as compared to control. The reduced vase life as concentration of thyme extracts increased could be attributed to scorching of vascular tissues of rose cut flower stems dipped in the vase solution as was observed on the fourth day (Plate 1). This appeared to have rendered the cut flower stems damaged at those particular sections.

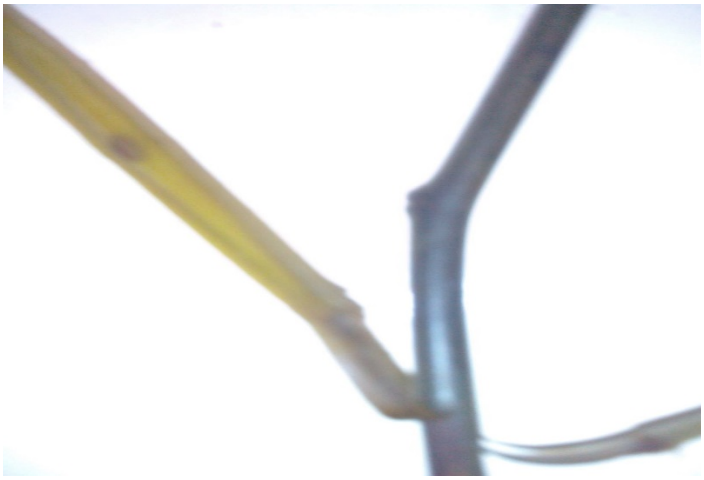

Plate 1. Scorching effects of thyme extract at 0.6 gL^{-1} on vascular tissue of rose cut flower

The low efficacy levels observed with increasing concentration levels of thyme, stevia and chrysal treatments could be attributed to increased sugar levels which may have led to increased microbial activity, vascular blockage and phytotoxicity which were not measured in this study. These factors have however been reported as possible causes of reduced vase life. For example, vascular blockage of cut flower stems occurred on the sixth day [6] in stevia treated cut gerbera.

Effects of Stevia and Thyme Extracts on Absorption Rate

Thyme extracts at 0.2gL^{-1} concentration had the highest mean absorption rate (99%) (Fig. 2). This may be attributed to the anti-microbial properties exhibited by thymol and carvacrol in thyme extracts [8] [7] which prevented vascular blockage [6] of the cut flower stems hence continued solution uptake. These two compounds (thymol and carvacrol) were found to be present in thyme extracts initial sample characterization at 46.21% and 2.44% concentrations respectively. The result concurs with [6] who reported that 100 mgL^{-1} carvacrol essential oil improved the relative fresh weight and vase solution absorption rate of gerbera flower.

Chrysal at 0.2gL^{-1} concentration had mean absorption rate of 88.6%. Chrysal has a strong germicide; aluminium sulphate that helps to prevent microbial infection of flower stems [19] ensuring continued vase solution uptake. [20] investigated the effect of aluminium sulfate at 50, 100 and 150 mgL^{-1} concentrations on vase solution uptake of cut *Eustoma grandiflora* and found that 150mgL^{-1}concentration of aluminium sulfate enhanced water uptake and fresh weight.

Thyme extracts at 0.6gL^{-1} concentration exhibited the lowest mean absorption rate of 5.7%. This was attributed to the phytotoxic effect of flower part immersed in the solution on the fourth day after treatment. Initial characterization of thyme plants in our study showed high content of polyphenols (51.35%) which could be attributed to the low efficacy of thyme extracts at higher concentrations.

Stevia extracts at 0.2gL^{-1} did not differ significantly ($p \leq 001$) with control and the rest of treatment concentrations in as far as absorption rate was concerned. It was found that the high sugar content present in stevia extracts [2] accelerated microbial growth leading to vascular blockage [6]of the flower stems hence low solution uptake.

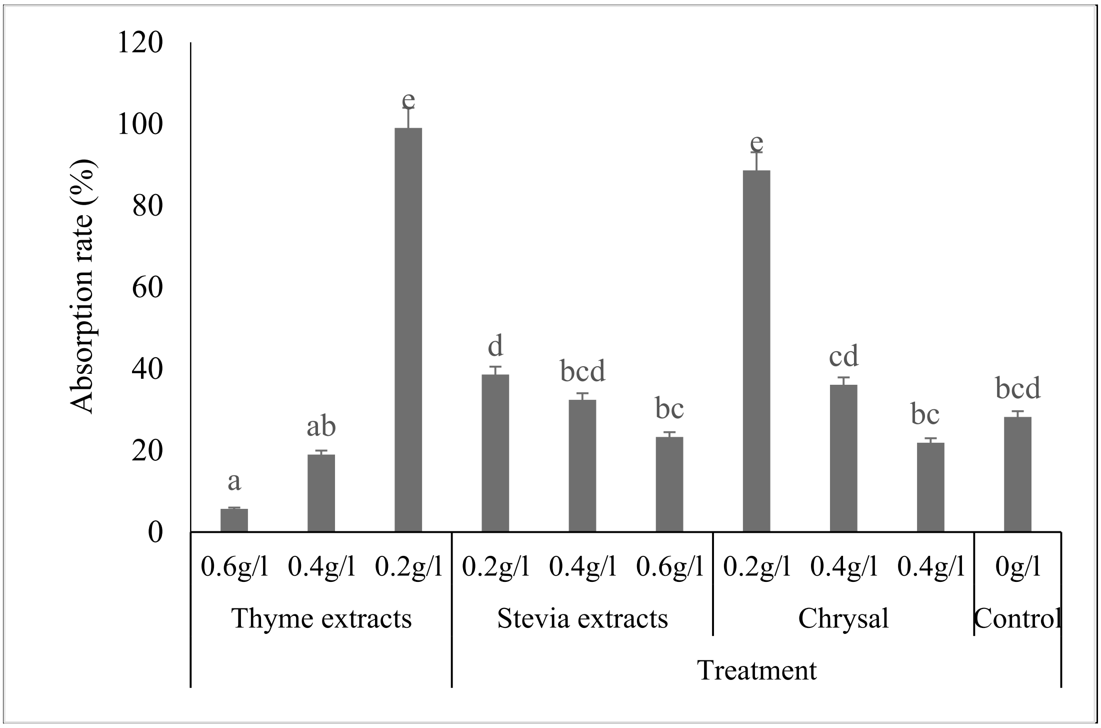

Figure 2. Effect of chrysal, stevia extracts and thyme extracts application dosages on vase solution absorption rate in rose flower

Effect of Treatments on bent neck of Rose Flowers

The effect of applied treatments significantly varied (p≤001) with type and concentration level (Table 4). Non-treatment (control) rose flower and treatment with thyme extracts at $0.4gL^{-1}$ and $0.6gL^{-1}$ recorded maximum bent neck score (4) at day 8 while treatment with stevia extracts ($0.2gL^{-1}$, $0.4gL^{-1}$, $0.6gL^{-1}$) and chrysal at $0.4gL^{-1}$ and $0.6gL^{-1}$ recorded maximum bent neck on the 10^{th} day. Rose flowers treated with chrysal at $0.2gL^{-1}$ showed the maximum bent neck of 4 on the day 12. The vase life of the rose flowers was terminated at the maximum bent neck level. Apart from the control, stevia extracts $0.2gL^{-1}$ concentration exhibited the highest level of bent neck compared to thyme and crysal at the same concentration. The high level of sugar component (10% in our stevia extract) and in $0.4gL^{-1}$ and $0.6gL^{-1}$ thyme and chrysal application levels may explain the early (at day 6) and maximum rose cut flower bent neck recorded on day 8. High sugar concentrations in vase solutions has been reported to cause vascular blockage and flower infection and the cut end in gerbera cut flower [2]; [6] .

The best treatment in preventing bent neck was observed on rose flower treated with thyme extracts at $0.2gLl^{-1}$ concentration. This treatment showed little or no signs of bent neck up to the twelfth day (12) of the vase life (Plate 2). The result may be attributed to the high levels of thymol (46.21%) and carvacrol (2.44%) oils observed in thyme plant extracts. The oils have been reported to exhibit antimicrobial properties which prevent vascular embolism and preserve the integrity of cut-flower. [8] reported anti-microbial property of thyme extracts as having detered infection of the cut flower stems hence ensuring continued solution uptake and hence cell turgidity is maintained. The result conforms to that of [17] who found that bent neck in thyme extracts treatment at a concentration of 0.1 mgL^{-1} remained low up to day 12 in cut gerbera in comparison with the control. [5], comparing stevia and thyme extracts reported lower stem bending in gerbera cut flower treated with thyme extracts.

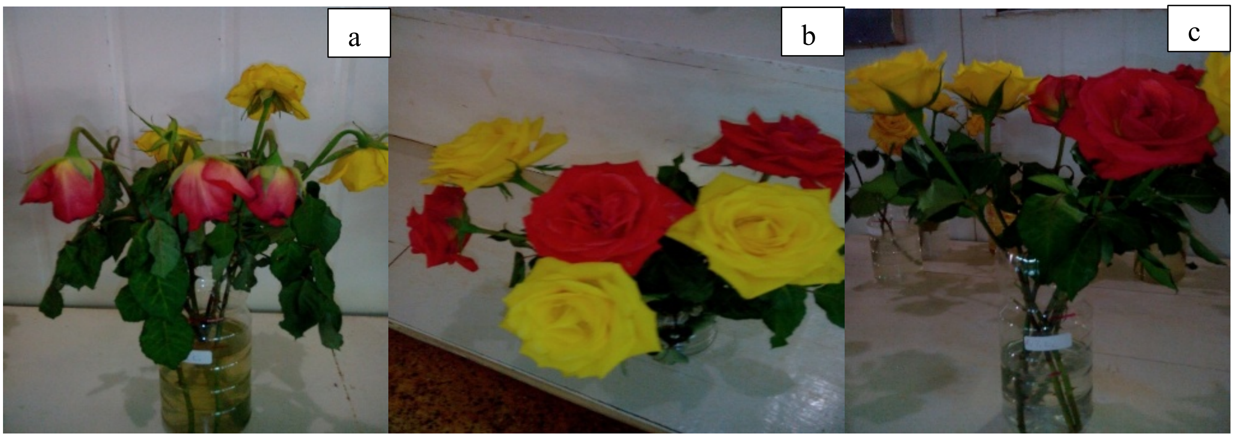

Plate 2. Effects of thyme, stevia and chrysal treatments on rose cut flower bent neck prevention on day 12. a) 0.2g/l thyme extracts b) 0.2g/l stevia extracts c) 0.2g/l stevia extracts

Conclusion

This study showed that natural plant extracts can be used to enhance rose flower vase life and floral quality. In particular, thyme extracts offer the best alternative to commercial chemical floral preservatives in extending the vase life and enhancing the quality of rose flower. The efficacy of the plant extracts however is not depended on the rose flower cultivar. The two cultivars (radiance and high and sparkling cultivars) used in our study had statistically the same response to the application of stevia, thyme extract treatments. This study also established that the efficacy of plant extracts is depended on the phytochemical composition, concentration level of the phytochemicals and the extract dosage applied. Application of low dosages (low concentration levels) of extract had best results in extending vase life and enhancing quality of rose cut flower as evidenced with the thyme extracts at $0.2gL^{-1}$ concentration level. Application of higher dosages could have undesirable effects on rose flower life and qualities as was observed with the application of $0.4gL^{-1}$ and $0.6gL^{-1}$ dosages which led to shorter vase life (6 days) and maximum bent neck records at day 8. Therefore this study unraveled the efficacy of extracts from stevia and thyme plants grown in Kenya on the rose flower vase life and quality and the results highlight the potential of the plants in offering environmentally sound alternatives to the use of chemical preservatives in cut flower preservation. Further studies should be undertaken to establish the economic viability in the use plant extracts as alternatives to chemical floral preservatives.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgement

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Effect of the Application of Poultry Manure and Wood Ash on Maize (*Zea mays* L.) Performance

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Keywords: Plant height, Poultry manure, Maize seeds, Wood ash.

Abstract. A field experiment was carried out to evaluate the effect of the application of poultry manure and wood ash on the growth and grain yield of maize (*Zea mays* L.). The poultry manure was applied two weeks prior to planting to allow for proper decomposition. Wood ash was applied a day before planting. There were three treatments in all including the control and the treatments were arranged in a randomized complete block design (RCBD) with three replicates. Plant height and leaf area were taken at three weeks after planting to nine weeks after planting with an interval of two weeks. The grain yield was taken at eleven weeks after planting and was dried, weighed and recorded. The results showed that poultry manure significantly increased plant height (192.0 cm) and grain yield (4.83 t/ha) but has no significant effect on the number of leaves and leaf area with 12cm and 3403.6cm^2 respectively. The values of plant height and leaf area of the control were relatively high compared with other treatments. This can be attributed to the availability of Nitrogen in the soil. The wood ash was found to give the lowest values for nitrogen as well as vegetative growth of maize, this could be attributed to the fact that nitrogen tends to volatilize when in contact with alkaline mediums and consequently affect vegetative growth of maize.

Introduction

Production of biomass by agriculture and forestry is one of the main functions the soil serves that has relevance to human life. This is possible by its ability to supply the nutrients needed to support plant growth and development [6]. Shifting cultivation (bush fallow or land rotation) practices had been adopted to ensure natural soil nutrient replenishment but pressure on arable land from the development of socio-economic infrastructure; urbanization and high population growth rate are responsible for shortening the fallow lengths, making the practice ineffective. Continuous cultivation, which the farmers are compelled to adopt has already been indicted for soil degradation characterized by rapid depletion of soil nutrients and organic matter with dire consequences on the food production [2, 12]. This nutrient depletion threatens the sustainability of crop production system such that considerations have always been given to the issue of nutrient replenishment as part of general improvement on soil fertility. The low fertilizer use rate and soils with inherent poor fertility put a ceiling on the yield of maize-a high nutrient demanding crop [3, 6]. This 'nutrient mining' that characterizes such crop production systems has stimulated interests in the potentials of organic materials, especially the huge quantities of agricultural and forest products processing wastes generated and which pose disposal challenges. The wastes (dung) from poultry production under intensive management systems and burning materials which generates smoke which fouls the air while harmful organic compounds from the decay processes are leached into ground water sources [6].

Poultry manure has been accepted as a source of nutrients for crop production and its application increases crop yield through a general improvement in growth parameters [5]. Wood ash lacks nitrogen (N), but contains oxides and hydroxides of basic cations such that its soil application in ancient agriculture raises soil pH, a process application which increases the availability of nutrient such as phosphorus (P) [13].

The different compositions of poultry manure and wood ash mean that their support of plant growth will vary. The objective of this investigation is therefore, to assess the response of maize (*Zea mays* L.) to application of poultry manure and wood ash as a sole application. This study sets out to determine the effect of poultry manure and wood ash on the growth and yield of maize (*Zea mays* L.)

Materials and Methods

The experiment was carried out at the Teaching and Research Farm of the Faculty of Agricultural Sciences, University of Ado Ekiti (Now Ekiti state University) located at $7^0\ 37^1$ N and longitude $5^0\ 15^1$E in south western, Nigeria. The area experiences a tropical climate with distinct wet and dry seasons. Mean annual total rainfall is about 1337 mm while temperature is almost uniform throughout the year with very little deviation from annual mean having an average minimum temperature of 21 ^{0}C and average maximum temperature of 27 ^{0}C. The annual total sunshine hour is about 2000 hours while mean annual radiation of about 130 Kcal cm^3 per year. The vegetation is forest mixed with various types of bush re-growths, grasses and creepers.

A land area measuring 40 × 25m was ploughed, harrowed and surface soil samples (0-15 cm) collected randomly and bulked together from which a composite sample was taken. The samples was air-dried and passed through 2 mm sieve and analyzed for major physical and chemical properties using methods outlined by International Institute of Tropical Agriculture IITA [9]. Soil pH was determined in 1:2 soil solutions using distilled water and read on a pH meter, particle size distribution by hydro meter method, organic method and exchangeable cations extracted with neutral normal ammonium acetate, exchangeable Potassium (K) and Sodium (Na) were read with flame photometer while Calcium (Ca) and Magnesium (Mg) were determined by Atomic Absorption Spectrophotometer.

Soil Amendments

Two materials were used as soil amendments: poultry manure and wood ash. Poultry manure was collected from the livestock unit of the Teaching and Research Farm, University of Ado Ekiti. Sawdust was collected from a sawmill at Ado Ekiti and was burnt to produce wood ash. The materials were evaluated singly as follows:

T_1 = Control
T_2 = Poultry manure
T_3 =Wood ash

The poultry manure was applied as a sole treatment. Wood ash was also applied as a sole treatment while T_1 (control) treatment do not have any poultry manure or wood ash treatment.

Planting Materials

Yellow maize variety TZSRE-Y was sourced from the seed processing unit of the Ekiti State Agricultural Development Programme. The seeds were treated with Apron Plus 50 DS before planting.

Establishment

The harrowed land was marked out into 3× 1.5m plots separated by 1m wide paths. Treatments were assigned to the plots in a randomized complete block design (RCBD) with three replications. Poultry manure was applied and mixed with the surface layer of each plot two weeks before planting. Wood ash was applied a day before planting to avoid it being washed away. The seeds were sown 2-3 seeds per hole at 75 × 25 cm spacing and seedlings thinned to one stand per whole 10 days after planting.

Data Collection

Three maize stands were tagged and used for collecting data to measure the growth trend in each treatment. The data collection started three weeks after planting and at an interval of two weeks of the following growth parameters: Plant height, leaf area, number of leaves.

Harvesting and Processing

Harvesting of the maize cob was carried out 11 weeks after planting. The harvested cobs were shelled and sundried for two weeks before final weighing.

Statistical Analysis

Statistical analyses of all data collected were carried out using Analysis of Variance (ANOVA) and the means were compared using the Least Significant Difference (LSD).

Results and Discussion

The physical and chemical properties of the soil in the experiment site are shown in Table 1. The soil was strongly acid organic content. Total N at 0.13 % was moderately low [1] but similar to the mean value soils in Southwestern Nigeria [7].

Exchangeable K was high being more than 0.16-0.20 Cmol-kg^{-1} critical levels established for maize in soils of Nigeria while available P was low [14]. Thus, the site can be regarded as moderately fertile.

The nutrient content of the poultry manure and wood ash used for the study are shown in Table 2. The fresh poultry manure obtained from the layers section contains 1.25 % N, 1.38 % P, 0.89 % K, 1.92 % Ca, 0.29 % Mg and 0.32 % S. The wood ash contains O % N and S. It is a product of burnt wood. During burning N and S are completely oxidized and lost through volatilization while more K and Ca in the woodash are released into the soil thereby increasing the availability for plants and to control soil acidity.

Table 1. Physical and chemical properties of the soil at the teaching and Research Farm, Ekiti State University, Ado Ekiti

Parameters	Values
pH (Water)	5.4
Sand, %	68.8
Clay, %	26.5
Silt, %	5.7
Textural class	sandy loam
Organic matter, %	2.48
Total N, %	0.13
Mg^{2+}, Cmol.Kg^{-1}	3.4
Ca^{2+}, Cmol.Kg^{-1}	6.50
Na, Cmol.Kg^{-1}	0.43
K^{+}, Cmol.Kg^{-1}	0.17
Available P	3.02

Table 2. Average nutrient values of the organic amendments and woodash(%)

Nutrient sources	N	P	K	Ca	Mg	S
Poultry manure	1.25	1.38	0.89	1.92	0.27	0.32
Wood ash	0.00	0.09	0.29	0.89	0.04	0.00

Table 3 shows that at 3 weeks after planting (WAP), the poultry manure treatment had the tallest plants while application of wood ash produced the shortest plants. There are no significant differences between the poultry manure treatment and control treatment. At 5 WAP, Poultry manure treatment and control treatment was not significant. At 7 and 9 WAP, the tallest plants were from the application of poultry manure. There were significant differences among the treatments. Though, at 9 WAP, the plant heights were almost the same because at this stage, the plants had produced ears. This trend in growth shows that poultry manure increased plant height up to 7 WAP which agrees with observations made by Boetang et al. [5] and O. Dayo-olagbende [6].

Table 3. Effects of soil amendments on heights (cm) of maize (*Zea mays* L.)

Amendments	3	5	7	9
Control	30.4ab	63.2ab	139.3b	191.8ab
Poultry manure	33.4a	66.8a	161.1a	192.0a
Wood ash	27.6b	54.5b	125.7c	186.6b

Means followed by the same letter are not significantly ($P < 0.05$) different according to LSD.

There were no significant differences between the treatments as regards number of leaves at 3 and 5 WAP. The poultry manure treatment gave the largest leaf area at 3WAP while the wood ash treatment had the least. At 5 WAP all the treatments have similar values while at 7 WAP only wood ash treatment had the lowest. This is due to the fact that N is lost as NH_3 gas when it comes in contact with high pH materials like wood ash [8].

Tables 4 and 5 show the effects of soil amendments on the number of leaves and leaf area per plant respectively.

The grain yield of maize as affected by soil amendments is presented in Table 6. The poultry manure amendment gave the highest maize yield while the control was the least. The poultry manure recorded the highest maize yield because it supplied nutrients which were probably not available in sufficient quantities in the soil and so confirms work done by Bhogal et al. [4], Saviozzi et al. [11]. Wood ash is known to be low in N and which accounts for its poor yield when compared with poultry manure [10].

Table 4. Effect of amendments on number of leafs

Amendments	3	5	7
Control	8.00a	12.00a	14.00a
Poultry manure	8.00a	12.00a	14.00a
Wood ash	8.00a	12.00a	14.00a

Means followed by the same letter are not significantly ($p < 0.05$) different according to LSD.

Table 5. Effect of amendments on leaf area (cm^2).$plant^{-1}$

Amendments	3	5	7
Control	436.9b	1127.8a	3422.8a
Poultry manure	553.2a	1165.9a	3403.6a
Wood ash	388.6a	118.9a	3055.4b

Means followed by the same letter are not significantly ($p < 0.05$) different according to LSD.

Table 6. Effects of soil amendments on maize grain yield. ($mt.ha^{-1}$).

Amendments	Grain yield
Control	2.27c
Poultry manure	4.83a
Wood ash	2.94b

Means followed by the same letter are not significantly ($p < 0.05$) different according to LSD.

Conclusion

The study was carried out to evaluate the effect of soil application of some environmentally hazardous materials namely poultry manure, wood ash on the growth and yield of maize (*Zea mays* L.). The amendments were applied and worked into the top soil prior to planting. Three maize seeds were planted which was later thinned to one stand after two weeks of planting. The treatments were replicated three times. Measurements of growth parameters are plant height, leaf area and number of leaves was recorded from 3-9 WAP while cobs were harvested, shelled and weighed.

The results showed that the application of poultry manure alone recorded the highest grain yield followed by wood ash application. In a situation where scarcity and high cost limits the availability of inorganic fertilizer, poultry manure will be a possible alternative. It can boost maize yield when cost of inorganic fertilizer is high. A soil rich in N and deficient in other nutrients can be amended by a mixture of poultry manure and wood ash. However, care should be taken to make sure that these organic amendments do not contain unknown or toxic additives that can depress the plant growth. This study did not evaluate the costs involved. Hence, further studies can be carried out to evaluate the cost implication.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Response of Rice (*Oryza sativa*) to the Application of Manganese in Makurdi, Benue State, Nigeria

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Abstract. A pot experiment was carried out at the Agronomy Teaching and Research Farm of the University of Agriculture Makurdi to determine the effect of manganese fertilizer on the growth and yield of rice. Treatment consists of five levels of Manganese (Mn) (0, 5, 10, 15 and 20 kg ha^{-1}) in form of $MnSO_4$. The treatments were laid out in a Completely Randomized Design (CRD) with three replications. The effect of Mn on the growth of rice indicate that there were no significant difference in the growth parameters measured with the exception of plant height at 8 weeks after planting and number of tillers at 4 weeks after planting. The tallest plants and highest number of tillers were obtained with 10 kg ha^{-1} Mn. The effect of Mn on the yield of rice indicate that there was a significant difference in the yield parameters measured with the exception of number of grain per panicle and root weight at 4 weeks after planting. Manganese at the rate of 10 kg ha^{-1} gave the highest grain yield (2,667 kg ha^{-1}) and highest dry matter weight. Levels of Mn above 10 kg ha^{-1} led to yield decrease, therefore application of 10 kg ha^{-1} Mn was recommended for optimum yield of rice.

Introduction

Micronutrients are chemical elements necessary for plant growth in only extremely small amount. Although required in minute quantities, they have the same agronomic importance as macronutrients and play vital roles in the growth of plants [1]. These metallic chemical elements include Zinc (Zn), Iron (Fe), Copper (cu) and manganese (Mn), amongst others. Micronutrients improve the yield and the crop quality for cereals, corn, beans, forages, and oil seed [2]. The deficiency of micronutrients reduces performance and profitability in the plant [3].

Manganese is one of the main micronutrients, which plays important role in plant as a component of enzymes involved in photosynthesis and other processes. Manganese is part of an important antioxidant (superoxide dismutase) structure that protects plant cells by deactivating free radicals which can destroy plant tissue. It plays vital roles in photosynthesis, as a structural component of the Photosystem II water splitting protein. It also serves as electron storage and delivery to the chlorophyll reaction centers [4, 5].

Rice *(Oryza sativa)* is a staple food in many countries of Africa and other parts of the world. This is the most important staple food for about half of the human race [6]. Saka and Lawal [7] classified rice as the most important food depended upon by over 50 percent of the World population for about 80 percent of their food need. Due to the growing importance of the crop, FAO [8] estimated that annual rice production should be increased from 586 million metric tons in 2001 to meet the projected global demand of about 756 million metric tons by 2030.

The drive towards self-sufficiency in food production through the adoption of more scientific intensive agricultural systems has necessitated the evaluation of the nutrient status of soils and their role in crop production; most especially the micronutrients which had hitherto been neglected [9].

However, few investigations carried out so far have revealed micronutrient deficiency in some Nigerian savanna soils [10-12]. These deficiencies may have resulted from intensively cultivated soil with high nutrient-demanding crops, highly weathered rocks and leaching. Mustapha and Loks [13] reported that the use of new high yielding crop varieties which are nutrient demanding have unraveled micronutrient deficiencies in some Nigeria Savanna soils. Also the non-inclusion of these important elements (Mn) in fertilization programs have led to its widespread deficiency hence, the need to assess the response of crops to the application of these nutrients, particularly Manganese which facilitates the production of carbohydrates and is required for optimum utilization of macro nutrients in plants.

The present research was undertaken to determine the growth and yield response of rice to the application of Manganese fertilizer.

Materials and Methods

The present investigation was in two parts; laboratory studies and pot experiment which were carried out in 2017. The laboratory studies include routine soil analysis and micronutrient determination and were carried out at the Advanced Analytical Soil Laboratory of the Department of Soil Science, University of Agriculture, Makurdi while the pot experiment was carried out at the Agronomy Teaching and Research Farm of the same institution which lies between Latitude $7^0\ 47^{'}$ N and Longitude $8^0\ 36^{'}$ E at an elevation of 82 m above sea level.

Soil Sampling and Analysis

Surface Soil samples were taken at a depth of 0–20 cm from Agronomy Teaching and Research Farm, Federal University of Agriculture Makurdi, taking into consideration all possible precautions prescribed for soil sampling [14]. The samples were brought to the laboratory, air dried and mixed together thoroughly and crushed to pass a 2 mm sieve.

Sample Analysis

The soil samples were analysed for the following parameters using standard procedures; pH was measured by glass electrode in a 1: 2 soil, water ratio. Exchange acidity was determined by the titration method [15]. Exchangeable bases were extracted with neutral ammonium acetate solution buffered at pH 7. Na and K in the extract were determined using flame photometer while Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) [15]. Organic matter was determined by wet acid digestion [16], Total Nitrogen by the Kjeldahl digestion method, phosphorus by Bray-1 procedure [17] particle size analysis by the hydrometer method of Bouyoucos [18]. The CEC was determined by neutral, 1N Ammonium acetate method while Base Saturation was calculated by dividing the sum of exchangeable bases by CEC and multiplying by 100. Mn was extracted using 0.1 N HCl and read with atomic absorption spectrophotometer. The DTPA extractant was used to extract available micronutrients and the values read on an Atomic Absorption Spectrophotometer [19].

Pot Experiment

A pot experiment was conducted at the Teaching and Research Farm of the University of Agriculture Makurdi, North Core using soil collected from the farm. Four (4) kg of the soil was weighed into perforated plastic pots of 5 litres capacity.

Treatment consists of five levels of Mn (0, 5, 10, 15 and 20 kg ha^{-1}) in the form of $MnSO_4$ which contains 27 % Mn. The treatments were laid out in a Completely Randomized Design (CRD) with three replications. Ten (10) seeds of rice (L 34 variety) obtained from Olam rice farm, Rukubi Nasarawa state, Nigeria were planted per pot and later thinned to 5 plants per pot two weeks after planting. Fertilizer equivalent to 80 kg N, 30 kg P_2O_5 and K_2O were applied to all the pots as basal application [20] and the Mn rates distributed accordingly to the pots at planting with the control treatment pots having no Mn application.

Data Collection

Data was collected on the following parameters:

i. Number of tillers at 4 and 6 weeks after planting
ii. Plant height at 4, 6, 8 and 10 weeks after planting
iii. Root weight at 4, 6 and 8 weeks after planting

iv. Leaf area at 4, 6, 8 and 10 weeks after planting
v. Number of grains per panicle at harvest
vi. Grain yield at harvest

Data Analysis

All the plant data collected were subjected to statistical analysis of variance (ANOVA) for the determination of significant treatment effects. Those that have significant effects were separated using Fisher's Least Significant Difference (FLSD).

Results and Discussion

Physical and Chemical Properties of the Experimental Soil

The physical and chemical properties of the experimental soils are presented in Table 1. The pH was slightly acidic (6.29), Textural class was clay loam with 56 g kg^{-1}sand, 36 g kg^{-1} silt and 74 g kg^{-1}clay. The soil was generally low in Phosphorus (3.54 mg kg^{-1}), Calcium (3.33 cmol kg^{-1}), Magnesium (1.36 cmol kg^{-1}), Potassium (0.12 cmol kg^{-1}) and Sodium (0.36 cmol kg^{-1}). The Nitrogen content was also very low (0.02 %). Organic matter was 3.08 %, the CEC was low with base saturation of 84 %. The micronutrient status of the soil include; Copper which was medium (0.72 mg kg^{-1}), iron was medium (3.5 mg kg^{-1}), Manganese was low (0.70 mg kg^{-1}) and the Zinc content was low (0.02 mg kg^{-1}).

The soil used for this research had low fertility status and was slightly acidic in nature. This could be due to the removal of basic cations from the surface of the soils to the lower depths [13, 22-23]. Results show that organic carbon content was high [23] this is contrary to the low organic carbon values reported by Yaro *et al.* [24] for the Nigerian Savanna soils, and those reported by Mustapha and Nnalee [25] and Mustapha *et al.* [26] for soils in the Northern Guinea Savanna Zone of Nigeria.

Table 1. Physical and Chemical Properties of the Soil Under Study

Parameters	Values
pH(1:1)	6.29
Sand (g kg^{-1})	56
Silt (g kg^{-1})	36
Clay (g kg^{-1})	74
Textural class	Clay Loam
Organic C (%)	1.79
Organic matter (%)	3.08
N (%)	0.02
Available P (mg kg^{-1})	3.54
Ca (cmol kg^{-1})	3.33
Mg (cmol kg^{-1})	1.36
K (cmol kg^{-1})	0.12
Na (cmol kg^{-1})	0.36
CEC (cmol kg^{-1})	5.17
B.S (%)	84
Exch A	0.83
Cu(mg kg^{-1})	0.72
Fe(mg kg^{-1})	3.50
Mn(mg kg^{-1})	0.70
Zn(mg kg^{-1})	0.22

The high organic carbon content could be due to the fact that plant residues where usually left on the soil after harvest year after year without burning. The decomposition of these residues may have contributed to the high organic carbon content.

The Zn level in the soils was low (0.02 mg kg^{-1}) [23]. The values recorded for the soil falls below the 1.2–4.0 mg kg^{-1} reported by Kparmwang and Malgwi [27] for the soils in the Northern Guinea Savanna of Nigeria, 0.81 to 1.34 mg kg^{-1} reported for Ustults in Galambi District in Bauchi State, Nigeria [28] and 1.1 to 6.9 mg kg^{-1} reported for volcanic ash soils elsewhere in Tanzania [29]. It is pertinent to note that the Zn values obtained in this study fall below the critical 0.90 mg kg^{-1}given by Lombin [11]. The low Zn content may be due to the non-inclusion of micronutrients in fertilizer programs which may lead to its deficiency as reported by Nziguheba *et al.* [30].

The low value of Cu (0.72 mg kg^{-1}) obtained in this research is lower than the results obtained by Mustapha and Singh [28] for soils elsewhere in Galambi, Bauchi State, Nigeria in similar Agro-Ecology but are similar to the 0.81 to 0.26 mg kg^{-1} obtained by Mustapha *et al.* [31] in Gombe State. The low Cu content may be due to increased use of high analysis NPK fertilizers containing no or lower quantities of micronutrient.

The Fe in the soils was low (3.5 mg kg^{-1}). These values are much higher than the critical value (2.5 mg kg^{-1}) reported by Esu [23], but lower to the 12.40 - 45.1 mg kg^{-1} reported by Mustapha and Singh [28] for Ustults in similar agro ecology in Nigeria.

The available Mn in the soil is low (0.7 mg kg^{-1}). This implies that the soils contain Mn below the critical available range of 3 to 5 mg kg^{-1} reported by Lindsay and Norvell [19] and 1–5 $mgkg^{-1}$ reported by Esu [23]. The values obtained for these soils is below those obtained for some Ustults in Bauchi, Nigeria (7.89–12.00 $mgkg^{-1}$) reported by Kparmwang [32] in similar Nigerian soils.. The low content of available Mn in the soils may have resulted from intensive cultivation of the soil with new high nutrient-demanding crops as reported by Mustapha and Loks [13]. These crops remove micronutrients (Mn) from the soil without been replaced which may lead to its depletion.

Effect of Manganese on the Growth of Rice

The effect of Mn on the growth of rice (Table 2) indicate that there were no significant difference in the growth parameters measured with the exception of plant height at 8 weeks after planting and number of tillers at 4 weeks after planting.

At 8 weeks after planting, the tallest plants (5.63 cm) were obtained with 10 kg ha^{-1} Mn however this was not significantly different from plants obtained with 5 kg ha^1 but was significantly taller than plants obtained with 0, 15 and 20 kg ha^{-1} Mn, which were not significantly different from themselves.

The highest number of tillers (3.67) was obtained with 10 kg ha^{-1} Mn at 4 weeks after planting which was significantly higher from the other treatments but there was no significant difference in number of tillers obtained with 0, 5, 15 and 20 kg ha^{-1} Mn.

No significant variation in growth parameters were noticed by the application of manganese (Mn) with the exception of plant height at 8 weeks after planting and number of tillers at 4 weeks after planting. This may be due to application manganese in the soil as reported by Qin [33] that rice responds to high Mn (about 0.5 mg/L) application with higher plant height, root length, and contents of chlorophyll a and chlorophyll b than at low Mn level. This is in contrast to reports by Prashad *et al.* [34] and Shanmugam and Veeraputran [35] that further increase in Mn rate was found to reduce the growth attributes with the minimum being observed in control.

The application of manganese significantly increased number of tillers only at 4 weeks after planting than without manganese this may be due to addition of Mn, this is similar to result obtained by Mousavi [36] who reported that rice fertilized with manganese at 4 weeks after planting had more productive tiller than without manganese this may be presumably caused by manganese which increased the content of chlorophyll in leaves of rice. Manganese played an important role in the production of chlorophyll and its presence was very important in photosynthesis [36]

Effect of Mn Fertilization on the Yield of Rice

The effect of Mn on the yield of rice (Table 3) indicated that there were no significant difference in the yield parameters measured with the exception of dry matter weight (DMW), grain yield and root weight (RW) at 8 weeks after planting.

The highest Dry matter weight (1.67 g) was obtained with 10 kg ha^{-1} Mn but there was no significant difference between 10 and 15 kg ha^{-1} Mn. However 10 kg ha^{-1} Mn was significantly different from what was obtained from the other treatments but no significant difference in the dry matter weight obtained with 0, 5 and 20 kg ha^{-1} Mn.

The highest grain yield (2,667 kg) per hectare was obtained with 10 kg ha^{-1} Mn. However, this was significantly different from what was obtained with the other treatments. There was no significant difference in the grain yield obtained with 0, 5, 15 and 20 kg ha^{-1} Mn.

Table 2. Effect of Mn Fertilizer on the Growth of Rice

Treatment	Plant height (cm)				Number Tillers		Leaf Area (cm^2)			
Mn	4WAP	6WAP	8WAP	10WAP	4WAP	6WAP	4WAP	6WAP	8WAP	10WAP
0 kg ha^{-1}	34.70	42.90	44.80	51.50	3.00	3.67	8.17	11.07	13.07	16.50
5 kg ha^{-1}	34.50	46.70	48.00	48.20	3.00	3.00	7.43	10.30	12.30	14.20
10 kg ha^{-1}	39.20	51.10	53.60	55.30	3.67	3.67	6.73	8.83	12.33	13.23
15 kg ha^{-1}	32.30	42.20	44.20	46.60	3.00	3.33	9.53	13.23	15.07	16.00
20 kg ha^{-1}	33.70	42.50	43.50	43.90	3.00	3.67	7.20	11.03	11.37	12.30
LSD(P<0.05)	NS	NS	7.75	NS	0.47	NS	NS	NS	NS	NS

WAP = Weeks after planting, NS = Not significant

Table 3. Effect of Mn fertilizer on Yield of Rice

Mn	DMW (g)	NGPP	RW4WAP (g)	RW8WAP(g)	Grain yield (kg ha^{-1})
0 kg ha^{-1}	0.87	46.7	0.02	0.09	1000
5 kg ha^{-1}	0.67	56.7	0.02	0.12	1333
10 kg ha^{-1}	1.67	112.3	0.04	0.08	2667
15 kg ha^{-1}	1.33	95.7	0.05	0.16	1800
20 kg ha^{-1}	1.00	70.0	0.05	0.16	1667
LSD(P<0.05)	0.63	NS	NS	0.04	999.8

DMW = Dry Matter Weight, NGPP = Number of Grain per Panicle, RW= Root Weight

At 8 weeks after planting 15 and 20 kg ha^{-1} Mn gave the highest root weight with no significant difference between them while 0 and 10 kg ha^{-1} Mn have the least root weight which are not significantly different from each other. There was no significant difference in the root weight obtained with 0 and 5 kg ha^{-1} Mn at 8 weeks after planting.

There was a significant response in yield parameters of rice by the application of manganese (Mn) with the exception number of grain per panicle and root weight at 4 weeks of planting. This may be as a result of application of manganese soil content as reported by Dube *et al.* [37] from a field trial on rice that the plant biomass, panicle weight, grain weight, 1000-grain weight, chlorophyll a and b content and Hill reaction activity increased with increasing concentrations of Mn up to 0.55 mg L^{-1} followed by a decrease with further increase in Mn.

The favorable effect on dry matter production might be due to higher leaf area per hill and leaf area index associated with high photosynthetic efficiency of rice plant leading to enhanced photosynthates accumulation and their translocation [38].

Conclusion

From the findings of this study, the experimental soil was low in most plant nutrients including micronutrients. The response of rice to manganese application is generally low in the growth parameters with the exception of plant height and number of tillers. However, significant differences were observed in the yield response of the crop to levels of Mn fertilization most especially in terms of root weight, grain yield and dry matter weight. For optimum yield of rice, 10 kg ha^{-1} Mn should be included in rice production fertilization programmes.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Impact of Flood 2010 on the Fertility Status of Soil of Tehsil Garhi Khairo, District Jacobabad, Pakistan

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Abstract. A field study was carried out to assess some measurable changes in chemical properties of the soil of tehsil Garhi Khairo, district Jacobabad that was affected by 'Supra flood 2010'. Forty-five composite soil samples were collected at sampling depths, 0-15 cm, 15-30 cm, and 30-45 cm from 15 different regions of tehsil Garhi Khairo before and after flood. Samples were analyzed for the determination of various chemical parameters such as pH, electrical conductivity, soluble sodium (Na^+), potassium (K^+), calcium (Ca^{+2}), and magnesium (Mg^{+2}). Results of the analysis were compared with the reference data that were analyzed before the flood. Results of the analysis revealed that due to flood, chemical nature of soil was changed from slightly alkaline to strongly alkaline. Before and after flood soil remains non-saline. There has been a significant increase in the optimum concentration of soluble sodium (Na^+), calcium (Ca^{+2}) and magnesium (Mg^{+2}). However; potassium (K^+) content of the soil was uniformly decreased.

Introduction

Flood is considered as a potential risk to lives, land, assets and ecosystem [3]. Pakistan has faced floods in 1950, 1956, 1957, 1973, 1976, 1978, 1992, and 2010. The flood 2010 was an extraordinary and unprecedented event in the known history of River Indus [14]. Since, Sindh province lies at the base of River Indus and is being almost flat consequentially the extra water in the form of rain or flood is crossing from it which is more often than the normal drain capacity. Left bank outfall drain (LBOD) has a release capacity of 4000 cusecs while the drain water discharges with the rate of 18000 cusecs, such addition water constrained the channels to overtop and break. It has been expected that flood 2010 had demonstrated to be more destroying particularly for the areas of upper Sindh, especially Jacobabad [12], [9].

In August 2010, two deadly and overwhelming rounds of monsoon rains had severely smashed the district by drowning them via affecting 197,320 peoples, causing around hundreds of human deaths and thousands of animal causalities. Peoples of this territory mainly depend on agriculture, livestock and fisheries. All of these divisions were massively crushed due to heavy rains that gave a financial loss of 160, 107 PKR millions and 4.5 million acres standing crops were destroyed. Losses caused by flood not constrained to only economic concern but these were expected to be long enduring in term of the destruction of natural resources including effecting the soil quality of the district [29], [10].

Usually, the agro-based economy relies more prominently on the fertility status of the soils of any area. The balance of nutrients in the soil is the key approach to enhance the yield of the crop. Overabundance and imbalanced status of nutrients due to flooding lead to cause nutrient mining from the soil, deteriorated the productivity of crops and eventually impact on the health of the soil [18], [21], [11].

This study was planned to evaluate the effect of flooding on the fertility status of soil. The information about status of nutrients in soil shall help in the selection of proper fertilizer to supply. Analysis of the chemical properties of soil is reported in a number of articles however no study has been published on the effect of flood water on the chemical properties of the soil of district Jacobabad, Pakistan.

Description of study area

Garhi Khairo is one of the Tehsil of Jacobabad district which is located on the border of Sindh and Balochistan province at latitude 28^{0}16’37.32’’N and longitude 68^{0}27’05.04’’E. Garhi khairo Tehsil is unique as the hottest spot in South Asia where the mercury in thermometer rises above 50^{0}C. Like other regions of province, this area is also deficient in rainfall. Due to shortage of water, artificial irrigation is the major resource to irrigate crops. Crops for instance rice, pulses, and vegetables like onion, tomato, and fruit trees like jujube are mainly growing throughout the Tehsil.

Materials and Methods

Sampling of soil

Soil samples collection was carried out in the rice farmland area of Goth Alahndo Jamali, tehsil Garhi Khairo, district Jacobabad, Sindh, Pakistan. Forty five samples before and after flood were collected at 0-15cm, 15-30cm, and 30-45cm from 15 different regions of tehsil Garhi Khairo, as to systematically investigate the effects of flood deeply in soil profile. Plants debris and stones were removed before taking samples. Samples were placed in clean polyethylene bags, which were labelled clearly. Analysis of soil samples before flood was carried out by Allah Wadhayo Gandahi and Javed Ali Babar in Department of Soil Sciences, Sindh Agriculture University Tandojam, while samples after flood was analysed by Adnan Murad Bhayo and Muhammad Latif in Department of Chemistry, Federal Urdu University of Arts, Science and Technology, Pakistan.

Methods used for laboratory analysis

Samples were air dried in the open air under shades, crushed, ground and passed through 1/8th inches mesh screen sieve. Samples were investigated for important chemical properties of soil including, pH and electrical conductivity (EC) using 1:5 soil water extract [20]. Calcium (Ca^{+2}) and magnesium (Mg^{+2}) were analyzed as proposed by [5]. Nutrient status categorization for sodium (Na^{+}) and potassium (K^{+}) were determined as reported by [19].

pH:

The availability of nutrients in soil is mainly dictated by Soil pH.. The pre-flood obtained data is suggested that the pH of the soil of the area is generally slightly alkaline (< 8.0) in reaction while, it tuned to strongly highly alkaline nature (>8.0) in almost all soil samples due to flood (Figure 1). Upon critical evaluation of data, it has been observed that the pH at all sites before the flood was in a range of 7.2-7.9 while after flood, pH was observed in the range of 8.1-9.2. The flooding and runoff from the upland may deposite layers of salts, hence an enhancement in pH is presumed from the outcomes [17]. These findings are in line with the research group of who revealed that the pH of the soil of rice cultivated area (after the flood) was alkaline in nature. It has been proved that the availability of toxic substances decreases with increasing pH of soil.

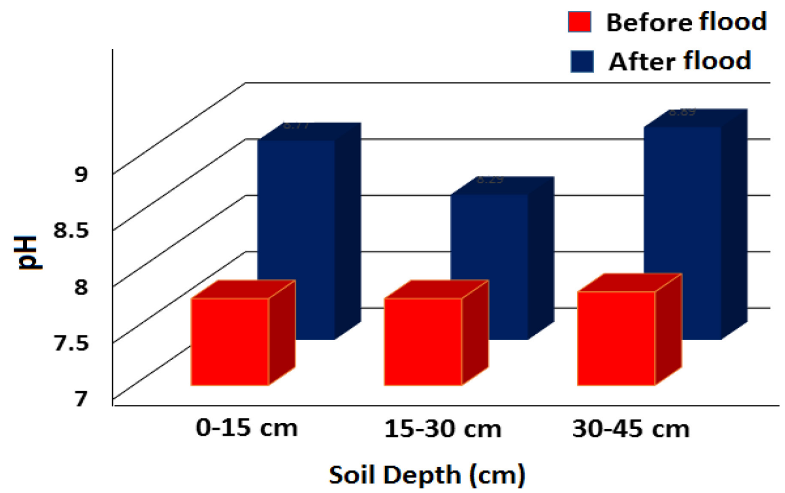

Figure 1. pH at three different depths of soil before and after the flood.

Electrical conductivity (EC)

Electrical conductivity (EC) is a measure of the extent of the current carrying ability of the analyte that gives a clear indication for the presence of soluble salts in the soil. EC values may influence by varying soil chemical properties such as, soil depth, salinity, porosity, and integrity of the presence of charge containing specie and their exchange capability [6], [23]. EC values of the sampled spots on three different soil layers are depicted in Figure 2. Average value of EC before flood at depth 0-15 cm, 15-30cm, 30-45 cm are 1390,990 and 580 µs/cm, respectively. While after flood average value of EC at depth 0-15 cm, 15-30cm, and 30-45 cm are 1470, 1120 and 860 µs/cm, respectively. This is due to the exogenous input of salts, ions and total dissolved solids carried by the flood from the ocean into the soil. EC values are in range of limit that are indicative of soils which have low salinity hazards to plants. These findings are in line with previous studies [16], [4].

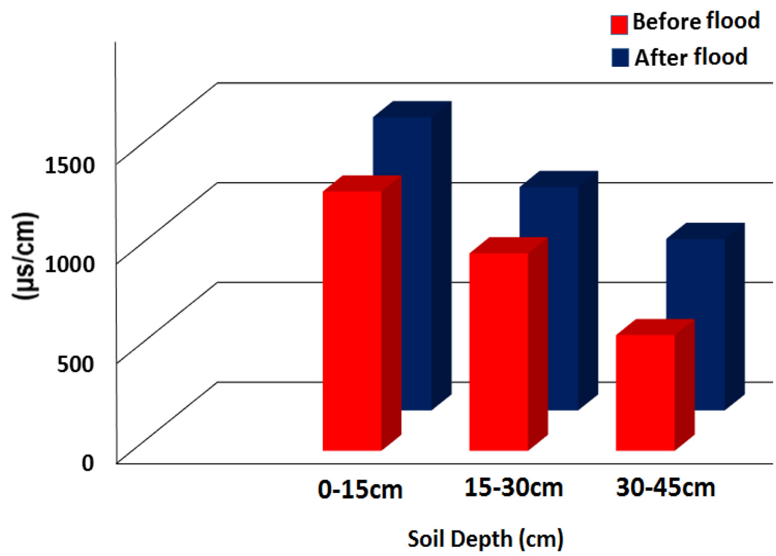

Figure 2. EC at three different depths of soil before and after the flood.

Sodium (Na^+)

Sodium helps plants in synthesis of chlorophyll and metabolic process. The Optimum value of sodium in agricultural soil for fertile soil should be in between 120-180 ppm [24], [15]. The content of sodium in reference spots was in a range of 52-208 ppm while, it ranged from 90-153 ppm after flood (Figure 3). The enhancement of sodium at depth 30-45 cm due to leaching and dilution because flooding increases the solubility of mineral nutrients. Increment in basic salt deposition in soil is also proved through pH and Electrical conductivity value. In practical terms, extreme alkaline pH due to soluble sodium (Na^+) in soil lead to nutrient imbalances in the roots of plants [8], [28]. More ever, before flood the maximum value of soluble sodium (116 ppm) was observed at depth 0-15 cm and minimum value of soluble sodium (22 ppm) was observed at depth 30-45cm. While after flood both maximum (325 ppm) and minimum value (10 ppm) of soluble sodium was noted at depth 0-15 cm. Such results were also observed in previous research [25].

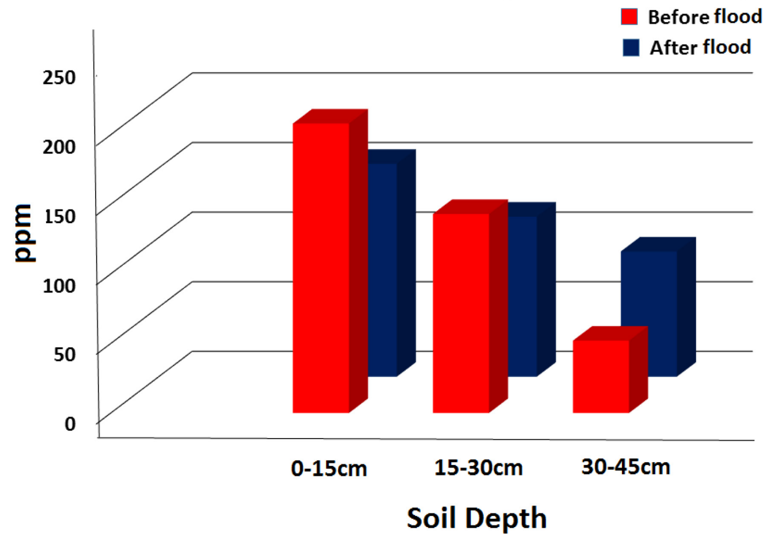

Figure 3. Na^+ at three different depths of soil before and after the flood

Potassium (K^+)

Potassium is crucial in almost all biological processes necessary to withstand plant life and catalyze important metabolic reactions, such as photosynthesis, regulation of nutrients and water intake [27]. On the basis of concentration of potassium, soil categorized as very low (<5 ppm), low (5-8 ppm), optimum (8-17 ppm) and high (17-30 ppm). Soil test potassium at different soil depths are given in Figure 4. The results of the study revealed that the potassium content of the sampled sites was generally high (>30 ppm) in all samples with no systematic trend. Before flood 84.21% soil samples at depth 0-15cm, 73.68% samples at depth 30-45 cm and 58.42 % soil samples at 30-45 cm soil depth were high in soluble potassium. After flood 33% soil sample at 0-15 cm, 13.33% at depth 15-30cm and and 0.00% soil samples at 30-45 cm soil depth were in the category of high in soluble potassium. On overall basis the potassium content was in a range of 16 to 25 ppm. Decrease in potassium content of soil after flood is also proved from previous study [22].

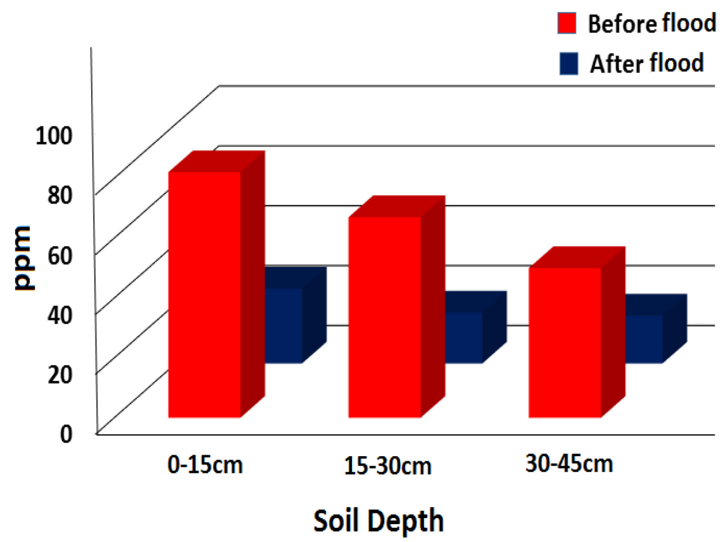

Figure 4. K^+ at three different depths of soil before and after the flood

Magnesium (Mg^{+2})

Magnesium is known for its important role in photosynthesis, as it is considered as a building block of the chlorophyll that enables leaves to appear green [13]. On the basis of concentration of magnesium, soil categorized as low (12.2 ppm), optimum (12.2-122 ppm) and high (>122 ppm). Before flood 5.26, 89.47, 5.26% at depth 0-15cm, 36.84, 63.15, 00% at depth 15-30cm and 68.42, 31.57, 00% samples at depth 30-45cm were low, optimum and high in magnesium concentration, respectively. After flood 6.66, 13.33, 80% at depth 0-15cm, 00, 26.66, 73.33% at depth 15-30cm and 00, 53.33, 46.66% samples at depth 30-45cm were low, optimum and high in magnesium concentration, respectively Figure 5. Increase in magnesium concentration sharply observed in all of three depths. These observations are in line with previous research [1].

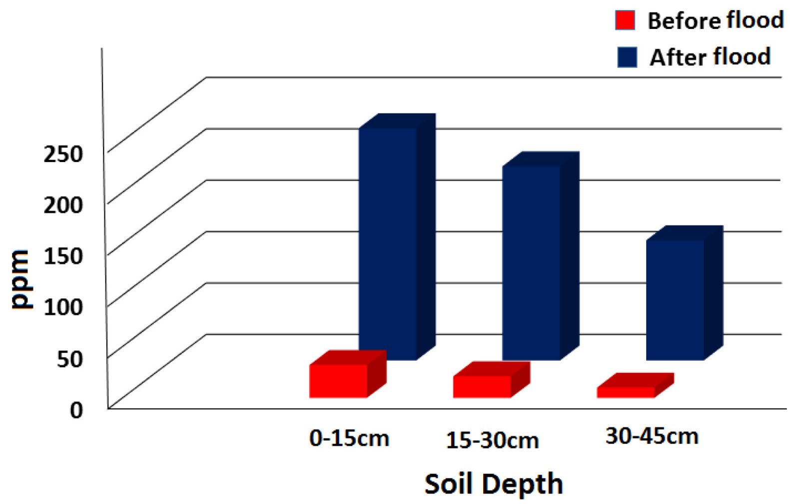

Figure 5. Mg^{+} at three different depths of soil before and after the flood

Calcium (Ca^{+2})

Calcium helps to maintain chemical balance in the soil, reduces soil salinity, and improves water penetration [7]. On the basis of concentration of calcium in soil, soil categorized as low (> 80ppm) optimum (80-400 ppm) and high (<400ppm) in calcium concentration. Before flood 72% and 28% soils at 0-15cm, 88 and 12% soil samples at 15-30cm and 100 and zero % soil samples at 30-45 cm soil depth were low and optimum in soluble calcium, respectively. While after flood, all samples that were analyzed were in optimum soluble calcium level, respectively (Figure 6). It was indicated that the soil of Tehsil changed from low to optimum calcium content category. Such outcomes were also observed in other research [18].

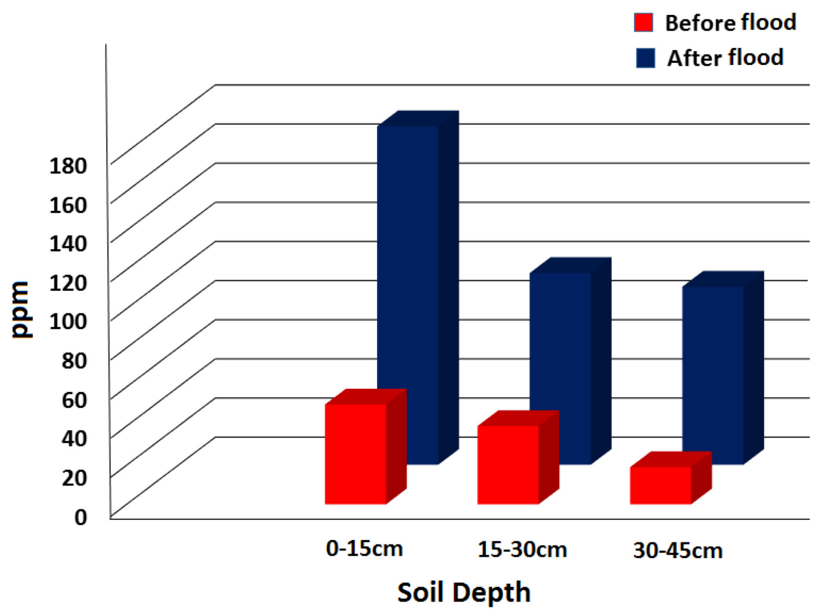

Figure 6. Ca^{+2} at three different depths of soil before and after the flood

Table 1. Comparison of data before and after flood

Parameters	Depth (cm)	Before Flood	Category (overall)	After Flood	Category (overall)
pH	0-15	7.77	SLIGHTLY ALKALINE	8.77	STRONGLY ALKALINE
	15-30	7.77		8.29	
	30-45	7.83		8.89	
Electrical conductivity (µs/cm)	0-15	1300	NON SALINE	1470	NON SALINE
	15-30	990		1120	
	30-45	580		860	
Sodium (ppm)	0-15	208	OPTIMUM	153	OPTIMUM
	15-30	143		115	
	30-45	52		90	
Potassium (ppm)	0-15	82	VERY HIGH	25	OPTIMUM
	15-30	67		17	
	30-45	50		16	
Calcium (ppm)	0-15	51	LOW	173	OPTIMUM
	15-30	40		98	
	30-45	19		91	
Magnesium (ppm)	0-15	32	OPTIMUM	226	HIGH
	15-30	21		189	
	30-45	10		117	

Conclusion

From the whole study, it can be concluded that flood has both beneficial and harmful effects on soil and ground water. Beneficial effect in the sense that, after flood calcium and potassium concentration changed from low to optimum level. Disadvantage in the sense that magnesium concentration increased much more after flood and reaches at hazardous level. The information of soils related to the status of nutrients shall help in selection of proper nutrients to supply.

Conflict of Interest

The authors declare that there is no conflict of interest.

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The Effects of EM (Effective Microorganisms) and Biochar on the Rate of Decomposition and the Nutrient Content of the Compost Manure Produced from the Locally Available Materials during Composting in Kakamega Central Sub County Kenya

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Abstract. Kakamega County is one of the most densely populated regions in Kenya and most people are dependent on agriculture for their livelihood. High population has led to continuous cultivation hence depletion of nutrients through the removal of crop residues, leaching and soil erosion. Inorganic fertilizers can restore soil fertility but are unaffordable for the majority of smallholder farmers living with 1240 KES (10.32 EUR) per month. However, despite government and NGOs interventions towards promoting the use of organic fertilizers in Kakamega County, the adoption rates are still low due to the long waiting period before the compost manure is ready. This study aimed at solving the problem of the period taken by the locally available organic matter to decompose and consequently the quality of the compost manure produced from various treatments. The objective of the study was to examine the effects of EM and Biochar on the rate of decomposition of locally available organic materials under Berkeley composting technique; and to evaluate the nutrient content of compost manure produced from the different treatments. Experimental design was used to examine the effects of EM and Biochar on the rate of decomposition under Berkeley composting technique and to evaluate the nutrient content of compost manure produced from different treatments. Four treatments; (i) Normal Berkeley (Control) (ii) EM+Berkeley (iii) Biochar+Berkeley, and (iv) EM+Biochar+Berkeley were evaluated in a completely randomized block design replicated three times. Nutrient content analysis used; Wet chemistry, LDPSA, PXRF and Mid-infrared (MIR) spectroscopy. Berkeley Hot/Rapid composting was the most adopted composting technique (28.65%), significance (χ^2 = 66.500). Combining Biochar and EM (T4) significantly ($P<0.05$) accelerated the rate of decomposition of organic matter by attaining the highest temperature of 60°C on the 4th day, followed by compost heap with biochar alone (T3) and compost heaps with EM (T2) which attained the highest temperature of 58°C respectively on the 6th day compared to compost piles without biochar or EM at a temperature of 55°C on 8th day. The results suggest that Biochar and EM accelerate the composting process. pH, total N, K and CEC were not significantly affected by the composting treatments, while Total Carbon was significantly ($p<0.05$) highest in the Biochar+Berkeley treatment, followed by EM+Berkeley treatment and lowest in EM+Biochar+Berkeley treatment. Phosphorus and Total carbon were also higher in EM compost (1.8% and 5.4%) ($p<0.05$) compared to non-EM compost (1.2% and 5.0%).

1. Introduction

The world population is growing and the United Nations expect there will be 8.9 billion people by 2050. Most of these people will live in developing countries, where nowadays already 20% of the population is underfed or malnourished [1-2]. The demand for food will increase as well as the need to produce more food on declining arable land [1-2].

Agriculture remains the most important economic activity in Kenya, although less than 8% of the land is used for crop and feed production. Farming in Kenya is typically carried out by small producers who usually cultivate no more than two hectares (about five acres) using limited technology [3]. Kakamega County is one of the most densely populated counties of Kenya, with most people living in rural communities. The main economic activity is farming and people are directly dependent on locally grown crops or food harvested from the environment [4]. Traditionally, farmers relied on long fallow periods to restore soil fertility. However, the increased population has shortened the fallow periods and decreased the available arable land. Shifting cultivation disappeared and now crops are grown continuously on poor fields. Furthermore, farmers remove all crop residues from the field, using them as feed for their livestock or as fuel. They also use small amounts of inorganic fertilizers because they are unaffordable, resulting in a negative nutrient balance of the soil [5]. High rates of erosion, leaching and the inherent poor fertility of most tropical soils have also contributed to the soil fertility decline in Western Kenya [6].

Soil health ecosystem services on degraded lands can be supported by nutrient management strategies that recouple nitrogen, phosphorus and carbon cycling within the agro-ecosystem. The use of compost or organic manure is currently being advocated as an option for improving soil fertility conditions for resource poor farmers.

Key Agricultural stakeholders in Kakamega county are encouraging and educating farmers to use various techniques in composting among which include Berkeley rapid and use of Inoculation technologies like EM [1]. Despite government and NGOs interventions towards promoting the use of organic fertilizers, there is a challenge of low adoption due to the long waiting period before the compost manure is ready for use [7]. This strategy aims to promote use of organic matter as the key source of fertilizers, which results into increased land fertility (8). This study examined the effects of EM and Biochar on the rate of decomposition of locally available materials under Berkeley composting technique decompose and consequently the quality of the compost manure produced from various treatments.

2. Literature Review

2.1 Berkeley rapid composting method - shredding and frequent turning

This method corrects some of the problems associated with the earlier methods of composting [9]. The process can produce compost in two to three weeks. Several factors are essential to the rapid composting method: Material composts best when it is 1.25-3.75 cm in size. Soft, succulent tissues do not need chopping into very small pieces because they decompose rapidly. The harder or woodier the tissues, the smaller they need to be in order to decompose rapidly. Woody material should be passed through a grinder. Chopping material with a sharp shovel is effective for the composting process to work most effectively (10). The material to be composted should have a C:N ratio of 30:1. Mixing equal volumes of green plant material with equal volumes of naturally dry plant material yields such a ratio. The green material can be grass clippings, old flowers, green prunings, weeds, fresh garbage and fruit and vegetable wastes. The dried material can be fallen leaves, dried grass, straw and woody materials from prunings. Materials that should not be added to a composting pile include: soil, ashes from a stove or fireplace, and manure from carnivorous animals. Manures from herbivorous animals such as rabbits, goats, cattle, horses, elephants and fowl can be used [11].

Once a pile has been started, nothing should be added. This is because it takes a certain length of time for the material to break down and anything added has to start at the beginning, thus lengthening the decomposition time for the whole pile. Excess material should be as dry as possible during storage until a new pile is started. Moist stored materials start to decompose. If this occurs, they will not be effective in the compost pile. Nothing needs to be added to the organic materials to make them decompose. The micro-organisms active in the decomposition process are ubiquitous where plant materials are found and develop rapidly in any compost pile [11].

Composting works best where the moisture content of materials in the pile is about 50 percent. Too much moisture creates a soggy mass, and decomposition will then be slow and the pile will smell. Where the organic material is too dry, decomposition is either very slow or does not occur at all. Heat, which is very important in rapid composting, is supplied by the respiration of the micro-organisms as they break down the organic materials. To prevent heat loss and to build up the amount of heat necessary, a minimum volume of material is essential [10].

2.2 EM-based compost enhancers

Effective micro-organisms (EM) consist of common and food-grade aerobic and anaerobic micro-organisms: photosynthetic bacteria, lactobacillus, Streptomyces, actinomycetes, yeast, etc. The strains of the micro-organisms are commonly available from microbe banks or from the environment. There are no genetically engineered strains that are in use. Since 1999, seven small-scale organic fertilizer units have been using the EM-based quick production process in Myanmar [10].

EM solution is prepared by mixing 10 ml of EM, 40 ml of molasses and 950 ml of water and leaving it for five to seven days, depending on temperature. The solution is then added to 1 litre of molasses and 98 litres of water to obtain 100 litres of ready-to-use EM solution. This amount is enough for three pits. The EM solution functioning as accelerator reduces the composting period from three months to one month. Critique of EM is that not so many smallholder farmers have the knowledge of preparing it.

2.3 Biochar Compost enhancers

Biochar is defined as charcoal that is used for agricultural purposes. It is created using a pyrolysis process, heating biomass in a low oxygen environment. Once the pyrolysis reaction has begun, it is self-sustaining, requiring no outside energy input. Byproducts of the process include syngas (H_2 + CO), minor quantities of methane (CH_4), tars, organic acids and excess heat [10].

Biochar can be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies [12]. Biochar also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution. Biochar is a relatively recent development, emerging in conjunction with soil management issues [12].

Biochar, produced from high carbon content solid biomass, is one of the best bulking agents for reducing N_2O emission in manure composting for the following reasons (10). First of all, its high porosity results in increased aeration in the composting process, which enhances the supply and distribution of O_2 in the composting pile, and may lead to reduction of N_2O as previously mentioned reasons [13]. Secondly, the high porosity and high surface area of biochar also enables it to absorb and retain large amounts of water which results in decreased N_2O emission by altering redox conditions and denitrifying communities. High moisture content also enhances the metabolic activities of microorganisms [14-15]. Furthermore, other recent studies confirmed that bulking poultry manure with biochar lessened N loss and improved N retention, while simultaneously enhanced humification, thereby produced mature composts with a high fertilizer value [16-18]. Fourthly, biochar with a higher pH alters the abundance of denitrifying bacteria significantly in manure composting, resulting in less N_2O producing but more N_2O-consuming bacteria communities [14].

3. Material and Methodology

3.1 Study Site

The field experiments were conducted in Kakamega central sub-county, Kakamega County, Kenya. Kakamega is situated 0°12'N; 34°48'E at an elevation of 1,250 m above sea level in the southwest and 2,000 m in the east. Annual mean temperature varies between 18 to 21°C and annual rainfall varies between 1,000 and 2,400 mm. There are two yearly rain seasons: the long rains, from March until June, and the short rains from August until November. About 500 to 1,100 mm falls during the long rains and 450 to 850 mm during the short rains. The rainy season is characterized by heavy afternoon showers with occasional thunderstorms. Soils in Kakamega are highly weathered and vary in texture from clay to sandy loam. However, due the heavy rains, soils are vulnerable to erosion leading to a reduced agricultural productivity. Therefore, 70% of the soils are low in fertility due the intensive weathering, leaching and continuous cultivation without using fertilizers [19].

According to the 2009 population census report, the total population of people in Kakamega County is 1,660,651 (male-48% and female-52%) and an area of 3, 2444km² while in Urban Kakamega is 58,832 with a population density of 515Sq.Km. It has an annual growth rate of 2.12%. Poverty level is at 57% as compared to Nationals level of 51%, Fig. 3.1 illustrates the study area.

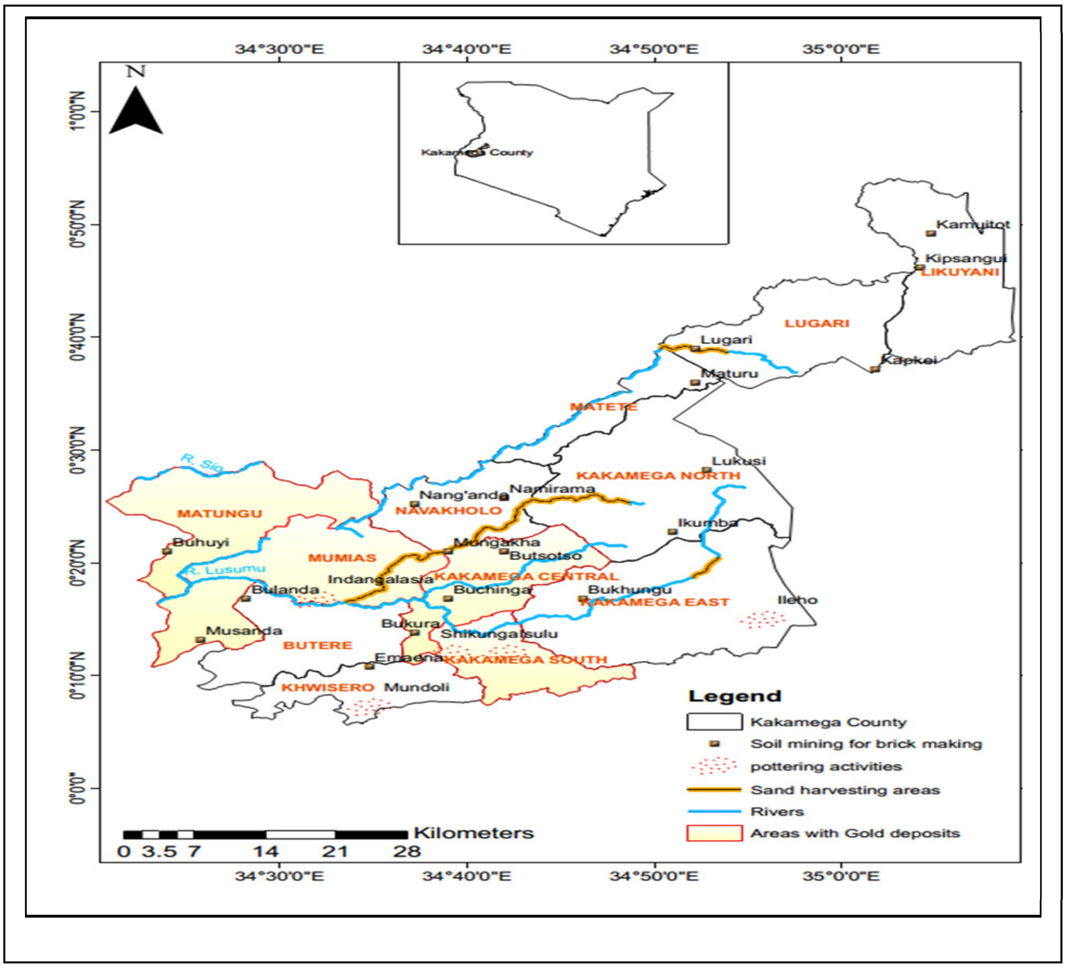

Figure 3.1. Study area map.

3.2 Research design and Data collection

Experimental research design was used to Examine the effects of EM and Biochar on the rate of decomposition and the nutrient content of the compost manure, of the locally available materials during composting in Kakamega Central sub county Kenya .

The On-station experiments were laid out in completely randomized block design with three [3] replications. The experiments were carried out during the short rains (September to November), 2016, at the Masinde Muliro University of Science and Technology (MMUST) School of Agriculture and Veterinary Sciences and Technology field trials. The treatments were (i) Normal Berkeley with No additions (Control), (ii) EM + Organic matter under Berkeley composting method, (iii) Biochar + Organic matter under Berkeley composting method and (iv) EM + Biochar + Organic matter under Berkeley composting method.

The compost heap was built by alternating Carbon and Nitrogen sources until a height of 1.5M was attained. The ratio of Carbon to Nitrogen was maintained at 30:1. Water was added, aiming for 50 percent moisture content. This was achieved by spraying each layer with water mixed with EM using a watering can while layering compost materials. However, care was taken so that the water does not become excess as it may make the compost water logged and smelly. The compost heap size was 1M by 1M by 1.5M and this was manageable size to be able to generate enough heat for decomposition to occur.

First turning was done on the fourth (4^{th}) day after building the compost heap. Subsequent turnings were done after every two (2) days until the compost was ready. Turning was done by putting the outside material from the pile into the middle and vice versa. Temperatures were taken using a thermometer from the first day and throughout the subsequent turnings. Finally compost with different treatments was attained within 21 days.

To determine the nutrient content of compost manure produced from different treatments under Berkeley composting technique, Compost manure samples from the four treatments, replicated three (3) times were taken for analysis at the World Agroforestry Centre(ICRAF), Nairobi; Soil and Plant Spectral Diagnostic Laboratory and Crop Nutrition Soil and Plant Laboratory. Determination of the Moisture content (Oven drying at 70°C for 48hrs) of the initial organic materials that were used to make the compost heaps was done at MMUST. Chemical analysis of both the initial organic materials that were used to make the compost heaps and the compost manure itself was done. A total of 53 compost manure samples and 8 plant samples were collected. Before the compost manure samples of specified treatments were taken, each compost heap was thoroughly mixed using the pitch forks. Each of the compost manure sample of specified treatments at specified days were taken with a spade at (0–20 cm) from the top, bottom and on both sides of the compost heap. This was then put into a small basin and thoroughly mixed. Double quartering was then used to obtain composite sample for each treatment on the specified day. Samples at the Laboratory were then air dried on shallow trays for two days before analysis was done.

Chemical and Physical parameters of the compost determined included: Carbon content of acid treated sample to remove carbonates, Nitrogen content of acid treated sample to remove carbonates, Total Carbon content, Total Nitrogen content, Soil pH in water (soil: water ratio of 1:2 weight to volume basis), Exchangeable Aluminium concentration by Mehlich III extraction, Boron concentration by Mehlich III extraction, Exchangeable calcium concentration by Mehlich III extraction, Copper concentration by Mehlich III extraction, Iron concentration by Mehlich III extraction, Potassium concentration by Mehlich III extraction, Exchangeable Magnesium by wet chemistry method, Exchangeable Manganese concentration by Mehlich III extraction, Exchangeable Sodium concentration by Mehlich III extraction, Phosphorus by Mehlich III extraction, Sulphur by Mehlich III extraction, Zinc by Mehlich III extraction, Sodium total element concentration, Magnesium total element concentration, Sulfur total element concentration, Chlorine total element concentration, Potassium total element concentration, Particle size analysis, CEC and EC.

4. Results

4.1 Temperature changes under the four different Treatments under Berkeley composting technique

The four treatments include: (i) Normal Berkeley with No additions (Control)-T1; (ii) EM + Organic matter under Berkeley composting method-T2; (iii) Biochar + Organic matter under Berkeley composting method-T3 and (iv) EM + Biochar + Organic matter under Berkeley composting method-T4. Temperature results for the four treatments replicated three times are as shown in Fig. 4.1, Tables 4.1 and 4.2.

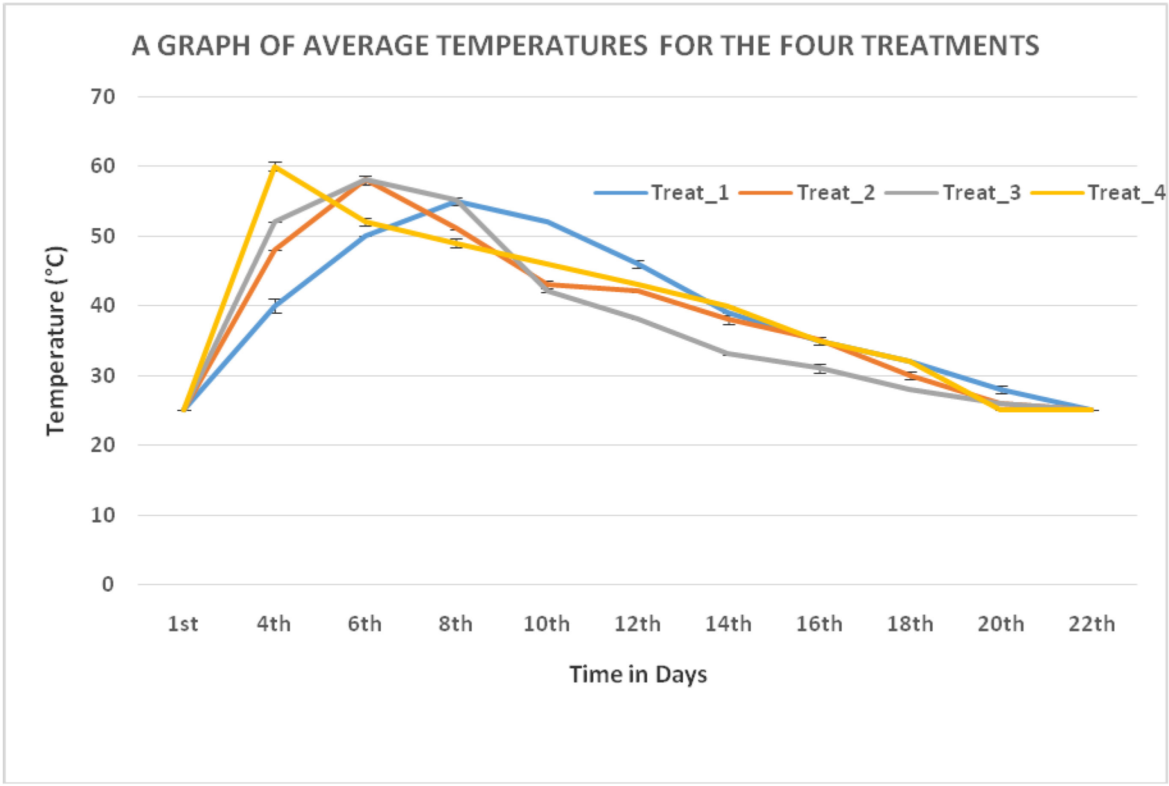

Figure 4.1. Temperature Verses Time in days for the four treatments under Berkeley composting technique with the Error Bars and Standard deviation for the On-station experiments

Under normal Berkley composting (Treat1), the temperature recorded on the first day was 25 °C, on the fourth day which was also the first turning; the temperature had reached 40°C. The highest temperature (55°C) was attained on the 8th day which is also the 3rd turning. When comparing composting with EM (Treat 2) and normal Berkley (Treat 1); both treatments show an increase in temperature right after composting started. On Day 1, the temperature rose to 48°C from 25°C for treatment with EM (Treat 2) and 40°C from 25°C for treatment without EM (Treat 1). The piles treated with EM reached the highest peak values of 58°C on Day 6 compared to composting treatment without EM, for which it was 55°C on Day 8. Composting with addition of Biochar showed temperature increase from 25°C on the first day to 52°C on the 4th day. The highest temperature of 58°C for piles with Biochar was attained on the 6th day. Under composting with both Biochar and EM, temperature increased from 25°Con the first day to 60°C on the 4th day/first turning. This was the highest temperature attained on the 4th day unlike under normal Berkley composting where the highest temperature 55°C was attained on the 8th day. The results show the importance of combining Biochar and EM in enhancing composting process.

Table 4.1. Temperature results for the four treatments replicated three times for different days.

Treatments			Temperature(°C)										
			1st day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day	20th day	22nd day
T 4	Replica III	EM_ Biochar_Berkeley	25	61	51	48	46	43	40	36	32	25	25
T 4	Replica II	EM_ Biochar_Berkeley	25	60	52	49	46	43	40	35	32	25	25
T 4	Replica 1	EM_ Biochar_Berkeley	25	60	52	49	46	43	40	35	32	25	25
		Standard Error	0	0.333333	0.333333	0.333333	0	0	0	0.333333	0	0	0
		Standard Deviation	0	0.57735	0.57735	0.57735	0	0	0	0.57735	0	0	0
T 4	**Mean**	**EM_ Biochar_Berkeley**	**25**	**60**	**52**	**49**	**46**	**43**	**40**	**35**	**32**	**25**	**25**
T 3	Replica III	Biochar _ Berkeley	25	52	58	55	42	38	33	30	28	25	25
T 3	Replica II	Biochar _ Berkeley	25	52	59	55	42	38	33	31	28	26	25
T 3	Replica 1	Biochar _ Berkeley	25	52	58	55	42	38	33	31	28	26	25
		Standard Error	0	0	0.333333	0	0	0	0	0.333333	0	0	0
		Standard Deviation	0	0	0.57735	0	0	0	0	0.57735	0	0	0
T 3	**Mean**	**Biochar _ Berkeley**	**25**	**52**	**58**	**55**	**42**	**38**	**33**	**31**	**28**	**26**	**25**
T 2	Replica III	EM_Berkeley	25	48	59	51	43	42	39	35	29	26	25
T 2	Replica II	EM_Berkeley	25	48	58	51	42	42	38	35	30	26	25
T 2	Replica 1	EM_Berkeley	25	48	58	51	43	42	38	35	30	26	25
		Standard Error	0	0	0.333333	0	0.333333	0	0.333333	0	0.333333	0	0
		Standard Deviation	0	0	0.57735	0	0.57735	0	0.57735	0	0.57735	0	0
T 2	**Mean**	**EM_Berkeley**	**25**	**48**	**58**	**51**	**43**	**42**	**38**	**35**	**30**	**26**	**25**
T 1	Replica III	Normal Berkeley(Control)	25	41	50	56	52	46	39	36	32	28	25
T 1	Replica II	Normal Berkeley(Control)	25	40	50	55	52	47	39	35	32	27	25
T 1	Replica 1	Normal Berkeley(Control)	25	39	50	55	52	46	39	35	32	28	25
		Standard Error	0	0.57735	0	0.333333	0	0.333333	0	0.333333	0	0.333333	0
		Standard Deviation	0	1	0	0.57735	0	0.57735	0	0.57735	0	0.57735	0
T 1	**Mean**	**Normal Berkeley(Control)**	**25**	**40**	**50**	**55**	**52**	**46**	**39**	**35**	**32**	**28**	**25**

Shapiro Wilk test was done to test for Normality of the data. R software version 3.2.4 was used; w=0.96743, p=0.1091 hence p>0.05. This means distribution of data are not significantly different from Normal distribution hence assuming normality. Parametric Two-way Analysis of Variance (ANOVA) using SAS version 6.12 was then used. Table 4.2 shows the results of effects on temperatures as days progressed during composting.

Table 4.2. The results of effects on temperatures as days progressed during composting.

Treatments	Time in Days								
	4th	6th	8th	10th	12th	14th	16th	18th	20th
Normal Berkeley	40.00d	50.00c	55.33aa	52.00a	46.33a	39.00b	35.33aa	32.00a	27.67a
EM_Berkeley	48.00c	58.33a	51.00b	42.67c	42.00c	38.33c	35.00a	29.67b	26.00bb
Biochar_Berkeley	52.00b	58.33aa	55.00a	42.00d	38.00d	33.00d	30.67b	28.00c	25.67bc
EM_Bioch_Berkeley	60.33a	51.67b	48.67c	46.00b	43.00b	40.00a	35.33aa	32.00aa	25.00c
C.V	1.07	0.97	0.83	0.65	0.71	0.80	1.55	0.98	1.57
L.S. D	1.03	1.02	0.84	0.58	0.58	0.58	1.02	0.58	0.79

Treatments having the same letters within a column are not significantly different with ANOVA T test at p<0.05

From the results (Tables 4.1; 4.2 and Fig. 4.1); On the 4th day, which was also the 1st turning, all the treatments were significantly(p<0.05) different from each other with EM-Biochar-Berkeley recording the highest peak mean temperatures of 60.33°C.This shows that EM-Biochar-Berkeley reached thermophilic stage on day 4.

On the 6th day, which was also the 2nd turning, EM-Berkeley and Biochar-Berkeley treatments were significantly (p<0.05) highest, (and their peak) than the rest of the treatments (Mean temperatures of 58.33°C). It shows that they reached the thermophilic stage on day 6.

Day 8 shows Normal Berkeley being significantly (p<0.05) highest (at its peak) than the rest of the treatments. It was attaining this temperature on the 3rd turning.

Day 10 shows the temperatures dropping for all the treatments but they remain significantly different (p<0.05). On day 16which is also the 7th turning, temperatures for all the treatments have steadily reduced significantly (p<0.05) and Normal Berkeley and EM-Biochar-Berkeley treatments recorded the same mean temperature of 35.33°C as they stabilize to the ambient temperatures.

4.2 Nutrient contents of organic materials and compost manure from different treatments under Berkeley technique in Kakamega central sub-county, Kenya

Table 4.3. Chemical and physical properties of locally available organic materials that were used to make the compost heaps in Kakamega central sub county, Kenya.

Parameters	Organic materials					
	Leucina	Green grass	Dry grass	Napier grass	Dry maize stalk	Dry bean husks
pH(Units)	-	-	-	-	-	-
Al(mg/kg)	648.21	1286.68	310.05	636.99	384.49	500.45
Ca(mg/kg)	7561.28	10080.34	3190.44	3558.37	2430.46	5274.53
EC(dS/m)	-	-	-	-	-	-
Fe(mg/kg)	166.5	482.65	830.63	1056.69	595.37	767.73
K(mg/kg)	27157.48	30698.46	10291.99	11816.61	13152.03	21454.56
Mg(mg/kg)	3160.65	4816.48	1589.01	2555.10	1526.63	2974.28
Clay(%by volume)	-	-	-	-	-	-
Silt (%by volume)	-	-	-	-	-	-
Sand(%by volume)	-	-	-	-	-	-
Mn(mg/kg)	55.21	83.00	175.35	148.64	108.77	58.95
Na(mg/kg)	32.38	46.99	17.09	25.35	13.99	26.94
P(mg/kg)	3703.21	4614.78	1309.07	1308.45	648.46	1860.37
S(mg/kg)	4592.57	3419.82	1246.30	1114.67	660.01	2673.87
Zn(mg/kg)	21.24	36.12	20.82	23.94	21.03	5.77
CEC	-	-	-	-	-	-
Total N(%by weight)	5.36	2.63	0.83	0.85	0.59	1.26
Total C(%by weight)	58.01	50.80	52.30	50.97	51.77	51.24

Parameters	Organic materials						
	Tithonia	Dry leaves (Assorted)	Top soil	Ash	Biochar	Cow manure	Chicken manure
pH(Units)	-	-	6.56	10.24	8.21	8.38	8.38
Al(mg/kg)	1089.19	5021.97	59.08	58.63	53.70	61.39	60.20
Ca(mg/kg)	9538.45	40316.63	45.99	62.11	64.44	50.75	41.05
EC(dS/m)	-	-	4.20	5.28	4.56	5.06	5.26
Fe(mg/kg)	276.23	4077.28	2120.35	8639.42	11782.93	17610.50	10596.46
K(mg/kg)	35,370.95	14933.36	76.05	70.21	94.90	49.51	52.22
Mg(mg/kg)	3425.57	7291.96	17.04	25.23	38.64	27.51	29.82
Clay(%by volume)	-	-	35.54	41.75	35.23	48.35	38.24
Silt (%by volume)	-	-	32.41	25.61	34.13	29.80	31.83
Sand(%by volume)	-	-	32.05	32.65	30.64	21.85	29.93
Mn(mg/kg)	143.43	686.61	20.33	23.17	18.65	20.74	19.84
Na(mg/kg)	38.35	65.57	72.78	167.33	195.60	162.44	197.68
P(mg/kg)	2496.56	2595.56	12.27	13.54	12.85	12.03	14.83
S(mg/kg)	2525.27	2184.6	13.00	14.99	12.37	12.41	13.22
Zn(mg/kg)	34.90	15.63	48.89	36.15	53.83	61.50	47.29
CEC	-	-	79.99	63.64	28.56	261.44	30.03
Total N(%by weight)	2.83	2.23	0.56	0.47	0.54	0.62	0.55
Total C(%by weight)	51.13	48.06	8.00	7.47	11.04	9.73	7.48

The results in Table 4.3 above shows heterogeneity of organic residues, nutrient and physical and chemical properties vary widely, even among materials from the same origin. The nutrient content of plant residues ranged, for N, P, K, Ca, Mg, Cu, Mn, and Zn, respectively: 11-73 g kg^{-1}, 1-29 g kg^{-1}, 5-38 g kg^{-1}, 4-54 g kg^{-1}, 1-6 g kg^{-1}, 23-18 mg kg^{-1}, 23-29 mg kg^{-1}, and 70-298 mg kg^{-1}. The nutrient content ranges of animal origin materials presented are, respectively, for N, P, K, Ca, Mg, S, Zn, Mn and Cu: 11-54 g kg^{-1}, 1-42 g kg^{-1}, 3-49 g kg^{-1}, 5-153 g kg^{-1}, 2.6 to 14 g kg^{-1}, 0.9-8 g kg^{-1}, 48-1189 mg kg^{-1}, 340-2055 mg kg^{-1}, and 15-1388 mg kg^{-1}.

Characteristics of plant residues vary depending on the plant species, plant tissues, and soil chemical and physical properties, but are generally nutrient-poor and have lower EC than animal or municipal wastes [20].

Table 4.4. Effects of EM and Biochar on the chemical and Physical properties of the compost manure in Kakamega central sub county, Kenya

Treatments	Parameters										
	pH	Al	Ca	EC	Fe	K	Mg	Clay%	Silt%	Sand%	Mn
Control	8.43a	64.10a	51.78bc	4.43a	11495ab	47.82a	21.99b	24.23a	23.81a	51.98a	19.95a
EM_Berkeley	8.34a	65.08a	49.81c	3.39b	12907a	42.99a	19.32b	21.69a	24.55a	53.75a	19.91a
Bioch_Berkeley	8.38a	58.58b	59.19a	2.89b	10447b	43.79a	32.86a	25.39a	25.34a	49.28a	20.01a
EM_Bioch_Berkeley	8.39a	54.22b	57.36ab	2.83b	12981a	49.78a	31.33a	26.93a	26.65a	46.43a	19.83a
Mean	**8.39**	**60.49**	**54.53**	**3.39**	**11957.45**	**46.10**	**26.37**	**24.56**	**25.10**	**50.36**	**19.92**
C.V	**2.60**	**9.16**	**13.31**	**26.59**	**23.90**	**19.30**	**13.21**	**30.60**	**17.85**	**22.38**	**6.62**
LSD	**0.18**	**4.67**	**6.12**	**0.76**	**2408.2**	**7.50**	**2.94**	**6.33**	**3.77**	**9.49**	**1.11**

Treatments having the same letters within a column are not significantly different with the ANOVA T test at $P<0.05$

Treatments	Na	P	S	Zn	CEC	total N	total C
Control	155.63ab	13.92ab	11.05ab	46.12a	61.83a	0.73a	10.33bc
EM_Berkeley	136.37b	13.36b	11.90a	45.55a	39.04a	0.62a	13.70ab
Bioch_Berkeley	172.26a	14.69ab	10.13b	40.28b	52.06a	0.75a	15.88a
EM_Bioch_Berkeley	171.33a	15.03a	11.76a	43.23ab	32.53a	0.66a	9.24c
Mean	**158.90**	**14.25**	**11.21**	**43.80**	**46.37**	**0.69**	**12.29**
C.V	**16.94**	**12.03**	**12.07**	**12.89**	**109.52**	**27.2**	**33.48**
LSD	**22.67**	**1.45**	**1.14**	**4.76**	**42.79**	**0.16**	**3.47**

From Table 4.4, pH was not significantly different across the four treatments. This could be attributed to the fact that pH varies with the raw material used in the compost and the production of various products (lactic and acetic acids) during the composting period. During the thermophilic stage, pH can rise up to 9 and thereby releasing NH_3. In the maturation stage, pH will drop to neutral [21].

Nitrogen was not significantly different in all the treatments. The reason could be attributed to the organic materials that were used to make the compost heaps for the treatments were all the same. Total Carbon was significantly ($p<0.05$) highest in the Biochar-Berkeley treatment, followed by EM-Berkeley treatment and lowest in EM-Biochar-Berkeley treatment. Total Carbon mean value was 12.29mg/kg. The EM's phototrophic bacteria are involved in various metabolic systems that play a major role in nitrogen cycle and carbon cycle [22].

P was significantly ($p<0.05$) higher in the EM-Biochar-Berkeley treatment as compared to the control (Normal Berkeley). Available K was not significantly different with the use of EM, and Biochar in the compost heaps when compared to the control experiment. CEC was not significantly different across all the treatments though it was lower in EM-Biochar-Berkeley treatment (32.53ds/m). Particle size analysis (Sand, Clay and Silt percentages) was not significantly different within all the treatments as the texture was Sandy-clay-loam all through. EC was significantly ($p<0.05$) lowest in EM-Biochar-Berkeley treatment as compared to the rest of the treatments as well as Al that was significantly ($p<0.05$) lowest in EM-Biochar-Berkeley treatment. Mg and Fe were significantly ($p<0.05$) highest in EM-Biochar- Berkeley as compared to the control.

5. Discussion

Normal Berkeley composting (T1) process matched the typical relationship between temperature and time that is present in typical compost [23]. There is an initial peak of temperature (of 55 °C) and this is the temperature when the Pathogens are normally destroyed. That temperature was attained on the 8th day, and this was the active phase. However, it's recommended that, peak temperatures of 62 °C are critical for elimination of weed seeds and this was not recorded under Normal Berkeley composting treatments. Farmers practicing normal Berkley may have some challenges of weeds on their farms when using the ready compost manure because it couldn't reach the highest temperature required to eliminate the weeds.

The piles treated with EM reached the highest peak values of 58°C on Day 6. T2 had the longest period of time above 55°C, that is, from 2nd turning to 3rd turning. This clearly indicates, that the compost heaps with EM had high microbial activity compared to (T1) based on the highest temperatures achieved. Effective Micro-organisms (EM) enhances the rate of decomposition of organic materials. EM is a liquid containing many coexisting microorganisms: lactic acid bacteria, yeast and phototrophic bacteria. When these organisms are placed in contact with organic matter, they secrete substances such as vitamins, organic acids, minerals and antioxidants that beneficially affect plants and other micro-organisms [24].

The peak temperature of 58°C was attained on the 6th day for piles with Biochar. This can be attributed to the ability of Biochar to accelerate the composting process. Biochar is commonly defined as charred organic matter, produced with the intent to deliberately apply to soils to sequester carbon and improve soil properties [12]. Biochar improves the homogeneity and structure of the mixture and stimulating microbialactivity in the composting mix. This increased activity translates to increased temperatures and a shorter overall time requirement for compost development. Increasing the use of biochar in compost operations requires education on the benefits of biochar to compostproducers, not only on emissions and odor reductions, but also on the potential economic benefits of accelerating the decomposition of organic matter.

Under T4(Biochar-EM-Berkeley), temperatures increased from 25°C on the first day to 60°C on the 4th day, which was also (1st) first turning. This was the highest temperatures attained comparing all the four treatments (T1, T2, T3 and T4). Temperatures were stabilizing on day 14th which was also the 6th turning. The results clearly show the importance of combining Biochar and EM in accelerating the rate of decomposition of organic matter under Berkeley composting technique. Biochar has high porosity which results in increased aeration in the composting process, which enhances the supply and distribution of O_2 in the composting pile & provides energy for the microorganisms feeding on the organic matter [13]. Effective micro-organisms (EMs) on the other hand, reduces decomposition period significantly. Therefore, a mixture of EM with Biochar fastened the rate of decomposition.

Chemical and physical properties of locally available organic materials that were used to make the compost heaps varied widely even among materials from the same origin. Characteristics of plant residues vary depending on the plant species, plant tissues, and soil chemical and physical properties, but are generally nutrient-poor and have lower EC than animal or municipal wastes [20].

Mean pH of the compost manures produced was 8.39. Soil pH reflects the acidity or alkalinity of the soil and controls many chemical processes but especially affects plant nutrient availability. Acid soils contain toxic concentrations of Al and/or Mn in the soil solution, which can restrict root and plant growth. Some plant nutrients like P are less available in acid soils due to precipitation with Al and Fe ions [25]. Microbial activity is optimal when pH ranges between 6.5 and 8. However, bacteria need a pH between 6 and 7.5 whereas fungi need a pH between 5.5 and 8.9 for their activity. The pH varies with the raw material used in the compost and the production of various products (lactic and acetic acids) during the composting period.

Fe, Mn, Cu, Zn, B, and Mo are essential elements for crop production and food quality. Applying organic matter to the soil can either decrease or increase metal availability, solubility, and plant uptake. Many organic amendments have a soluble C component or produce soluble decomposition products, which can increase metal solubility by forming soluble organometallic complexes. Micronutrients are also released through the biodegradation of OM by micro-organisms [26]. Soil structure and soil aggregate stability improve with increased SOM, because OM binds mineral particles (sand, silt and clay) together. This could be a result of the increased microbial activity and their synthesized products, like polysaccharides.

Total Carbon mean value was 12.29mg/kg. The EM's phototrophic bacteria are involved in various metabolic systems that plays a major role in nitrogen cycle and carbon cycle [22], [27]. This explains why Total Carbon was lowest in the EM-Biochar- Berkeley treatment though still adequate for the plant requirements. Increase of soluble N, P and K contents could be attributed to activity of nitrogen fixers and organic acids excreted by the different organisms in EM. According to Saravanan et al. [28], macronutrient Nitrogen in EM compost is higher (1.2%) compared to non-EM compost (0.9%). Phosphorus and Total carbon was also higher in EM compost (1.8% and 5.4%) compare to non-EM compost (1.2% and 5.0%). Besides, the number of Potassium (K) is increased in compost added with EM (55%) compared to in compost without EM (17%) [29].

Generally, compost treated with EM resulted in low quantities of heavy metals. This is because natural process which relies on bacteria, fungi, and plants alter contaminants such heavy metals as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or less toxic products in most cases [30]. Compost usually contains heavy metals based on their initial raw materials. These heavy metals (micronutrients) are required by the plant for perfect growth and they are absorbed by plants during the fertilizing process; but in large quantities, they can cause phytotoxicity.

The beneficial effects of adding Biochar to composts were: increased pH, CEC, soil water retention, nutrient retention, improved soil structure, soil aeration, hydraulic conductivity and adsorption of heavy metals [31-32]. The carboxyl groups (functional groups) found in Biochar can explain the high CEC, liming effect and high charge density of Biochar [12]. The physical structure characterized by a network of micro-, meso and macro pores allows for improved soil structure by increasing aeration, decreasing bulk density and reducing the soils tensile strength [33]. Biochar addition also had a large effect on the microbial activity, soil organic matter (SOM) levels [34], C cycling [35], and nitrogen (N) dynamics [12]. The total surface area in biochar allows for "storage space" of different nutrients and organic compounds that optimizes microbial growth [12]. Biochar is commonly applied for environmental purposes such as (i) managing pollution and eutrophication risks, (ii) re-vegetation of degraded land, and (iii) C sequestration [36].

6. Conclusions

Overall conclusion is that combining both Effective Microorganisms (EM) and Biochar under the most preferred Berkeley composting technique accelerated the rate of decomposition of the organic materials hence it was the most effective process of composting and on top of that, EM and Biochar had positive impacts on the chemical and physical properties of compost manure produced from these treatments in Kakamega central sub county, Kenya. This can sustainably restore the soil fertility of depleted soils hence ensuring neutrality in land degradation, thus increasing crop production that will ensure food security of the ever-increasing population in Kakamega central sub county. Composts produced from the treatments contained both Macro and micro nutrients that are within the recommended ranges. EM and Biochar had positive impacts on the chemical and physical properties of composts.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Keyword Index

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