EFFECT OF SPENT MUSHROOM SUBSTRATE ADMIXED WITH TOP SOIL ON THE GROWTH AND HERBAGE YIELD OF AMARANTH (*Amaranthus hybridus*)

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF B.AGRIC (OPTION: CROP SCIENCE)

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CERTIFICATION

This project work was carried out by Precious Omemi OGINI with the Matriculation number AGR1800229 has been certified by the undersigned in the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Edo state, Nigeria.

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(HEAD OF DEPARTMENT)

DEDICATION

This work is dedicated to God Almighty, who in His infinite mercy saw me through everything and also my wonderful family and friends for their support all through my stay in the University of Benin, Benin City, Edo State, Nigeria.

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ABSTRACT

An explorative study on the effectiveness of incorporating spent mushroom substrate (SMS) admixed with topsoil on the growth and herbage yield of Amaranth was conducted at the screen house of the Department of Crop Science, Faculty of Agriculture, University of Benin, Nigeria. The study involved five application rates (0, 50, 100, 150, and 200 g) of SMS per 3 kg topsoil laid out in a completely randomized design and replicated three times. Data were collected on the physical and chemical properties of topsoil admixed with SMS. Data were also collected on growth parameters (plant height, stem girth, leaf area, and number of leaves), and dry herbage yield. Results indicated substantial improvements in soil fertility with SMS incorporation. Treatments with SMS demonstrated taller plants, thicker stems, higher number of leaves, increased leaf area, and higher herbage yields compared to the control (topsoil only). Herbage yield was highest with SMS applied at 150 g (11.1 tha^{-1}) but at par with other SMS treated media except topsoil only media. Based on these findings, topsoil treated with SMS at 50 g is thereby suggested for urban Amaranth growers.

CHAPTER ONE

INTRODUCTION

Amaranths, spanning various forms from grains to leafy vegetables, dye plants, ornamentals, and even weeds, hold a longstanding presence in global agriculture across tropical, subtropical, and temperate regions (Jimoh *et al*., 2018). Comprising approximately 74 annual species, the Amaranthus genus exhibits extensive morphological diversity, notably characterized by monoecy and dioecy (Waselkov *et al*., 2018). These versatile plants offer a promising source of plant-based proteins, essential nutrients, unsaturated fatty acids, and other organic minerals obtained from their leaves, seeds, and roots (Venskutonis and Kraujalis, 2013; Jimoh *et al*., 2020). These compounds include phenolic phytochemicals, lectins, anthocyanins, flavonoids, and antioxidants, crucial for scavenging free radicals that may otherwise disrupt biological processes (Jiménez-Aguilar and Grusak, 2017; Jimoh *et al*., 2019a and b). Such bioactive compounds contribute to Amaranthus' nutritional and medicinal value, making them not only a dietary staple but also a potential source of functional ingredients with health-promoting properties.

In Sub-Saharan Africa, commonly cultivated species of Amaranthus serve diverse purposes ranging from grain production to leafy vegetables for human consumption and animal feed. Moreover, these species are utilized for treating chronic diseases like diabetes, hypertension, cardiac disorders, and other nutraceutical purposes.

Spent Mushroom Substrate (SMS) is a residue produced during mushroom cultivation, offering considerable potential as a soil enhancer owing to its distinctive composition and attributes (Leong *et al*., 2022). Primarily, SMS is abundant in organic material derived from the substrates used in mushroom farming, such as agricultural residues, straw, sawdust, or composted organic matter (Martín *et al*., 2023). This organic content acts as a vital carbon and energy source for soil microbes, fostering microbial activity and facilitating nutrient cycling within the soil ecosystem.

When incorporated into topsoil, which is the upper layer of soil vital for plant growth due to its richness in nutrients and organic matter, SMS serves as a beneficial organic supplement. It enhances the soil's nutrient content, including nitrogen, phosphorus, potassium, and micronutrients, essential for plant development (Becher *et al*., 2021). Research indicated that crops cultivated in SMS-admixed soil demonstrated improved absorption of nutrients, resulting in enhanced growth metrics like increased plant height, leaf area, and biomass production (Mohd Hanafi *et al*., 2018). This demonstrates the significant role SMS can plays in promoting the overall health and development of Amaranth crops when mixed with topsoil.

In Sub-Saharan Africa, Amaranth cultivation plays a vital role in local agriculture and dietary practices (Achigan-Dako *et al*., 2014). However, to fully capitalize on its benefits, optimizing soil conditions and nutrient availability is crucial for ensuring robust plant growth and maximizing yields. A promising avenue for enhancing Amaranth growth lies in the utilization of Spent Mushroom Substrate (SMS), a residue from mushroom cultivation renowned for its nutrient-rich composition. Hence this study was undertaken to evaluate the effect of top soil admixed with spent mushroom substrate on the growth and herbage yield of Amaranth.

CHAPTER TWO

LITERATURE REVIEW

2.1. Soil fertility and its importance for crop growth

Soil fertility is a critical component of agricultural production, supporting crop development and guarantying global food security (Rojas *et al*., 2016). It includes the soil's ability to give important nutrients, maintain ideal pH levels, support microbial activity, and retain moisture—all of which have a significant impact on plant health and productivity.

Nutrient availability is critical to soil fertility. Plant growth and development require essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients such as calcium, magnesium, and sulphur (Ahmed *et al*., 2020). These nutrients are derived from organic matter, mineral weathering, and fertilizers. Soil fertility management measures, including as adequate fertilization, crop rotation, and organic soil amendments, are critical for replenishing and sustaining soil nutrient levels. The soil's pH level has a substantial impact on fertility (Ge *et al*., 2018). Most crops flourish in slightly acidic to neutral soils with a pH ranging from 6 to 7. Soil pH influences nutrient availability, microbial activity, and the solubility of hazardous substances. Lime and sulphur are important soil additions used to enhance pH levels.

Assessing soil quality offers a valuable approach to gauge the collective biological, chemical, and physical responses of soil to various land use and management practices

(Seybold *et al*., 2018). Several methods are available for evaluating soil quality, including integrated soil quality indexes, multi-variable indicator kriging, and soil quality dynamics. Among these, integrated soil quality indexes are widely utilized (Bünemann *et al*., 2018). They quantify measurable soil parameters that influence the soil's ability to perform specific functions. Key considerations in soil quality index methods include selecting appropriate indicators, determining their weights, and establishing calculation methodologies.

Changes in soil fertility quality often manifest over several years and may not be adequately captured in short-term experiments (Lehman *et al*., 2015). Long-term experiments (LTEs) serve as invaluable tools for studying soil property and process changes over time (Johnston *et al*., 2018). LTEs are crucial for understanding the long-term sustainability of agricultural systems and formulating strategies to maintain soil fertility effectively. They provide essential insights into the dynamic nature of soil fertility, aiding in the development of future agricultural practices and policies aimed at promoting sustainable soil management and preserving agricultural productivity.

Microbial activity in the soil is another important indicator of soil fertility. Beneficial soil microorganisms, such as bacteria, fungus, and protozoa, are vital for nutrient cycling, organic matter breakdown, and disease suppression (Tahat *et al*., 20200. Soil biodiversity-promoting practices, such as low tillage, cover cropping, and organic matter additions, boost microbial activity and improve soil fertility. Furthermore, soil structure and texture affect fertility by influencing water retention, aeration, and root penetration. Well-structured soils with adequate aggregation create an ideal environment for root growth and microbial colonization, allowing plants to absorb nutrients and water more efficiently. Practices that improve soil structure, such as adding organic matter and reducing soil compaction, increase fertility and promote healthy crop development.

2.2. Effect of top soil on the herbage yield of Amaranth

The uppermost layer of soil, known as topsoil, harbours a dense concentration of roots as it serves as the primary source of vital nutrients for plants (Bhattacharyya *et al*., 2015). Moreover, topsoil supports a diverse ecosystem of bacteria, fungi, and insects, all of which are integral to maintaining soil quality and supporting plant growth (De Deyn and Kooistra, 2021). Bacteria and fungi play crucial roles in facilitating nutrient uptake by plants and decomposing organic matter into forms that roots can readily absorb. A thriving topsoil layer hosts a rich microbiome encompassing various species, ultimately fostering stronger and more resilient plants (Delitte *et al*., 2021).

The significance of topsoil in crop cultivation cannot be overstated. Its nutrient-rich composition directly impacts plant health and development. Adequate levels of essential nutrients in the soil are vital for optimal plant growth, ensuring proper root development, foliage expansion, and reproductive success. Furthermore, topsoil's ability to retain moisture and facilitate nutrient uptake by plant roots is essential for sustaining crop growth, especially during periods of drought or limited irrigation (Ma *et al*., 2022). When considering the specific case of Amaranth cultivation, the role of topsoil becomes even more pronounced. Amaranth, a highly nutritious leafy vegetable, thrives in well-draining soils rich in organic matter. The nutrient requirements of Amaranth are relatively high, particularly for nitrogen, which is crucial for leafy growth and protein synthesis (Bressani, 2018). Therefore, the nutrient-rich environment provided by topsoil is particularly beneficial for promoting vigorous Amaranth growth and maximizing yield.

Additionally, topsoil's influence on soil structure can be critical for Amaranth cultivation. Amaranth plants require adequate root penetration and aeration to support their growth and nutrient uptake. Well-structured topsoil with good aggregation and porosity provides an optimal environment for root growth, allowing Amaranth plants to access nutrients efficiently and develop strong root systems that acquire enough nutrients for its herbage yield.

2.3. Effect of Spent Mushroom on the Herbage Yield of Amaranth

The use of spent mushroom substrate (SMS) in agriculture has attracted attention because to its potential to improve crop development and yields (Cunha Zied *et al.*, 2020). When absorbed into soil, SMS can have a variety of beneficial effects on crops, making it an appealing organic amendment. SMS has a remarkable effect of enriching the soil with critical nutrients like as nitrogen, phosphorus, potassium, and micronutrients (Wei *et al.*, 2020). These minerals are essential for plant growth, development, and overall health. Furthermore, SMS helps to improve soil structure by increasing aggregation, porosity, and aeration (Gümüş and Şeker, 2017). This improves the environment for root growth and microbial activity, hence promoting plant growth.

When contemplating Amaranth cultivation, the consequences of spent mushroom substrate become very important. Amaranth, a very nutritious green vegetable, thrives on fertile soils with adequate drainage and microbiological activity. As a result, SMS's nutrient enrichment and soil conditioning capabilities can help Amaranth grow and produce more. The enhanced availability of key nutrients in the soil can encourage vigorous foliage growth and raise the nutritional value of Amaranth leaves. Furthermore, the increased soil structure caused by SMS (Hajabbasi, 2016) insertion can allow for higher root penetration and nutrient uptake by Amaranth plants, promoting their growth and development.

SMS's rich microbial population plays an important function in disease suppression (Wang *et al*., 2020; Moraes *et al*., 2020). This microbial community has a wide variety of bacteria, fungus, and other microorganisms that can compete with hazardous pathogens for nutrients and space in the soil. By populating the soil and rhizosphere, these beneficial bacteria create a competitive environment that inhibits the multiplication of soilborne pathogens, lowering the risk of disease transmission. Furthermore, certain bacteria in SMS create antibiotic chemicals or enzymes that directly impede pathogen development and activity (Stubbendieck and Straight, 2016). For example, some fungus in SMS creates antibiotics that can inhibit the growth of pathogenic fungi, but certain bacteria produce enzymes that destroy pathogen cell walls, making them less virulent. SMS helps to improve plant health and vigour by controlling soilborne infections. Healthy plants can better endure environmental challenges like drought and nutrient deficits, as well as pest infestations. Furthermore, SMS-mediated disease suppression can boost plant nutrient uptake and utilization, hence enhancing growth and production including herbage yield for Amaranth.

2.4. Effect of Spent Mushroom Admixed with Top Soil on the Growth of Amaranth

The utilization of spent mushroom substrate (SMS) in agricultural top soil has become a widely adopted practice aimed at enhancing crop productivity and improving soil fertility (Jaiarree *et al*., 2014). Instead of being disposed of in landfills or spread over land, SMS is increasingly recognized for its potential as a soil amendment or potting material (Ko *et al*., 2005; Zhang and Sun, 2014). Particularly in organic farming, SMS plays a crucial role in enhancing soil properties such as water infiltration, retention, permeability, and aeration (Uzun, 2004). Through its incorporation into soil, SMS offers a stable source of organic matter, contributing to improved physical soil characteristics such as nutrient and water holding capacity, pore space, aggregate stability, erosion resistance, and thermal insulation (Gümüş and Şeker, 2017). Notably, SMS exhibits favourable attributes including low bulk density, minimal heavy metal content, and the absence of plant pathogens and weed seeds (Curtin and Mullen, 2007; Zhang and Sun, 2014). These qualities make SMS a valuable resource for sustainable soil management practices and agricultural productivity enhancement.

Integrating spent mushroom substrate (SMS) into topsoil can have a beneficial impact on the growth and herbage yield of Amaranth. The organic material within SMS enhances soil structure, increases water retention, and improves nutrient availability, fostering strong root development and overall plant vitality. Moreover, SMS contains residual nutrients like nitrogen, phosphorus, and potassium from the mushroom cultivation process, serving as natural fertilizers for topsoil (Othman *et al*., 2020), that support the health and growth of Amaranth plants. Additionally, SMS is known to harbour bioactive compounds with properties that promote plant growth, including beneficial microorganisms and enzymes (Baptista *et al*., 2023). These compounds play crucial role in enhancing nutrient absorption, bolstering disease resistance, and improving stress tolerance, all of which are important factors for the optimal growth and herbage yield of Amaranth.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Area

This experiment was carried out at the screen house of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria. The site is located at latitude of 6°23'37" and 6°24'26" North and longitude 5°36'25"and 5°38'09 East and altitude of 162m above sea level. The site is located at a tropical rainforest. It has a bimodal rainfall and annual mean of 2300mm, with a mean temperature of 25.10^{0} C. It lies within the rainforest region.

3.2. Source of Experimental Materials

Santo Agro garden, Benin City, was where the top soil was collected. The University of Benin's Plant Biology and Biotechnology (PBB) Department provided spent mushroom substrate for the research. An established vendor at the market provided the Amaranth seeds. The poly bags for the test were purchased from a shop in New Benin market, Benin City.

3.3. Experimental design

This experiment involved five application rates (0, 50, 100, 150 and 250g)) spent mushroom substrate (SMS) for 3kg of topsoil laid out in completely randomized design (CRD) and replicated three times. The top soil and spent mushroom substrate (SMS)were weighed, mixed and homogenized as a composite and placed in polythene bags as per treatment.

3.4. Management practices

After filling the polythene bags with the different treatment and randomized, the bottom of polybags was perforated to allow drainage and promote optimum aeration. The bags were irrigated with 100ml of water for one week and then the Amaranth seeds were sowed. Germination began there from days after sowing, the seedlings were thinned to a population of two per polybag at two weeks after sowing (WAS). Hand weeding was carried out regularly within and around the polythene bags. The seedlings were watered throughout the duration of the experiment, three times a week with 200ml of water.

3.5. Data collection

3.5.1. Soil Analysis

Soil was admixed with spent mushroom substrate (SMS) and before cropping with Amaranth, samples were taken from each treatment combination separately for its physical and chemical characteristics using Standard laboratory procedures properties using standard laboratory described by Mylavarapu and Kennelly (2002).

3.5.2. Vegetative growth

Data on plant height, stem girth, leaf area (leaf length and width) and number of leaves were collected every two weeks starting four weeks after sowing (WAS). The plant height was measured using a meter ruler calibrated in centimetres (cm) from the base of the stem to the tip of the plant. Stem girth was measured using a measuring tape by measuring the circumference of the stem of three randomly selected plants per treatment and the mean computed. The leaf length was measured using a meter rule from the node of the plant to the end tip of the leaf and the width was measured from side to side of the leaf from the three selected plants and the average was taken to get the leaf area. Number of leaves was determined by directly counting fully expanded leaves of the three selected plants and mean computed.

The total leaf area was computed as thus:

$(LA = LL \times LW \times C \times NL \times 0.65)$

Total leaf area/ plant

Where:

LL= Leaf length

LW= Leaf width

C= Leaf constant

NL= Number of leaves

LA= Leaf area

3.5.3 Herbage yield

Herbage yield was estimated from the herbage weight per plant (g plant^{-1}). This involved cutting off the shoot portion of randomly selected three (3) plants from each treatment, weighing them, summing them together, and then dividing by 3 to get the mean per plant. From the herbage weight per plant, herbage yield was estimated as follows:

$\frac{2000 \times 1000 \times x}{3 \times 1000 \times 1000}$ tha^{-1}, $\frac{2x}{3}$ tha^{-1}

Where x is the herbage weight

3.6 Data Analysis

Using the GENSTAT tool, an analysis of variance (ANOVA) was performed on all collected data. At a 5% level of probability, significant differences between treatment means were detected using the Least Significant Difference (LSD) Test.

CHAPTER FOUR

RESULTS

4.1. Physical and chemical properties of topsoil admixed with spent mushroom substrate

The results of the analysis of the physical and chemical properties of topsoil admixed with varying levels of spent mushroom substrate (SMS) are presented in Table 1. Sand content was highest in topsoil-only media (899gkg^{-1}), which was comparable to its content in topsoil treated with SMS at an application level of 50 and 100g (884gkg^{-1}). Silt content increased with the increasing application rate of SMS, with topsoil without SMS treated media having the lowest content (58 gkg^{-1}), and topsoil treated with 100 and 150g of SMS having the highest (65gkg^{-1}), but not significantly higher than its content in topsoil treated with 200g SMS (64gkg^{-1}). This distribution trend was repeated for clay content. However, the highest clay content was recorded in topsoil treated with 200g SMS media (68gkg^{-1}). Topsoil without SMS treatment was the most porous, which was comparable with topsoil treatment with 50g SMS (50%). The least porous was recorded in the topsoil treated with 200g SMS media (43.8%). The application of SMS increased bulk density. Topsoil-only media had the lowest bulk density, which was identical with topsoil treated with 50g SMS ($1.0gcm^{-3}$). Topsoil treated with 150g and 200g SMS had the highest bulk density ($1.2gcm^{-3}$). Electrical conductivity was lowest in topsoil without SMS treatment and highest in topsoil with 200g SMS treatment ($0.45dsm^{-1}$). This was repeated for pH, total N, organic content, available phosphorus, exchangeable cations (Ca, Mg, K, Na). Exchangeable H and Al decreased with increasing SMS application rate. The lowest and highest H and Al were observed in topsoil only and topsoil treated with 200g SMS.

4.2. Effect of topsoil admixed with spent mushroom substrate on the growth and herbage yield of Amaranth

The effect of topsoil admixed with spent mushroom substrate (SMS) on the growth and herbage yield of Amaranth are presented in table 2. SMS application significantly ($p<0.05$) influenced plant heights at 4 – 8 weeks after sowing (WAS). The tallest plants were recorded in plants sown in topsoil media treated with 100g SMS which was similar with those sowed with SMS at 150g and 200g but significantly taller than plants raised with SMS at 0 and 50g at 4 WAS. At 6 WAS, topsoil only media had plants with the shortest heights while the plants with the tallest heights were recorded from topsoil media treated with 50g and 100g SMS. At 8 WAS, all SMS treated media had similar heights but significantly ($p<0.05$) taller than plants without SMS treatment.

Stem girth responded significantly ($p<0.05$) to SMS application. At 4 WAS, topsoil which received 100g SMS had plants with the widest stem which was similar with plants raised in media treated with SMS but significantly different from non-SMS treated plants. At 6 WAS, stem girth ranged within 0.83 and 2.22cm for plants grown in topsoil treated with SMS at 0 and 50g respectively. At 8 WAS, topsoil only media had plants with the thinnest stems while plants from topsoil treated with 150g SMS media had the widest stems which was similar with those treated with 50g SMS.

Number of leaves responded significantly to SMS application. Topsoil only media produced plants with the fewest number of leaves while those fortified with SMS at 100g had the most number of leaves at 4 WAS. At 6 WAS, plants from topsoil only had the fewest number of leaves while those from media treated with 50g SMS had the highest number of leaves which were similar with plants treated with 100 and 150g SMS. At 8 WAS, number of leaves ranged between 14.2 and 23.0 leaves of plants grown in media fertilized with 0 and 50g SMS respectively.

SMS application had significant effect on leaf area at 4 – 8 WAS. At 4 WAS, plants grown in media treated with 100g SMS had the largest leaf area (137cm^2) which were similar with plants grown in media treated with 50, 150 and 200g SMS but significantly higher than those from topsoil media. At 6WAS, plants from media treated with SMS at 50g had the largest leaf area (386cm^2) but similar with those produced from media treated with 100g SMS. Non-SMS treated media had the smallest leaf area (76cm^2). At 8 WAS, media without SMS treatment had the smallest area (76cm^2) while those treated with

SMS at 100g had the largest leaf area (475cm^2) which was significantly different from those recorded from plants treated with 50, 150 and 200g SMS.

Herbage yield responded significantly with SMS application. All media treated with SMS had similar herbage yield values but significantly higher than those produced from topsoil only media.

Table 1: Physical and chemical properties of topsoil admixed with spent mushroom substrate

SMS (g)	Particle size (g)			Porosity	Bulk density	EC	pH	Total N	Organic content	Available P		Exchangeable cation(cmolkg⁻¹)			EA(cmolkg⁻¹)	
	Sand	Silt	Clay	(%)	(g/cm³)	(dsm⁻¹)		(gkg⁻¹)	(gkg⁻¹)		Ca	Mg	K	Na	H	Al
0	889	58	53	51	1.0	0.3	5.75	0.64	10.8	8.11	0.8	0.24	0.23	0.13	0.2	0.12
50	884	60	56	50	1.0	0.35	5.81	0.73	15.4	11.2	0.84	0.30	0.28	0.15	0.16	0.07
100	884	65	53	45.2	1.1	0.38	6	0.8	17.6	13.6	0.90	0.40	0.24	0.18	0.11	0.05
150	875	65	60	45	1.2	0.38	5.09	0.84	16.6	12.0	0.85	0.35	0.30	0.16	0.12	0.05
200	868	64	68	43.8	1.2	0.45	6.08	1.22	20.0	18.5	1.10	0.43	0.36	0.20	0.10	0.04
LSD (0.05)	7.0	2.6	5.2	2.70	0.08	0.044	0.111	0.115	2.81	3.241	0.098	0.056	0.037	0.019	0.037	0.026

Key: SMS = Spent mushroom substrate, ns = not significant at 0.05 level of probability, EC = Electrical conductivity, EA = Exchangeable anions, Available P = Available phosphorus

Table 2: Effect of topsoil admixed with spent mushroom substrate on the growth and herbage yield of Amaranth

(g)	Plant height (cm)			Stem girth (cm)			Number of leaves/plants			Leaf area (m²)			Herbage yield (tha⁻¹))
	Weeks after sowing			Weeks after sowing			Weeks after sowing			Weeks after sowing			
	4	6	8	4	6	8	4	6	8	4	6	8	
0	11.4	17.2	27.9	0.91	0.83	1.5	9.78	9.2	14.20	50	76	186	3.10
50	12.7	33.4	36.4	1.04	2.22	1.94	10.78	15.3	23.0	96	386	377	7.60
100	17.3	30.1	37.8	1.33	1.61	1.53	14.56	14.6	18.9	137	306	475	10.90
150	15.1	26.6	35	1.22	1.67	2.03	12.22	14.9	18.1	117	225	411	11.10
200	14.4	22.7	27.4	0.98	1.25	1.44	12.33	12.7	14.5	110	260	373	9.10
LSD $_{(0.05)}$	2.94	5.51	7.6	0.265	0.303	0.379	1.603	2.35	3.28	50.9	130.6	204.4	3.81

SMS = Spent mushroom substrate

CHAPTER FIVE
DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1. Discussion

Findings from this study shed light on the potential benefits of incorporating SMS into topsoil for the cultivation of Amaranth. The physical properties was improved with the incorporation of SMS. The increase in silt and clay content with SMS application is an implication of improved soil texture, which can enhance water retention capacity and nutrient availability. This finding aligned with previous studies indicating that organic amendments enhanced soil aggregation and structure, thereby protecting the soil against compaction and erosion (Gupta *et al*., 2019). The observed increase in bulk density signified greater soil compaction following SMS incorporation, which may influence root penetration and overall plant growth. However, improvement of the media physical attributes minimized this effect. The elevation of electrical conductivity and pH levels indicated enhanced nutrient availability and soil buffering capacity, which are crucial for supporting plant growth (Khan et al., 2020). Changes in soil chemical properties further emphasize the positive impact of SMS on soil fertility. The rise in organic content, total nitrogen, and available phosphorus emphasized the role of SMS in supplying essential nutrients to plants, promoting vigorous growth and development. Moreover, the positive alteration in exchangeable cations suggested improved soil nutrient retention and ion exchange dynamics, contributing to sustained fertility over time.

The enhancement of growth parameters of Amaranth exhibited in response to SMS application is a demonstration of highlighting its efficacy as a soil amendment. The increase in plant height, stem girth, number of leaves, and leaf area signified enhanced vegetative growth through the application of SMS. These findings corroborate earlier studies demonstrating the stimulatory effects of organic amendments on plant growth attributes (Atiyeh *et al*., 2002). The observed variations in growth parameters across different SMS application rates underscored the importance of optimizing application levels to maximize plant performance while minimizing resource inputs. The substantial enhancement in herbage yield with SMS incorporation showed its role in augmenting crop productivity. The significant increase in yield across all SMS-treated media compared to the control signified the positive influence of SMS on crop biomass accumulation and nutrient uptake. This finding aligns with previous research indicating the beneficial effects of organic amendments on crop yield and quality (Bhat *et al*., 2018). Therefore, careful consideration of SMS dosage is imperative to ensure cost-effective and sustainable agronomic practices.

5.2. Conclusion and Recommendation

This present study has demonstrated SMS who ought to be a pollutant is utilized in this experiment as its improves soil fertility in the top soil which has undergone leaching and continuous cropping. The improvement of this media has been manifested in the plant height, stem girth, number of leaves and leaf area. This improvement in growth has resulted in increased production of assimilate which has resulted in increase in herbage yield of Amaranth. Though, the herbage yield was highest yield was 150 g of SMS admixed media, however it is similar to the media which that was added with 50g SMS.

Based on the outcomes of this study, topsoil treated with 50g of SMS per 3kg should be suggested for urban Amaranth cultivation. This application rate not only enhances soil fertility and physical properties but also promotes robust plant growth and yield. However, further research is warranted to investigate the long-term effects of SMS incorporation on soil health, crop performance, and environmental sustainability.

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