Plant Health 03 (01) 2024. 135-143 DOI: 10.33687/planthealth.03.01.5462

Available Online at EScience Press
Plant Health
ISSN: 2305-6835
https://esciencepress.net/journals/planthealth

Integrated Influence of Banana Pseudostem Scuture Waste Compost and Mineral Fertilizer on Growth and Yield of Chia (*Salvia hispanica*)

[a]Shaukat Ali Abro, [b]Dhani Bux, [c]Mumtaz Ali, [b]Shakeel Ahmed, [c]Shazia Parveen, [d]Juma Khan, [c]Hamz Ali, [a]Shahzeb Ali, [e]Sana Khokhar, [f]Sameer Ali, [g]Farkhunda Warsi

[a] *Department of Soil Science Sindh Agriculture University Tandojam Sindh, Pakistan.*
[b] *Department of Zoology Government College University Hyderabad Sindh, Pakistan.*
[c] *Water and Agricultural Waste Management Institute Tandojam Sindh, Pakistan.*
[d] *Social Science Research Institute, PARC Tandojam Sindh, Pakistan.*
[e] *Department of Biotechnology Sindh Agriculture University Tandojam Sindh, Pakistan.*
[f] *Department of Surgery FAHVS Sindh Agriculture University Tandojam Sindh, Pakistan.*
[g] *Faculty of Agriculture Social Sciences Sindh Agriculture University Tandojam Sindh, Pakistan.*

ARTICLE INFO

Article History
Received: March 19, 2024
Revised: April 22, 2024
Accepted: May 11, 2024

Keywords
Chia yield
Banana scuture waste compost
Recycling
Climate change

ABSTRACT

Integrated use of mineral fertilizers with organic sources like compost as a source of nutrients becomes more efficient in terms of boosting growth, increasing yield, and restoring soil fertility and soil health. A field experiment was initiated at the Medicinal Plants and Tobacco Research Institute (ARC) in Tandojam focusing on the cultivation of kalongi seed. The experiment was laid out in a Complete Randomized Block Design with six treatments with four replicates. The treatments were T1. Control T2, Compost+ 25% NPK, T3, Compost+ 50% NPK, T4, Compost+ 75% NPK and T6, Compost+ 100% NPK. The compost was uniformly applied in all treatments except control. The recommended dose of mineral fertilizer NPK (70: 30, 30, kg ha^{-1}) was applied. Before conducting of field experiment banana waste compost was prepared banana waste fiber extraction unit in the Department of soil science. Banana psuedotem after the fiber extraction scuture waste was collected and blended with sugarcane press mud at a ratio of (70% banana scuture waste+30% sugarcane press mud) to have optimum compost product. The banana scuture waste was applied at the rate of 5 tons ha^{-1}. The physicochemical properties of soil used for this Chia field experiment were slightly alkaline in reaction with EC 0.9 dSm^{-1}, respectively. The soil texture of the experimental soil was silty loam, EC (0.9 dm^{-1}), pH (6.0), OM% (2.7), N (0.25 %), P (25 ppm), K(36 ppm respectively. The results revealed that based on the mean, treatment T5 (Compost+ 100% NPK) applied had the maximum 127.54 cm plant height, 24.16 number of leaves plant^{-1}, 2.00 cm stem girth, 111.40 g fresh weight, 31.08 g dry weight and 31.10 g grain yield of chia crop. Parallel to this control treatment (farmer practice) had a minimum plant height 71.63 cm number of leaves plant^{-1} 14.31 stem girth 1.11, fresh weight 51.36g, plant dry weight 10.89 g, and grain yield 9.60 g plant^{-1}. Whereas T4 compost + 75% NPK resulted in maximum 116.47 cm plant height, 22.14 numbers of leaves plant^{-1}, 1.76 cm stem girth, 99.46 g fresh weight, 26.95 g dry weight, and 26.86 g grain yield. It was concluded T_4 was statistically and economically significant and had better results for all growth parameters and seed yield recorded in the experiment. It is suggested that growers should apply banana scuture waste compost @ 5 tons ha along with 75% recommended NPK fertilizer by reducing 25% of chemical fertilizer for chia yield, soil fertility soil health, and eco and environmental sustainability under changing climate.

Corresponding Author: Abro
Email: abro.shaukat@gmail.com

INTRODUCTION

Chia (*Salvia hispanica*) is a very important medicinal crop. Chia seeds contain proteins, vitamins, and some minerals. Besides this, Chia oil is today one of the most valuable oils on the market (Rashmi et al., 2024; Masa et al., 2019). Chia has recently been introduced in Pakistan as a superfood, but its production is affected by frost and weather extremes (Sana et al., 2020). The yield of chia is very low due to low organic matter and poor soil fertility (Khanyile et al., 2022; Karim et al., 2015). Further, the growers are only inclined to use chemical fertilizers which increases the cost of input in arable fields (Baboo, 2022; Bijay and Singh 2018). Sindh is the major banana producing province of Pakistan, contributing 93% of the national banana acreage (35000 ha. After fruit harvest large quantities of residues like banana stalks, pseudo stem, leaves, and trash are left over containing as much nutrients as the fruit harvested. Significant quantities of organic carbon and nutrients are traditionally disposed-off through landfills and dumped in soil or incinerated (Khokhar, 2019; Abro et al., 2023). (Banana brochure, 2018). The growers burn this waste CO_2 emissions and environmental pollution. However, after fiber extraction from psuedostem the rest of scuture waste could be recycled with manures to produce compost. Composting is a methodical process of breaking down organic materials, resulting in nutrient-rich humus that can be integrated into the soil. This enhances the activity of microorganisms and by maintaining the structure of the soil provides a good substrate for growth, and helps keep the plant healthy (Chew et al., 2019). It will enhance soil fertility and improve crop yields in the region (Wakeel et al., 2023). Utilizing banana waste compost reduces the environmental burden associated with waste disposal. This could also serve the soil health and crop growth Hashim et al., 2022). Integrating banana waste compost with mineral fertilizers can offer a synergistic effect, promoting optimal plant growth and yield (Brinton, 2018). The impact of such a combined application on Chia cultivation. However, like any other crop, Chia cultivation requires an optimal soil environment for robust growth and maximum yield.

Previously it was hypothesized that the composts made from banana waste many fibrous materials like cellulose lignin etc. However, in this method after the fiber extraction, the rest of the scuture waste is purely cleaned. Until now to our knowledge, no one has prepared compost from the scuture waste of banana plant pseudostem. This was our hypothesis to determine the optimum compost product after the extraction of fiber from banana pseudostem. The banana pseudostem scuture waste obtained the fiber extraction could be the best source of organic fertilizer rich in organic matter, and nutrients for plant growth and development. These nutrients contribute to the overall soil health water retention and development of Chia plants (Marschner, 2012). This approach aligns with the principles of sustainable and regenerative agriculture, addressing both waste-related concerns and contributing to global efforts to achieve food security while minimizing environmental impact.). Integrating banana waste compost with mineral fertilizers allows for a reduction in the dependence on synthetic fertilizers (Singh, 2019). This dual nutrient supply supports sustained growth throughout the crop cycle. The nutrient-rich soil resulting from the integrated approach can contribute to higher nutrient content growth of Chia seeds (Chaitanya et al., 2022). This study was therefore designed to a) prepare banana waste compost and its analysis for C and NPK b) evaluate the optimum rate of compost for maximum Chia yield and its effect on soil properties.

MATERIALS AND METHODS

Experimental site and study area

The research trial was carried out in the composting area, Department of Soil Science at Sindh Agriculture University Tandojam. The focus of the study involved the utilization of banana scuture waste (BSW) in combination with farmyard manure (FYM) for the composting process. In the experiment, a pile method of composting was employed. This method typically involves the layering and stacking of organic materials to facilitate the decomposition and transformation into nutrient-rich compost. Further, banana scuture waste and farmyard manure were blended in specific proportions and then deposited systematically to form compost piles. Farmyard manure was mixed with banana scuture waste, which included waste of the banana psuedostem after the fiber extraction. The blending of banana scuture waste with press mud ensured a balanced mix of carbon and nitrogen sources, crucial for achieving optimal composting conditions. The compost piles were carefully constructed to promote aeration and facilitate the microbial activity responsible for breaking down the organic matter into humus-rich compost. The Treatments included = T1 = BSW 90% +

FYM 10%, T2 = BSW 80% + FYM 20% and T3 = BSW 70% + FYM 30% replicated thrice. The compost was prepared by pile method.

Collection of materials

Banana psuedostems were collected from the farmers 'fields of local farmers in the vicinity of Tandojam. Concurrently, sugar cane press mud was sourced from Mehran Sugar Mills TandoAllahyar. The compost was carefully created in specially marked cemented piles that were on premises near the Greenhouses, Department of Soil Science at Sindh Agriculture University Tandojam. The dimensions of each compost pile were precisely measured to be 1 meter in width, 3 meters in length, and 1 meter in height (1x3x1m). This dedicated space served as the designated area for the controlled decomposition and transformation of organic materials into nutrient-rich compost.

Piles filling and compost turning

The scuture waste obtained from the banana plant psuedostem fiber extraction was systematically layered at the bottom of the compost pile in 9-inch increments. On top of this layer, farmyard manure was added in 3-inch layers. This alternating pattern of layering, consisting of FYM+BPSW, was consistently maintained until the compost pile reached its full capacity. Further, at intervals of 15 days, each composting material underwent a turning process, involving the transfer of the material to an empty pile. Throughout this period, the temperature of the composting material was regularly monitored, and if necessary, additional moisture was applied to maintain optimal conditions. This turning process persisted for 90 days, after which an additional month was dedicated to the stabilization of the compost. This meticulous approach aimed to ensure proper aeration, temperature regulation, and moisture content for the effective decomposition and maturation of the composting materials. After 90 days of composting period, samples of the compost were systematically collected from the pile, adhering to the methodology recommended by Manna et al. (2012). This approach ensured a standardized and scientifically sound method of sample collection for subsequent analysis and assessment of the compost's characteristics and quality.

Compost analysis

Furthermore, in the laboratory Department of Soil Science, the compost materials were allowed to air dry. A 2 mm stainless steel sieve was then used to filter the dried materials. Electrical conductivity (EC), pH level, total carbon content, C/N ratio, and NPK contents were among the parameters that were examined after the samples were processed.

Field experiment

A field research experiment was initiated at the Medicinal Plants and Tobacco Research Institute (ARC) in Tandojam, focusing on Chia seed cultivation. The optimal banana scuture waste compost product was selected for integration with mineral fertilizers in a Randomized Complete Block Design (RCBD) with three replicates. The application rate for compost was set at 5 tons per hectare, establishing a systematic and controlled approach for evaluating the impact of the compost on Chia seed growth and yield in the field trial. The variety grown was Maj. 17 with net field plot size: (3 m x 3 m (9 m^2).

Treatments

Six (6) T_1 = Control (without compost), T_2 = Rec. NPK (70: 30, 30, kg ha^{-1}), T_3 = compost + 25% NPK, T_4 = Compost + 50% NPK, T_5 = Compost + 75% NPK, T_6 = Compost + 100% NPK.

Plant attributes

A plant height (cm), leaves /plant, stem girth (cm), fresh weight (g), dry weight (g), grain yield (g).

Plant height (cm)

The height of the randomly chosen plants in each plot was measured from bottom to top at crop maturity. The average was calculated in centimeters.

Number of leaves plant^{-1}

Visual counting was used to determine the average number of leaves on various randomly chosen plants from each treatment.

Stem girth (cm)

Using a measurement tap on randomly chosen plants in each plot, the stem girth (cm) was measured at crop maturity, and the average was calculated in centimeters.

Fresh weight (g)

This method was typically used to estimate a plant yield, but it is also an accurate measure of fresh weight (g).

Dry weight (g)

This method was typically used to estimate a plant's yield, but it is also an accurate measure of dry weight (g).

Grain yield (g)

The grain yield (kg ha^{-1}) was calculated by using the followingformula: Grain yield plot^{-1} / Plot size (m) X 1000

Soil analysis

Soil samples were collected before sowing and the collected samples were analyzed for Texture, EC (dSm-^{1}), pH, C (%), and NPK.

Statistical analysis

The collected data from the field experiment, including the growth and yield parameters of Chia seed under different treatments, was subjected to statistical analysis using analysis of variance (ANOVA). The statistical software Statistix 8.1 was employed for this purpose.

RESULTS

Physicochemical properties

The physicochemical properties of the experimental soil are shown in Table 1. The soil of the Chia field experiment was slightly alkaline in reaction with electrical dSm^{-1} values of 0.9, respectively. The soil used in the trail has a pH value of 6.7, and the total C concentration was noted as 2.7, respectively. The soil C/N ratio was 25:1, the nitrogen concentration in the soil was 0.025% and the phosphorus (ppm) in the soil was 25, cm respectively, and the potassium concentration in the soil was 36, respectively.

Table 1. Soil physicochemical properties.

Treatments	Mean
EC dSm^{-1}	0.9
pH	6.7
Total C mg kg^{-1}	2.7
C/N ratio	25:1
Nitrogen (%)	0.25
Phosphorus (ppm)	45
Potassium (ppm)	136

The values are result of three replicates of the samples.

Plant vegetative attributes

Plant height (cm)

Table 2 provides information on the correlation between plant height (cm) and the various compost and NPK treatments applied to chia crops. The height of the plants (in centimeters) was statistically significant ($P<0.05$). According to the trial results, compost + 100% NPK produced the tallest plants (127.54 cm). Subsequently, the treatment involving compost + 75% NPK and compost + 50% NPK resulted in an average plant height of (116.47 cm and 105.50 cm). However, a significant reduction in plant height (94.67 cm and 83.50 cm) was noted with compost + 25% NPK and recommended. NPK (70: 30, 30, kg ha^{-1}), respectively. Whereas minimum plant height (71.63 cm) was observed with control.

Table 2. Plant height (cm) of Chai crop under different treatments.

Treatments	Plant height (cm)	Number of leaves $plant^{-1}$	Stem girth (cm)
T_1 = Control	71.63 F	14.31 F	1.11 F
T_2 = Rec. NPK (70: 30, 30, kg ha^{-1})	83.50 E	16.28 E	1.27 E
T_3 = Compost + 25% NPK	94.67 D	18.33 D	1.43 D
T_4 = Compost + 50% NPK	105.50 C	20.22 C	1.60 C
T_5 = Compost + 75% NPK	116.47 B	22.14 B	1.76 B
T_6 = Compost + 100% NPK	127.54 A	24.16 A	2.00 A

Number of leaves $plant^{-1}$

Table 2 presents the results on the number of leaves per plant as a function of the various compost and NPK treatments applied to the Chia crop. The data showed a statistically significant ratio ($P<0.05$). The experimental result shows that the maximum number of leaves $plant^{-1}$ (24.16) was recorded in compost + 100% NPK. Subsequently, the treatment involving compost + 75% NPK and compost + 50% NPK resulted in an average number of leaves $plant^{-1}$ of (22.14 and 20.22). However, a significant reduction in number of leaves $plant^{-1}$ (18.33 and 16.28) was noted with compost+25% NPK and recommended. NPK (70: 30, 30, kg ha^{-1}), respectively. Whereas the minimum number of leaves $plant^{-1}$ (14.31) were observed with control.

Stem girth (cm)

Table 2 presents the stem girth (cm) data for the Chia crop as influenced by the various compost and NPK treatments respectively.4. P<0.05 indicated statistical significance for stem girth (cm). According to the trial results, compost + 100% NPK produced the largest stem girth (2.00 cm). Subsequently, the treatment involving compost + 75% NPK and compost + 50% NPK resulted in an average stem girth of (1.76 cm and 1.60 cm). However, a significant reduction in stem girth (1.43 cm and 1.27 cm) was noted with compost + 25% NPK and recommended. NPK (70: 30, 30, kg.ha^{-1}), respectively. Whereas minimum stem girth (1.11 cm) was observed with control.

Yield attributes

Fresh weight (g)

Table 3 provides information on how the various compost and NPK treatments affected the fresh weight (g) of the chia crop. P<0.05 indicated that five new weights (g) were statistically significant. According to the trial results, compost + 100% NPK had the highest fresh weight (111.40g). Subsequently, the treatment involving compost + 75% NPK and compost + 50% NPK resulted in an average fresh weight of (99.46g and 87.57g). However, a significant reduction in fresh weight (75.39g and 63.37g) was noted with compost + 25% NPK and recommended. NPK (70: 30, 30, kg ha^{-1}), respectively. Whereas minimum fresh weight (51.36g) was observed with control.

Dry weight (g)

Table 3 presents data on the dry weight (g) of Chia crops as a function of NPK treatment and the various compost formulations. A statistically significant 6 dry weight (g) was found (P<0.05). According to the trial results, compost + 100% NPK had the highest dry weight (31.08g). Subsequently, the treatment involving compost + 75% NPK and compost + 50% NPK resulted in an average dry weight of (26.95g and 23.10g). However, a significant reduction in dry weight (19.05g and 14.87g) was noted with compost + 25% NPK and recommended. NPK (70: 30, 30, kg ha^{-1}), respectively. Whereas minimum dry weight (10.89g) was observed with control.

Grain yield (g)

The data regarding grain yield (g) as affected by the different compost and NPK treatments on Chia crop in relation to grain yield (g) is given in Table 3 grain yield (g) was statistically significant (P<0.05). The experimental result shows that the maximum grain yield (31.10g) was recorded in compost + 100% NPK. Subsequently, the treatment involving compost + 75% NPK and compost + 50% NPK resulted in an average grain yield of (26.86g and 22.53g). However, a significant reduction in grain yield (18.23 g and 13.86g) was noted with compost + 25% NPK and recommended. NPK (70: 30, 30, kg ha^{-1}), respectively. Whereas minimum grain yields (9.60g) were observed with control.

Table 3. of Chai crop under different treatments.

Treatments	Fresh weight (g) Mean	Dry weight (g)	Grain yield (g)
T_1 = Control	51.36 F	10.89 F	9.60 F
T_2 = Rec. NPK (70: 30, 30, kg ha^{-1})	63.37 E	14.87 E	13.86 E
T_3 = Compost + 25% NPK	75.39 D	19.05 D	18.23 D
T_4 = Compost + 50% NPK	87.57 C	23.10 C	22.53 C
T_5 = Compost + 75% NPK	99.46 B	26.95 B	26.86 B
T_6 = Compost + 100% NPK	111.40 A	31.08 A	31.10 A

DISCUSSION

It was inferred from the experimental results that soil utilized for the chia crop cultivation was significantly affected by the integrated use of banana pseudostem scuture waste compost chemical fertilizers. The optimum compost product is 70% banana scuture waste compost along with 30% farmyard manure. The soil was in pH with a value of 6.7, and total C concentrations were noted at 2.7, respectively. The results showed that compost + 75% NPK resulted in 116.47 cm plant height, 22.14 number of leaves plant^{-1}, 1.76 cm stem girth, 99.46 g fresh weight, 26.95 g dry weight, and 26.86 g grain yield. However, the control resulted in a minimum 71.63 cm plant height, 14.31 numbers of leaves plant^{-1}, 1.11 cm stem girth, 51.36 g fresh weight, 10.89 g dry weight, and 9.60 g grain yield. The results are further compared with the study of Saha & Mondal (2018) reported that banana waste compost is an eco-friendly and sustainable approach to managing the organic residues generated from banana cultivation and processing. The utilization of banana scuture waste compost for enhancing yield and quality of crops demonstrates its potential as a valuable organic amendment. The results are in complete agreement with the results found by Rashmi et al., (2024). Banana scuture waste compost provides a sustainable solution for the management of agro-waste, providing a rich source of nutrients for soil fertility soil health, and crop production. The references cited above underscore the importance of banana waste compost in sustainable agriculture, soil health improvement, and waste reduction, contributing to the broader concept of a circular bioeconomy (Subbarao & Chandran, 2020). The utilization of banana scuture waste compost can have several positive effects on quality enhancement and yield. The banana scuture waste, after fiber extraction in mechanical terms, is rich in organic matter and essential nutrients. Banana scuture waste is a good source of essential nutrients such as NPK micronutrients needed for crop growth. The composting banana scuture waste enhances nutrient availability in the soil, promoting healthy plant growth and development. The soil drainage, aeration, and moisture retention, the organic carbon in compost made from banana scuture waste solidifies the soil's structure and improves moisture retention. Organic matter decomposition, nutrient cycling, and prevention of disease all depend on these microorganisms for further process. The crop growth eventually benefits from the more favorable conditions this creates for microbial activity and root development. Banana scuure waste compost provides a habitat for beneficial soil microorganisms (Ramanathan & Nanthagopal, 2019). The results found in our study fully support the results observed in the research work by Baboo (2022).

It was observed that the addition of banana scuture waste compost to the soil helps in preventing soil health, fertility, and moisture retention for better chai crop growth and development. The increased organic carbon binds soil particles together, reducing the risk of soil salinity and low soil fertility. The use of banana scuture waste compost, including banana waste compost, can have suppressive effects on certain soil-borne pathogens and diseases fertility decrease in chia production (Abro *et al*, 2019). This can be attributed to healthier soil and crop by reducing the incidence of lowering soil fertility and soil health and vigor chia crop yield (Subbarao & Chandran, 2020). The integrated approach increases soil structure and moisture retention properties of banana waste compost and can enhance water and fertilizer use efficiency throughout crop production. Plants grown in compost-amended soil may require less irrigation, especially in areas with water scarcity (Pathak & Raizada, 2017). The integration of improved nutrient availability, soil structure, microbial activity, and disease suppression often leads to increased crop yields and better crop development. The growers can have increased productivity in terms of both quantity and quality of the harvested produce for better economical margins. Utilizing banana scuture waste compost is a sustainable waste management practice. This helps in recycling organic materials that might otherwise end up in landfills, contributing to environmental conservation and benefits. The results are in line with results found by (Khanlyie et al., 2024). The efficiency of scuture waste compost made from banana waste might differ based on several variables, including crop species, soil type, and composting techniques and novelty. Based on appropriate application rates and timing should be considered to maximize the benefits while minimizing any potential negative effects on chia crop development and vegetative growth. Furthermore, banana growers' farmers should conduct soil tests to determine specific nutrient requirements for their crops and adjust compost application accordingly (Kumar & Sharma, 2018). Further Selim (2020) reported that proper management of NPK fertilizers is essential to ensure an optimal balance of these nutrients in the soil, promoting healthy crop growth and maximizing yields. Appropriate nitrogen supply promotes robust vegetative growth, enhancing leaf and stem development. It is particularly crucial during the early stages of plant growth. Insufficient nitrogen can result in stunted growth, yellowing of leaves (chlorosis), and reduced overall plant vigor (Lammerts et al., 2017). Potassium is involved in various physiological processes, including water regulation, enzyme activation, and disease resistance. Adequate potassium promotes strong stalks, improves drought tolerance, and contributes to overall plant health. The scutre waste after fiber extraction from banana psuedsotem could be best for the compost preparation and overall crop development of chia and soil health Abro et al., 2023.

The application of banana scuture waste compost along with mineral fertilizers had positive effects on the soil properties, chia crop growth, and yield. The integrated effect of compost and mineral fertilizers may have a significant effect on crop yield. Further potassium which is a key element might have come from banana scture waste compost increases a plant's resistance to environmental stresses like drought and disease, which eventually results in increased yields for a better environment (Kuan et al., 2016) of soil. The specific nutrient requirements of different crops and soil conditions are crucial for tailoring NPK fertilizer applications to maximize crop growth and yield. Proper nutrient management practices contribute not only to agricultural productivity but also to sustainable and environmentally friendly farming (Shah and 2019). To increase crop output, nitrogen is essential. Applying the right amount of nitrogen is thought to be essential to producing an abundance of crops. Gosavi and associates. (2017). In many agricultural production systems, phosphorus (P) has been identified as the most deficient essential nutrient after nitrogen (N). Nutrient inputs into production systems have increased as a result of a heavy need for high-yielding crops to feed the growing population across the globe. Potassium is a 'workhorse' plant nutrient due to which it is not bound to any specific plant compound. This sentence is quite unclear and therefore difficult to understand. It should not be surprising that a shortage of potassium can result in the loss of crop yield, quality, and profitability Burhan and Taey (2018). The results are further endorsed by the research work of Khanylie *et al*., (2024).

CONCLUSION

From the present study, it is concluded that the combination of compost with 75% NPK fertilizer resulted in the optimum economical and sustained growth and yield parameters for the Chai crop. Therefore, it is recommended to use compost in combination with NPK fertilizer, with the proportion of NPK tailored to specific soil and crop requirements for optimal results. Farmers should consider using a balanced combination of compost and NPK fertilizer tailored to their specific soil conditions and crop requirements.

CONFLICT OF INTEREST

The authors affirm that the research was conducted without any commercial or financial affiliations that could be perceived as potential conflicts of interest.

REFERENCES

Abro, S. A., M. Fazal, G. Qadir, I. Shah, M. Gadehi and A. Abro.2019. Managing organic manures for carbon sequestration to improve soil health and sustained vegetable yield, *Pakistan Journal of Analytical and Environmental Chemistry*, 20 (1): 54-59.

Abro, S.A., I.H. Shah, A.A. Abro, G.Q. Shar and A.Q. Mahar. 2016. Nutritional survey and fertilizer management of banana cultivation in district Hyderabad. *Science. International* (Lahore), 28(3): 3079-3081.

Abro, S.A., Z.A. Channa, M. Gadehi, A.A. Abro and A. Samo. 2019. Preparation of Banana residue-based compost and its nutrient analysis. *Sindh University Research Journal of Science Series*, 51(03): 569-572.

Abubakar, A. M., Y. Luka, S. Abdullahi, P. Baboo and S.A. Kareem. 2024. NPK Biofertilizer Production from Banana Peel, Feather and Bone Ashes and their Comparative Advantage to 20: 10: 10. *Inorganic Fertilizer. Science, Engineering and Technology*, 4(1): 68-79.

Akbarabadi, A., D. Kahrizi, A. Rezaizad, G.H. Ahmadi, M. Ghobadi, M. Molsaghi. 2015. Study of variability of bread wheat lines based on drought resistance indices. *Biharean Journal of Biology*, 9(2): 88-92.

AL-Taey, D.K.A., J.C. Imad and B.H. Kshash. 2019. A study on effects of water quality, cultivars, organic and chemical fertilizers on potato (*Solanum tuberosum* L.) growth and yield to calculate the economic feasibility. *Bulgarian Journal of Agricultural Science*, 25(6): 1239 -1245.

Awan, B., M. Sabeen, S. Shaheen, Q. Mahmood, A. Ebadi and M. Toughani. 2020. Phytoremediation of zinc contaminated water by marigold (*Tagetes minuta* L). *Central Asian Journal of Environmental Science and Technology Innovation*, 1(3): 150-158.

Chaitanya, A., K. Murali, N. Devakumar, G.G. Eswarrao, S.R. Anand, T. Chikkaramappa and U. Ravindra. 2022. Evaluation of Different Organic Manures on Growth and Yield of Chia (*Salvia hispanica* L.). *International Journal of Environment and Climate Change*, 12(12): 560-568.

Chew, K.W., S.R. Chia, H.W. Yen, S. Nomanbhay and P.L. Show. 2019. Transformation of biomass waste into sustainable organic fertilizers. *Sustainability*, 11(8): 2266.

ElNour, M.E., A.G. Elfadil, F.A. Manal and B.A. Saeed. 2015. Effects of banana compost on growth, development and productivity of sorghum bicolor cultivar (Tabat). Journal: *Journal of Advances in Biology*, 8(2).

Gosavi, A.B., K.P. Deolankar, J.S. Chaure and D.A. Gadekar. 2017. Response of wheat for NPK foliar sprays under water stress condition. *International Journal of Chemical Studies*, 5(4): 766-768.

Guzmán, J. 2018. Banana plants (*Musa* spp.) from peel and pulp waste: Agronomic performance and efficiency for nutrient cycling. *Waste Management*, 72, 41-48.

Hashim, S., M. Waqas, R.P. Rudra, A. Akhtar Khan, A.A. Mirani, T. Sultan and M. Saifullah. 2022. On-farm composting of agricultural waste materials for sustainable agriculture in Pakistan. *Scientifica*, 2022.

Kadam, K. L. 2015. Chia (*Salvia hispanica* L.) seeds–research review. *International Journal of Scientific and Research Publications*, 5(3): 1-7.

Kammann, C., B. Glaser and H.P. Schmidt. 2016. Combining biochar and organic amendments. *Biochar in European soils and agriculture: Science and Practice*, 1, 136-60.

Karim, M.M, Md. Ashrafuzzaman and Md. Hossain. 2015. Effect of planting time on the growth and yield of chia (*Salvia hispanica* L.). *Asian Journal of Medicinal and Biological Research*, 2015, 1 (3): 502-507.

Khanyile, N., N. Dlamini, A. Masenya, N.C. Madlala and S. Shezi. 2024. Preparation of Biofertilizers from Banana Peels: Their Impact on Soil and Crop Enhancement. *Agriculture*, 14(11): p.1894.

Khokhar, M. S. 2019. Preparation and analysis of composts made from banana plant residues and animal manures. MSc Thesis submitted to Department of Soil Science, Sindh Agriculture University Tandojam.

Kim, D. Y., A. Kadam, S. Shinde, R.G. Saratale, J. Patra and G. Ghodake. 2018. Recent developments in nanotechnology transforming the agricultural sector: a transition replete with opportunities. *Journal of the Science of Food and Agriculture*, 98(3): 849-864.

Knez Hrnčič, M., M. Ivanovski, D. Cör and Z. Knez. 2019. Chia Seeds (*Salvia hispanica* L.): An overview—Phytochemical profile, isolation methods, and application. *Molecules*, 25(1): p.11.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, 7(5): 5875-5895.

Li, R., J. Hu, C. Hu, W. Su and C. Liu. 2017. Chemical changes of banana stalk during composting process and its microbial community structure. *Bioresource Technology*, 147, 188-195.

Manna, M. C., M.M. Rahman, R. Naidu, A.F. Bari, A. B. Singh, J.K. Thakur, A. Ghosh, A.K. Patra, S.K. Chaudhari and A. Subbarao. 2021. Organic farming: A prospect for food, environment and livelihood security in Indian agriculture. *Advances in Agronomy*, 170, 101-153.

Memon, M., K.S. Memon, S. Mirani and G.M. Jamro. 2012. Comparative evaluation of organic wastes for improving maize growth and NPK content. *African Journal of Biotechnology*, 11(39): pp.9343-9349.

Pathak, H. and A. Raizada. 2017. Banana peels: A novel approach for nutrient enrichment in soil—a review. *Journal of Environmental Science and Health*, Part B, 52(3): 188-197.

Ramanathan, S. and K. Nanthagopal. 2019. Circular economy approaches for banana waste management. *Journal of Cleaner Production*, 239, 118066.

Rashmi, T., M. Prasad BN, G. AS, S. TH and P. SV. 2024. Effect of Organics on Yield and Yield Components of Chia (Salvia hispanica L.). *Asian Journal of Soil Science and Plant Nutrition*, 10(2): pp.88-100.

Rathod, D. S. and A. Pandey. 2017. Composting of Banana Peels: A Sustainable Way of Recycling Fruit Waste. *Waste and Biomass Valorization*, 8(7): 2269-2277.

Saha, N. and D. Mondal. 2018. Effect of banana pseudostem and banana waste compost on yield and quality of tomato. *International Journal of Recycling of Organic Waste in Agriculture*, 7(4): 345-355.

Sarker, M., S. Choudhury, N. Islam, T. Zeb, B. Zeb and Q. Mahmood. 2020. The effects of climatic change mediated water stress on growth and yield of tomato. *Asian Journal of Environmental Science and Technology*, 1(2): 85-92.

Selim, M. M. 2020. Introduction to the integrated nutrient management strategies and their contribution to yield and soil properties. *International Journal of Agronomy*, 2020.

Shah, F. and W. Wu. 2019. Soil and crop management strategies to ensure higher crop productivity within sustainable environments. *Sustainability*, 11(5): 1485.

Shaukat, S., A. Idrees, A. Hanif, M. Munir, A. Maqbool, Q. Zara, S. Rasheed and S. Jameel. 2020. Foliar Application of Ascorbic Acid, H2O2 and Moringa leaf extract on Chia (*Salvia hispanica* L.) to induce terminal heat tolerance. *The International Journal of Biological Research* (tijobr) issn Online, 3 (2): 2618-1444.

Singh, R. P. 2019. Effect of integrated nutrient management on growth, yield, quality, and soil fertility in Chia (*Salvia hispanica* L.). *Industrial Crops and Products*, 137, 111-118.

Subbarao, P. M. and P. Chandran. 2020. Impact of banana waste compost on soil microbial activity and health. *Journal of Soil Science and Plant Nutrition*, 20(4): 1997-2006.

Wakeel, M., T. Hayat, N.S. Shah, J. Iqbal, Z.U.H. Khan, G.M. Shah and A. Rasool. 2023. Biogas Energy Resources in Pakistan Status, Potential, and Barriers. Utilities Policy, 84, 101643.