

RESEARCH ARTICLE



Formulation of optimum banana residue based compost product and its efficacy on maize and soil properties

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Abstract

Background/Objectives: Recycling banana residue in the form of compost presents good potential for carbon sequestration and improved nutrient supply. The main objectives of the study were to formulate a banana residue-based product and determine its impact on maize growth, nutrition and soil properties. **Methods:** Selected compost products (0+100, 50+50, 60+40 and 70+30 banana residue and farmyard manure) designated as CP-1, CP-2, CP-3, and CP-4) and four fertilizer rates (0, 1/3rd, 2/3rd and Full NP) were placed in a randomized complete block design with three replications, using maize as a test crop. Standard procedures were used for compost, soil and plant analysis. Total organic C and N in compost were analyzed on CHNS Analyzer and P and K by acid (1:5 HClO₄ - HNO₃) digestion, followed by quantification, correspondingly using spectrophotometry and emission spectroscopy. **Findings:** The banana residue had higher N (1.51%) and K (3.10%) than farmyard manure (1.24% and 0.9%) but it had relatively more P (0.5%) than banana residue (0.24%), The N (1.57-1.71%) and K (1.10-3.10%) contents of the compost products increased with the decrease in the quantity of farmyard manure and increase in banana residue, while, P decreased under the same scenario. Maize plants grew healthier with compost products or fertilizer treatments. This was reflected in the increase in mean shoot dry weights by 38.4% over control. Shoot N increased from 1.50-3.36%, P 0.29-0.51% and K 0.74-1.06% receiving compost products and NP fertilizers. There was no effect of compost products on EC or pH of soil. The soil organic matter (0.9-1.70%), and Olsen P (7.70-13.23 mg kg⁻¹) almost doubled, while, NH₄OAc-K (240-307 mg kg⁻¹) also increased by 30%. The co-composting of banana residue with farmyard manure narrowed the C: N ratio over individual materials, increased the nutrient concentration and growth of maize and enhanced the efficiency of NP fertilizer and increased the fertility of the soil. Based on physical appearance and properties, four compost products CP-1, CP-2, CP-3 equally. This study showed that banana residue could be beneficially composted with farmyard manure for improved yield and nutrition of maize. It is proposed that compost products should be evaluated under a natural soil environment. **Novelty/Applications:** Co-composting of

banana residue with farmyard manure is a new aspect of preparing compost products. A mixed blend of both materials, in the form of compost products, consisted of significant quantities of major nutrients like nitrogen, phosphorus and potassium.

Keywords: Banana residue; compost product; Maize; soil properties

1 Introduction

Chemical fertilizers have been a significant source of available nutrients and are a crucial integral part of modern technology for crop production. On average, fertilizer usage has increased to 197 kg NPK ha⁻¹ (1). Being a costly input, it is necessary that all available nutrient sources of plant origin are utilized and recycled. Therefore, the approaches for efficient, balanced and optimum use of fertilizers in conjunction with organic sources will play a vital role in achieving production targets.

Most of the Pakistani soils under cultivation are deficient in nitrogen, phosphorus and some in potassium (2,3). According to FAO (4), 94% farmers used NPK fertilizers, 32.6% farmyard manure, 1.6% micronutrients, 2.7% crop residues and less than 1% bio-fertilizers. Nonetheless, the usage of fertilizers and organic sources of nutrients varied according to the type, and value of the crop and the expected profit. In this connection, the banana residue being a nutrient-rich source has received the utmost attention of the farmer community. Sindh is the main banana-producing province, covering 87.65% of the total banana area (32.06 thousand ha) in the country (5). Banana growers generally rely on nitrogenous and phosphate fertilizers along with an intermittent application of farmyard manure. Entire plant biomass, containing as many nutrients as removed through fruit harvest and significant quantities of organic carbon is removed from the field after the harvest of bananas. It has been estimated that each ton of harvested banana, leaves two tons of banana waste behind (6). Thus the banana waste is one of the potential plant residues available to be utilized as a source of NPK and micronutrients for plant growth and development.

Farmyard manure is locally available and consists of animal droppings, beddings, and domestic sweep. About 50% of the animal dropping is not collected. Of that collected, about 50% is used as fuel. Thus, nutrients recycled to crops are about 1/4th of the total droppings (4,7). Farmyard manure contains approximately 70-80% of the nitrogen, 60-85% of the phosphorus and 80-90% of the potassium in the feed are excreted in the manure (8). Manure contains all the plant nutrients needed for crop growth including trace elements (7,9). It is estimated that one ton of dropping of cattle yield approximately 10 kg N, 16 kg P₂O₅ and 23 kg K₂O (10). Its value as a soil amendment can be increased through composting which is a biological process in which micro-organisms convert organic materials such as manure, sludge, leaves, paper and food waste into soil-like material called compost (11). In other words, it is a rapid breakdown of organic matter, which produces humus (12).

Recycling of banana residue in the form of compost, therefore, stands a good potential as a source for carbon sequestration in the form of organic matter and for improved plant nutrition. Composted materials are remarkably regarded for their ability to improve soil health and plant growth, and suppress pathogens and plant diseases (13). Compost applied as a soil amendment can improve the soil organic matter, water and nutrient retention in soil susceptible to leaching, and stabilize pH. Compost can be a source of both macro and micro-nutrients (14). This study was carried out with the main objectives to formulate an optimum blend of the banana residue by co-composting it with farmyard manure, conduct laboratory evaluation and determine the efficacy of the product on maize and soil properties.

2 Materials and Methods

2.1 Preparation of compost products

Unwanted suckers of 3-5-month-old banana (*Musa Cavendish*) plantations established at Agriculture Farm, Tando Soomro-Taluka Tando Allahyar were removed and chopped into 5 cm pieces. While farm manure was collected from the vicinity of the same fields. Seven soil-raised beds (6 inches thick, 6 ft long and 5 ft wide) were constructed as a composting platform (Figure 1 a). This exercise of making raised beds was done to avoid possible rainwater inflow into compost piles. The composting was done by pile method with pile size of 1 m³ that was confined in plastic-lined iron bar structure (Figure 1 b & c) with an open top. The banana residue was mixed manually with FYM as per treatment plan (Figure 1 d) and 75% volume of the container was filled with the mixture (Figure 1 e).



Fig 1. Formulation of compost products from banana residue and farmyard manure

In case of sole FYM and BR treatments, no mixing was done and the entire pile of 1 m³ was made from FYM (100% FYM) or from BR (100% BR). Water was sprinkled onto the compost piles to keep the mixture moist at about 50% moisture content to accelerate the decomposition process. Finally, the containers were covered with the same plastic sheet. Quantities of FYM and BR used to fill 75% volume of the composting bins are given in Table 1 for each treatment. The composting was continued for a period of 12 weeks from November 30, 2009 to February 22, 2010 when the composting process was completed i.e. when the core temperature of the material was similar to the ambient air temperature. During this period, composting material of each treatment was mixed three times after 2, 4, and 6 weeks of initiating the process in order to avoid excessive temperature buildup. The treatments involved mixing of BR with FYM in five different ratios (50-50, 60-40, 70-30, 80-20, 90-10), in addition to the treatments with 100% BR or 100% FYM. Treatment-wise filling of composting material is detailed under Table 1.

2.2 Laboratory evaluation of banana residue based compost

After completion of the composting process, the samples were taken from each treatment in duplicate, and processed for analysis. The materials (BR and FYM) used for composting were also sampled and all the pre- and post-composting samples were analyzed for total N, P and K, total organic C and C:N ratio. For total organic C and N, the samples were analyzed on CHNS Analyzer with the support of the National Center of Excellence in Analytical Chemistry, University of Sindh, Jamshoro. Total P and K were determined by wet digestion of the samples in 1:5 HClO₄ - HNO₃ acid, followed by analysis of the digests for P

Table 1. Treatment-wise weight of the BR and FYM added to the pile

S. No.	Treatment Details	Weight of banana residue (kg)	Weight of farm-yard manure (kg)	Total weight of pile (kg)
1	Compost (100 % FYM)	0	520	520
2	Compost (50% BR + 50% FYM)	216	260	476
3	Compost (60% BR + 40% FYM)	259	208	467
4	Compost (70% BR + 30% FYM)	304	156	460
5	Compost (80% BR + 20% FYM)	346	104	450
6	Compost (90% BR + 10% FYM)	389	52	441
7	Compost (100% BR)	432	0	432

by vanadomolybdophosphoric acid yellow color method, and for K on flame photometer. Based on these data and on physical appearance of the compost material, four of the seven treatments were selected for subsequent evaluation of the composted material in a pot experiment on maize.

2.3 Effect of banana residue based compost on maize

In this part of the study, a pot experiment was conducted to observe the effect of banana residue based compost on soil properties and dry matter yield using maize as a test crop. For this purpose, four compost products, chosen in Part 2 of the study, were used with and without the application of inorganic fertilizers.

Fertile soil (plough layer) collected from Latif Experimental Farm of Sindh Agriculture University Tandojam was air dried, ground, and passed through 4 mm garden sieve. Ten kilogram air dried soil was placed in each of 51 plastic pots. A sub-sample was saved for soil physico-chemical analysis. The treatments were a factorial combination of four compost products having farmyard manure and banana residue in the ratio of (100:0, 50:50, 40:60 and 30:70) designated as CP-1, CP-2, CP-3, CP-4 and 4 rates of mineral fertilizers (control, and 1/3, 2/3 and full recommended rate of NP), in addition to a complete control without any compost product and mineral fertilizer. The treatments were replicated thrice in a randomized complete block design. Nitrogen was applied as urea (46%N) in three splits at 1, 3 and 5 weeks after planting. The entire quantity of P was applied as single super phosphate (SSP, 20% P₂O₅) at the time of planting. In each case, the fertilizer was applied in form of solution, keeping in view solubility of each fertilizer. Each compost product applied at the rate of 12.5 tons ha⁻¹ was thoroughly mixed with soil. Ten seeds of maize variety Akbar were sown and each pot was irrigated. Few days after emergence, only five seedlings were maintained in each pot in such a way that every plant was far away from each other at equal distance. The pots were regularly irrigated by normal irrigation water.

Maize was grown for 9 weeks; and harvested after recording plant height for each treatment. Each plant sample was rinsed with distilled water and cleaned to make it free from dust particles and other contaminations. The samples were then dried in an oven at 68°C, weighed by each treatment, ground, and stored in plastic vials for N, P, and K analyses. The soil samples collected before and from each pot after harvesting of maize plants were analyzed for EC (Model Hi-8033) and pH (JENWAY Model 3010) in 1:5 soil-water extracts, total organic C by Walkley-Black method⁽¹⁵⁾, available P by Olsen method⁽¹⁶⁾ using spectrophotometer (Shamaduzu UV-1800, Japan) and available K by extraction with 1N NH₄OAc⁽¹⁷⁾ and analysis on flame photometer (Jenway PFP-7, Dunmow, Essex England).

The plant samples were analyzed for total N by Kjeldahl's method, P and K by wet digestion of the samples in 1:5 HClO₄ - HNO₃ acid, followed by the analysis of the digests for P by vanadomolybdophosphoric acid yellow color method, and for K on flame photometer. The data was statistically analyzed using the Statistix 8.1 software package.

3 Results

3.1 Nutrient composition and C: N ratio of composting material

The composting material i.e. farmyard manure and banana residue were considerably different in NPK content (Figure 2). The banana residue was a better source of K, containing three times more K (3.1%) over that present in farmyard manure (0.90%). While, the same composting material had 20% more N (1.51%) compared to that in farmyard manure (1.24%). While, farmyard manure was a better source of P, containing twice as much P (0.50%) as in banana residue (0.24%). The C:N ratios of the two

composting materials i.e. farmyard manure and banana residue were, correspondingly 21.67 and 25.41.

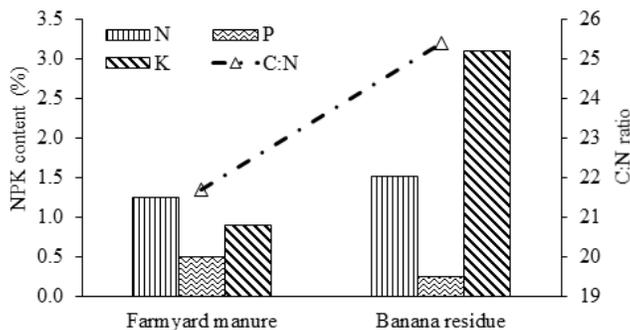


Fig 2. Nutrient composition and C:N ratio of the composting

3.2 Nutrient composition and C:N ratio of compost products

The data clearly illustrates about 50% reduction in C: N ratios of the composting materials i.e. farmyard manure and banana residue (21.67-25.41 to 12.67-15.32). This reflects upon the maturity of the compost products. Likewise, the nutrient contents had also undergone changes in accordance with the nutrients present in the two materials and their ratios used in preparation of the compost products (Figure 3). The nutrient contents i.e. N (1.57-1.71%) and K (1.1-3.1%) increased as the quantity of farmyard manure was decreased (100-0%) and quantity of banana residue was increased (0-100%). While, P content decreased (0.60-0.24%) with the decrease in quantity of farmyard manure and increase in quantity of banana residue.

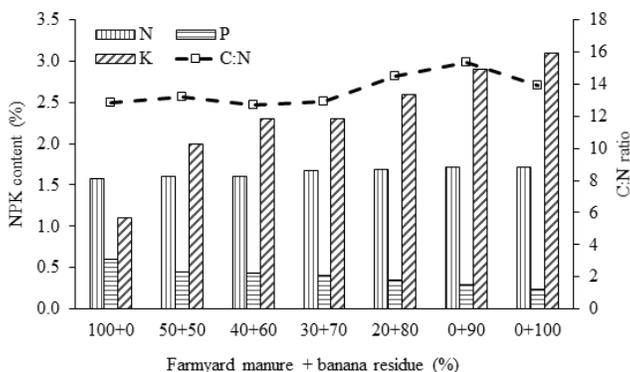


Fig 3. Nutrient composition and C:N ratio of compost products

3.3 Experimental soil

A pot study on the efficacy of prepared compost products on maize variety i.e. Akbar used silty clay textured soil with pH 7.76, EC 0.34 dS m⁻¹, Olsen P 9.86 mg kg⁻¹, NH₄OAc K 288 mg kg⁻¹ and organic matter 0.928%.

3.4 Efficacy of compost products on maize

Plant height: Height of maize plants increased from 71.36 cm to 87.33 cm with average value of 77.57 cm (Figure 4a). Plant height showed an increasing trend with compost products or chemical fertilizer application, nonetheless, the treatment differences of 9-week old maize plants were not large enough to be statistically significant (Table 2). Visual growth reflected healthier plants under chemical fertilizer or compost products. This was not reflected in plant height but it did increase plant dry weight as detailed in a subsequent section.

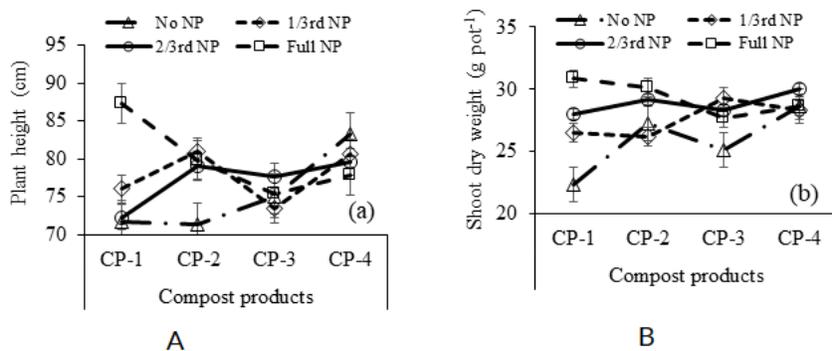


Fig 4. Plantheight (a) and shoot dry weight (b) of maize affected by compost products and NP application

Table 2. F values and significance from analysis of variance for plant height, shoot dry weight, shoot NPK content of maize and some soil properties i.e. EC, pH, organic matter, Olsen P and NH₄OAc-K of soil after the harvest of maize

Parameter	Control vs others	Compost products (CP)	Chemical fertilizer (NP)	CP x NP
Plant height	0.245 NS	1.885 NS	1.454 NS	1.821 NS
Shoot dry weight	17.122 **	0.874 NS	2.925 *	0.996 NS
Shoot N content	9.234**	3.245 *	0.228 NS	0.207 *
Shoot P content	45.753 **	2.053 NS	3.093 *	0.529 NS
Shoot K content	0.024 NS	1.327 NS	5.987 **	3.061 *
EC	0.006 NS	1.049 NS	0.998 NS	1.269 NS
pH	0.028 NS	0.312 NS	0.546 NS	0.598 NS
Organic matter	249.155 **	3.117 *	0.243 NS	2.907 *
Olsen P	49.459 **	2.358 NS	7.583 **	0.594 NS
NH ₄ OAc-K	2.847 NS	1.459NS	1.358 NS	0.426 NS

NS - non significant; * and ** - significant at 0.05 and 0.01 probability level according to honestly significant difference (HSD) test

Shoot dry weight : A highly significant increase in shoot dry weights was observed as a result of compost products and NP fertilizer rates. On average, shoot dry weight increased from 20.17 g pot⁻¹ under complete control (no compost no fertilizer) to 27.91 g pot⁻¹ for the compost products and chemical fertilizer. Although the overall effect of compost products and NP fertilizer rates was highly significant in increasing dry weights, the differences between various compost products were non-significant. Figure 4 b showed that the values varied within a narrow range from 26.92 to 28.91 g pot⁻¹. As for NP fertilizer, the dry weights increased significantly from 25.86 g pot⁻¹ under no fertilizer to 29.33 g pot⁻¹ under full NP (Table 2). This corresponded to an increase of 13.41% over and above the dry weight increase resulting from compost products. It is worth mentioning that increasing fertilizer rate beyond 1/3rd NP did not give a significant increase in shoot dry weight. The interaction between NP fertilizer and compost products was non-significant.

Nitrogen in maize shoot : Mean N content of complete control (no NP, no compost) was 1.50%. While, the treatments receiving compost products and NP, mean N content was more than double (3.36%). Increasing the rate of NP increased the N content of maize (3.23 to 3.49%), however, the differences between treatments were too small to be statistically significant (Figure 5 a, Table 2). This was not the case with the effect of compost products. The compost product involving banana residue as a part of the product performed significantly better than the compost prepared from farmyard manure alone. The mean values ranged from 3.02% to 3.59% (Figure 5 a). This effect of compost products and NP was independent of each other and thus the interaction between compost products and NP was non-significant.

Phosphorus in maize shoot : The mean value ranged from 0.29% for complete control to 0.51% for the treatments receiving compost and fertilizer application. The effect of different compost products was similar, and therefore non-significant from

each other but significantly higher as compared to the control not receiving compost. The values for different compost products ranged from 0.43 to 0.47% (Figure 5b). In the case of fertilizer treatments, total P contents increased from 0.43% for the treatment receiving no fertilizer to 0.47% with the recommended rate of NP (Figure 5b and Table 2). Each increment of NP fertilizer increased P contents until 2/3rd recommended rate, beyond which there was no significant increase in P content.

Potassium in maize shoot : Total K ranged from 0.74% to 1.06%, with a mean value of 0.90 as a result of compost products and NP fertilizer (Figure 5c). On average, unfertilized treatment contained 0.97% plant K which declined to a minimum of 0.83% at 2/3rd rate of NP application. However, the effect of various compost treatments was non-significant with the values ranging from 0.86% to 0.93%. Further, the data showed that the effect of fertilizer treatments was influenced by compost products. Thus, there was a significant interaction between compost and fertilizer treatments (Table 2). Comparison of the effect of NP by each compost product revealed a highly significant decrease only where compost product was used. No such decline in plant K was observed with compost products (i.e. CP-2, CP-3 and CP-4) indicating improved K supply to the plant.

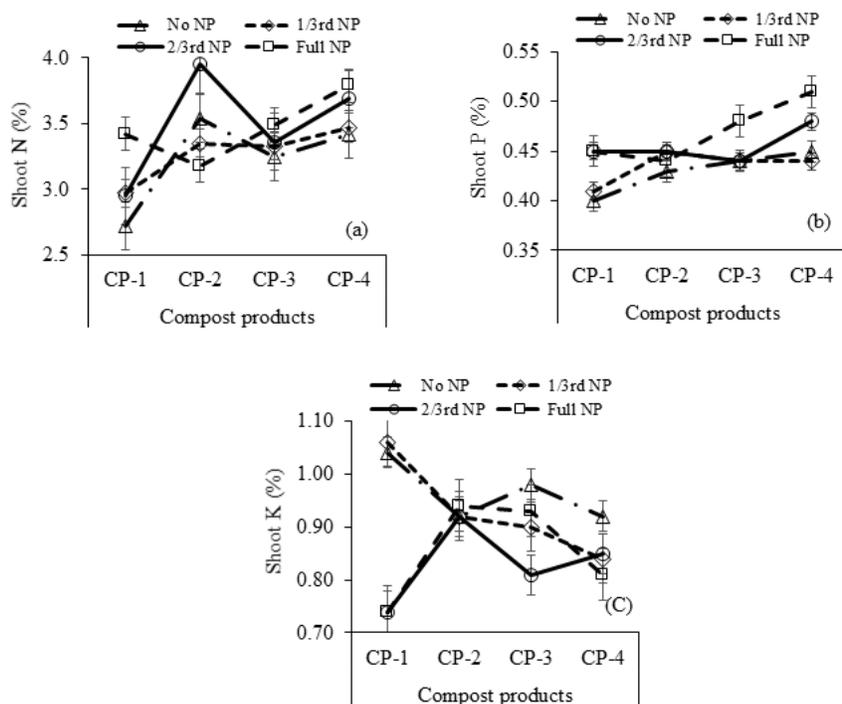


Fig 5. Nitrogen(a), phosphorus (b) and potassium (c) content in maize shoot affected bycompost products and NP application

3.5 Effect of compost products on soil properties

Figure 6 illustrates the effect of compost products on soil EC, pH, organic matter, Olsen P and NH₄OAc-K contents

EC and pH : Statistical analysis of the data indicated that there was no significant effect of either compost products or NP application on soil EC and pH. Similarly, the interaction between compost products and NP was also non-significant (Table 2). Soil EC values (Figure 6a) ranged from 0.26 to 0.80 dS m⁻¹ for various treatments, with average value of 0.50 dS m⁻¹. While, pH ranged from 7.8 to 7.9, with an average value of 7.9 (Figure 6b).

Organic matter : Organic matter in soil showed a highly significant increase as a result of the application of compost products and NP application (Table 1). The mean values ranged from 0.40% for complete control to 1.8% for the treatments receiving compost products and NP. The effect of various NP rates was similar, and therefore non-significant amongst (Table 2). The mean value ranged from 1.7% where no NP was applied to 1.8% with NP application. Unlike the effect of NP, the application of compost products contributed to a significant increase in soil organic matter (Figure 6c). The effect of compost products varied

with the nature of compost treatments as well as with the rate of NP, thus the interaction between compost products and NP was significant. The data revealed that compost product CP-1 (100% farmyard manure) and CP-2 (50% farmyard manure + 50% banana residue) were equally effective and contributed the most in increasing the level of soil organic matter. This effect of CP-1 and CP-2 compost products was similar and not affected by any NP rate. In case of compost products containing a higher percentage of banana residue i.e. CP-3 (60% banana residue + 40% farmyard manure) and CP-4 (70% banana residue + 0% farmyard manure), the interaction with NP was significant at a higher NP rate displaying higher soil organic matter contents as well.

Olsen P : Both the compost products and NP treatments were highly effective in increasing soil available P. The mean values almost doubled and ranged from 7.70 mg kg⁻¹ for complete control to 14.77 mg kg⁻¹ for the treatments receiving compost and NP. The effect of different compost treatments was similar, and therefore non-significant from each other but significantly higher as compared to the control treatment not receiving compost. This was not the case with fertilizer treatments where available P contents increased significantly from 13.23 mg kg⁻¹ for the treatment receiving no fertilizer to 16.12 mg kg⁻¹ when full NP was applied. The first increment of fertilizer i.e. 1/3rd NP did not significantly increase P contents in soil (Figure 6d). Increasing the fertilizer rate to 2/3rd NP or full NP produced a highly significant increase in soil P over control and 1/3rd NP. Further, the effect of 2/3rd NP and full NP was equally beneficial in improving soil P status. Further, the data showed that there was non-significant interaction between compost products NP (Table 2).

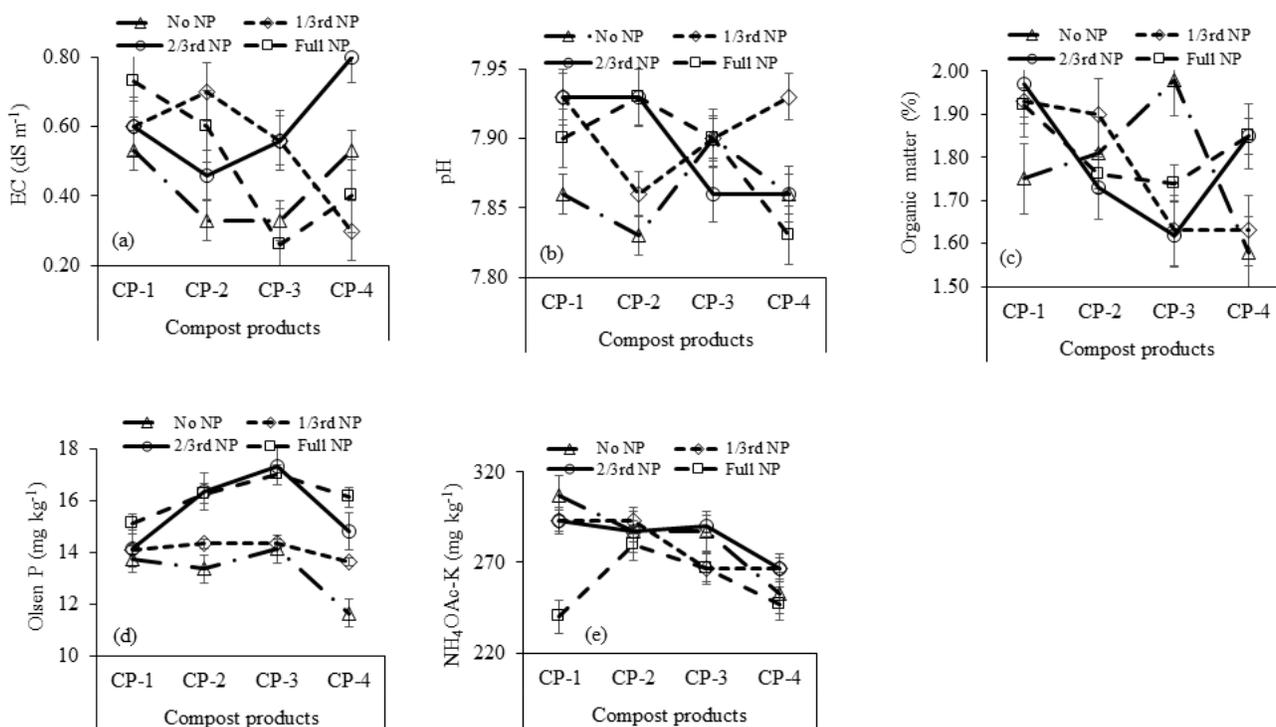


Fig 6. Soil properties EC (a), pH (b), organic matter (c), Olsen P (d) and NH₄OAc-K (e) after the harvest of maize affected by compost products and NP application

NH₄OAc-K : Available K ranged from 240 to 307 mg kg⁻¹ for various treatments, with an average value of 276 mg kg⁻¹. Statistical analysis of the data indicated that there was no significant effect of either compost products or NP on the available K content of soil. Similarly, the interaction between compost and fertilizer treatments was also non-significant (Figure 6 and Table 2).

3.6 Discussion

This study comprised of three parts i.e. preparation of banana based compost products by co-composting banana residue with farmyard manure, laboratory testing of compost products and greenhouse evaluation of selected compost products on maize as test crop.

The NPK content of farmyard manure (1.24%, 0.5% and 0.9%) and banana residue (1.51%, 0.24% and 3.1%) used in this study were correspondingly similar to the contents (1.4%, 0.29% and 2.1% and 2%, 0.2% and 3.8%) reported by⁽⁷⁾. The banana residue used in this study comprised of pseudostem and leaves of 3-5 month old suckers. The nutrient composition of banana residue will however, vary according to the plant part i.e. pseudo stem, leaf or both. Expressed on the basis of percent molar proportion, leaf blade (24.3%) has the highest lignin, followed by petioles/mid rib (18.0%) and pseudostem (12%). while cellulose is higher in pseudostem (34-40%), followed by mid rib (31.0%) and leaf blade (20.4%). Ash contents are higher in leaf blade (19.4%), followed by pseudostem (14%) and petioles/mid rib (11.6%). Considering nutrient contents, there is higher K (33.4%), followed by P (2.2%) and a very minor quantity of N⁽¹⁸⁾. On a percent basis, the N content of the composted products increased from 1.57 to 1.71 and K 1.10 to 3.10. Both the nutrients increased with the decrease in the quantity of farmyard manure and increase in banana residue. However, P contents decreased with the decrease in farmyard manure and an increase in banana residue. The findings⁽⁷⁾ were also in agreement with the results of this study. They reported an increase in NPK contents when banana stalks and leaves were converted into compost products. In the case of farmyard manure, they reported that both N and K decreased and P contents increased after compost formation. Research reports^(19,20) were also in support of our results. The studies utilizing banana residue with farmyard manure for preparing compost products are however scarce.

There was no effect of either compost or fertilizer treatments on plant height. However, the plants were healthier with the application of compost products or fertilizer treatments. This was reflected in an increase in mean shoot dry weights by 38.4% over un-amended complete control treatment. Unlike, plant height, shoot dry weights increased significantly from 25.86 g pot⁻¹ under no chemical fertilizer to 29.33 g pot⁻¹ with recommended NP, corresponding to 13.41% over and above the dry weight increase due to compost treatments. The N content of shoot was significantly influenced by compost products and fertilizer, while, P was influenced by later one and in the case of K, former and later, both did not have any significant effect. The treatments receiving compost products prepared from the mixture of farmyard manure and banana residue in 50:50, 40:60 or 30:70 ratios behaved similarly to the one where compost was prepared from 100% farmyard manure. These findings imply that banana residue co-composted with farmyard manure could be beneficially utilized for improved crop growth. Many studies have reported beneficial effects of combined⁽²¹⁾ or separate⁽²⁰⁾ use of the compost prepared from banana residue and farmyard manure on growth, nutrient content and quality of the outcome. The banana compost product based treatments outperformed the other treatments involving farmyard manure, poultry manure or wheat straw⁽²¹⁾. Composting improved the plant growth and nutrient contents of maize and that maize response was better with composted material than that with uncomposted one⁽⁷⁾.

One of the benefits of using compost products is that they consist of relatively stable decomposed organic matter, which results from the biological degradation of composting materials⁽²²⁾. The composted products have enhanced concentration of essential plant nutrients, narrow C: N ratio, better fertilizer use efficiency and yet improved properties of soil^(7,12). This study on the application of compost products highlighted no effect of compost or even chemical fertilizer on soil properties such as electrical conductivity or pH. On the other side, organic matter increased from 0.9% to 1.70%. The compost products i.e. 100% farmyard manure and 50% banana residue + 50% farmyard manure equally improved the organic matter of the soil, which further improved when chemical fertilizer was used with compost. Olsen P increased from 7.70 mg kg⁻¹ in control to 13.23 mg kg⁻¹ under compost products and chemical fertilizer increased it further, which shows the benefit of coupling the compost with NP fertilizer. The NH₄OAc-K was although not significantly influenced the values ranged from 240 to 307 mg kg⁻¹. Soil organic matter demand of agricultural soil can be fulfilled by applying more than 10 tons of compost ha⁻¹⁽²³⁾. Other studies have also supported the organic form of nutrients in the form of compost^(24,25). The compost rate of 12.5 tons ha⁻¹ used in our study is in accordance with the suggestion and also according to the organic matter content of Pakistani soils, which is generally <1.0% or even less^(26,27).

4 Conclusion

The co-composting of banana shoots with farmyard manure resulted in a narrow C: N ratio, enhanced NPK contents of composted products, and efficiency of inorganic fertilizer, ultimately maize growth, nutrient concentration and fertility of the soil. The compost products CP-1, CP-2, CP-3 were statistically similar and therefore could be further tested under field conditions.

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References

- 1) Fertilizer Review 2018-19. Publication No. 1/2019. Planning and Development Division, National Fertilizer Development Center. Islamabad. 2019.
- 2) Memon M, Akhtar MS, Memon KS, Stuben D. Phosphorus forms in the Indus River alluvial and loess, shale and lime stone derived alluvial soils. *Asian Journal of Chemistry*. 2011;23:1952–1962.
- 3) Ahmad N, Rashid M. Fertilizer and their use in Pakistan. *Government of Pakistan Planning and Development Division, National Fertilizer Development Centre, Islamabad*. 2004.
- 4) Fao. Fertilizer use by crop in Pakistan. Food and Agriculture Organization of the United Nations, Rome, Italy. Rome, Italy. 2004.
- 5) [5] Agriculture Statistics of Pakistan, Government of Pakistan, Ministry of Food and Agriculture (Economic Wing), Islamabad. Economic Wing. 2017-18.
- 6) Environment Leaflet. . Available from: http://www.bananalink.org.uk/1.5/images/stories/resources/environmentleaflet_2008.pdf.
- 7) Memon M, Memon KS, Mirani S, Jamro GM. Comparative evaluation of organic wastes for improving maize growth and NPK content. *African Journal of Biotechnology*. 2012;11(39):9343–9349. Available from: <https://dx.doi.org/10.5897/ajb12.004>.
- 8) Stephen HJ. Alternative use of manure. *Crops, Dairy, Livestock News*.3:1 . Amherst. Northeast Publications, University of Massachusetts. 1998.
- 9) Mashori NM, Memon M, Memon KS, Kakar H. Maize dry matter yield and P uptake as influenced by rock phosphate and single super phosphate treated with farm manure. *Soil Environment*. 2013;32(2):130–134.
- 10) Hussain T. Manures and Organic Wastes. In: Bashir E, Bantel R, editors. In: Elena Bashir and Robyn Bantel (eds.), *Soil Science*. Islamabad, Pakistan. National Book Foundation. 2001;p. 397.
- 11) Rynk RF. Northeast Regional Agricultural Engineering Service. In: and others, editor. *On-Farm Composting Handbook*. Ithaca, USA. Coop. Ext. N^oRAES-54. 1992.
- 12) Parr JF, Willson GB, Chaney RL, Sikora LJ, Tester CF. Effect of certain chemical physical factors on the composting and product quality, in proceeding of the national conference on Design of municipal sludge compost Facilities. Silver Spring, Maryland, USA. 1978;p. 130–137.
- 13) Ahmad R, Jilani G, Arshad M, Zahir ZA, Khalid A. Bio-conversion of organic wastes for their recycling in agriculture: an overview of perspectives and prospects. *Annals of Microbiology*. 2007;57(4):471–479. Available from: <https://dx.doi.org/10.1007/bf03175343>.
- 14) Obreza TA, Reeder RK. Municipal soil waste compost use in tomato watermelon successional cropping. *Proceedings of Soil Crop Science Society, Florida*. 1994;53:13–19.
- 15) Tahir H, Jabbar A. *Soil and Plant Analysis Manual - 3*. 1985.
- 16) Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (U.S. Department of Agriculture Circular No. 939). U.S; Washington, D.C. USDA. 1954.
- 17) Knudsen D, Peterson GA, Pratt PF. Lithium, Sodium and Potassium. In: and others, editor. In *Methods of Soil Analysis*. p. 199–224.
- 18) Mohapatra D, Mishra S, Sutar N. Banana and its by-product utilization: an overview. *Journal of Scientific and Industrial Research*. 2010;69:323–329.
- 19) Satisha GC, Devarajan L. Effect of amendments on windrow composting of sugar industry pressmud. *Waste Management*. 2007;27(9):1083–1091. Available from: <https://dx.doi.org/10.1016/j.wasman.2006.04.020>.
- 20) Doran I, Sen B, Kaya Z. The effects of compost prepared from waste material of banana plants on the nutrient contents of banana leaves. *Journal of Environmental Biology*. 2003;24(4):437–444.
- 21) Turemis N. The effects of different organic deposits on yield and quality of strawberry cultivar dorit (216). *Acta Horticulturae*. 2002;567:507–510.
- 22) Hussain T. Manures and organic wastes. In: Rashid A, Memon KS, editors. In: *Soil Science*. Islamabad. National Book Foundation. 2000.
- 23) Amlinger F, Peyr S, Geszti J, Dreher P, Karlheinz W, Nortcliff S. Beneficial effects of compost application on fertility and productivity of soils. In: *Literature Study*, Federal Ministry for Agriculture and Forestry, Environment and Water Management. Austria. 2007.
- 24) Memon KS, Jarwar AJ, Memon M, ul hassan Z. Development of a correction factor to account for the effect of temperature on Olsen's soil Phosphorus. *Communications in Soil Science and Plant Analysis*. 2009;40(1-6):141–149. Available from: <https://dx.doi.org/10.1080/00103620802625492>.
- 25) Memon M, Jamro GM, Memon N, Memon KS, Akhtar MS. Micronutrient availability assessment of tomato grown in Taluka Badin, Sindh. *Pakistan Journal of Botany*. 2012;44(2):649–654.
- 26) Zhang J, Li B, Zhang J, Christie P, Li X. Organic fertilizer application and Mg fertilizer promote banana yield and quality in an Udic Ferralsol. *PLOS ONE*. 2020;15(3):e0230593. Available from: <https://dx.doi.org/10.1371/journal.pone.0230593>.
- 27) Corato UD. Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: A review under the perspective of a circular economy. *Science of The Total Environment*. 2020;738:139840–139840. Available from: <https://dx.doi.org/10.1016/j.scitotenv.2020.139840>.