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ORIGINAL RESEARCH

Relative performance of various composts and NPK fertilizer on upgrowth and quality of fodder maize

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Abstract

Purpose Shortage, high prices and adverse effects of fertilizers drive to hunt alternative sources (such as compost) for crop husbandry and environment sustainability. A field trial was executed to observe the effect of various composts on growth and macronutrients' concentration in fodder maize (*Zea mays* L. cv. Akbar).

Method The treatments with four repeats included: Control (No amendment), Recommended NPK, Water hyacinth compost, Fruits + vegetables compost, and Banana leaves compost; each compost was supplemented at the rate of 15 tons ha^{-1}. The experimental soil was fine textured (clayey), slightly alkaline in reaction, non-saline, poor in organic matter content, calcareous in nature, low in nitrogen, marginal in phosphorus and adequate in potassium.

Results The supplementation of composts and NPK fertilizer significantly increased the growth and yield parameters (plant height up to 26%, number of leaves plant^{-1} up to 20%, stem girth up to 22%, and fresh weight of maize fodder up to 25%), and the concentrations of selected macronutrients (N up to 46%, P up to 27%, and K up to 38%) in maize leaves with respect to control. There was no significant variation among various compost treatments and NPK fertilizer application for defined parameters, except for P concentration in maize leaves. A significant enhancement in macronutrients' concentrations in surface and subsurface soil, over control plots, has also been observed where inorganic and organic applications were made.

Conclusion We conclude that compost should be included in maize husbandry for enhanced productivity and quality and to minimize the dependence on inorganic fertilizers.

Keywords Composting, Inorganic fertilizers, Maize productivity and quality, Organic waste management

Introduction

Municipal solid waste (MSW) has become a critical issue worldwide because of increase in human population, economic growth, urbanization, and change in lifestyle (Al-Khatib et al. 2010; Thi et al. 2015; Akmal and Jamal 2021). The generation and composition of the MSW is variable among developed and developing countries; High-income countries usually generate less organic waste and more recyclable waste, whereas in low-income countries majority of the MSW (65%) is organic in nature (Al-Khatib et al. 2010; Colon et al. 2010). Food waste comprises the main fraction (50-55%) of the total municipal solid waste in developing nations (Thi et al. 2015).

In Pakistan, no comprehensive study is available which describes the municipal solid waste generation, collection, composition and disposal data for the entire country or most of its regions. However, some studies are carried out which describe the practices of solid waste management in few major cities or towns of a particular city (Mahar et al. 2007; Batool and Chaudry 2009; Aslam et al. 2021). These studies describe that the municipal solid waste generation is variable within cities (Mahar et al. 2007), ranging up to 15,600 metric tons per day in Karachi, the largest city of Pakistan (Aslam et al. 2021). The collection rate of solid waste is different among cities, ranging from 51% to 75%

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(Mahar et al. 2007; Masood et al. 2014; Aslam et al. 2021). Sadly, no city has official material recovery, recycling and disposal facility and/or an integrated solid waste management system (Mahar et al. 2007; Masood et al. 2014; Aslam et al. 2021); therefore, the collected waste is dumped in open spaces (Batool and Chaudry 2009; Korai et al. 2017). The uncollected waste remains lying in vacant plots, along streets, roads and railway lines, open drains, and low-lying areas within the city vicinity (Batool and Chaudry 2009). This open dumping of waste leads to the production of compounds which can pollute the environment and underground aquifer (Anikwe and Nwobodo 2002; Nagendran et al. 2006; Buteh et al. 2013; Hassan et al. 2021), ultimately affecting the wellbeing of humans (Akmal and Jamil 2021). Collection and disposal of waste also incurs a huge amount of money; for example, a cost of 3.2 million dollars was estimated for only collection and disposal of waste in a town of Lahore (Batool and Chaudhry 2009). The characterization of the collected solid waste indicates that the largest proportion (67%) of the waste is organic in nature (Batool and Chaudry 2009; Jadoon et al. 2014), with no defined data for food waste proportion. This organic waste should be considered as a valuable resource and convincing strategies should be adopted in the country for its efficient utilization.

Many countries have adopted such techniques of waste management, which are eco-friendly and can recycle waste into valuable product, such as producing energy, organic fertilizer and compost (Evangelisti et al. 2015, Thi et al. 2015; Tumwesigye et al. 2016; Saleh 2021). Composting is an eco-friendly method of recycling organic wastes (Courtney and Mullen 2008; Pellejero et al. 2017; Alsri et al. 2018). Composting is a bio-oxidative process, which involves the mineralization and humification of organic waste resulting in a stabilized product having humic properties and free from pathogens and phytotoxicity (Bernal et al. 2009). Composting is a versatile technique for converting organic waste into soil amendment (Gajalakshmi and Abbasi 2008; Sayara et al. 2020). High prices of inorganic fertilizers and their negative impacts on agriculture sustainability grow interest in converting organic municipal solid waste into compost which can enhance soil fertility and health, and crop productivity (Mahajan et al. 2008; Giannakis et al. 2014; Pellejero et al. 2017; Zahra et al. 2021). Compost application can contribute to agricultural sustainability through enhancing organic matter content, water retention capacity, soil aggregation, nutrient availability, biomass production, microbial activity, and reducing soil bulk density and plant pathogens (Wells et al. 2000; Montemurro et al. 2006; Gajalakshmi and Abbasi 2008; Doan et al. 2015; Miller et al. 2015). The application of composts is also involved in reducing gases' emission and leaching of N from soils (Dalal et al. 2009; Dalal et al. 2010; Vaughan et al. 2011) and remediating the soils contaminated with hazardous materials and excess salts (Hanay et al. 2004; Sayara et al. 2020). Hence, it is urgently required to adopt this approach of composting for crop husbandry.

Current study is an effort to recognize the impacts of various composts on a test crop, maize (*Zea mays* L.) in the agro-climatic conditions of Tando Jam, Pakistan. Maize has been selected for this study because the crop mainly relies on commercial fertilizers for its production (Arif et al. 2012). Maize has also its role as a source of food for humans, fodder for animals and raw material for industries because of its broad global distribution, low price, diverse grain types and biological and industrial properties (Dowswell et al. 1996; Kumar et al. 2014). Maize is an important cereal crop, and it ranks 2nd in production in the world while ranks 3rd in Asia after rice and wheat (Dowswell et al. 1996; FAOSTAT 2019). In Pakistan, maize is grown over 1318 thousand hectares with an annual production of 6309 thousand tons (Pakistan Economic Survey 2018-19). However, the potential yield of maize crop is still below when compared to yields in other countries (Farhad et al. 2009). The major factors associated to lower yields of maize are low fertility status of soils and inappropriate fertilization (Oad et al. 2004). Considerable work has been done overseas where the effect of various composts (individually or in combination with inorganic fertilizers) has been considered on maize crop and enhancement in growth and yield components, and nutrient concentrations have been documented (Rahman et al. 2013; Abdulraheem et al. 2018; Olowoake et al. 2018). Additionally, the improvement in soil physical parameters, nutrient contents and microbial biomass has also been reported by compost and compost + inorganic fertilization (Adediran et al. 2005; Ahmad et al. 2008). In Pakistan, the effect of compost (individually or in combination with various inorganic fertilizers) is quantified and increase in growth and yield components in maize, and soil physical and chemical parameters have been documented (Amanullah et al. 2015; Bilal et al. 2017; Iqbal et al. 2019; Zahra et al. 2021).

The present study is unique in a sense that three different organic wastes (Water hyacinth plants, Fruits and Vegetables waste, and Banana leaves) having diverse origins were converted to compost and utilized to compare their efficiency with recommended NPK fertilizer for maize production. The effectiveness of these wastes on maize productivity and quality will encourage their usage for crop husbandry in Pakistan and globally. Additionally, the assessment of quality of maize tissues and fertility of amended soils (with respect to NPK) as a function of organic-and-inorganic amendments in current study will add data to limited scientific inventory (Adediran et al. 2005; Bharath et al. 2017; Zahra et al. 2021). Hence, the present study was carried out to assess the impacts of various composts and NPK fertilizer on the growth and NPK concentration in maize plants and their subsequent buildup in soil.

Materials and methods

Experimental details

The experiment was laid out using randomized complete block design at Latif experimental farm of Sindh Agriculture University (SAU) Tandojam (Latitude 25°44'40" N and longitude 68°53'91" E), during Rabi season 2017-2018. The climate of the study area is generally arid to subtropical, where summers are moderately hot, and winters are cool. Such type of climate is generally preferred for maize cultivation. A total of 396 m^2 land was selected, which was ploughed, levelled and then divided in to 20 equal experimental units of 16 m^2 (4 m × 4 m). The treatments comprised of different organic and inorganic amendments with four replication each: T1: Control (No amendment), T2: Recommended NPK (130 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}), $T_{3:}$ Water hyacinth compost (15 tons ha^{-1}), T_4: Fruits + vegetables compost (15 tons ha^{-1}), and T_5: Banana leaves compost (15 tons ha^{-1}). The seeds of maize (cv. Akbar) were purchased from local market, presoaked for overnight and sown using hand drill. The irrigation and agronomic practices were kept same for all plots. The experiment was terminated before the initiation of flowering (90 days after sowing).

Amendments application

The inorganic amendment was applied as suggested by Gandahi (2010). Full dose of P and a fraction of N was applied as DAP, while full dose of K was supplied as SOP during land preparation. Remaining portion of nitrogen was applied as Urea at the time of second irrigation. The soil was amended with composts during land preparation. During land preparation, the calculated amounts of composts were spread on the soil by the hand, followed by ploughing and levelling. The composts used in this study were prepared locally at the Department of Soil Science, SAU Tandojam. Three different composts having diverse organic materials (Fruits and vegetable, Banana leaves and Water hyacinth plants) were collected from the vicinity of Tando Jam. Before filling in the pit, the banana leaves, and fruits and vegetables wastes were chopped into small pieces (< 1 inches) while the plants of water hyacinth were air dried for three days. These organic wastes were blended with cattle manure in 3:1 (9 inches layer of organic wastes and 3 inches layer of cattle manure: called one-unit layer); in total 4-unit layers were developed. Each waste was turned regularly on 15 days interval, and on each turning, temperature was recorded, and the waste was moistened, if necessary. The wastes were processed for three months, followed by one month for stabilization and drying.

Plant observations and analysis

Agronomic observations

Nine healthy plants were chosen from each replication plot for recording agronomic observations at the time of harvest. Plant height was taken from the base to the tip of the plant by measuring scale. The leaves per plant were counted manually. Stem girth of selected plants was taken from 4 inches above soil using Vernier caliper (Tricle Brand, China). The fresh weight of plants was taken using digital weight balance in kilograms (Accurate, Model No. TCS-80). This mass was converted to tons per hectare.

Plant analysis

At harvest, the uppermost fully developed leaf (the leaf with collar visible) was collected (as suggested by Schwab et al. 2007), for nutrient analysis. The samples were cleaned and washed with 1% HCl, followed by rinsing with distilled water. Afterwards, the samples were oven dried at 70 ^{0}C for 48 hours and ground in mechanical grinder (Retsch GmbH mill, West Germany).

Nitrogen concentration in plant tissues

The N concentration was determined by the method delineated by Estefan et al. (2013). In brief, plant samples were digested using catalyst mixture 100:1 (K_2SO_4-Se) and concentrated sulfuric acid, followed by distillation with 40% NaOH, and titration with 0.1 N HCl till the navy blue color appeared.

Phosphorus and Potassium concentrations in plant tissues

Phosphorus and potassium in plant tissues were determined by Wet digestion technique, as outlined by Estefan et al. (2013). In brief, plant materials were digested with di-acid mixture (HNO_3-$HClO_4$, 2:1) using hot plate. The samples were cooled, filtered and their volume was raised to 50 ml by adding distilled water. The samples were determined for phosphorus using Spectrophotometer at the wavelength of 480 nm, while the determination of potassium was carried out using Flame Photometer.

Soil sampling and analysis

The composite samples were taken before sowing and after crop harvest from each replication plot at desired depths (0-15 and 15-30 cm) using stainless steel auger. The EC and pH were determined in 1:2.5 soil water extracts using EC meter (Sartorius PB-11) and pH meter (Schott Lab 960). The texture, organic matter and lime content, and available P and K contents were determined by following the procedures outlined by Estefan et al. (2013). In brief, for texture, the Bouyoucos Hydrometer technique was adopted. The defined amount of soil, sodium hexametaphosphate and distilled water was mixed and left for overnight. After dispersion, transfer and insertion of hydrometer, the reading was recorded at prescribed times to determine the amount of soil particles and textural class. For organic matter content, the specified amount of soil was added with proposed amount of potassium dichromate and sulphuric acid and left for overnight. Next day, with defined amount of distilled water, orthophosphoric acid and diphenylamine indicator, the samples were titrated with ferrous ammonium sulphate until color switched to brilliant green. In case of lime content, one gram of soil was added with ten ml HCl, and samples were allowed to stand for overnight. Next day, the stuff was added with prescribed amount of distilled water and phenolphthalein indicator, followed by titration with sodium hydroxide until the color switched to light pink. Phosphorus and potassium concentration in samples were analyzed by AB-DTPA method, for which ten grams of soil along with twenty ml of AB-DTPA solution was shaken, filtered and used for analysis of P and K. The concentration of P was determined using Spectrophotometer while the concentration of K was determined using Flame photometer. The soil nitrogen content was calculated from soil organic matter.

Statistical analysis

The soil and plant data were subjected to ANOVA using Minitab 17 software. The difference among treatments was assessed by Tukey's test at 0.05 *P* value.

Results and discussion

Physico-chemical properties of soil before sowing of maize fodder

The physico-chemical characteristics of the experimental site, before sowing, indicate that the soil at the depth of 0-15 and 15-30 cm was clay and sandy clay in texture, slightly alkaline in reaction (pH 7.65 ± 0.09 and 7.68 ± 0.09), non-saline (EC 1.24 ± 0.15 dS m^{-1} and 1.05 ± 0.12 dS m^{-1}), poor in organic matter content (0.78 ± 0.08% and 0.76 ± 0.03%), calcareous in nature (15.4 ± 0.66% and 16.4 ± 0.83%), low in total nitrogen concentration (0.039 ± 0.004% and 0.038 ± 0.002%), marginal in available phosphorus concentration (5.40 ± 0.60 mg kg^{-1} and 5.00 ± 0.36 mg kg^{-1}) and adequate in available potassium concentration (202 ± 35.6 mg kg^{-1} and 190 ± 10.0 mg kg^{-1}), respectively.

Effects of organic-and-inorganic amendments on growth and yield of maize fodder

Growth and yield attributes of maize fodder were significantly influenced by the application of inorganic NPK and various composts ($P<0.05$, Table 1). The supplementation of inorganic NPK and organic composts were found equal for enhancing growth and yield parameters (plant height, number of leaves, stem girth and fresh weight). The application of amendments increased plant height of maize fodder from 24.9 to 25.9%, number of leaves $plant^{-1}$ from 13.9 to 20.4%, stem girth from

16.1 to 22.5%, and fresh weight from 22.2 to 25.4% over control plants. The possible reason for increase in growth and yield parameters of maize fodder may be associated with the presence and availability of macronutrients (e.g., N, P, and K) from organic and inorganic sources and the subsequent accumulation of these nutrients by maize crop (Table 2). These nutrients play an important role in many physiological processes involved in the growth and development of plants (Inam-ul-Haque and Jakhro 1996; Bharath et al. 2017; Pellejero et al. 2016). Higher growth and yield of maize crop with organic and inorganic amendments over control may also be associated with better physiological attributes (e.g., stomatal conductance, transpiration rate, photosynthesis, and chlorophyll content) in plants (Tabbasum et al. 2021). The positive effect of organic and inorganic amendments on growth and yield components of maize has been reported by many researchers. For example, Masowa et al. (2015) reported that application of NPK fertilizer and various composts significantly increased plant height, stem diameter, number of functional leaves plant^{-1}, and dry matter yield over control treatment. In another study, Sallah et al. (2017) observed that the maize height, number of leaves plant^{-1} and stem girth were relatively better in organic and inorganic treatments than control treatment.

Table 1 Effect of soil amendments on growth and yield characters of maize fodder

Treatments	Plant height (cm)	Number of leaves plant^{-1}	Stem girth (cm)	Fresh weight (t ha^{-1})
Control	130.2 ± 6.6 ^{B}	10.8 ± 0.18 ^{B}	3.29 ± 0.09 ^{B}	22.08 ± 1.13 ^{B}
NPK	163.9 ± 5.4 ^{A}	13.0 ± 0.32 ^{A}	3.99 ± 0.12 ^{A}	27.59 ± 1.05 ^{A}
Water hyacinth compost	163.5 ± 5.6 ^{A}	12.8 ± 0.54 ^{A}	3.88 ± 0.10 ^{A}	26.99 ± 0.68 ^{A}
Fruits + vegetables compost	162.6 ± 4.4 ^{A}	12.6 ± 0.14 ^{A}	3.82 ± 0.13 ^{AB}	27.70 ± 033 ^{A}
Banana leaves compost	162.8 ± 6.8 ^{A}	12.3 ± 0.44 ^{A}	4.03 ± 0.16 ^{A}	27.65 ± 0.94 ^{A}

Each value is a mean ± SE (*n*=4); Means followed by different capital letters are significantly different from each other ($P < 0.05$) with respect to soil amendments.

In current study, there was no significant difference for selected growth and yield parameters in maize between compost treatments and NPK fertilization. These results are very promising with respect to compost application and offer a viable alternate to expensive inorganic fertilizers. A comparable growth and yield of maize with various composts to inorganic fertilizer may be credited to additional benefits of compost application which include improved total microbial biomass, organic matter content, availability of essential macronutrients, aggregate stability, permeability and water retention capacity of the soil (Adediran et al. 2005; Ahmad et al. 2008; Aziz et al. 2010). Earlier studies have reported a variable outcome of organic and inorganic supplementation on maize productivity. A better growth and yield of maize has been reported in organic amendments when compared with the inorganic fertilizers (Rahman et al. 2013; Bilal et al. 2017; Sallah et al. 2017; Olowoake et al. 2018). In contrast, inorganic sources have also found superior for maize growth and yield over organic sources (Kanton et al. 2016). Nonetheless, other studies recommend a combined application of organic and inorganic amendments for maximizing the maize growth and yield (Iqbal et al. 2017; Mahmood et al. 2017; Naeem et al. 2017; Tabbasum et al. 2021). Such contrasting results on maize production may be attributed to different rate and sources of organic and inorganic fertilizers, soil conditions, crop growth stage, and maize varieties (Khan et al. 2008; Shah et al. 2009; Oyun et al. 2016; Manolikaki and Diamadopoulos 2019).

Effect of soil amendments on selected macronutrients' concentration in maize leaves

The data regarding the effect of various composts and NPK amendments on macronutrients' concentration (%) in maize leaves are reported in Table 2. The concentration of N in maize leaves increased from 36.7 to 45.6% over control, where all organic and inorganic treatments were found equal. The application of NPK accounted for highest concentration of P in maize leaves with 27% increase over control. While the K concentration increased from 21.6 to 38.1% over control, where maximum concentration was found in plants which were treated with NPK, fruits + vegetables compost and banana leaves compost. The increase in NPK concentrations in maize leaves may be associated to addition of composts and NPK fertilizer to the crop and its subsequent uptake by maize crop. The application of organic and/or inorganic fertilizers increases the ion concentration in soil solution, thus results in improved nutrient uptake by plants (Aziz et al. 2010; Bharat et al. 2017). Increase in NPK concentration in maize tissues by organic and inorganic treatments has also been reported. Adediran et al. (2005) documented relatively higher concentration of N, P and K in maize ear leaf for organic and inorganic fertilizers than the control treatment. Rasool et al. (2008) observed a higher NPK uptake in maize crop with FYM (farm yard manure) and inorganic fertilizer treatments than the control plots. Similarly, few recent studies have reported a high concentration/uptake of NPK in maize tissues (shoot and grains) by the application of organic and inorganic amendments (Bharat et al. 2017; Naeem et al. 2017; Tabbasum et al. 2021).

Table 2 Effect of soil amendments on selected macronutrients' concentration (%) in maize leaves

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Control	1.69 ± 0.07 ^{B}	0.198 ± 0.003 ^{C}	1.34 ± 0.02 ^{B}
NPK	2.31 ± 0.07 ^{A}	0.251 ± 0.004 ^{A}	1.85 ± 0.10 ^{A}
Water hyacinth compost	2.36 ± 0.19 ^{A}	0.233 ± 0.002 ^{B}	1.63 ± 0.09 ^{AB}
Fruits + vegetables compost	2.46 ± 0.18 ^{A}	0.233 ± 0.005 ^{B}	1.78 ± 0.06 ^{A}
Banana leaves compost	2.37 ± 0.06 ^{A}	0.229 ± 0.005 ^{B}	1.75 ± 0.06 ^{A}

Each value is a mean ± SE (n=4); Means followed by different capital letters are significantly different from each other ($P < 0.05$) with respect to soil amendments

Effect of soil amendments on selected macronutrients concentration in soil after harvest of maize fodder

The organic and inorganic soil amendments significantly enhanced N, P and K concentrations in surface and subsurface soil than the control plots (Table 3). The total N increased by 97.8 to 142.2%, available P increased by 36.9 to 59.8%, and available K enhanced by 48.9 to 77.0% in both soil surfaces, over control plots. Such an increase may be associated to the application of the compost and NPK fertilizer in experimental soil. Similar findings of enhanced nutrient contents in soils by applications of organic and inorganic fertilizers are also documented. Soils treated with compost and inorganic N fertilizer improved NO_3-N and P content in experimental soil with respect to control plots (De Toledo et al. 1996; Adediran et al. 2005; Courtney and Mullen 2008; Pellejero et al. 2021). Organic and inorganic treatments significantly increased the N, P and K concentrations in soil at maize harvest (Olowoake et al. 2018). In few other studies, the soil organic carbon, N, P, K, and soil moisture content increased while soil EC and pH decreased with sole compost application or combined application of organic-inorganic amendments (Rahman et al. 2013; Naeem et al. 2017; Iqbal et al. 2019).

Although the physical and biological properties in post-harvest soils were not investigated in current study, the review of previous studies of maize highlights the positive effect of organic-and-inorganic fertilizers on these properties (Adediran et al. 2005; Ahmad et al. 2008; Rasool et al. 2008; Iqbal et al. 2019), hence these benefits may also be the contributor of higher productivity and quality of maize fodder, and soil fertility in our study.

Conclusion

The application of different composts and NPK fertilizer significantly enhanced (in most cases) the selected

Table 3 Effect of soil amendments on selected macronutrients' concentration (mg kg^{-1}) in surface and subsurface soil after harvest

Treatments	Nitrogen (mg kg^{-1})	Phosphorus (mg kg^{-1})	Potassium (mg kg^{-1})
Concentration of macronutrients in surface soil (0-15 cm)			
Control	0.046 ± 0.001 B	5.15 ± 0.21 B	185 ± 25.0 B
NPK	0.091 ± 0.003 A	7.05 ± 0.34 A	285 ± 12.8 AB
Water hyacinth compost	0.091 ± 0.012 A	7.25 ± 0.17 A	316 ± 25.6 A
Fruits + vegetables compost	0.104 ± 0.001 A	7.40 ± 0.39 A	312 ± 25.2 A
Banana leaves compost	0.099 ± 0.006 A	7.45 ± 0.25 A	325 ± 25.0 A
Concentration of macronutrients in sub-surface soil (15-30 cm)			
Control	0.045 ± 0.001 C	4.60 ± 0.45 B	178 ± 8.4 B
NPK	0.090 ± 0.002 B	6.85 ± 0.22 A	265 ± 14.8 A
Water hyacinth compost	0.102 ± 0.002 AB	7.05 ± 0.24 A	305 ± 23.9 A
Fruits + vegetables compost	0.109 ± 0.005 A	7.35 ± 0.26 A	313 ± 13.7 A
Banana leaves compost	0.097 ± 0.002 AB	7.00 ± 0.37 A	315 ± 20.6 A

Each value is a mean ± SE (*n*=4); Means followed by different capital letters are significantly different from each other ($P < 0.05$) with respect to soil amendments

growth and yield components, and NPK concentration in maize leaves and soil (after harvest, in surface and subsurface levels) than control treatment. It is suggested that maize crop should be fertilized with inorganic or organic manures to improve its growth, yield and nutrients' content. A comparable effect of various composts on maize crop and soil fertility to NPK fertilizer is also encouraging and suggests composts use for maize crop to minimize the dependence on inorganic fertilizers. Future studies with various crops and soil conditions are also advised to validate the findings of this study.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

References

Abdulraheem MI, Charles EF, Moshood AY, Omogoye AM (2018) Comparative performances of different varieties of maize under organic, inorganic and combined (organic and inorganic) fertilization. Int Technol Sci 2: 89-98. https://doi.org/ 10.31058/j.as.2018.22008

Adediran JA, Taiwo LB, Akande MO, Sobulo RA, Idowu OJ (2005) Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. J Plant Nutr 27(7): 1163-1181. https://doi.org/10.1081/PLN-120038542

Ahmad R, Khalid A, Arshad M, Zahir ZA, Mahmood T (2008) Effect of compost enriched with N and L-tryptophan on soil and maize. Agron Sustain Dev 28(2): 299-305

Akmal T, Jamil F (2021) Assessing health damages from improper disposal of solid waste in Metropolitan Islamabad-Rawalpindi, Pakistan. Sustainability 13: 2717. https://doi.org/10.3390/su13052717

Al-Khatib IA, Monou M, Abu-Zahra ASF, Shaheen HQ, Kassinos D (2010) Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district-Palestine. J Environ Manage 91: 1131-1138. https://doi.org/10.1016/j.jenvman.2010.01.003

Alsri MI, Sarhan MAA, Al-Khatib IA (2018) Assessment of compost quality and usage for agricultural use: a case study of Hebron, Palestine. Environ Monit Assess 190: 223. https://doi.org/10.1007/s10661-018-6610-x

Amanullah, Khan I, Jan A, Jan MT, Khalil SK, Shah Z, Afzal M (2015) Compost and nitrogen management influence productivity of spring maize (*Zea mays* L.) under deep and conventional tillage systems in semi-arid regions. Commun Soil Sci Plant Anal 46(12): 1566-1578. https://doi.org/10.1080/00103624.2015.1043462

Anikwe MAN, Nwobodo KCA (2002) Long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki Nigeria. Bioresour Technol 83: 241-250. https://doi.org/10.1016/s0960-8524(01)00154-7

Arif M, Ali A, Umair M, Munsif F, Ali K, Inamullah, Saleem M, Ayub G (2012) Effect of biochar, FYM and mineral nitrogen alone and in combination on yield and yield components of maize. Sarhad J Agric 28(2):191-195

Aslam S, Ali F, Naseer A, Sheikh Z (2021) Application of material flow analysis for the assessment of current municipal solid waste management in Karachi, Pakistan. Waste Manage Res. https://doi.org/10.1177/0734242X211000427

Aziz T, Ullah S, Sattar A, Nasim M, Farooq M, Khan MM (2010) Nutrient availability and maize (*Zea mays*) growth in soil amended with organic manures. Int J Agric Biol 12(4): 621-624. https://doi.org/10–070/RAS/2010/12–4–621–624

Batool SA, Chaudry MN (2009) Municipal solid waste management in Lahore City District, Pakistan. Waste Manage 29: 1971-1981. https://doi.org/10.1016/j.wasman.2008.12.016

Bernal MP, Alburquerque JA, Moral R (2009) Composting of animal manures and chemical criteria for compost maturity assessment: A review. Bioresour Technol 100: 5444-5453. https://doi.org/10.1016/j.biortech.2008.11.027

Bharath T, Vidyasagar GE, Rao VP, Madhavi A (2017) Effect of integrated nutrient management on NPK uptakes and soil properties of maize in maize- groundnut cropping system. Green Farming 8(2): 409-412

Bilal M, Tayyab M, Aziz I, Basir A, Ahmed B, Khan U, Zahid M, Ali N (2017) Impact of integrated fertilization (Organic and In-Organic) on grain yield of maize. Agric Forestr Fisher 6(5): 178-183. https://doi.org/10.11648/j.aff.20170605.16

Buteh DS, Chindo IY, Ekanem EO, Williams EM (2013) Impact assessment of contamination pattern of solid waste dumpsites soil: A comparative study of Bauchi Metropolis. World J Anal Chem 1(4): 59-62. https://doi.org/10.12691/wjac-1-4-3

Colon J, Martinez-Blanco J, Gabarrell X, Artola A, Sanchez A, Rieradevall J, Font X (2010) Environmental assessment of home composting. Resour Conserv Recycl 54: 893-904. https://doi.org/10.1016/j.resconrec.2010.01.008

Courtney RG, Mullen GJ (2008) Soil quality and barley growth as influenced by the land application of two compost types. Biores Tech 99(8): 2913-2918. https://doi.org/10.1016/j.biortech.2007.06.034

Dalal RC, Gibson IR, Menzies NW (2009) Nitrous oxide emission from feedlot manure and green waste compost applied to Vertisols. Biol Fertil Soils 45(8): 809-819. https://doi.org/ 10.1007/s00374-009-0394-7

Dalal RC, Gibbson IR, Allen DE, Menzies NW (2010) Green waste compost reduces nitrous oxide emissions from feedlot manure applied to soil. Agric Ecosyst Environ 136: 273-281. https://doi.org/10.1016/j.agee.2009.06.010

De Toledo VC, Lee HC, Watt TA, Lopez-Real JM (1996) The use of dairy manure compost for maize production and its effects on soil nutrients, maize maturity and maize nutrition. *In*: M. de Bertoldi, P. Sequi, B. Lemmes, T. Papi (ed), The Science of Composting. Springer Dordrecht

Doan TT, Henry-Des-Tureaux T, Rumpel C, Janeau JL, Jouquet P (2015) Impact of compost, vermicompost and biochar on soil fertility, maize yield and soil erosion in Northern Vietnam: A three year mesocosm experiment. Sci Total Env 514: 147-154. https://doi.org/10.1016/j.scitotenv.2015.02.005

Dowswell CR, Paliwal RL, Cantrell RP (1996) Maize in the third world. Taylor and Francis Group

Estefan G, Sommer R, Ryan J (2013) Methods of soil, plant, and water analysis: A manual for the West Asia and North Africa region. ICARDA. Third edition

Evangelisti S, Lettieri P, Clift R, Borello D (2015) Distributed generation by energy from waste technology: a life cycle perspective. Process Saf Environ Prot 93: 161-172. https://doi.org/10.1016/j.psep.2014.03.008

FAOSTAT (2019) Food and Agriculture Organization of the Untied Nations. https://www.fao.org/faostat/en/#data

Farhad W, Saleem MF, Cheema MA, Hammad HM (2009) Effect of poultry manure levels on the productivity of spring maize (*Zea mays* L.). J Anim Plant Sci 19(3): 122-125

Gajalakshmi S, Abbasi SA (2008) Solid waste management by composting: State of the art. Critic Rev Environ Sci Technol 38(5): 311-400. https://doi.org/10.1080/10643380701413633

Gandahi AW (2010) Integrated saline water management in maize (*Zea mays* L.) fodder production. PhD Dissertation, Sindh Agriculture University Tandojam

Giannakis GV, Kourgialas NN, Paranychianakis NV, Nikolaidis NP, Kalogerakis N (2014) Effects of municipal solid waste compost on soil properties and vegetables growth. Compost Sci Utiliz 22: 116-131. https://doi.org/10.1080/1065657X.2014.899938

Hanay A, Büyüksönmez F, Kiziloglu FM, Canbolat MY (2004) Reclamation of saline-sodic soils with gypsum and MSW compost. Comp Sci Utiliz 12(2): 175-179. https://doi.org/10.1080/1065657X.2004.10702177

Hassan M, Khan MJ, Ali SS (2021) Ground water quality assessment in industrial zones of central Punjab, Pakistan. Pakistan J Sci 73(1): 177

Inam-ul-Haque, Jakhro AA (1996) Soil and fertilizer nitrogen. *In*: E. Bashir and R. Bantel (ed), Soil Science. National Book Foundation Islamabad

Iqbal S, Thierfelder C, Khan HZ, Javeed HMR, Arif M, Shehzad M (2017) Maximizing maize quality, productivity and profitability through a combined use of compost and nitrogen fertilizer in a semi-arid environment in Pakistan. Nutr Cycl Agroecosyst 107(2):197-213. https://doi.org/10.1007/s10705-017-9829-y

Iqbal S, Arif MS, Khan HZ, Yasmeen T, Thierfelder C, Li T, Khan S, Nadir S, Xu J (2019) Compost amended with N enhances maize productivity and soil properties in semi-arid agriculture. Agron J 111(5): 2536-2544. https://doi.org/10.2134/agronj2019.03.0176

Jadoon A, Batool SA, Chaudhry MN (2014) Assessment of factors affecting household solid waste generation and its composition in Gulberg Town, Lahore, Pakistan. J Mater Cycles Waste Manag 16(1): 73-81. https://doi.org/ 10.1007/s10163-013-0146-5

Kanton RAL, Prasad PVV, Mohammed AM, Bidzakin JK, Ansoba EY, Asungre PA, Lamini S, Mahama G, Kusi F, Sugri I (2016) Organic and inorganic fertilizer effects on the growth and yield of maize in a dry agro-ecology in northern Ghana. J Crop Improv 30(1): 1-6. https://doi.org/ 10.1080/15427528.2015.1085939

Khan HZ, Malik MA, Saleem MF (2008) Effect of rate and source of organic material on the production potential of spring maize (*Zea mays* L.). Pak J Agric Sci 45(1): 40-43

Korai MS, Mahar RB, Uqaili MA (2017) The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan. Renew Sustain Energ Rev 72: 338-353. http://dx.doi.org/10.1016/j.rser.2017.01.051

Kumar R, Srinivas K, Miah MM, Shah H, Dahlan HA, Qiu H (2014) Assessment of the maize situation, outlook and opportunities in Asia. Book of Extended Summaries, 12th Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Bangkok, Thailand

Mahajan A, Bhagat RM, Gupta RD (2008) Integrated nutrient management in sustainable rice-wheat cropping system for food security in India. SAARC J Agric 6(2): 1-16

Mahar A, Malik RN, Qadir A, Ahmed T, Khan Z, Khan MA (2007) Review and analysis of current solid waste management situation in urban areas of Pakistan. Proc Int Conf Sust Sol Waste Manage 34-41

Mahmood F, Khan I, Ashraf U, Shahzad T, Hussain S, Shahid M, Abid M, Ullah S (2017) Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. J Soil Sci Plant Nutr 17(1): 22-32

Manolikaki I, Diamadopoulos E (2019) Positive effects of biochar and biochar-compost on maize growth and nutrient availability in two agricultural soils. Commun Soil Sci Plant Analy 50(5): 512-526. https://doi.org/10.1080/00103624.2019.1566468

Masood M, Barlow CY, Wilson DC (2014) An assessment of the current municipal solid waste management system in Lahore, Pakistan. Waste Manage Res 32 (9): 834-847. https://doi.org/ 10.1177/0734242X14545373

Masowa MM, Kutu FR, Shange PL, Mulidzi R, Vanassche FMG (2015) The effect of winery solid waste compost application on maize growth, biomass yield, and nutrient content under greenhouse conditions. Arch Agron Soil Sci 62(8): 1082-1094. https://doi.org/10.1080/03650340.2015.1115018

Miller JJ, Beasley BW, Drury CF, Larney FJ, Hao X (2015) Influence of long-term (9 yr) composted and stockpiled feedlot manure application on selected soil physical properties of a clay loam soil in Southern Alberta. Compost Sci Utiliz 23: 1-10. https://doi.org/10.1080/1065657X.2014.963741

Montemurro F, Maiorana M, Convertini G, Ferri D (2006) Compost organic amendments in fodder crops: Effects on yield, nitrogen utilization and soil characteristics. Compost Sci Utiliz 14 (2): 114-123. https://doi.org/ 10.1080/1065657X.2014.963741

Naeem MA, Khalid M, Aon M, Abbas G, Amjad M, Murtaza B, Khan WU, Ahmad N (2017) Combined application of biochar with compost and fertilizer improves soil properties and grain yield of maize. J Plant Nutr 41(1): 112-22. https://doi.org/10.1080/01904167.2017.1381734

Nagendran R, Selvam A, Joseph K, Chiemchaisri C (2006) Phytoremediation and rehabilitation of municipal solid waste landfills and dumpsites: A brief review. Waste Manage 26: 1357–1369. https://doi.org/10.1016/j.wasman.2006.05.003

Oad FC, Buriro UA, Agha SK (2004) Effect of organic and inorganic fertilizer application on maize fodder production. Asian J Plant Sci 3(3): 375-377. https://doi.org/10.3923/ajps.2004.375.377

Olowoake AA, Osunlola OS, Ojo J A (2018) Influence of compost supplemented with jatropha cake on soil fertility, growth, and yield of maize (*Zea mays* L.) in a degraded soil of Ilorin, Nigeria. Int J Recycl Org Waste Agricult 7: 67-73. https://doi.org/10.1007/s40093-017-0192-4

Oyun MB, Fasinmirin J, Olufolaji OO, Ogunrinde OS (2016) Growth of maize (*Zea mays*. l) in response to varying organic and inorganic fertilizer treatment. Appl Trop Agri 20(2): 74-77

Pakistan Economic Survey (2018-2019) Ministry of Finance, Government of Pakistan, Islamabad

Pellejero G, Miglierina A, Aschkar G, Turcato M, Jiménez-Ballesta R (2016) Use of compost with onion (*Allium cepa*) waste and cattle manure as substrate component for horticultural seedlings. Int J Plant Soil Sci 12 (4): 1-10

Pellejero G, Miglierina A, Aschkar G, Turcato M, Jiménez-Ballesta R (2017) Effects of the onion residue compost as an organic fertilizer in a vegetable culture in the Lower Valley of the Rio Negro. Int J Recycl Org Waste Agricult 6(2): 159 -166. https://doi.org/ 10.1007/s40093-017-0164-8

Pellejero G, Palacios J, Vela E , Gajardo O, Albrech L, Aschkar G, Chorolque A, Garcia-Navarro FJ, Jiménez-Ballesta R (2021) Effect of the application of compost as an organic fertilizer on a tomato crop (*Solanum lycopersicum* L.) produced in the field in the Lower Valley of the Río Negro (Argentina). Int J Recycl Org Waste Agricult 10: 145-155. https://doi.org/103486.IJROWA/2021.1909797.1135

Rahman MA, Hashem MA, Rahman MM, Rahman SME, Hossain MM, Azad MAK, Haque ME (2013) Comparison of struvite compost with other fertilizers on maize fodder production. J Environ Sci Natur Resour 6(2): 227-231. https://doi.org/10.3329/JESNR.V6I2.22123

Rasool R, Kukal SS, Hira GS (2008) Soil organic carbon and physical properties as affected by long-term application of FYM and inorganic fertilizers in maize-wheat system. Soil Till Res 101: 31-36. https://doi.org/10.1016/j.still.2008.05.015

Saleh HM (2021) Strategies for sustainable solid waste management. IntechOpen. https://doi.org/10.5772/intechopen.87682

Sallah A, Azinwie AG, Alobwede NJ, Ngang F D (2017) Effect of different organic manures and mineral NPK fertilizer on maize yield on volcanic soils of the Mt Cameroon area under minimum tillage. Greener J Agricul Sci 7(4): 097-104. http://doi.org/10.15580/GJAS.2017.4.051617062

Sayara T, Basheer-Salimia R, Hawamde F, Sánchez A (2020) Recycling of organic wastes through composting: process performance and compost application in agriculture. Agronomy 10(11):1838. https://doi.org/10.3390/agronomy10111838

Schwab GJ, Lee CD, Pearce R (2007) Sampling plant tissue for nutrient analysis. University of Kentucky, Cooperative Extension Service

Shah STH, Zamir MS, Waseem M, Ali A, Tahir M, Khalid WB (2009) Growth and yield response of maize (*Zea mays* L.) to organic and inorganic sources of nitrogen. Pak J Life Soc Sci 7(2): 108-111

Tabbasum S, Akhtar M, Sarwar N, Tipu MI, Ikram W, Ashraf A, Ejaz A, Murtaza B, Khan MR (2021) Relative effectiveness of phosphorus and potassium along with compost and organic acids on maize crop grown in calcareous soil: A multivariate analysis. J Soil Sci Plant Nutr 21(1): 437-449. https://doi.org/10.1007/s42729-020-00372-1

Thi NBD, Kumar G, Lin C (2015) An overview of food waste management in developing countries: Current status and future perspective. J Environ Manage 157: 220-229. https://doi.org/10.1016/j.jenvman.2015.04.022

Tumwesigye KS, Morales-Oyervides L, Oliveira JC, Sousa-Gallagher MJ (2016) Effective utilisation of cassava bio-wastes through integrated process design: A sustainable approach to indirect waste management. Process Saf Environ Prot 102: 159-167. https://doi.org/10.1016/j.psep.2016.03.008

Vaughan SM, Dalal RC, Harper SM, Menzies NW (2011) Effect of fresh green waste and green waste compost on mineral nitrogen, nitrous oxide and carbon dioxide from a Vertisols. Waste Manage 31: 1720-1728. https://doi.org/10.1016/j.wasman.2011.03.019

Wells AT, Chan KY, Cornish PS (2000) Comparison of conventional and alternative vegetable farming systems on the properties of a yellow earth in New South Wales. Agric Ecosyst Environ 80: 47-60. https://doi.org/10.1016/S0167-8809(00)00133-X

Zahra MB, Aftab ZE, Akhter A, Haider MS (2021) Cumulative effect of biochar and compost on nutritional profile of soil and maize productivity. J Plant Nutr. https://doi.org/10.1080/01904167.2021.1871743