ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2023; 23(9): 24644-24661 https://doi.org/10.18697/ajfand.124.20990

HUMAN FECES COMPOST AS AN ORGANIC FERTILIZER FOR SWEET CORN CULTIVATION IN VOLCANIC SOIL OF MT. MERAPI, INDONESIA

Budiyanto G[1]* and I Prabasari[1]

Gunawan Budiyanto

*Corresponding author email: goenb2016@gmail.com

[1]Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Indonesia

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Volcanic material sedimentation of Mt. Merapi causes changes in surface soil's physical and chemical properties that reduce soil fertility. The eruption of the mountain also builds volcanic soil layers, which are generally porous and have a low water-holding capacity. The chemical properties of this layer have low nutrient content and organic matter. Solid human feces composted for 30 days has a water content of 51.62%, carbon 15.62%, nitrogen 1.50%, and phosphorus 6.45%. The potential of nutrients possessed by human feces compost has the opportunity to be used as a source of fertilizer for plants because the plant, animal biomass, and human excreta are essential components of material and energy flow in ecosystems. However, the human feces compost as an organic fertilizer has not yet been widely utilized. Therefore, the research aims are to study the potential of sanitized human feces composts to improve the fertility of volcanic soil from Mt. Merapi Indonesia and find its optimum dosage for sweet corn cultivation. Volcanic soil from Mt Merapi was brought to the greenhouse from the mountain area and used as media to cultivate sweet corn plants. The research was conducted using a completely randomized design (CRD) with five treatments consisting of four dosages of human feces compost and one control treatment using cattle manure. The four dosages of composted human feces were applied in the volcanic soil with the dose of 5, 10, 15, and 20 tons/hectare. Organic fertilizer from cattle manure with a dose of 20 tons/hectare was used as a control. The result showed that human feces compost has similar potential as cattle manure (control treatment) in increasing the growth and yield of sweet corn. Furthermore, the result also showed that the optimum dosage of organic fertilizer from human feces compost to increase sweet corn's productivity was 15 tons per hectare.

Key words: human feces, soil quality, sweet corn, organic fertilizer, Indonesia

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

The eruption of Mt. Merapi in 2010 has led to a negative impact on environmental aspects and the quality of the surrounding land [1]. The eruption damaged of primary forest in the Mt. Merapi National Park and the agricultural land on the slope of the mountain. The damage of primary forest decreases the number of vegetation stands and ultimately affects the water system, and those results in reduced water supply for the cultivation of food and feed crops.

Meanwhile, the damage of agricultural land can be in the form of surface soil covered by volcanic material in the form of sand ($0.02 \leq Ø \leq 2.00$ mm) and ash ($0.002 \leq Ø \leq 0.02$ mm) with a thickness from 5 to 30 cm. Volcanic material sedimentation inflicts changes in the physical and chemical properties of surface soil that reduce the fertility of the soil [2]. The eruption also builds a form of soil layers, which generally are porous and have a low water-binding capacity. This layer contains low nutrient content and organic matter [3].

The eruption of Mt. Merapi produces sediments dominated by silicate minerals 60%, Fe_2O_3 18.20%, Al_2O_3 14%, K_2O 3.86%, and CaO 16.10% [4]. Determination of nutrient content in the region with the highest mountain eruption exposure, Kepuharjo village, was found to contain N 0.019%, P_2O_5 0.77%, K_2O 3.02%, CaO 9.46%, MgO 0.318%, C 0.67% and cation exchange capacity 2.61% [5]. Agricultural land cover by the Mt. Merapi sediments has had an adverse effect because these sediments are granular and not bound in the aggregate soil system so that they are unable to store water and cause drought in the dry season. Whereas in the rainy season, these sediments are easily eroded and cause the impermeable layer to form. Therefore, they reduce the rate of water infiltration into the soil. The soils formed from the eruption of Mt. Merapi have low water content, low nitrogen, carbon, and cation content. Although, in general, the soils are rich in primary nutrients, they are not yet available for plants [2, 6]. The research gap could fill in human feces compost as an organic fertilizer is rarely studied, such the result was later contradicted by Wang *et al.* [7] showed catalytic hydrothermal liquefaction (HTL) of human feces, and [2] improve the provisioning of agroecosystem services impacts of organic agriculture on soil dynamics, and thermophilic composting of human feces [8].

Organic matter is mixed in the soil to improve the physical properties of volcanic sediments which tend not to form soil aggregates. The decomposition of animal and plant tissue residues, when inserted into the soil immediately, affects soil properties, such as, growth of bacterial mycelium, glomalin, and soil aggregates

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 9 September 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

that can store water [9, 10]. Various sources of organic material commonly used are compost, cattle manure, and human feces compost. Compost is the usual sources of organic material among farmers, while human feces compost is commonly used as fertilizers in Indonesia, and this has been widely studied [7, 8, 11]. Attentions has mainly given to the process of biodegradation in which organics and human feces nitrogen is transformed under the action of microorganisms. Although the studies of human feces compost element as an organic fertilizer effect among organic systems are limited, there is a great deal of literature. Those are especially in conventional systems [3], examining how cover crops improve soil health [2], might explore the importance of its management in organic systems on soil, and nutrient cycling in particular, potential of an organic amendment varies by the type of material [12], climate factors, and soil management [13].

Human excreta (feces and urine) contain plant nutrients, such as urea, nitrogen, phosphorus, but also contain pathogenic bacteria that are harmful to humans [14]. Solid human feces composted for 30 days has a water content of 51.62%, carbon 15.62%, nitrogen 1.50%, and phosphorus 6.45% [15]. Tthe average human feces contains nitrogen 4.8-7%, P_2O_5 3-5.4%, and K_2O 1-2.5% [16]. Recycling of nutrients in solid human feces as fertilizer reduces the use of energy and non-renewable resources in the production of synthetic fertilizers, which is beneficial for ecosystems [17, 18, 19, 20]. The potential of nutrients possessed by human feces compost has the opportunity to be used as a source of fertilizer for plants, because basically plant, animal biomass, and human excreta are essential components of material and energy flow in ecosystems [21, 22]. Therefore, the use of sanitized human feces on volcanic soil of Mt. Merapi is expected to improve the physical and chemical properties of the soil, as well as to be a source of nutrients for sweet corn plants. The objective of the research was to study the potential use of human feces compost as an organic fertilizer for sweet corn cultivation in sedimentary soil of Mt. Merapi, Indonesia.

MATERIAL AND METHODS

Soil for the study was taken from Kepuharjo village, Yogyakarta, Indonesia, which was profoundly affected by the Mt. Merapi eruption in 2010. The soil sample was collected from a depth of 0-50 cm, while sanitized human feces was taken from a waste treatment installation in Druwo, a small hamlet in Bantul village, Yogyakarta, Indonesia. Sweet corn seeds (Zea mays saccharata, Sturt), nitrogen fertilizer (urea), phosphorus fertilizer (SP-36), and potassium fertilizer (KCl) were from the local farm shop in Yogyakarta, Indonesia.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 9 September 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

The study was conducted using an experimental method arranged in a completely randomized design (CRD) with five treatments consisting of four dosages of human feces compost and one control treatment using cattle manure. The treatments were human feces compost of 5 tons/hectare (treatment A), 10 tons/hectare (treatment B), 15 tons/hectare (treatment C) and 20 tons/hectare (treatment D). Cattle manure compost of 20 tons/hectare (treatment E) worked as control. Each treatment was repeated nine times and made 45 samples altogether.

The soil was air-dried for one week then sieved with a diameter of 2.0 mm for soil properties analysis using technical soil analysis based on the technical of soil analysis [32]. For each sample, the air-dried soil was weighed 21.06 kg with 5.3% moisture content and fertilized with 200 kg urea/hectare, 300 kg SP-36/hectare, and 250 kg KCl /hectare. According to the planned treatment dosage, each of nine soil samples was treated with human feces compost and cattle manure. Each treated soil sample was put into a polybag and incubated for one week at the water content field capacity. After the incubation period was complete, seeds were planted in polybags and grown in the greenhouse until the harvest period. Measurements of growth parameters were carried out during vegetative (age eight weeks) and generative stages (age 13 weeks) to determine the effect of human feces compost on the growth and yield of sweet corn.

Eight weeks after planting, some parameters such as plant height, fresh weight, and dry weight of plant biomass were measured using the gravimetric method to determine the quality of vegetative growth. The generative growth was performed after the plant growth reached 13 weeks age by measured fresh weight and dry weight of plant biomass (all parts of plant morphology), and weight of sweet corn cobs. The data was analyzed using SAS software for Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) with a significance level of 5% to distinguish a significant difference among treatments.

RESULTS AND DISCUSSION

The determination of soil properties is presented in Table 1 to determine the potential of agricultural land affected by the sediments of the Merapi eruption.

The results of the soil characteristics presented in Table 1 show that the land affected by Merapi's eruption has low fertility. This soil has low soil moisture content (1.98%). The soil fraction was dominated by sand (98.86%), while the dust and clay contents were 0.38% and 0.76%, respectively. These sandy soils generally do not form aggregates and have a low ability to store water, so they are

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 9 September 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

always in dry. The particle density and bulk density of 2.57 g / cm^3 and 1.32 g / cm^3 respectively shows that half of one unit of soil volume consists of macropores. Soil porosity of 48.64% indicates that this soil does not form soil aggregates, as research by Idjudin *et al.* [23]. This condition is also supported by the determination of the C-organic content in the soil (0.88%). C-organic content is closely related to the content of organic matter in the soil. Low C-organic content describes low organic matter content. The low content of clay and organic matter in the soil can inhibit soil aggregates formation. The results of the physical properties of the sedimentary soil of Mount Merapi are following the research results by Wardoyo and Santoso [24].

Table 1 shows that this soil has low fertility with nutrient content as follows P_2O_5 (21.24 ppm), K_2O (0.192 me / 100 g), Ca (0.019 me / 100 g) and Mg (0.318 me / 100 g). Meanwhile, the determination of cation exchangeable capacity (CEC) shows that this soil has a nutrient binding capacity of 2.89 me / 100 g. In general, this soil requires a lot of nutrient input to increase its fertility potential and productivity. The application of organic matter into the soil is expected to increase nutrient supply and increase its capacity to bind nutrient cations. Research conducted by Suprapto and Saputra [25] proved that the combination treatment of organic matter and planting space could increase shallot plants' growth in sedimentary sand land of Mount Merapi.

The results showed that human feces compost and cattle manure compost had the same effect on plant height, fresh weight, and dry weight of the plant (Table 2).

Table 2 shows that all treatments gave the same effect in supporting the growth of sweet corn plants. The data pointed out that during vegetative growth, human feces compost was able to replace cattle manure as organic fertilizer in sweet corn cultivation. It suggests that human feces compost improved sediment soil quality by increasing water holding capacity and decreasing the rate of gravity water so that water could be available in the root zone. These results are similar to the study from Hübner *et al.* [18]. Also, the compost strengthened the absorption of nutrients derived from synthetic fertilizers and ultimately increasing nutrient uptake. Studies from Sallah *et al.* and Hollyer *et al.* [12, 14] also concluded similar responses that human feces compost could act as a nutrient supplier for sweet corn plants, but they have not determined its optimum dosage yet. The dry weight of plant biomass is usually to measure the quality of growth when it reaches a maximum period of vegetative growth, as shown in Figure 1.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

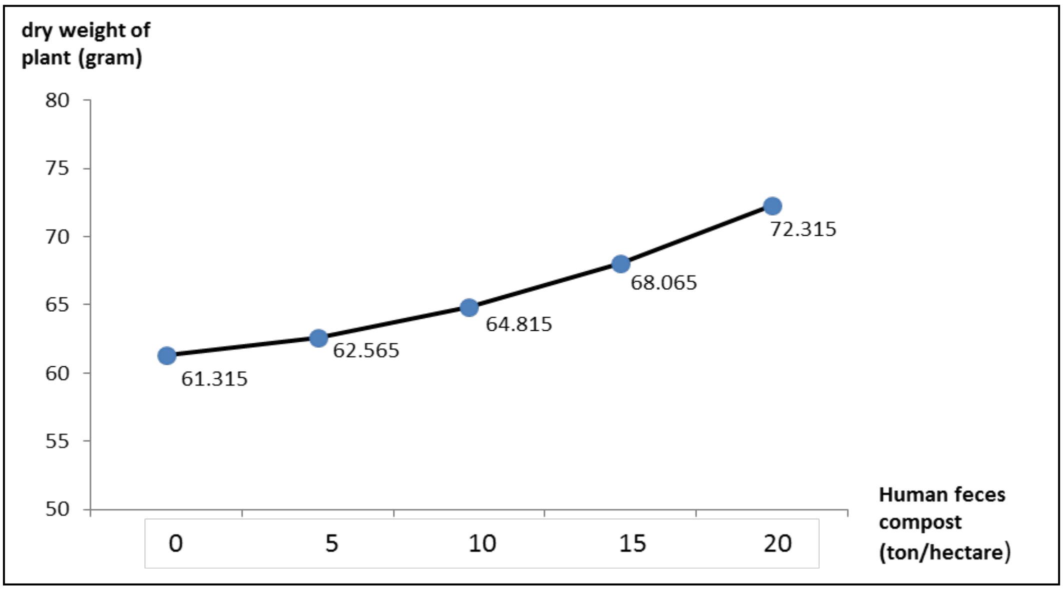

Figure 1: The influence of dose of human feces compost on the dry weight of plant biomass at 8 weeks old

In Figure 1, correlation between human feces compost dose and dry weight was formulated in the equation of $Y = 0.020X^2 + 0.150X + 61.315$. The effect of human feces compost dosage on plant dry weight correlated 0.67, with the coefficient of determination 45.50%, meaning that the effect of human feces compost dosage on plant dry weight was 45.50%. Human feces compost is a slow-release organic fertilizer that takes a certain amount of time to release its nutrient content to be absorbed by plants. The coefficient of determination of 45.50% indicated the availability of other sources of nutrients derived from synthetic fertilizer, such as urea, SP-36, and KCl, which were also applied as basic fertilizer to support vegetative growth of sweet corn.

Table 1 and Figure 1 altogether show that increasing the dosage of human feces compost increased the dry weight of sweet corn biomass during vegetative growth. Statistical analysis indicated that the trend was similar to the effect of cattle manure. In other words, human feces compost and cattle manure both were good sources of nutrients for sweet corn plants. The finding supports studies that human feces compost derived from human excreta contains elements that could be recycled, applied to the soil, and used as plant fertilizer [26, 27, 28].

Observation of generative growth was carried out at harvest time (approx. 13 weeks), and the results exhibited that the treatment of human feces compost significantly differed with cattle manure compost on fresh weight and dry weight of plant biomass. On the other hand, the treatment of human feces compost and

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 9 September 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

cattle manure compost gave similar effects on the weight of cobs per plant, as shown in Table 3.

Fresh weight of biomass

Table 3 shows that at 13 weeks old, the treatment of 20 tons of cattle manure per hectare (treatment E) significantly produced more fresh weight of biomass/plant than human feces compost treatments, while, treatments of human feces compost with a dose of 5, 10, 15 and 20 tons/hectare (A, B, C, and D) did not give specific response.

The researchers formulated the effect of human feces compost application on fresh weight into the equation that $Y = -0.904X^2 + 27.903X + 389{,}712$ with a regression coefficient of 0.85, and a coefficient of determination of 72.90%. Compare to the vegetative growth stage (8 weeks old), when the coefficient of determination was 45.50%, the role of human feces compost in providing nutrients for sweet corn in generative growth was greater. The finding indicated that at the final stage, human feces compost had been able to provide more nutrients for sweet corn plants. The effect of human feces compost dose on the fresh weight of sweet corn is in Figure 2. Adding more human feces compost provided more nutrients to sweet corn plants, increased fresh weight, and reached the optimum dosage at 15 tons/hectare. The proportion of human feces converted into organic fertilizer depends on human waste collection, length of time and conditions of decomposition processes [2]. Further, organic fertilizer provides protection from nutrient losses, along with many other agroecosystem benefits.

The concept of sustainable agriculture makes government to make consistent strategies to support organic agriculture. For example, policy measures make provision for training of government staff in organic techniques, while still keeping crop yields as the main benchmark.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

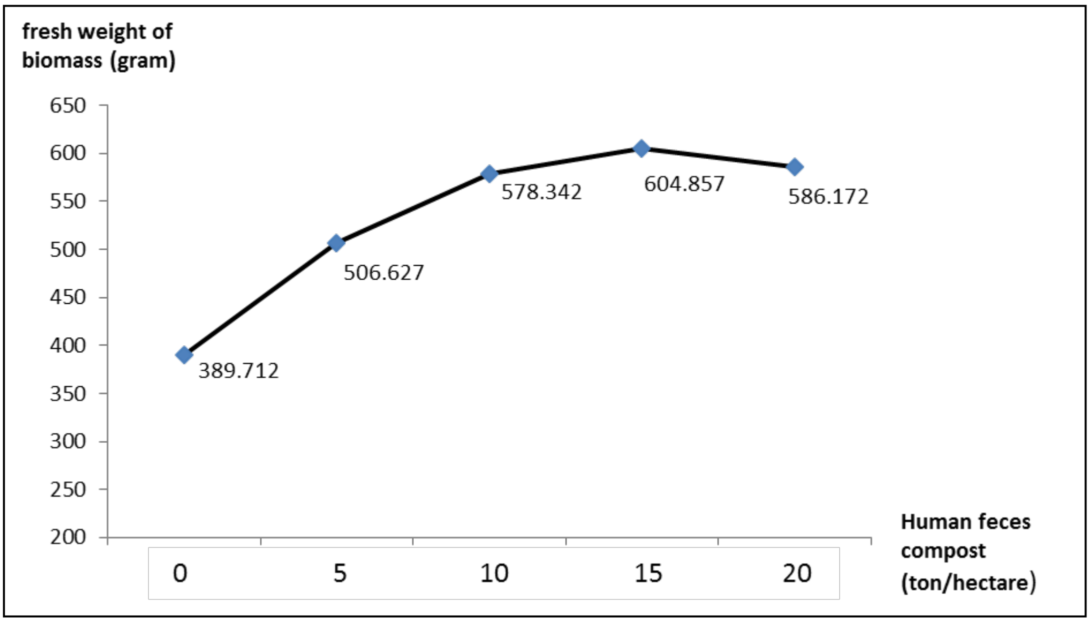

Figure 2: The influence of dose of human feces compost on fresh weight of plant biomass at 13 weeks old

Dry weight of biomass

Similar to the fresh weight of biomass, data on dry weight of biomass gave the same response where cattle manure produced the highest dry weight of biomass, and human feces compost with various dosages did not give specific responses as shown in Table 3.

Correlation between human feces compost dosage and dry weight of biomass existed in an equation that $Y = -0.191X^2 + 5.544X + 32.457$, with a regression coefficient of 0.97 and a coefficient of determination of 95.50%. The equation proved the significant influence of human feces compost on the dry weight of biomass, and that 95.5% application of human feces compost influenced the growth of sweet corn plants. The effect of human feces compost doses on the dry weight of sweet corn is presented in Figure 3.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

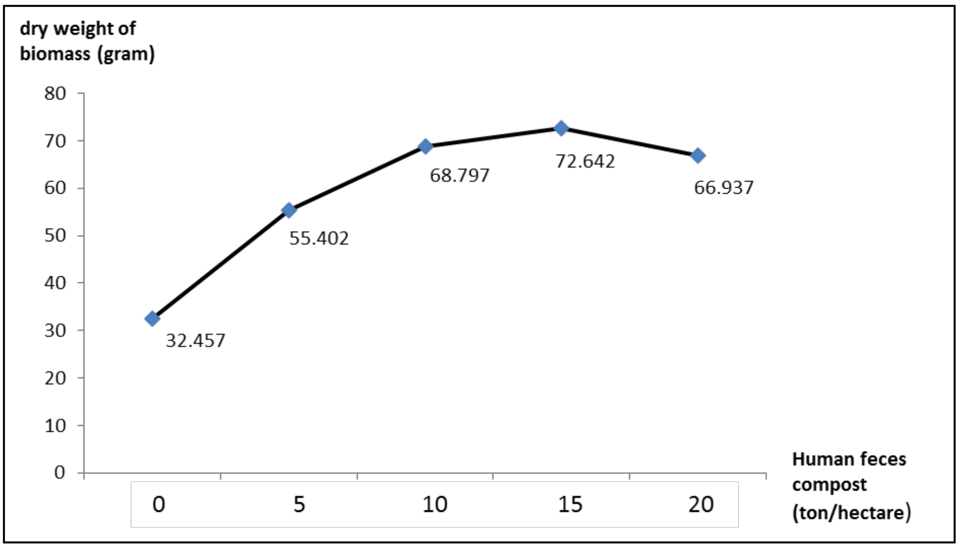

Figure 3: The influence of dose of compost on the dry weight of plant biomass at 13 weeks old

Figures 2 and 3 exhibits that increasing the dosage of human feces compost induce an increase in the generative growth of sweet corn. Application of human feces compost up to 15 tons/hectare increased generative plant growth, but as the dosage was more than 15 tons/hectare, the growth of sweet corn began to decrease. The curve between human feces compost dosage and plant growth in Figure 3 also indicated that a dosage of 15 tons of human feces compost/hectare produced the highest dry weight of biomass (72.64 g) and therefore is the optimum dosage to be applied on the slope of Mt. Merapi.

In vegetative growth, the contribution of human feces compost to dry weight of biomass is only 45.5%. Whereas in the generative growth phase, the contribution of human feces compost to dry weight of sweet corn biomass increased to 95.50%. It proved that as a slow-release fertilizer, human feces compost took a longer time to release most of its nutrient content. It also indicated that in the stage of vegetative growth, sweet corn plants had more nutrients from synthetic fertilizers (Urea, SP-36, and KCl). While they were entering generative growth stage and cob production, nutrient release from human feces compost supported the sweet corn plants well. This is similar to the result of Hübner *et al.* and Krounbi *et al.* [18, 27]. They mentioned that human feces works as soil amendments and sources of nutrients for plants.

Weight of corn cobs/plant

The results showed that all dosages of human feces compost treatments (5, 10, 15, and 20 tons/hectare) and a dose of 20 tons of cattle manure/hectare had the

https://doi.org/10.18697/ajfand.124.20990

same effect on the weight of corn cobs. This data proves that human feces compost can replace cattle manure as the nutrient supply for sweet corn. Both of them had the same potential to provide nutrients for the growth of sweet corn. The effect of human feces compost on the weight of corn cobs is in Figure 4.

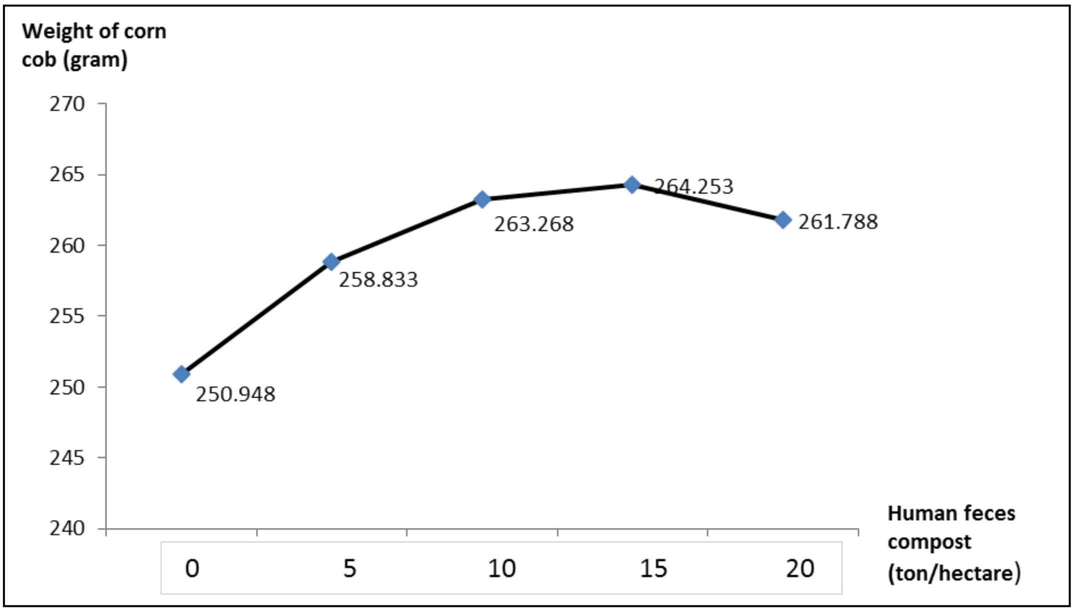

Figure 4: The influence of dose of human feces compost on sweet corn cobs weight

Figure 4 shows the relationship between human feces compost dosage and weight of corn cobs formulated in the equation of Y = -0.069X^2 + 1,922X + 250,948 with a regression coefficient of 0.93 and a coefficient of determination of 86.10%. The coefficient of determination shows a significant role (86.10%) of human feces compost as a nutrient provider for the formation and growth of sweet corn cobs. Some studies show that human feces compost is one useful source of organic material as fertilizer because it improves chemical and physical properties of the soil, as well as increasing of yield and production of plants/hectare of 18.57% [29, 30, 31]. Other researchers also reveal the suitability of human feces as soil amendments and sources of nitrogen [18, 27]. Those findings were similar to the researchers' experiment, and the application of 15 tons human feces compost/hectare producing the highest weight of corn cobs (263.21g; Table 2). Therefore, there was the optimum dose for sweet corn cultivation on sedimentary soil of Mt. Merapi that was 15 tons human feces compost per hectare.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

In the contexts of vulnerable areas and in dealing with the eruption, it can be concluded that human feces compost has similar potential as cattle manure in increasing the yield of sweet corn in the volcanic soil of Mt. Merapi. Compared to other dosages, the dosage of 15 tons of human feces compost/hectare produced a heavier dry weight of sweet corn and weight of sweet corn cobs/plant. Based on these findings, human feces compost can be used as soil ameliorant in increasing the productivity of volcanic soil of Mt. Merapi.

ACKNOWLEDGEMENTS

The authors acknowledged the local government for the permits to study the slope of Mt. Merapi and also the Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, especially Laboratory of Soil Science and Laboratory Plant Nutrition for all facilities and supports.

Table 1: The Properties of soil sample

Soil characterisrtics (0 – 50 cm. depth)	Value
Water content (%)	1.98
Sand (%)	98.86
Silt (%)	0.38
Clay (%)	0,76
Particle density (g/cm^3)	2.57
Bulk density (g/cm^3)	1.32
Total porosity (%)	48.64
pH (H_2O)	6.10
C-organik (%)	0.88
Total-N (%)	0.019
C/N-ratio	45.83
P_2O_5 (ppm)	21.24
K_2O (me/100 g)	0.192
Ca (me/100 g)	0.019
Mg (me/100 g)	0.318
CEC (me/100 g)	2.89

Table 2: Growth of sweet corn at 8 weeks old

Treatment	Height (cm)	Fresh weight (g)	Dry weight (g)
5 tons/hectare (hfc)	240.30 a	580.2 a	64.32 a
10 tons/hectare (hfc)	255.47 a	528.6 a	59.47 a
15 tons/hectare (hfc)	242.63 a	666.9 a	73.27 a
20 tons/hectare (hfc)	251.73 a	665.2 a	70.38 a
20 tons/hectare (cmc)	255.57 a	855.0 a	91.34 a

hfc= human feces compost, cmc= cattle manure compost
The averages in a column followed by the same letter indicates not significantly different based on Duncan's multiple range test of 5%

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 9
September 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Growth and yield of sweet corn at 13 weeks old

Treatment	Fresh weight of biomass (g)	The dry weight of biomass (g)	Weigh of cobs/plant (g)
5 tons/hectare (hfc)	496.46 c	54.780 c	258.47 a
10 tons/hectare (hfc)	608.92 b	70.648 b	254.41 a
15 tons/hectare (hfc)	574.43 bc	70.757 b	263.21 a
20 tons/hectare (hfc)	596.54 b	67.513 bc	262.28 a
20 tons/hectare (cmc)	878.79 a	94.137 a	280.92 a

hfc= human feces compost, cmc= cattle manure compost
The averages in a column followed by the same letter indicates not significantly different based on Duncan's multiple range test of 5%

REFERENCES

1. **Rahman MB, Nurhasanah IS and SP Nugroho** Community Resilience: Learning from Mt Merapi Eruption 2010. *Procedia - Social and Behavioral Sciences*. 2016; **227:** 387–394. https://doi.org/10.1016/j.sbspro.2016.06.090

2. **Tully KL and C McAskill** Promoting soil health in organically managed systems: a review. *Org. Agr.* 2019; **10:** 339–358 (2020). https://doi.org/10.1007/s13165-019-00275-1

3. **Schreer V and M Padmanabhan** The many meanings of organic farming: framing food security and food sovereignty in Indonesia. *Org. Agr.* 2019; **10:** 327–338. https://doi.org/10.1007/s13165-019-00277-z

4. **Kusumastuti E** Utilization of Mount Merapi's volcanic ash as a geopolymer, an aluminosilicate inorganic polymer. *Indonesian Journal of Mathematic and Natural Science*. 2012; **35(1):** 66–76. https://journal.unnes.ac.id/nju/index.php/JM/article/view/2098

5. **Khoirunissa N** Identification of Merapi Volcanic Material Nutrient Content and Its Suitability for Agricultural and Forestry Crop Cultivation in Cangkringan District, Sleman Regency 2017. http://repository.umy.ac.id/handle/123456789/11356 *Accessed May 2019.*

6. **Soelaeman Y and A Idjudin** Rehabilitation of the Physical Properties of Agricultural Soil after the Eruption of Merapi. Innovation-Based Agricultural Development in the Mount Merap Eruption Disaster Area. Balai Litbang Pertanian. 2013. http://www.litbang.pertanian.go.id/buku/Erupsi-Gunung-Merapi/Bab-II/2.2.pdf *Accessed July 2018.*

7. **Wang W, Yang L, Yin Z, Kong S, Han W and J Zhang** Catalytic liquefaction of human feces over Ni-Tm/TiO2 catalyst and the influence of operating conditions on products. *Energy Conversion and Management*. 2018; **157:** 239–245. https://doi.org/10.1016/j.enconman.2017.11.081

8. **Bai F and X Wang** Biodegradation of Organic Matter and Holding of N,P during Aerobic Thermophilic Composting of Human Feces. *Procedia Environmental Sciences.* 2011; **10:** 2631–2637. https://doi.org/10.1016/j.proenv.2011.09.409

9. **Cooperband I** Building Soil Organic Matter with Organic Amendments. Center for Integrated Agriculture System (CIAS). *College of Agriculture and Life Science*. 2002. https://www.cias.wisc.edu/wp-content/uploads/2008/07/soilorgmtr.pdf *Accessed November 2018.*

10. **Valarini PJ, Curaqueo G, Seguel A, Manzano K, Rubio R, Cornejo P and F Borie** Effect of Compost Application on Some Properties of a Volcanic Soil from Central South Chile. *Chilean Journal of Agricultural Research*. 2009; **69(3).** http://doi.org/10.4067/S0718-58392009000300015

11. **Niwagaba C, Nalubega M, Vinnerås B, Sundberg C and H Jönsson** Bench-scale composting of source-separated human faeces for sanitation. *Waste Management*. 2009; **29(2):** 585–589. https://doi.org/10.1016/j.wasman.2008.06.022

12. **Sallah A, Asongwe GA, Alobwede NJ and FD Ngang** Effect of different Organic Manures and Mineral NPK Fertilizer on Maize Yield on Volcanic Soils of the Mt Cameroon area under Minimum Tillage. *Greener Journal of Agricultural Sciences.* 2017; **7(4):** 097–104. http://doi.org/10.15580/GJAS.2017.4.051617062

13. **Joergensen RG, Toncea I, Boner M and J Heß** Evaluation of organic sunflower fertilization using δ^{15}N values. *Org. Agr.* 2019; **9:** 365–372. https://doi.org/10.1007/s13165-018-00241-3

14. **Hollyer J, Brooks F and L Castro** The Use of Human Wastes on Food in Hawai'i: What is Allowed and What Is not. Food Safety and Technology. College of Tropical Agric. and Human Resources Univ. of Hawai'i at Manca. 2014.

15. **Oktiawan W and I Priyambada** Optimization of Fecal Sludge Treatment Plants by Composting Fecal Sludge (IPLT Semarang Case Study). *Journal of Presipitasi.* 2007; **3(2):** 53–57. https://doi.org/10.14710/presipitasi.v3i2.53-57

16. **Timmer L and C Visker** Possibilities and Impossibilities if the Use of Human Excreta as Fertilizer in Agriculture in sub-Sahara Africa. Royal Tropical Institute and the Univ. of Amsterdam. 1998; 30. https://www.ircwash.org/sites/default/files/352.2-98PO-16640.pdf *Accessed January 2019.*

17. **Ahmed I, Ofori-amanfo D, Awuah E and F Cobbold** A Comprehensive Study on the Physicochemical Characteristics of Faecal Sludge in Greater Accra Region and Analysis of Its Potential Use as Feedstock for Green Energy. Journal of Renewable Energy. 2019; 1–11. https://doi.org/10.1155/2019/8696058

18. **Hübner T, Herrmann A, Kretzschmar J and F Harnisch** Suitability of fecal sludge from composting toilets as feedstock for carbonization. *Journal of Water, Sanitation and Hygiene for Development*. 2017. https://doi.org/10.2166/washdev.2019.047

19. **Odey EA, Li Z, Zhou X and K Kalakodio** Fecal sludge management in developing urban centers: a review on the collection, treatment, and composting. Environ Sci Pollut Res Int. 2017; **24(30):** 23441–23452. https://doi.org/10.1007/s11356-017-0151-7

20. **Osibote BA, Osibote I, Bolaji O and GREE Ana** Effect of Thermal Treatment on Microbial load of Faecal Sludge From Some Faecal Sludge Collection Sites in Oyo State, South-Western, Nigeria. Jordan Journal of Biological Sciences. 2016; **9(4):** 243–248. http://jjbs.hu.edu.jo/files/v9n4/Paper%20Number%20%206.pdf

21. **Spangberg J, Tidaker P and H Jonsson** Environmental impact of recycling nutrients in human excreta to agriculture compared with enhanced wastewater treatment. *Sci Total Environ.* 2014; **493:** 209–219. https://doi.org/10.1016/j.scitotenv.2014.05.123

22. **Zseni A** Human excreta management: human excreta as an important base of sustainable agriculture. 2015. https://www.researchgate.net/publication/273382957_Human_excreta_management_human_excreta_as_an_important_base_of_sustainable_agriculture

23. **Idjudin AA, Erfandi MD and S Sutono** Post-Mount Merapi Volcanic Sedimentation Land Productivity Improvement Technology. 2012: **6(1).** https://doi.org/10.2018/jsdl.v6i1.6300

24. **Wardoyo SS and AZPB Santoso** Environmental adaptability of Canavalia virosa and Flemingia congesta to sandy ash soil of Merapi Volcano, Java. *Journal of Degraded and Mining Lands Management*. 2016; **3(4):** 659–662. https://doi.org/10.15243/jdmlm.2016.034.659

25. **Suprapto A and BA Saputra** The role of organic matter and planting space on shallot (*Allium cepa fa. Ascalonicum*, L.) on the erupted sand of Merapi. VIGOR: Journal of Tropical and Subtropical Agricultural Sciences. 2017; **2(1):** 34–36. https://doi.org/10.31002/vigor.v2i1.325

26. **Heinonen-Tanski H and VC Wijk-Sijbesma** Human excreta for plant production. Bioresour Technol. *Bioresource technology*. 2005; **96(4):** 403–411. https://doi.org/10.1016/j.biortech.2003.10.036

27. **Krounbi L, Enders A, van Es H, Woolf D, von Herzen B and J Lehmann** Biological and thermochemical conversion of human solid waste to soil amendments. *Waste Manag*. 2019; **86:** 366–378. https://doi.org/10.1016/j.wasman.2019.04.010

28. Schouw NL, Danteravanich S, Mosbaek H and J Tjell Composition of human excreta, a case study from Southern Thailand. *Science of The Total Environment.* 2002; **286(1–3):** 155–166. https://doi.org/10.1016/S0048-9697(01)00973-1

29. **Amos H, Voncir ASF and A Garba** Effect of Cattle Manure on the Growth and Yield Performance of Vegetable Maize (*Zea mays saccharata*) Varieties under Irrigation. *Scholars Journal of Agriculture and Veterinary Sciences.* 2015; **2(4A):** 319–323. http://saspjournals.com/wp-content/uploads/2015/08/SJAVS-24A319-323.pdf

30. **Okoroafor I, Okelola E, Edeh O, Nemehute V, Onu C, Nwaneri T and G Chinaka** Effect of Organic Manure on the Growth and Yield Performance of Maize in Ishiagu, Ebonyi State, Nigeria. *Journal of Agriculture and Veterinary Science.* 2013; **5(4):** 28–31. http://www.iosrjournals.org/iosr-javs/papers/vol5-issue4/G0542831.pdf

31. **Pangaribuan DH, Hendarto K, Elzhivago SR and A Yulistiani** The effect of organic fertilizer and urea fertilizer on growth, yield, and quality of sweet corn and soil health. Asian J Agri & Biol. 2018; **6(3):** 335–344. https://www.asianjab.com/wp-content/uploads/2018/10/7-192.-The-Effect-of-Organic-Fertilizer-and-Urea-Fertilizer-on-Growth-Yield-Quality-of-Sweet-Corn.pdf

32. **Rowell DI** Soil Science and Applications. Longman Scientific Technical. 1994, London UK. 350p.