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Effect of Municipal Solid Waste Compost, Farm Yard Manure, Inorganic Fertilizers and Their Combinations on Potato Yield in Wolmera District, Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study was conducted in Wolmera district of Oromia Regional State, Ethiopia. The main research objective was to evaluate the effect of municipal solid waste compost on potato yield in comparison to inorganic fertilizers and farm yard manure and combined applications. The experimental design was a factorial in randomized complete block design (RCBD) with three replications. The treatments were: i) combination of diammonium phosphate (97.5 kg/ha), urea (82.5 kg/ha) and municipal solid waste compost (10,000 kg/ha), ii) combination of diammonium phosphate (97.5 kg/ha), urea (82.5 kg/ha) and farm yard manure (10,000 kg/ha), iii) diammonium phosphate (195k g/ha) and urea (165 kg/ha), iv) farm yard manure (20,000 kg/ha), v) municipal solid waste compost (20,000 kg/ha), and vi) control. The findings of the research indicated that the combination of municipal solid waste compost and inorganic fertilizers resulted in the highest total tuber yield and total marketable yield, 18.2±0.7 ton/ha and 17.8±0.7 ton/ha, respectively, with 149% relative marketable yield advantage over control. Sole application of municipal solid waste compost was also resulted in significant (P=.05) potato yield increment compared to the control. It resulted in an increase of marketable potato tuber yield advantage of

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52% over the control with total marketable yield of 10.9±0.9 ton/ha. Hence, combined use of municipal solid waste compost and inorganic fertilizers may be a promising option for poor potato farmers around the City of Addis Ababa.

Keywords: Municipal solid waste compost; potato yield; manure.

1. INTRODUCTION

In sub-Saharan Africa (SSA) soil fertility depletion is a major threat to food security [1,2]. This problem is exacerbated by wind and water surface soil erosion [3], poor rainfall distribution [4], restricted fallow periods in which to restore soil fertility [5] and low rates of fertilizer application [6]. The region is also characterized by climatic conditions that accelerate the degradation of soil organic matter [7] which, in turn, reduces the water holding capacity of the soils leading to soil deficiency in various essential plant nutrients [8,9].

Like other SSA countries, soil fertility decline is a major constraint to agricultural production and food security in Ethiopian farming systems [10,11,12]. Subsistence farmers have very limited capacity to invest in inorganic fertilizers which are expensive [13]. As a result, crop yields are low and many farmers are forced to put marginal lands into production to meet their food needs [10,14,15,11,12].

Municipal Solid Waste (MSW) is a type of household waste consisting of everyday items that are discarded by the public. The high organic content in the MSW stream of developing countries is ideal for composting [16,17,18,19]. Hence, composting is becoming one of the alternative strategies viable and economical for effective municipal solid waste management both in developed and developing countries. It has advantages over land filling and incineration because of lower operational costs, less environmental pollution, and beneficial use of the end product [20,21]. Studies indicated that addition of MSW compost to the soil improved its structure and increased aggregate stability [22,23]. It was also found that additions of MSW compost to crop field increased microbial biomass and improved soil fertility status [22,23].

Currently, in Ethiopia there is a promising effort being made to manage municipal solid waste by composting. Studies indicated that about 60% of the solid waste in Addis Ababa is compostable [24,25,26,27]. Similar proportion is expected in other towns in the country. The use of MSW compost as a soil organic amendment is of an economic and environmental interest given the current environmental degradation due to inappropriate handling and disposal of solid waste [28,29,26,27]. However, little is known about the effectiveness of MSW compost application on agricultural soils in the country. So far, no robust research has been done regarding the effect of municipal solid waste compost on potato yield on farmer's field. In light of this, the study was conducted to scrutinize the potential of municipal solid waste compost for small holder potato grower farmers around the City of Addis Ababa, Ethiopia.

2. MATERIALS AND METHODS

2.1 Location

The experiment was conducted in Wolmera District, Ethiopia, from September 2008 to June 2009. It is located at about 40 km west of Addis Ababa on latitude 24°34'S and longitude 25°57'E elevated at 2408 m above sea level. The average annual rainfall of the area is 1040 mm and the mean minimum and maximum daily temperatures are 6°C and 25°C, respectively.

2.2 Experimental Design and Treatments

Experiment was carried out through a factorial in randomized complete block design (RCBD) with three replications. Plot size was 3mX3m ($9m^2$) with 1m pathways between replications and 1.5m between blocks. One improved potato variety, Jalene (CIP-384321.19), was planted and evaluated under different types of fertilizer sources. The inorganic fertilizers include diammonium phosphate (DAP) and Urea, farm yard manure (FYM), municipal solid waste (MSW) compost, combination of inorganic fertilizers and FYM and combination of inorganic fertilizers and MSW compost were applied at different rates.

Experimental plot was well prepared prior to planting. It was ploughed three times. Planting was made in rows and the spacing was 30 cm between plants and 75cm between rows. Total number of plants per plot was 40. MSW compost used for this study was produced from the municipal organic garbage in Addis Ababa City. The biodegradable materials were properly sorted before the materials were composted. The composted material included: remains of vegetables and fruits, grasses, leaves, cow dung, top soil and water. FYM was collected from the cattle barnyard in Wolmera District. It comprised cattle dung, cattle urine and waste straw.

Detail description of treatments was as follows:

- T1: Combination of DAP (97.5 kg/ha), urea (82.5 kg/ha) and MSW compost (10,000 kg/ha)
- T2 :Combination of DAP (97.5 kg/ha), urea (82.5 kg/ha) and FYM (10,000 kg/ha)
- T3: DAP (195 kg/ha) and urea (165 kg/ha)
- T4: FYM (20,000 kg/ha)
- T5: MSW compost (20,000 kg/ha)
- T6: Control (no fertilizer application)

2.3 Sampling and Analysis

2.3.1 Soil, MSW compost and FYM sampling and analysis

Soil samples from a depth of 0-15cm were randomly taken from experimental field before planting. The samples were thoroughly mixed to make one composite sample representing the field and analyzed for some selected physical and chemical properties. The soil was air-dried and grounded to pass a 2 mm sieve. Physical and chemical parameters such as total nitrogen (N), available phosphorus (P), available potassium (K), pH, Electrical conductivity (EC), cation exchange capacity (CEC), exchangeable bases (sodium, potassium, calcium and magnesium), organic matter and texture were determined in order to know the initial fertility status of the soil. Also composite samples of FYM and MSW compost were analyzed for the same parameters except texture. The analysis of the selected physical and chemical parameters of soil, MSW compost and FYM was carried out at Addis Ababa Environmental Protection Authority (AAEPA) laboratory.

Total nitrogen determination was performed using Kjeldhal procedure [30]. Available P was estimated following the method of Olsen et al. [31]. CEC and exchangeable bases were extracted by saturating the samples with 1 N NH_4OAc and displacing it with 1N NaOAc. Calcium (Ca) and magnesium (Mg) values were then read using Atomic Absorption Spectrophotometer (AAS) while potassium (K) and sodium were determined by using flame photometer [32]. The percent base saturation was calculated from the CEC data. pH was measured in H_2O (1:2.5, soil: water ratio) [33]. The EC was also determined in H_2O (1:2.5, soil: water ratio). Soil texture was determined using Bouyoucous hydrometer method [34]. Organic matter was measured according to Walkley and Black [35].

2.3.2 Agronomic data collection

Average plant height, number of main stems, total fresh tuber yield, total marketable yield, and graded yield as <20 mm, 20-30 mm, 30-40 mm, 40-50 mm, and > 50 mm [36] were collected. Marketable yield is the yield above 20 mm and which is free from disease, insect attack and crack.

Plant height was measured using meter at plant flowering stage. Number of main stems was counted also at flowering stage. Total, marketable and graded yield were collected at plant harvest and weight was measured using balance. Grading of potato tubers was carried out using a caliper that has different diameter.

2.3.3 Data analysis

Data were analyzed using SAS software for statistical analysis of variance (ANOVA). All crop parameters including yield and associated agronomic traits related to response of the treatments were determined by comparing all of the treatments used for the experiment. Differences among treatment means were delineated using Least Significant Difference (LSD) test (P=.05).

In addition, relative increase % (RI) was calculated for fresh tubers yield compared with control as follows [37].

$$RI\ \% = \frac{\text{Yield treatment} - \text{Yield control (ton/ha)}}{\text{Yield control (ton/ha)}} * 100$$

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of Soil, FYM and MSW Compost

Physicochemical properties of the soil of the experimental site, FYM and MSW compost used for the experiment are shown in Table 1.

Table 1. Results of the physicochemical analysis of soil prior to planting, FYM and MSW compost

Physicochemical properties	Parameters		
	Soil	MSW compost	FYM
pH	5.7	7.8	7.1
EC (dS/m)	0.1	3.4	8.4
Total N (%)	0.3	0.6	0.4
Organic matter (%)	2.8	11.7	15.1
Organic carbon (%)	1.6	6.8	8.8
C:N ratio	5.3	11.3	22
Available P (ppm)	33	109	83
Available K (ppm)	147	153	136
CEC (cmol$^+$/kg)	23	39	41
Ca^{2+} (cmol$^+$/kg)	2.9	3	2.8
Mg^{2+}(cmol$^+$/kg)	0.6	0.6	0.6
K^+ (cmol$^+$/kg)	0.4	11.2	12
Na^+ (cmol$^+$/kg)	0.03	0.2	0.4
Sand (%)	29	-	-
Silt (%)	37	-	-
Clay (%)	34	-	-
Textural class	Silt clay loam	-	-

The result of soil analysis indicated that the soil of the experimental site was acidic in reaction with pH value of 5.7 as shown in Table 1. However, both MSW compost and FYM were near neutral with pH values of 7.8 and 7.1, respectively. The pH value of the MSW compost used for the experiment had met the compost quality standards used for agriculture in Switzerland (pH < 8.2), and in Great Britain (7.5-8.5) [38]. Furthermore, according to Langenberg [39], it was in the recommended range for the quality compost used by the countries such as Dutch, Belgium and Italy (6.5-8.5). Similar pH values were reported by Holmer [40] between 5.5 - 8.5 and Cooperband [41] between 5.5-9.0.

Electrical conductivity (EC) of FYM was very high with the value of 8.4 dS/m. Such soils need gypsum application to minimize the negative effects of salinity. This could harm most plants as explained by Mamo et al. [42] who stated that most plants could not tolerate a soluble salt content greater than 4dS/m. On the other hand, the EC of the MSW compost was 3.4 dS/m. According to Langenberg [43], the MSW compost had met also the compost quality used in countries such as Dutch, Belgium and Italy in terms of its EC which was stated as < 5.5 dS/m.

Organic matter content of the soil was found to be 2.8 %. This could be mainly due to the removal of crop residues from the crop field for animal feed. Similarly, the total nitrogen of the soil was only 0.3% (low) [44], whereas the available phosphorous and available potassium contents of the soil were high [44], with values of 33 and 147 ppm, respectively.

Total nitrogen content of the MSW compost was 0.6% (low) [44]. But, according to Kuo et al. [45], in order for a compost to have fertilizing capabilities in agriculture, the total nitrogen content must be in the range of 1-3%. Hence, the MSW compost used for the experiment had low (0.6%) content of total nitrogen. Such MSW compost usually requires supplemental nitrogen fertilizer application [45]. The available phosphorous and available potassium found in MSW compost were 109 and 153 ppm, respectively. According to Mamo et al. [42] and Kuo et al. [45], the range of available phosphorous in typical compost is usually between 40 -110 ppm dry weights. According to Schulte and Kelling [46], available potassium content of MSW compost should be 60-120 ppm for most field crops and some what higher for potato and some vegetable crops, including cabbage, carrot, and tomato. Hence, the MSW compost used for this experiment had excess content of available potassium (153 ppm).

Amount of exchangeable cations of the soil was small and cation exchange capacity (CEC) was also 23 Cmol+/kg. This could be due to the high rainfall prevailing in the area which could cause the leaching of exchangeable cations. In contrast, the amount of exchangeable cations of MSW compost was relatively higher with the values of 3 (Ca^{2+}), 0.6 (Mg^{2+}), 11.2 (K^+) and 0.2 Cmol$^+$/kg (Na^+). CEC of MSW compost and FYM were also found to be high with the values of 39 and 41 Cmol$^+$/kg, respectively. Textural class of the soil was found to be silt clay loam (Table 1).

3.2 Plant Height and Number of Main Stems

Potato plant height data were taken at flowering stage. The effects of each treatment on potato plant height and number of main stems are indicated in Table 2.

Table 2. The effect of MSW compost, FYM, inorganic fertilizers and their combinations on potato height and number of main stems

Treatments	Height (cm)	Number of main stems	Height increase relative to the control (%)
Combination of DAP, urea and MSW compost (T1)	69.3±3.6 a	5±0.4 a	57
Combination of DAP, urea and FYM (T2)	64.1±0.9 ab	4±1.0 a	45
DAP and urea (T3)	73.7±2.7 a	5±1.0 a	66
FYM (T4)	55.8±3.1 b	4±0.3 a	26
MSW compost (T5)	64.9±5.0 ab	4±0.2 a	47
Control (no fertilizer application) (T6)	44.3±2.8 c	4±0.3 a	
LSD	9.96	1.44	
CV (%)	9.03	19.04	

Means followed by the same letters within the same column are not significantly different at p=.05 using LSD test

Potato height was significantly affected by combined application of MSW compost and DAP and Urea (T1), and sole application of inorganic fertilizers (T3) (P=.05). The results revealed that individual application of inorganic fertilizers, combination of inorganic fertilizers and MSW compost and individual application of MSW compost increased potato height 66%, 57% and 47% and 45%, respectively, relative to the control (T6) (Table 2). This could be due to the higher availability of major plant nutrients in inorganic fertilizers and MSW compost and their combination.

The highest plant height was recorded using individual application of inorganic fertilizers (T3) followed by combination of inorganic fertilizers and MSW compost (T1) with the values of 73.7±2.7 cm and 69.3±3.6 cm, respectively. The increase in plant height by the two treatments was found to be 36-40% higher than the control (T6). Combination of inorganic fertilizers and farm yard manure (T2) was resulted in 45% height increase than the control (T6).

All plants showed almost the same number of main stems, between 4-5. There was no statistically significant difference detected among the treatments. Plants treated with inorganic fertilizers (T3) and combinations of inorganic fertilizers and municipal solid waste compost (T1) were higher than the other plants treated with the remaining treatments in terms of number of main stems. The maximum number of main stems was recorded with sole application of inorganic fertilizer (5± 0.9) and its combination with MSW compost (5± 0.4) (Table 2) whereas the least number of main stems were recorded from sole application of municipal solid waste compost (T5).

Table 3. Effect of MSW compost, FYM, inorganic fertilizers and their combinations on total tuber yield and total marketable yield

Treatments	Total tuber yield (t/ha)	Total marketable tuber yield (t/ha)	Marketable tuber yield increase relative to the control (%)
Combination of DAP, urea and MSW compost (T1)	18.2±0.7 a	17.8±0.7 a	149
Combination of DAP, urea and FYM (T2)	15.5±1.2 a	15.3±1.2 a	112
DAP and urea (T3)	16.4±0.5 a	16.2±0.6 a	125
FYM (T4)	10.4±0.7 bc	10.3±0.7 bc	42
MSW compost (T5)	11.1±1.0 b	10.9±0.9 b	52
Control (no fertilizer application) (T6)	7.3±1.9 c	7.2±2.0 c	
LSD	3.4	3.4	
CV (%)	14.5	14.7	

Means followed by the same letters within the same column are not significantly different at p=.05 using LSD test

3.3 Total and Marketable Tuber Yield

Total tuber yield and total marketable yield obtained using each treatments as well as the relative yield increase are described in Table 3.

Combination of MSW compost and inorganic fertilizers (T1) and sole application of inorganic fertilizers (T3) resulted in the highest total tuber yield, 18.2±0.7 t/ha and 16.4±0.5 t/ha, respectively followed by 15.5±1.2 t/ha by combination of inorganic fertilizers and farmyard manure (T2) (Table 3). The least tuber yield of 7.3±1.9 t/ha was recorded from untreated control plants.

The highest marketable tuber yield was recorded as 17.8±0.7 t/ha with treatment of inorganic fertilizer and municipal solid waste compost (T1) followed by 16.2±0.6 t/ha and 15.3±1.2 t/ha with inorganic fertilizers (T3) and combination of inorganic fertilizer and farm yard manure (T2), respectively. The least amount of marketable yield of 7.2±2.0 t/ha was recorded from untreated control plants. Although there was no any statistically significant difference amongst T1, T2, and T3, the latter showed difference in marketable yield compared with the application of only farm yard manure (T4) and MSW compost alone (T5). In general, different treatments were found to increase 52-149% in marketable yield compared to the control (Table 3).

Similar results were reported by several researchers [47,48,49,50]. According to Erich et al. [49], yields of potato were significantly higher in plots amended with compost than control. Compost resulted in potato yield increase from 11.97 to 21.41 ton/ha at 10, 20, 30 and 40 tons/ha rates of application whereas the yield from the control plot was 4.36 tons/ha [49]. This tends to imply that high expenditure on inorganic fertilizers may be minimized by combining them either with MSW compost or FYM without yield reduction. The results on the total marketable tuber yield of the different treatments showed the same pattern as that of the total tuber yield (Table 3).

The yield increment obtained by the application of MSW compost and FYM either alone or in combination with inorganic fertilizers could be due to the positive effects of MSW compost and FYM on the physical, chemical and biological properties of the soil. Similarly, Warman and Harvard [48], and Maynard [47] found that MSW compost increased potato (15.4 - 24.6 t/ha) and other vegetables yield. In addition to this, it was reported that MSW compost could be used in place of inorganic fertilizer to supply major plant nutrients except nitrogen [50].

In this study, the total yield obtained using sole application of MSW compost (11.1± 1.0 ton/ha) was less than the one obtained through the application of inorganic fertilizers alone (16.4±0.5 ton/ha) (Table 3). This could be due to the slow release of major plant nutrients from MSW compost in the first year of application. Various researchers [51,52,53,50] also reported the slow release of plant nutrients from MSW compost and less amount of availability of nutrients in the first cropping season.

The implication of the significance of potato yield increment found in this research due to the application of MSW compost alone and in combination with inorganic fertilizers (Table 3) is paramount. This is because management of solid waste is currently putting a great burden in cities of both developed and developing countries coupled with rapid population growth [19]. This depicts that composting MSW may be a sensible way of managing solid wastes.

3.4 Potato Tuber Size

After harvest, fresh potato tubers from each plot were graded into various size classes and weighed. The size classes were as indicated in Table 4.

Effect of the treatments on potato tuber sizes is indicated in Table 4. Combination of inorganic fertilizers and MSW compost resulted in statistically significant difference (P=.05) of tuber size above 50 mm in diameter. Regarding the yield of 40 -50 mm size tubers, both T1 and T3 showed a significant increase compared to the treatments T2, T4 and T5. No significant variation were recorded in the other size groups, except the smallest size group (<20 mm). It is interesting to note that no significant variation was recorded among the yields of 30-40 mm and 20-30mm groups with all treatments (Table 4). The difference in the yields of smaller tubers (<20mm) was not significantly different between the treated plants and the control. This could be due to the appreciable amounts of the major plant nutrients supplied through both the application of inorganic fertilizers alone and integration with MSW compost and farm yard manure.

Table 4. Effect of MSW compost, FYM, inorganic fertilizers and their combinations on the size of potato tuber

Treatments	Mean of graded potato tuber yield (t/ha)				
	>50 mm	40-50 mm	30-40 mm	20-30 mm	<20 mm
Combination of DAP, urea and MSW compost (T1)	5.5±0.3 a	7.3±0.6 a	3.9±0.27a	1.1±0.2 a	0.3 ±0.0 a
Combination of DAP, urea and FYM (T2)	3.9±0.6 b	4.9±0.5 b	5.1±1.0 a	1.4±0.48 a	0.2 ±0.0 bc
DAP and urea (T3)	3.7±0.2 b	7.2±0.5 a	4.3±0.8 a	1.0±0.3 a	0.3 ±0.1 ab
FYM (T4)	2.1±0.2 c	4.1±0.1 bc	3.2±0.2 a	1.0±0.3 a	0.1 ±0.0 c
MSW compost (T5)	1.9±0.1 c	4.6±0.6 b	3.4±0.1 a	1.0±0.1 a	0.2 ±0.0 bc
Control (no fertilizer application) (T6)	0.9±0.2 d	2.4±1.0 c	3.1±1.1 a	0.7±0.1 a	0.1 ±0.0 c
LSD	4.7	5.1	3.7	3.9	6.4
CV (%)	18..5	20..4	31.9	42..9	33.0

Means followed by the same letters within the same column are not significantly different at p=.05 using LSD test

4. CONCLUSION

Although this study is based on an experiment in one cropping season, the findings suggest that use of MSW compost in combination with inorganic fertilizers could be a promising alternative for smallholder potato grower farmers for whom high cost of inorganic fertilizers has remained a critical challenge. Composting municipal solid waste for agricultural purpose at large scale may also be considered as a long-term solution for the problems associated with municipal solid waste management in the City of Addis Ababa. Going forward, more research is needed to better understand the potential of MSW compost for potato production including its economic feasibility in smallholder farmers context.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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