STUDY ON LANDFILL MINING OF OLD DUMP SITE FOR COMPOSTABLE MATTERS IN COMPARISON WITH FRESH DUMP SITE

Malghalara[†1], Mohammad Nafees[†2], Yousaf Noor[3]
[1]Department of Environmental Sciences, the University of Peshawar, Khyber Pakhtunkhwa, Pakistan
[2]Department of Environmental Sciences, the University of Peshawar, Khyber Pakhtunkhwa Pakistan
[3]Agricultural Research Institute (ARI), Tarnab, Peshawar, Khyber Pakhtunkhwa, Pakistan

Abstract
Organic soil amendments derived from municipal solid waste (MSW) have the potential to improve the health and productivity of soil. To study solid waste dump site and its use, a two-year field experiment was conducted by preparing two types of compost, i.e. fresh (D_1: derived from the mining of the freshly dumped MSW) and old composts (D_2: obtained from the mining of an old landfill site). The prepared composts were applied to spring maize (*Zea mays* L.) at the rate of 06, 12, 18 and 24 t/ha^{-1}. It was recorded that MSWC at the rate of 24 t ha^{-1} increased the leaf area, number of leaves per plant, plant height, cobs per plant, cob yield, 1000 grain weight, grain yield, and biological yield by 27.62, 7.33, 13.15, 33.84, 0.257, 17.38, 12.43, 32.23, and 28.85%, respectively, relative to the control. The number of leaves per plant, plant height, number of cobs per plant, 1000 grain weight, grain yield and biological yield were increased by 3.50, 1.78, 4.81, 0.82, 4.02, and 3.69%, respectively, during the 2nd year of experiment as compared to the 1st year. The effect of compost types as a factor showed that plant height, cob yield, 1000 grain weight, grain yield, and biological yield were enhanced by 1.61, 2.74, 1.10, 5.48, and 1.81% with the fresh compost as compared to the old. It can be concluded that compost derived from different municipal solid waste landfill sites positively influenced the growth of the maize crop and soil condition. Moreover, the compost application at the rate of 24 t ha^{-1} reduced the use of commercial fertilizer without affecting the grain yield.

Keywords: Landfill mining, Zea mays L., Crop yield, Compost, Municipal solid waste.

1. Introduction

Composting of this waste collected from landfills is rich in organic content that can be used as organic fertilizer to improve soil fertility and agricultural land productivity (Liu et al., 2019). Municipal solid waste-derived compost in agricultural fields is a cost-effective option for MSW recycling. It will not only reduce the burden of landfill but also minimize the energy requirements of fertilizer manufacturing industries (Srivastava et al., 2016). In many parts of the world, the practice of recycling MSW into compost has been widely adopted to maintain soil fertility and improve the productivity of agro-ecosystems (Crecchio et al., 2004). In many studies, the use of MSWC is recommended, because of its soil conditioning properties and positive effects on physical, chemical and biological properties it is known as soil enhancer (Hargreaves et al., 2008) and nutrient supplement for crops (Mandal, et al., 2020). However, application of MSWC not only influences soil structure improvement, organic matter restoration, stimulation of microbial activity and supply of essential nutrients (Giannakis et al., 2014). But also creating a suitable soil environment for plant growth (Kebede et al., 2023).Studies conducted in other parts of the world revealed that compost prepared from landfill mining has reduced volume of the waste, destroys malodorous compounds, decreases germination of weeds and kills pathogens in agricultural fields (Rahman et al., 2020). Hence, the use of MSWC in agriculture not only improve overall quality of soil but also maintaining long term productivity of soil (Hossain et al., 2017).

Maize (*Zea mays* L.) is an important cereal crop that belongs to the Poacea family and has good nutritional and economic value (Khan et al., 2014). This crop is composed of starch, protein, fiber, oil, sugar, vitamins and some other minerals such as sulphur, calcium, and phosphorus (Faisal et al., 2021). This crop is considered a multipurpose crop that is used as food, fodder, feed and one a major source of raw materials for industry (Khan et al., 2011). Maize is widely grown in Khyber Pakhtunkhwa province of Pakistan on 475.3 thousand hectares of land with a yield of 887.8 thousand tons (Imran, 2015). Although the climatic and soil conditions are favorable for maize production (Bakht et al., 2006), the average maize yield is still lower than the other parts of the Pakistan (Amanullah and Khan, 2015). Problems associated with low yield include soil degradation, indiscriminate fertilizer application, poor management practices, poor quality seeds, and lack of modern technologies (Shah et al., 2009). To improve the yield, the present study was conducted to evaluate the effects of different types of MSWC (i.e., freshly dumped waste and old abandoned landfill sites) on the growth and yield of spring maize during 2017-2018 under field conditions.

2. Materials and Methods

2.1. Sampling and preparation of composts

A detailed reconnaissance landfill sites survey of dumpsite was conducted at ring road Hazar-khwani in Town-1, Peshawar. For cluster sample collection, the whole dumpsite was divided into two major blocks i.e. fresh waste dumping area (D_1) and old filled pits area (D_2). Furthermore, each block was divided into five zones. One subsample of approximately 500 kg was collected from a 3x3 ft^2 area from each zone. A 1000 kg portion of compostable solid waste material was separated from old and freshly dumped materials and transported to the Agricultural Research Institute (ARI), Peshawar, Pakistan. The collected samples were further sorted out and compost was prepared (Rahman et al., 2020). The organic components were chopped into small pieces, mixed well, and then placed into the compost pit with a moisture content maintained at around 60%. During the composting, the organic materials in the pit were mixed fortnightly. After 90 days, the final compost was shifted to the laboratory, where it was air-dried at room temperature and then homogenized by passing through a 2 mm sieve. The prepared MSWC was stored in plastic bags till its use in the field experiment.

2.2. Collection of Soil Samples

Before the application of composts, a composite sample of soil was collected at a depth of 30 cm from the experimental area. At post-harvest stage, 5 random spots from each treatment were sampled and a composite sample of each treatment was collected. The soil samples in fresh condition were transported to the laboratory of ARI, Tarnab Peshawar. The collected samples of soil were first dried at room temperature, sorted out then grinded and sieved through a mesh size <2mm in diameter. After the necessary processing, the samples were labelled and kept in plastic bags before use.

2.3. Analysis of Composts and Soil Samples

The collected composts and soil samples were analyzed for various physico-chemical properties, by using standard analytical procedures as adopted by Khan et al., 2010, Ryan et al., 2001, Iqbal et al., 2015, Ahmad et al., 2018, Shah et al., 2014 and Soltanpour & Schwab, 1977 for different parameters as listed in table. 1.

Table-1: Physico-chemical properties of control, fresh and old dumpsite compost

Characteristics	Composite soil	Fresh dumpsite compost (D_1)	Old dumpsite compost (D_2)
pH	7.32	7.58	8.65
EC (dS m^{-1})	0.34	0.61	1.39
$CaCO_3$ (%)	7.25	1.09	3.85
Organic matter (%)	0.75	27.3	12.9
Texture	Silty loam	-	-
Total Nitrogen (%)	0.18	1.23	0.65
Total Phosphorous (%)	0.15	0.27	0.25
Total Potassium (%)	0.12	0.48	0.44

2.4. Application of Composts to Maize Crop

For the field experiment, a randomized complete block design (RCBD) with split plot arrangement in three replicates was used, whereas main plots were used for types of MSWC and the sub-plots comprised of the rate of MSWC (Table 2).

Table -2: Detail of the types of MSWC and its levels applied to the maize crop.

Treatments	Composition
	Fresh MSWC (D_1) / Old MSWC (D_2)*
T_1	Control
T_2	Fertilizer (NPK) at the rate 120-90-60 Kg ha^{-1}
T_3	6 ton ha^{-1} MSWC
T_4	12 ton ha^{-1} MSWC
T_5	18 ton ha^{-1} MSWC
T_6	24 ton ha^{-1} MSWC

*same treatment composition was used for D1 and D2

During the growth phase and at the time of harvesting, observations of different agronomic parameters were recorded on 10th July 2017 and 14th July 2018. The data were recorded for leaf area (cm^2), number of leaves per plant, plant height (cm), number of cobs per plant, cobs at harvest (ha^{-1}), cobs yield (kg ha^{-1}), 1000 grain weight (g), grain yield (kg ha^{-1}), and biological yield (kg ha^{-1}).

2.5. Data analysis

All the data were subjected to statistical analysis (Steel and Torrie, 1980). The variations among the treatments were assessed using the least significant difference (LSD) test. All the computation was done through statistical software SPSS and the figures were drawn using Origin-pro.

3. Results and Discussion

a. **Characteristics of post-harvest soil with application of composts**

Data on pH level in post-harvested soil samples are presented in Table 3. The pH level in post-harvested soil ranged from 7.4-7.7. Higher values (7.8) were observed in NPK fertilizer treated soil followed by treatment received 24 t ha^{-1} MSWC (7.7). While, non-significant effect was observed among treatments at the rate 6, 12, and 18 t ha^{-1} respectively. While the minimum value of pH was recorded in control treatment (7.4). This study confirmed that repeated application of MSWC improved the physico-chemical properties of the post-harvest soil sample. It was observed that with increasing rate of MSWC, the pH of the soil also increased. These results were in line with other researchers (Lee et al., 2019). Increase in soil pH after application of compost was due to mineralization of N and decomplexation of cation producing OH-, Mg^{2+}, Ca^{2+} and K^+ in degradation of organic products (Erana et al., 2019).

Furthermore, the results showed that different levels of treatment significantly affected the soil EC. The soil EC in D_1 ranged from 0.24- 0.42 (dSm^{-1}). The high EC value was observed at 24 t ha^{-1} treatment (0.42 dSm^{-1}) which was found non-significant to the treatments at the rate 18 t ha^{-1} (0.42 dSm^{-1}) and 12 t ha^{-1} (0.41dSm^{-1}) treatments, respectively. While, the minimum EC values were observed in NPK (0.22 dSm^{-1}) and control treatment (0.24 dSm^{-1}). Similarly, the value of EC (dSm^{-1}) in soil samples treated with D2 ranged from 0.28- 0.42 (dSm^{-1}). The high EC value was observed at 12 t ha^{-1} (0.42 dSm^{-1}) followed by 24 t ha^{-1} (0.40 dSm^{-1}), 18 t ha^{-1} (0.38 dSm^{-1}) and 6 t ha^{-1} (0.32 dSm^{-1}).

The value of OC in post-harvested soil samples treated with D1 ranged from 0.13-0.56% as presented in Table 3. Significant increase was observed in plots treated with NPK fertilizer (0.56%) followed by 24 t ha^{-1} (0.48 %), 18 t ha^{-1} (0.45 %), 12 t ha^{-1} (0.37 %) and 6 t ha^{-1} (0.31%). Similarly, value of OC in soil treated with D_2 was found in the range of 0.14-0.43 (%). Significant increase was observed in plots treated with NPK fertilizer (0.56%) followed by treatment at the rate of 24 tha^{-1} (0.43%), 18 tha^{-1} (0.41%), 12 tha^{-1} (0.35%) and 6 tha^{-1} (0.30%) respectively. Furthermore, it was observed that the compost derived from D_1 significantly increases OC in the soil as compared to D_2.

The OM in post-harvested soil samples treated with D1 ranged from 0.24-0.97%. Significant increase was observed with NPK fertilizer (0.97%) treatment followed 24 t ha^{-1} (0.83 %), 18 t ha^{-1} (0.78 %), 12 t ha^{-1} (0.65 %) and 6 t ha^{-1} (0.54%). Similarly, value of OC in soil samples treated with D2 were found in the range of 0.25-0.97 (%). Furthermore, it was observed that D_1 significantly increased OM in the soil as compared to D_2. It was observed that the concentration of OC and OM in the soil increased with increasing levels of MSWC. These observations are in conformity to other researchers, that higher application rates of MSWC consistently increased the soil C/N ratio and OM (Walter et al., 2006).

The N concentrations in soil samples treated with D_1 ranged from 0.013 – 0.050 (%). Highest N concentration was observed with 24 t ha^{-1} (0.050 %) followed by NPK (0.049 %), 18 t ha^{-1} (0.046 %), 12 t ha^{-1} (0.038 %) and 6 t ha^{-1} (0.034 %) respectively. Similarly concentration of N in soil samples treated with D_2 were found in the range of 0.015-0.047 (%).Significant increase was observed in plots treated with NPK (0.047%) followed by 24 t ha^{-1} (0.046 %), 18 t ha^{-1} (0.040 %), 6 t ha^{-1} (0.036 %) and 12 t ha^{-1} (0.035%) respectively. Higher concentration of N was observed at high doses of MSWC. Similar results on increase in N concentration with application of compost was reported by Kelly et al., (2020).

The P concentration in soil amended with–D_1 ranged from 7.37-10.03 (mg kg^{-1}). Higher P concentration was observed in 24 t ha^{-1} (10.03 mg kg^{-1}) followed by 18 t ha^{-1} (9.30 mg kg^{-1}), 12 t ha^{-1} (8.16 mg kg^{-1}) and 6 t ha^{-1} (7.93 mg kg^{-1}) respectively. Similarly the P concentration in soil treated with D_2 were ranged from 7.27-9.90 (mg kg^{-1}). Higher P concentration was observed in NPK (10.03 mg kg^{-1}) followed by 24 t ha^{-1}(8.80 mg kg^{-1}), 18 t ha^{-1} (8.30 mg kg^{-1}), 12 t ha^{-1} (7.90 mg kg^{-1}) and 6 t ha^{-1} (7.53 mg kg^{-1}) respectively. The non-significant effect were observed between 24 t ha^{-1} and 18 t ha^{-1}.Similar results with significant increase of P as mineral fertilizers to the soil treated with compost was reported by (Civeira, 2010).

The K concentration in soil samples treated with D_1 ranged from 150.00–178.33 (mg kg^{-1}). The higher concentration of K was found at 24 t ha^{-1} (178.33 mg kg^{-1}) followed by 18 t ha^{-1} (170.33 mg kg^{-1}), 12 t ha^{-1} (168.67mg kg^{-1}), NPK (166.67 mg kg^{-1}) and 6 t ha^{-1} (156.67 mg kg^{-1}) respectively. Similarly the K in soil samples treated with D_2 were ranged from 147.33-172.33 (mg kg^{-1}). Higher concentration was observed in 24 t ha^{-1}(172.33 mg kg^{-1}) followed by 18 t ha^{-1}(167.33 mg kg^{-1}), 12 t ha^{-1} (165.00 mg kg^{-1}), NPK (163.00 mg kg^{-1}) and 6 t ha^{-1} (147.33 mg kg^{-1}) respectively. According to another research study, the soil treated with MSWC at high application level significantly increase K in the soil (Akoijam et al., 2017).This is due to the high presence of K in MSWC which later on released through microbial degradation into soil (Manirakiza and Seker, 2020). As pointed out by other researchers, increasing application rates of MSWC not always increased OC and some nutrients such as total N and available P in the soil (Barzegar et al., 2002). Although, limited nutrients and OC after addition of high application levels attributed to rapid mineralization of OM in the soil (Civeira, 2010).

Table-3. Physico-chemical characteristics of post-harvest soil with application of compost

Properties of post-harvest soil with application of Fresh compost (D_1)								
	Treatment (T)	**pH**	**EC (dSm^{-1})**	**OC (%)**	**OM (%)**	**N (%)**	**P (mg kg^{-1})**	**K (mg kg^{-1})**
	T_1	7.4	0.24	0.139	0.24	0.013	7.37	150
	T_2	7.8	0.22	0.56	0.97	0.049	9.67	166.67
	T_3	7.6	0.38	0.31	0.54	0.034	7.93	156.67

	T_4	7.6	0.41	0.37	0.65	0.038	8.16	168.67
	T_5	7.6	0.42	0.45	0.78	0.046	9.3	170.33
	T_6	7.7	0.42	0.48	0.83	0.05	10.03	178.33
Properties of post-harvest soil with application of Old compost (D_2)								
	Treatment (T)	**pH**	**EC (dSm-^{1})**	**OC (%)**	**OM (%)**	**N (%)**	**P (mg kg^{-1})**	**K (mg kg^{-1})**
	T_1	7.4	0.28	0.14	0.25	0.015	7.27	147.33
	T_2	7.8	0.29	0.56	0.97	0.047	9.9	163
	T_3	7.6	0.32	0.3	0.53	0.036	7.53	152.33
	T_4	7.6	0.42	0.35	0.61	0.035	7.9	165
	T_5	7.6	0.38	0.41	0.72	0.04	8.3	167.33
	T_6	7.7	0.4	0.43	0.74	0.046	8.8	172.33

b. Post-harvest physiological parameters of maize

I. Leaf Area (cm^2)

Results on the leaf area of maize as affected by different types and levels of MSWC for two consecutive years are showed in Table-4. It was observed that MSWC at the rate 24 t ha^{-1} produced significantly broader leaf area (438 cm^2) followed by NPK (421 cm^2) and 18 ton ha^{-1} (415.6 cm^2). Moreover, the MSWC treatment at the rate 12 t ha^{-1} produced leaves with an area of 330 cm^2 that was significantly higher than the control treatment (317 cm^2). However, it was observed that all the interactions, MSWC and years (D x Y), treatments and years (T x Y), treatments and MSWC (T x D) and treatments, years and MSWC (T x Y x D) were also found non- significant for leaf area cm^{-2} (Table-4). Naderi and Ghadiri, (2010) reported that application of MSWC at the rate 25 t ha-1 significantly increased leaf area of maize crops. Chen, J. H. (2006) in his study analyzed the comparative effect of MSWC and other organic and inorganic amendments on growth of maize crops and reported similar results to our findings. Similarly, Obidebube et al., (2012) in their study concluded that the growth of maize crops was significantly influenced by higher application levels of fertilizers than lower rates.

II. Number of Leaves Plant^{-1}

It was observed that MSWC at the rate 24 t ha^{-1} produced more number of leaves per plant (14.7) followed by NPK (14.6). Whereas, MSWC at the rate 18 t ha^{-1} (14.4) was statistically at par with all the other treatments but was significantly better then control. The statistical analysis of data revealed that years as source of variation had significant effect on number of leaf per plant. It was recorded that the number of leaves per plant were higher (14.56) during second year of experiment as compared to the first year (14.05). The effect of types of MSWC and all interactions remained non- significant for number of leaves per plant (Table-4). It was observed that the MSWC application resulted in a higher number of leaves per plant, especially with higher compost levels. These results were in line with the findings of Simeon and Ambah, (2013) who reported that the application of compost derived from MSW increased the number of leaves per plant, plant height and leaf area of maize. Naderi and Ghadiri, (2010) also reported that increasing the MSW compost level up to 50 t ha-^{1} significantly increased the number of maize leaves.

III. .Plant Height (cm)

It was observed that MSWC application at the rate of 24 t ha^{-1} produced taller plants (207 cm) followed by NPK (202 cm) and 18 t ha^{-1} (199 cm) respectively. Whereas, MSWC application at the rate 12 t ha^{-1} significantly increased the plant height (185.42 cm) compared to the control treatment (180 cm). The effect of year as factor showed that plant height was significantly higher (194 cm) in the second year as compared to the first year (191 cm) of experiment. Similarly, the effect of types of compost showed that plots treated with MSWC derived from freshly dumped waste (D_1) had significantly higher plant height (194 cm) as compared to the plots treated with MSWC derived from mining of old dumped waste i.e. D_2 (191 cm) as shown in Table-4. This study confirmed that MSWC application improved the vegetative growth such as height of the maize crop with increasing application levels of MSWC. These observations are in conformity to the work of other researchers reported that increasing application levels of MSWC significantly increased height of maize crop (Ghaly et al., 2010; Khan, 2015).Furthermore, taller maize plants were observed during second year compared to the results of the first year of the experiment, indicating the gradual improvement in soil fertility with the application of MSWC over the years. These findings were in line with the work of Oljaca et al., (2007).

IV. Number of Cobs Plant^{-1}

Results showed that MSWC at the rate of 24 t ha^{-1} produced the highest number of cobs per plant (1.95) followed by NPK (1.92). It was observed that MSWC treatments at the rate 24, 18, 12 t ha^{-1} produced 1.95, 1.77 and 1.43 number of cobs per plant, respectively. Moreover, the NPK treatment was at par to the MSWC at the rate 24 t ha^{-1} but was significantly higher (1.95) then all the other treatments. Furthermore, higher number of cobs per plant were produced in second year (1.66) of the experiment as compared to the first year (1.58). The effect of types of compost and all interactions remained non-significant as reported in Table-4.

The number of cobs per plant is determined by the growth behavior of the plant, which is dependent upon edaphic and climatic factors and management practices (Shah et al., 2009). Our observations are comparable with the findings of Khaliq et al., (2004) who reported that the number of cobs per plant was increased with increasing levels of organic amendments. With the application of MSWC, plants received an adequate supply of nutrients throughout their growth period, which resulted in a prolific number of cobs per plant. Furthermore, regular application of organic fertilizers improved soil fertility which resulted in a higher number of cobs in the second year as compared to the first year.

Table-4: Effect of MSWC application on leaf area, number of leaves per plant, plant height, and number of Cobs per plant

Factors/ parameters	Leaf Area (cm^2)	Number of leaves plant^{-1}	Plant height (cm)	Number of cobs plant^{-1}
Treatments (T)				
Control	317.6 d	13.65 b	180.42 d	1.29 d
NPK (120-90-60)	421.3 b	14.63 a	202.58 b	1.92 a
MSW Compost 6 t ha^{-1}	322.8 cd	14.13 ab	182.75cd	1.38 cd
MSW Compost 12 t ha^{-1}	330.3 c	14.27 ab	185.42 c	1.43 c
MSW Compost 18 t ha^{-1}	415.6 b	14.42 a	199.03 b	1.77 b
MSW Compost 24 t ha^{-1}	438.8 a	14.73 a	207.75 a	1.95 a
Significance/LSD	7.823	0.679	3.575	0.133
Years (Y)				
Year 1	371.86	14.05 b	191.25 b	1.58 b
Year 2	377.02	14.56 a	194.73 a	1.66 a
Significance/LSD	Ns	0.354	2.450	0.057
Composts (D)				
Fresh Dumpsite (D_1)	375.42	14.40	194.57 a	1.65
Old Dumpsite (D_2)	373.46	14.21	191.42 b	1.59
Significance/LSD	Ns	Ns	2.639	Ns
Interaction	**Significance levels**			
D x Y	Ns	Ns	Ns	Ns
T x Y	Ns	Ns	Ns	Ns
T x D	Ns	Ns	Ns	Ns
T x Y x D	Ns	Ns	Ns	Ns

T= Treatments, Y = Years, D = Dumpsite compost, D x Y= Interaction between dumpsite composts and years, T x Y= interaction between treatments and years, T x D = Interaction between treatments and dumpsite composts, T x Y x D = Interaction between treatments, years and dumpsite composts, Ns = Non-significant, means with similar letters are not significantly different at $P < 0.05$.

V. Cobs Yield kg ha^{-1}

Results regarding cobs yield (kg ha^{-1}) as affected by different types and rate of application of MSWC are presented in Table-5. The results showed that treatments and types of MSWC significantly affected cobs yield of maize crop. The higher cobs yield was obtained when MSWC applied at the rate of 24 t ha^{-1} (4658) followed by NPK treatment, MSWC at the rate 18 and 12 t ha^{-1} treatments with an average cob yield 4474, 4383 and 4102 kg ha^{-1} cobs, respectively. Moreover, it was observed that the effect of fertilizer treatment was statistically at par with MSWC applied at the rate 24 t ha^{-1}, and MSWC treatment of 12 t ha^{-1} was statistically at par with 6 t ha^{-1} (4102). Though, the effect of year as a source of variation was insignificant, higher number of cobs (4289) were reported in the second year of experiment as compared to cobs yield (4211) in first year of the experiment. Furthermore, the statistical analysis of data revealed that significantly greater cobs yield was recorded with the compost derived from freshly dumped waste collected from dumpsite D_1 (4309) as compared to the compost derived from mining of old dumpsite D_2 (4191).

The results indicated that the cobs yield of maize significantly increased with an increasing rate of MSWC application. In a similar study, Prabpai et al., (2009) reported that the application of compost increased the yield by 50-85 %. Likewise, Reddy (2000) reported that compost application at the rate 20 t ha-^{1} increased the yield of vegetable crops. The increase in growth and yield of a crop depends on the type and rate of MSWC application (Lilly white et al., 2009).

VI. 1000 Grain Weight (g)

The higher 1000 grain weight (270 g) was recorded with MSWC applied at the rate of 24 t ha^{-1} followed by NPK (265 g) and MSWC at the rate 18 t ha^{-1} (261 g). Furthermore, it was recorded that MSWC at the rate 6 t ha^{-1} and 12 t ha^{-1} were statistically at par with each other yielding 238 g and 242 g weight of 1000 grains, respectively. Similarly, the years as a factor showed that significantly greater 1000 grain weight were recorded during second year (253 g) of experiment as compared to first year (251 g). The effect of types of compost showed that MSWC derived from freshly dumped waste (D_1) had significantly greater 1000 grain weight (254 g) of maize crops as compared to the compost derived from old dumpsite D_2 (191 g). A quick review of Table 5 points out the fact that the effect of all the possible interactions for 1000 grain weight of maize crops were non-significant.

The 1000 grain weight of maize increased with an increasing level of MSWC application. Similar observations were also recorded by Mantovani and spadon (2017), reporting that the yield parameters of maize, such as 1000 grain weight, increased with an increasing level of urban waste compost application up to 40 M t ha-^{1}. The heaviest 1000 grain weight with higher compost level may be due the accessibility of higher nutrients absorption at grain filling stage and their translocation in to the sinks which may have resulted in highest 1000 grain weight (Amanullah et al., 2009).

Grain weight and grain development is the interaction of temperature, humidity and availability of water in soils. These were favorable reported during second year and hence resulted in higher 1000 gain weight. Muhammad and Jan (2016) findings also support our results who concluded that increased in 1000 grain weight might be result of prolonged and better growth of crops due to the carry over effect of the nutrients during second year of the experiment.

VII. Grain Yield (kg ha^{-1})

Grain yield is a standard measurement of the production harvest for the crops, which mainly depends on soil fertility, water availability, agronomic practices and environmental factors. The statistical analysis of data indicated that treatments, years and types of compost significantly enhanced the grain yield of maize crop. The highest grain yield of maize was recorded with application of MSWC at the rate of 24 t ha^{-1} (4087 kg ha^{-1}) followed by NPK treatment (3861 kg ha^{-1}). Likewise, MSWC at the rate 18, 12 and 6 t ha^{-1} produced 3660, 3492 and 3492 kg ha^{-1} grains, respectively, which were significantly greater than control (2769 kg ha^{-1}). However, the effect of MSWC at the rate 18 t ha^{-1}was at par to the NPK treatment. The years as factor also had significant effect on grain yield of maize. The higher grain yield was recorded in second year (3605 kg ha^{-1}) of experiment, as compared to first year (3460 kg ha^{-1}). Furthermore, it was observed that MSWC derived from freshly dumped waste (D_1) produced significantly higher grain yield (3633 kg ha^{-1}) as compared to the grain yield (3433 kg ha^{-1}) obtained with compost derived from old dumpsite D_2 (Table-5).

Khan, 2015 in his study, also reported that increasing the compost application up to 20 t ha-^{1} significantly increased the grain yield of maize from 1855 kg ha-^{1} to 2318 kg ha-^{1}. Similarly, Mantovani and Spadon, (2017) reported that compost application at the rate 30 and 40 Mg ha-^{1} significantly increased the grain yield of maize. Moreover, Onwudiwe et al., (2014) reported that the application of compost at a higher rate not only increases the grain yield but also enhances the biological yield of a crop. Furthermore, different types of MSW used for composting also have significant effects on grain yield. The higher yields were recorded with the compost derived from freshly dumped MSW due to the higher content of organic matter. A number of researchers (Nasim et al., 2012) reported that MSW when freshly used for composting purposes had significant impact on soil and crop yield. Karthika et al., (2018) reported that application of MSWC improved soil health which in turn improved all the physiological processes of crops. It was recorded in the present study that continuous use of MSWC over years significantly increased the grain yield of maize.

VIII. Biological Yield kg ha^{-1}

Statistical analysis of data showed that different rates, types of compost and years as a factor significantly affected the biological yield of maize crops (Table-5).. It was recorded that greater biological yield (10059 kg ha^{-1}) was gained with the application of MSWC at the rate 24 t ha^{-1} followed by NPK treatment (9853 kg ha^{-1}) and MSWC at the rate 18 t ha^{-1} with 9679 kg ha^{-1}

biological yield. Similarly, MSWC applied at the rate 12 t ha^{-1} and 6 t ha^{-1} produce 9290.4 and 8868.2 t ha^{-1} biological yield respectively. Which was significantly higher as compared to the control treatment (7156 kg ha^{-1}). Data regarding the effect of types of compost showed that the compost made of the mining materials of the freshly dumped waste, designated as D_1, produced significantly higher biological yield, mounting to 9235 kg ha^{-1} as compared to that of the compost obtained from the mining of old landfill site designated as D_2 with a production of 9067 kg ha^{-1} biological yield. The effect of years as a factor revealed that significantly higher biological yield (9322 kg ha^{-1}) was recorded in the second year of the experiment as compared to the results of the first year (8978 kg ha^{-1}). In addition, it was observed that among all the possible interactions the effect of treatment into year ($T \times Y$) was found significant (Table-5). The results revealed that the higher dose of MSWC application increased the biological yield of maize crop as compared to the all other treatments and the increase was compounded in the second year of experiment showing a linear increase across the rate of application (Fig-1).

In present study, the biological yield of maize crops increased constantly with increasing levels of MSWC. The increase in biological yield can be attributed to the overall improvement in growth and yield indicators due to the enhanced availability of nutrients and other physicochemical properties of soil with MSWC application. Similar results to our findings were also reported by Khan et al., (2008) reporting that accessibility to nutrients throughout the growing period enhances the biological yield of crops. Similarly, it was observed that MSWC derived from freshly dumped waste significantly increased the biological yield compared to the compost derived from longstanding dumped waste. The compost derived from the freshly dumped waste contains quantities of organic matter compared to the old dumped waste. Our findings were in conformity to the findings of Zhou et al., (2015) who reported that the composting materials from landfill sites has a high level of plant essential nutrients and organic matter content, which significantly promoted the growth of plants.

Fig. 1: Interactive effect of treatment into year (TxY) interaction of MSWC on the biological yield of Maize crop.

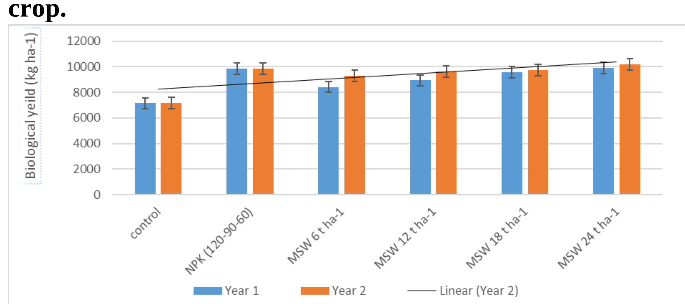

Table-5: Effect of Compost Application on Cob Yield, 1000 Grain Weight, Grain Yield and Biological Yield of Maize.

Factors/ parameters	Cob Yield (Kg ha^{-1})	1000 Grain Weight (g)	Grain yield (Kg ha^{-1})	Biological Yield (Kg ha^{-1})
Treatments (T)				
Control	3848.5 d	237.08 e	2769.8 e	7156.8 e
NPK (120-90-60)	4473.6 ab	265.75 b	3861.2 ab	9853.6 ab
MSW Compost 6 t ha^{-1}	4035.8 cd	238.92 de	3328.5 d	8868.2 d
MSW Compost 12 t ha^{-1}	4102.5 c	242.42 d	3492.3 cd	9290.4 c
MSW Compost 18 t ha^{-1}	4383.8 b	261.50 c	3660.9 bc	9679.6 b
MSW Compost 24 t ha^{-1}	4658.1 a	270.75 a	4087.3 a	10059.0 a
Significance/LSD	192.95	3.703	278.17	315.42
Years (Y)				
Year 1	4211.4	251.69 b	3460.8 b	8978.7 b
Year 2	4289.4	253.78 a	3605.9 a	9322.8 a
Significance/LSD	Ns	1.849	143.55	85.40
Composts (D)				
Fresh Dumpsite (D_1)	4309.5 a	254.14 a	3633.0 a	9235.3 a
Old Dumpsite (D_2)	4191.3 b	251.33 b	3433.7 b	9067.3 b
Significance/LSD	93.419	4.064	179.53	70.61
Interaction	**Significance levels**			
D x Y	Ns	Ns	Ns	Ns
T x Y	Ns	Ns	Ns	*
T x D	Ns	Ns	Ns	Ns

T x Y x D	Ns	Ns	Ns	Ns

T= Treatments, Y = Years, D = Dumpsite compost, D x Y= Interaction between dumpsite composts and years, T x Y= interaction between treatments and years, T x D = Interaction between treatments and dumpsite composts, T x Y x D = Interaction between treatments, years and dumpsite composts, * = Significance level at $P < 0.05$, Ns = Non-significant, means with similar letters are not significantly different at $P < 0.05$.

4. Conclusions

The result obtained from the present study revealed that application of composts derived from MSW significantly improve the physico-chemical properties of the soil. Two different types of composts (fresh and old composts) derived from municipal solid waste were used for the growth of maize crops. The results showed that treatments, years and types of dumpsite composts were the major sources of variation and significantly affected the growth and yield of spring maize. Application of compost derived from freshly dumped waste (D_1) significantly increased the growth and yield parameters of maize as compared to compost derived from old dumpsite (D_2). The compost application at the rate 24 t ha^{-1} reduced the need for commercial fertilizer without affecting the grain yield. Therefore, application of MSWC at the rate 24 t ha^{-1} is suggested to boost the growth and yield of maize crop and minimize the cost of production in Peshawar.

Data Availability Statement:

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