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Influence of compost Amendments on the germination and Growth performance of *Zea mays* L.

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ABSTRACT

Maize is a highly consumed staple food in developing countries and the demand is predicted to double in the coming years. Therefore, there is a need to improve production through the use of compost amendments for sustainability. The aim of this study was to examine the effect of three compost amendments (lemon peels, vegetable waste, and cooked food waste) on the germination and growth of maize (*Zea mays*). The results showed that the application of 17% (116 t/ha) of vegetable waste or lemon peel composts supported maximum maize growth. However, vegetable waste compost had the highest potassium content, which supported maximum root growth and biomass yield. Although the addition of 17% cooked food waste compost resulted in excess nitrogen supply, reducing its application to 7% (50t/ha) supplied the required level for maize germination.

Key words: *Available K, Biomass, Root length, Shoot length, Total N*

Introduction

Maize (*Zea mays* L.) is among one of the three most consumed cereal crops worldwide, after wheat and rice (Ayalew and Sekar, 2016). Presently, maize is a preferred staple food of approximately 900 million individuals and approximately one-third of all malnourished children. In 2011, it was estimated that the demand for maize in developing countries will double by the year 2050, and would also become the most cultivated crop globally (CIMMYT and IITA, 2011). In India, maize is cultivated year-round in most states for various purposes, including for grain, fodder, green cobs, sweet corn, and industrial use. Recently, maize area production and productivity in India has shown a steady upward trend. Current consumption pattern of maize is mainly for poultry, pig, and fish feed (52%), human consumption (24%), cattle feed and starch (11%), and brewery industry (1%) (Nirupama *et al.* 2012). Landraces of maize from the Northeast region of India constitutes 36% of the total collection from the whole of India, which was the highest (Pandey *et al.,* 2014). Although maize production has shown an increasing trend recently, India's population is expected to exceed that of China shortly, which may further increase food grain demand. To meet the increasing demand, green revolution technologies and chemical fertilizers have been employed in crop production. However, continuous chemical fertilizer usage can result in soil toxicity and environmental pollution. Moreover, chemical fertilizers are expensive and not feasible for subsistent agriculture, which is mostly practiced in developing and underdeveloped countries. Additionally, prolonged and indiscriminate land use could cause depletion of the total organic carbon content necessary for soil microbial activity,resulting low soil fertility and productivity (Nain *et al.,* 2009). Therefore, it is necessary to adopt organic farming practices, including the use of organic manure and compost, for sustainable land use and crop production.

Compost is decomposed organic matter, such as biodegradable municipal solid waste, crop residues, and animal manures. Although compost has been used to improve agricultural soils for hundreds of years, the understanding of the mechanism of compost in soil fertility is fairly recent (Richard, 2005). Application of compost is necessary to increase soil organic content, which can improve soil fertility. Overall, compost application could be an effective solution to the problems associated with chemical manure use (Hargreaves *et al.,* 2008) and domestic waste management. However, the safety, suitability, and effectiveness of compost in improving soil fertility depends on the quality of the compost (Kandil 2020). Although a few studies on compost amendments have been performed, studies on the effect of the type and application level of compost on crop growth are limited.

Therefore, the aim of this study was to examine the effect of three compost amendments on the germination and growth performance of maize.

Materials and Methods

Study location

Compost preparation was performed at Mizoram University campus, Tanhril and maize germination experiment was conducted at a residential area, approximately 7 km Northwards of the campus situated in Aizawl district, Mizoram state, Northeast India because of restriction on movement during the COVID-19 lockdown.

The average annual rainfall in the study area is 2757mm, with average relative humidity of 70%. On an average, 2.5% of annual rainfall occurs in the months, November–February, 87% in May–October, and 10.49% in March–May. Average air temperature range from 17.4 °C– 24.5 °C, with minimum temperature ranging from 8.8 °C in January to 10.2 °C in December and maximum temperature ranging from 25.7 °C in October to 31.7 °C in May (State Met. Centre 2016). Based on rainfall pattern and air temperature, the months from June–October are classified as warm-humid rainy season, November–February as cold-dry winter season, and March–May as hot summer season.

Compost preparation

The three types of composts: lemon peel (LP), vegetable waste (VW), and cooked food waste (CF) composts, were prepared according to the procedures described in Lalremruati and Devi (2021). The chemical characteristics of the three composts, include organic C (OC), total nitrogen (TN), C:N ratio, available P (AP), and available K (AK) were calculated for the different application rates based on the initial quality of the composts provided in Lalremruati and Devi (2021).

Experimental design of maize germination experiment

The germination experiment was arranged in a randomised complete block design, consisting of three treatments (LP, VW, and CF) at five compost: soil mixtures [50% (1:1), 33% (1:2), 25% (1:3), 20% (1:4), and 17% (1:5)], with three replicates per level. Additionally, three bags were filled with soils without amendments to serve as the control, making a total of 48 bags.

The germination experiment was performed using polyethylene bags (diameter, 11.43 cm; depth, 7.62 cm), with small holes at the bottom for draining excess water. The compost, which was mixed with the same garden soil, according to the ratios above, were transferred into the polyethylene bags, and arranged according to the experimental design. Details of the amount of compost applied in t/ha is provided in Table 2.

Maize seeds were collected from the State Agriculture Department, and screened for size, colour, and texture. Selected seeds were washed with tap water and air-dried for approximately 1 h before planting. The seeds were planted in each bag at a seeding rate of four seeds per bag at equal spacing. The germination experiment was performed from the month of April–May, 2020. During the experimental period, the bags were sprinkled with the same amount of water when necessary to maintain 35%–40% of moisture. Additionally, the bags were monitored daily for the first 7 days after planting to determine the germination rate.

Maize seed germination rate (G) in each level of amendment was determined using the formula below:

$$G\% = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

The heights of the seedlings were measured every 5 days using a measuring scale to determine shoot growth. After 27 days, the seedlings were carefully removed from each bag, dipped in a bucket of water, and gently shaken to remove adhering soil particles. Shoot and root lengths were measured and air-dried till constant weight, and dry weight was determined for each seedling using a digital balance.

Data analysis

The data obtained during the study were subjected to analysis of variance (ANOVA), and mean separation using Tukey's HSD test. Coefficient of variation of the chemical properties was estimated for the different levels of composts. The relationship between the chemical characteristics of the amendments and crop parameters was determined using Pearson's correlation analysis. Student's t- test was used for determining level of significance of the correlation. All the statistical analysis were performed using MS-Excel and SPSS version 20. Means were considered significant at $p < 0.05$.

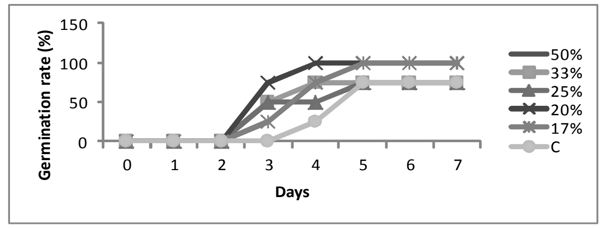
Results

Seed germination

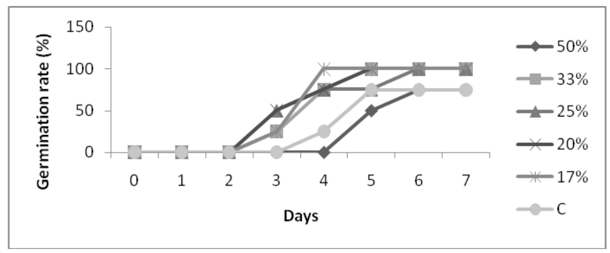
There was no significant difference in seed germination rate among the different application levels and between the treatments 7 days after planting. However,25%, 20%, and 17% compost application supported 100% seed germination rate in the three treatment groups after 7 days of planting (Figs. 1a, b, and c). Additionally, rapid seed germination was observed in 20% and 17% compost amendments, with 100% germination rate within 5 days. However, only 75% germination rate was observed in the control group. Moreover, 50% CF compost amendment supported only 50% germination rate, which was lower than that of the control group (Fig. 1c). Pearson's correlation analysis showed that there was no significant correlation between germination rate and the chemical properties of LP compost amendment (Table 6), although an inverse relationship was observed. In contrast, there was a significant inverse relationship ($p < 0.05$) between germination rate and the OC, TN, AP, and AK contents of VW and CF amendments, indicating that germination rate increased with decrease in compost levels.

Shoot length

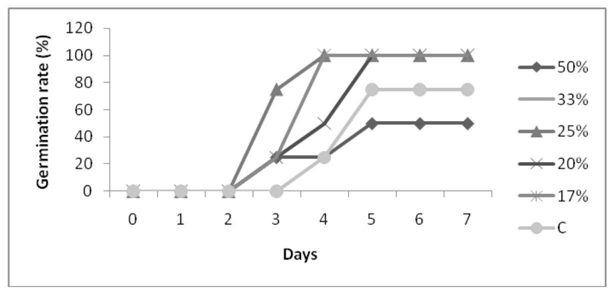
There was a significant difference in shoot length among the different compost levels ($p < 0.001$) and between the treatments ($p < 0.04$) 27 days after planting. Generally, there was a progressive increase in shoot lengths in all amendments; however, lesser increments were observed in 50% and 30% compost:soil mixtures and control group. The average shoot length of maize in the control group was 26.5±3.40 cm (Table 1). Generally, 17% compost level supported maximum shoot length across the three treatment groups: CF(35.0±2.4 cm), LP (33.0±2.1 cm), and VW (31.5±2.0cm). Compared with the control group, maize grown in 25% and 17% LP, VW, and CF compost amendments exhibited 5.3% and 20.0%, 11.6% and 20.0%, and 11.6% and 22.0% increase in shoot length, respectively.



1(a)



1(b)



1(c)

Fig. 1. The effect of different compost amendments on rate of seed germination. (a) Effect of lemon peel (LP) compost amendment on seed germination. (b) Effect of vegetable waste (VW) compost amendment on seed germination. (c) Effect of cooked food waste (CF) compost amendment on seed germination.

Table 1. Soil physicochemical characteristics* and maize growth characteristics in control

Soil parameters	Mean
pH	5.45±0.08
Carbon (%)	2.18±0.17
Nitrogen (%)	0.087±0.001
Phosphorus (g/kg)	0.011±0.01
Potassium (g/kg)	0.030±0.005
Carbon: Nitrogen	25
Maize growth parameters	
Bulk density (g/cm^3)	0.70±0.01
Shoot length (cm)	26.5±3.40
Root length (cm)	5.60±1.10
Biomass (g)	1.69±0.50

*(From Lalremruati and Devi (2021)

Table 2. Levels of compost in experimental soils

Compost: Soil ratio	Compost (%)	Compost dosage (t/ha)
1:1	50	350
1:2	33	233
1:3	25	175
1:4	20	140
1:5	17	116

Compared to the control group, 50% and 33% compost levels did not significantly increase shoot growth across the treatments. Correlation analysis showed that there was asignificantly inverse relationship between shoot length and the TN, AP, and AK contents of treatments (Table 6), indicating that shoot length increased with decrease in compost levels. Additionally, significantly inverse relationship was observed between shoot length and OC only in VW compost treatment.

Root length

There was a significant difference ($p< 0.003$) in root length among the different compost levels, but no significant difference ($p< 0.09$) was observed between the treatment groups. However, 50%compost level did not significantly increase root growth compared with the control group across the three treatments. Overall, the highest root length (12 ± 1.1 cm) was obtained in maize grown in 17% VW compost amendment (Table 5). Compared with the control group, maize grownin 25% and 17% LP, VW, and CF compost amendments exhibited 49% and 50%, 44.0% and 64.0%, and 12.5% and 49.0% increase in root length, respectively. Pearson's correlation analysis showed that root length was significantly inversely correlated with the OC, TN, AP, and AK contents of the amendments, indicating root length increased with decrease in composts levels.

Biomass

There was a significant difference ($p< 0.01$) in biomass yield among the different compost levels, but no

Table 3. The effect of different compost at different levels on soil organic C (OC), total nitrogen (TN) content and C:N.

Compost	OC (t/ha)				TN (t/ha)				C:N			
Dose (%)	LP	VW	CF	CV%	LP	VW	CF	CV%	LP	VW	CF	CV%
50	12.6	9.60	15.0	21.77	0.43	0.43	1.78	87.5	29.30	22.32	8.42	53.07
33	8.40	6.40	10.6	25.10	0.28	0.28	1.19	89.65	30.00	22.85	8.90	52.13
25	6.30	4.80	7.90	23.80	0.22	0.22	0.89	86.36	28.63	21.81	8.87	50.73
20	5.00	3.80	6.30	24.00	0.17	0.17	0.71	88.57	29.41	22.35	8.87	51.60
17	4.20	3.20	5.30	23.80	0.14	0.14	0.59	86.20	30.00	22.85	8.98	51.81

LP, lemon peelcompost; VW, vegetable waste compost; CF, cooked food waste compost; CV%, coefficient of variation; C:N, Carbon: Nitrogen

Table 4. The effect of different compost at different levels on soil available P (AP) and available K (AK) content.

Compost Dose(%)	AP (kg/ha)				AK (kg/ha)			
	LP	VW	CF	CV%	LP	VW	CF	CV%
50	37.8	35.7	42.0	8.311	154.0	213.5	45.5	61.87
33	25.2	23.8	28.0	8.300	102.2	142.1	30.1	62.07
25	18.9	17.5	21.0	9.20	77.0	106.4	22.4	62.12
20	14.7	14.0	16.8	9.564	61.6	85.4	18.2	61.87
17	12.6	11.9	14.0	8.33	51.1	70.7	14.7	62.43

LP, lemon peel compost; VW, vegetable waste compost; CF, cooked food waste compost; CV%, coefficient of variation significant difference (p< 0.57) was observed between the treatment groups. Compared with the control group (1.69 ± 0.50 g), 50% and 33% LP and VW amendments and 25% CF amendments did not significantly affect biomass yield. Overall, the highest biomass yield (1.75 ± 0.02 g) was obtained in maize grown in 17% VW amendment. Compared with the control group, 20% LP compost, 17% VW compost, and 20% CF compost amendments caused 3.4%, 3.42%, 2.31% increase in biomass yield, which were the highest for each treatment. Additionally, there was a significantly inverse relationship between biomass yield and the OC, TN, AP, and AK contents of the amendments.

Discussion

Generally, seed germination test is an effective and economical bioassay to evaluate the potential toxicity of compost before it can be applied in field production (Luo *et al.,* 2018). In the present study, 20% and 17% compost amendments, which corresponds to 140 t/ha and 116 t/ha, respectively, significantly improved seed germination rate. Similarly, Afriyie *et al.* (2017) reported that application of 25% combined straw, chicken manure, and grass clipping compost amendment enhanced soil fertility levels for radish production.

Shoot height is an indication of the growth rate of the plant, which is possible only in fertile soils. In the present study, maize grown in 17% compost amendments had the highest shoot length, indicating that 17% (116 t/ha) compost amendments supplied the necessary nutrients required for shoot growth. Nigussie *et al.* (2021) reported tallest height of maize from application of 10 t/ha of compost along with application of 138kgN/ha. Height of maize increased by 18-23% in the compost treatments in both wet and dry treatments and shoot biomass was doubled compared to unamended soil (Sisouvanh *et al.,* 2021). Maximum increase of 16% was recorded over recommended application of N, P and K fertilizers in height of wheat by the application of 500 kg/ha of compost (Ibrahim *et al.,* 2008). Mawussi *et al.* (2020) also reported plots treated with compost at dose of 30 t/ha and 40t/ha constituted maximum height in maize.

The root plays important role in nutrient and water uptake, and efficient root growth is necessary for plant survival. In the present study, maize grown in 17% VW compost amendment had the highest root length, indicating that the amendment

Table 5. The effect of different compost at different levels on the shoot and root length and biomass of maize.

Compost	Shoot length (cm)			Root length (cm)			Biomass (g)		
dose (%)	LP	VW	CF	LP	VW	CF	LP	VW	CF
50	25.3±1.4[d]	25.3±1.5[c]	25.3±1.6[c]	4.8±0.9[c]	4.8±0.8[c]	4.8±0.9[b]	1.57±0.01[d]	1.65±0.01[c]	1.52±0.01[d]
33	27.0±1.2[c]	27.0±1.0[c]	25.5±2.0[c]	7.5±0.8[b]	6.0±1.0[b]	5.5±1.6[b]	1.60±0.01[c]	1.66±0.01[c]	1.69±0.02[c]
25	28.0±1.9[c]	30.0±1.3[b]	30.0±2.2[b]	11.0±1.2[a]	10.0±1.6[a]	6.4±1.2[b]	1.72±0.02[b]	1.70±0.02[b]	1.68±0.02[c]
20	31.4±2.0[b]	30.0±2.0[a]	30.0±2.2[b]	11.0±1.1[a]	11.5±1.2[a]	10.0±1.4[a]	1.75±0.02[a]	1.70±0.02[b]	1.73±0.03[b]
17	33.0±2.1[a]	33.5±2.0[a]	34.0±2.4[a]	11.3±1.3[a]	12.0±1.1[a]	11.0±1.6[a]	1.72±0.02[b]	1.75±0.02[a]	1.70±0.03[a]

Values are mean ± SE. Different lowercase letters in each column indicates significant difference.LP, lemon peel compost; VW, vegetable waste compost; CF, cooked food waste compost

Table 6. Relationship between crop parameters and chemical compositions of compost amendments (n=5).

	LP				VW				CF			
	GR (%)	SL (cm)	RL (cm)	Biom. (g)	GR (%)	SL (cm)	RL (cm)	Biom. (g)	GR	SL (cm)	RL (cm)	Biom. (g)
OC(t/ha)	-0.64[ns]	-0.69[ns]	-0.87[*]	-0.91[**]	-0.88[*]	-0.86[*]	-0.97[**]	-0.87[*]	-0.92[**]	-0.67[ns]	-0.72[*]	-0.89[*]
TN(t/ha)	-0.58[ns]	-0.72[*]	-0.90[**]	-0.89[*]	-0.90[**]	-0.87[*]	-0.98[**]	-0.86[*]	-0.94[**]	-0.71[*]	-0.74[*]	-0.91[**]
AP(kg/ha)	-0.59[ns]	-0.72[*]	-0.90[**]	-0.91[**]	-0.93[**]	-0.82[*]	-0.93[**]	-0.86[*]	-0.75[*]	-0.73[*]	-0.75[*]	-0.91[**]
AK(kg/ha)	-0.58[ns]	-0.71[*]	-0.89[*]	-0.91[**]	-0.93[**]	-0.82[*]	-0.96[**]	-0.87[*]	-0.93[**]	-0.73[*]	-0.75[*]	-0.91[**]
C:N	-0.30[ns]	0.33[ns]	-0.13[ns]	-0.21[ns]	-0.23[ns]	0.35[ns]	0.33[ns]	0.14[ns]	0.23[ns]	0.74[*]	0.96[**]	0.94[**]

Pearson's correlation analysis was performed. LP, lemon peel compost; VW, vegetable waste compost; CF, cooked food waste compost; GR, Germination rate; SL, Shoot length; RL, Root length; AP, available P;AK, available K; OC, organic C; TN, total nitrogen; Biom.,Biomass;ns,not significant; * significant at p<0.05; ** significant at P<0.001a provided sufficient nutrient for root growth. Moreover, the improved root growth could be attributed to the higher levels of K in 17% VW compost, which is necessary for root growth and development. Compost improves both maize development and production of root biomass increased by 56% in dry conditions and 122% in wet conditions (Sisouvanh *et al.,* 2021). The addition of compost increase phosphorus mobilization and soil microbial activities contributing in improving nutrition as well as crop root system (Ibrahim *et al.,* 2008).

In the present study, 17% VW compost amendment supported maximum biomass yield. Weerarisinghe and DeSilva (2017) obtained significantly higher growth rate in maize grown on 33% and 50% compost amendments, which was higher than the level used in the present study. Despite the higher level of compost used in Weerarisinghe and DeSilva (2017), the nutrient levels of the amendments were similar to those of the presents study, apart from OC, which could be responsible for the comparable growth rates. Courtney and Mullen (2008) recommended 50–100 t/ha of spent mushroom compost for improved biomass yield in barley. Additionally, Binshuhaimi *et al.* (2019) recommended 50% food waste compost amendment for optimal yield of *Hibiscus sabdariffa* (roselle). Moreover, Srivastava *et al.* (2018) recommended 20% and 40% compost amendment for optimal yield in okra plant. Rady *et al.* (2016) reported that the application of organic matter fertilizer compost at a rate of 20t/ha was promising for common bean production. However, Villena *et al.* (2018) reported that the application of winery and distillery waste compost (13 t/ha) resulted in moderate increase in plant biomass, leaf area index, and melon fruit yield. Moreover, application of compost manure at either 5 or 10 t/ha supported maximum maize grain yield (Kandil *et al.* 2020). Khan *et al.* (2019) reported that compost application (10t/ha) as mulch after seed sowing enhanced germination, seedling growth, crop productivity, and quality of spinach and radish under controlled conditions. The discrepancies in the results of the studies could be attributed to differences in compost type, which influenced the chemical composition (OC, TN, AP, and AK) of the amendments, and consequently biomass yield.

According to the FAO, 80–100 kg/ha of N and 30–100 kg/ha of AP and AK, is necessary for the maize growth. Nitrogen is a key nutrient for plant growth and yields are strongly related to N supply (Keeling *et al.,* 2003). In the present study the TN content of 17% CF compost amendment was 0.59t/ha (590 kg/ha), which was higher than the recommended level. However, although the N levels of both LP (140 kg N/ha) and VW (140 kg N/ha) amendments were higher than the FAO recommended level, Harrison (2008) stated 250 kg N/ha/yr supplied using composts was suitable for maize growth. Therefore, the N levelsof 17% LP and VW amendments was within the acceptable limit, which could be the reason for maize performing better on these amendments than on CF compost amendment.

Apart from low N levels, addition of large amounts of low-nutrient compostscan cause nutrient deficiency. Moreover, excessive supply of compost containing only a few nutrients can prove fatal to plants. Therefore, it is important to ensure balance between nutrients in supplied compost, one of which is C:N ratio. In the present study, C:N ratio of 17% CF compost was low (8.98), which could cause excess N supply to the soil and crop. Therefore, reducing CF compost level to 7% (50t/ha) will supply approximately 254 kgN/ha. Furthermore, the AP content of the three compost at 17% level (11.9–14.0kg/ha) was lower than the recommended level. However, the AK contents of 17% LP and VW composts were higher than that of 17% CF compost. Generally, 17% LP and VW composts provided the required level of TN, AP, and AK for maize germination, shoot and root growth, and biomass yield. Therefore, the application of 17% LP and VW composts could be recommended for optimal maize growth.

Although, 17% CF compost level induced maximum shoot growth,the highest root length and biomass yield was observed in maize grown on 17% VW compost amendment, followed by those grown on 17% LP compost amendment. Therefore, the performance of the composts could be in the order of VW>LP>CF. The higher amount of AK in VW compost could be important for root growth and biomass yield. Moreover, Kandil *et al.* (2020) reported that 10 t/ha of compost with 500 cm^3/ha of nano K improved maize yield, further confirming the importance of AK in maize production. Similar results have been observed in *Solanum melongena* (Akoijam *et al.,* 2018) and *Capsicum annum* (Akoijam *et al.,* 2017).

Conclusion

Overall, the findings of this study showed that 17% (1:5; 116 t/ha)VW and LP compost amendment scan be recommended for maize cultivation. Additionally, CF compost application level could be reduced from 17%–7% (50 t/ha) for optimal maize production.

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