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The Evolution of Compost Phytotoxicity during Municipal Waste and Poultry Manure Composting

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ABSTRACT

Composting is commonly used for waste management and the evaluation of its quality is important for successful application. Seed germination test is commonly adopted due to its capacity to examine the toxicity level of compost. The seed test is usually evaluated on the final product and the results can vary with the different methods and the type of seed utilized. In this study, the evolution of seed germination tests during the composting process of municipal waste (MSW) mixed with poultry manure (PM) of two species tomato and sugar beet was examined. The impact of compost water extracts on seed germination and plant primary root growth for each sampling was reported. The chemical parametrs were evaluated on the final product. Results show that mixture C1 with a higher amount of municipal waste gave less compost yield than mixture C2. After 35 days of composting, the compost was phytotoxic for tomato and sugar beet seeds. The seeds of the two cultures reacted differently to the same compost. The compost could stimulate sugar beet germination at days 110, 140, 180, 212 and 252. Seed germination of sugar beet was increased and delayed by one day by the compost stabilized and mature as compared with the control.

Keywords: composting, seed germination, root length, phytotoxicity, *Beta vulgaris L*, *Solanum lycopersicon L*.

INTRODUCTION

Soil fertility is given increasing attention in the world. Particularly in Morocco, where most farms are small and for which the cost of inorganic fertilizers is fairly high. Morocco produces a large quantity of household waste and chickens. Poultry waste is mainly concentrated in coastal areas and is often used in agriculture without any treatment. Organic waste composting could be an adequate solution to contribute to the resolution of the waste accumulation problem and to increase the organic matter in the soil without using a large quantity of inorganic fertilizers and peat. The physicochemical characteristics of poultry manure are enhanced and the phytotoxicity is reduced when it is co-composted with other organic wastes [Rizzo et al. 2013]. Furthermore, fertilizers stimulate plant growth, and affect soil stability [Rigby et al., 2016; Luo et al., 2018]. Compost can act both as a soil improver to the physical structure of the soil and as a fertilizer. It maintains the activity of the soil microorganisms and ensures long- term fertility. Moreover, it is free or very cheap.

Phytotoxicity has been already related to immaturity of compost and decrease of organic acids is correlated with progressed plant performance [Young et al., 2016b; Gong et al., 2021]. The most important aspect of compost quality is its toxicity, which can be measured using seed germination. Germination index parameter is commonly used as test to evaluate the toxicity from different kind of samples [Tiquia 2010; Kebrom et al.

2019; Zhan et al., 2021]. This test is widely used. However, the main issue is that the findings vary depending on the methods and types of seed species, which restricts its advancement and applicability [Luo et al. 2018].

Raw poultry manure is frequently used as an organic additive on farmland [Bolan et al. 2010]. This waste includes pathogens, nutrients [N, P, K), and certain chemical pollutants, such as (As, Pb, Zn, Ni, Cd, Cu, Mn), probiotics, antibiotics, antioxidants, antiprotozoals, mold inhibitors, tetrachloro dibenzop-dioxin, polychlorinated phenols and hormones [Faissal. 2017; Rizzo et al. 2020] that may have a negative impact on the ecosystem through leaching and runoff.

The composting treatment system is a way of producing organic amendment that improves the physicochemical and biological properties of soils and therefore yields and crop quality. Favoring organic manure could be an alternative for producers in Morocco, given the cost of mineral fertilizers. The use of the germination bioassay test to measure compost maturity is relatively problematic, because a uniform threshold GI to signify maturity cannot be established for all types of composts.

Compost maturity has a major economic impact on the flow of product compost. Bioassays are an important complement to the physicochemical characterization of the compost.

The province of El Jadida (Morocco) produces a significant amount of poultry manure that is characterized by high level of nitrogen and low humidity. The majority of household waste landfill in El Jadida is made of compostable materials with high level of moisture [Aylaj et al. 2018]. The combination of these two cheaper materials, municipal waste and poultry manure gives a mixture which has the characteristics of being composted. A composting test was conducted on these solid wastes. This test enabled to transform all organic fermentable matter to nitrogen fertilizers.

Phytotoxicity parameters were studied to monitor the temporal evolution of the composting process. In this article, the phytotoxicity of two composts in two mixtures using seed germination bioassay was investigated. The present experiment was performed to compare a germination test protocol in two plants to assess the phytotoxicity of municipal solid waste and poultry manure compost on germination and early growth of plants. The study of phytotoxicity compost on tomato and sugar beet, helped to distinguish the mature compost used. It was hypothesized, that the selection of model seeds, as well as the assessment and correlation of the different methods of the seed germination test would be beneficial in improving the validity and reproducibility of the effective and economical bioassay (seed germination test) for determining the toxicity of compost products before they are used.

MATERIAL AND METHODS

Composting

Experiment

Two compost types were obtained from the composting of separation of selected organic materials from municipal waste mixed with poultry manure at the ratio (C1 3:2 weight weight^{-1} (ww^{-1}) and C2 2:3 (ww^{-1})). The process started in the composting apparatus at a higher rate in a reactor vessel and lasted for 15 days. This was determined by observing temperature behavior, with mesophilic temperatures indicating the end stage of composting. After the completion of the active phase, the maturation phase in a plastic container for 247 d followed.

Eight samples were collected at different composting times: 15th, 35th, 80th, 110th, 140th, 180th, 212th and 252nd day. The samples were vacuum-dried at 60 °C, ground to a size of 0.5 mm and used for chemical analysis [Genevini et al. 1997].

Physicochemical analysis

Wet samples were evaluated for moisture content (MC), pH, and electrical conductivity (EC), whereas dry samples were evaluated for total organic carbon (TOC) and total Kjeldahl nitrogen (TKN) [The U.S. Composting Council, 1997]. Following aqua regia digestion, macro and micronutrients, including (Ca, Mg, K, Na, P, Fe, Cu, Zn and Mn) were measured using the techniques described by the U.S. Composting Council (1997).

First, 1 g (dry weight) of sample was combined with 10 mL of distilled water and shaken at 125 rpm for 2 hours at room temperature to obtain water extracts. The samples were then centrifuged at 10,000 rpm and filtered using 0.45 m Millipore filter paper. Water total soluble carbon (TOC) and total soluble nitrogen (TKN) were measured in water extracts, as suggested in [Ciavatta et al. 1989b] and the Kjeldahl method.

Ammonium nitrogen was determined by a colorimetric method based on Nessler's method [The U.S. Composting Council 1997]. NO_3^--N was detected by using the AFNOR NFT 90-012 method [AFNOR 1987].

Toxicity tests

Aqueous extracts were prepared by mixing a dry compost sample with deionized water (1:5.7 w/v). These extracts were stirred using method outlined in [DI.VA.P.R.A. 1998] at room temperature (27 °C).

Plant species

The phytotoxicity test was made with two species so as to have a better understanding of compost effects. Sugar beet seeds (*Beta vulgaris L* variety Polyflor) were selected because of the sensitivity to these seeds at the stage of germination. Tomato seeds (*Solanum lycopersicon L*, variety Marmande) were selected due to a good response to toxic materials.

Seed germination and root elongation test

According to the test extract compost [DI. VA.P.R.A 1998], the proportion 1/5.7 (w/v) (compost (g dry matter)/distilled water (ml)) was prepared for each compost test. Compost/distilled water is left in contact for 2 hours. After that, this mixture was centrifuged for 15 minutes at 600 rpm. With filter paper with a diameter of 0.8 um, the supernatant was filtered twice. Two dilutions were prepared from the final filtrate to have a concentration of 50 to 75% of the extract. The seeds were soaked in distilled water for 1 hour and allowed to germinate in the Petri dishes containing filter paper (10 seeds per plate constituting a repetition). Each Petri dish was soaked with 5 mL of aqueous extract of compost for each dilution, while the control boxes receive 5 ml of distilled water. Germination took place in the dark at 27 °C. The experimental design was a randomized complete block with five repetitions. The number of germinated seeds per box is determined and the root length was measured after 14 days for sugar beet and 8 days for tomato.

The germination index was calculated by multiplying germination rate (GX) and relative root length (RRL), both expressed as percentages (%) of the control values. The germination index GI [Zucconi 1983] is determined by with following formula:

$$\mathrm{GIX} = (\mathrm{GX\%} \times \mathrm{RRL\%}) \times 100 \quad (1)$$

where: GX% – number of seeds germinated in a simple / number of seeds germinated in the control × 100;
RRL% – mean root length in a sample/ mean root length in the control × 100.
X – 50 and 75% extract dilution.

$$\mathrm{GI} = (\mathrm{GI}\ 50\% + \mathrm{GI}\ 75\%)\ /\ 2 \quad (2)$$

Statistical analysis

The experimental assay was developed in completely randomized design with two composts in two mixtures, seven stages of composting and two levels of seed types. The data were assessed by one-way ANOVA. Significant statistical differences were examined using a Tukey's test for testing the effect of different compost water extracts concentrations on seed germination. Levels of significance are represented by * at $p<0.05$, ** at $p<0.01$, *** at $p<0.001$ and NS for not statistically significant. Statistical analysis was performed using IBM SPSS software.

RESULTS

Composting

Physicochemical characterization

Table 1 presents the primary chemical characteristics of the composted mixtures and reports target values in the literature for each parameter. At the end of the process, the pH was reaching subalkaline values (pH of 7.59 ± 0.35 for C1 and 7.33±0.67 for C2, respectively).

EC parameters increased in both composts. The EC in compost C2 (9.65 ± 0.87) was significantly higher than in compost C1 (8.18 ±0.43). The composts had a moisture content of 20% for C1 and for C2. After 252 days of composting, the compost had final values of TOC higher in compost C1 than for compost C2 (32.67% vs 25.67%). The TKN concentrations were similar for both composts at the end of the process. Final values of C/N ratio were lower in compost C2 than compost C1 (12.14 vs 13.06).

The final process saw an increase in the NO_3^--N concentration and a drop in ammonium concentration. Both treatments had comparably low ammonium concentration values at the time of

Table 1. Physicochemical characteristics during the final stage of composting of C1 and C2 mixtures and limit values of final composts

Parameter	Measure unit	Compost C1[a]	Compost C2	Range values limit (WRAP, 2011and SENASA, 2011)
pH		[b]7.59±0.35	7.33±0.67	6–9
CE		8.18±0.43	9.65±0.87	<1.5
C:N ratio		13.06±0.09	12.14±0.16	20:1
MC (%)		20.23±0.41	20.28±0.36	35–50
TOC		32.67±4.06	25.67±2.96	TKN ≥6
TKN	(ds cm^{-1})	2.45±0.093	2.14±0.03	-
NH_4^+		0.05±0.005	0.07±0	-
NO_3^-		0.1	0.09±	-
MgO		1.8±0.15	2.25±0.16	-
CaO		7.2±0.12	8.21±0.15	-
K_2O		11.16±0.08	13.18±0.43	-
P_2O_5	(% DM)	8.59±0.138	9.89±0.22	-
Fe		0.33±0.033	0.34±0.02	<0.04
Zn		0.05±0.0014	0.051±0.002	-
Mn		0.068±0.003	0.056±0.003	<0.01
Cu		0.006±0.001	0.009±0	

Note: a C1 – mixtures of separated municipal solid wastes (SMSW) and poultry manure (PM) at the ratio of 3:2 ww^{-1}. C2 – mixtures of SMSW and PM at the ratio of 2:3 ww^{-1}. b Mean ± standard deviation of three replicates.

the final sample. Both mixes had similar final NO_3^--N levels. The heavy metal concentration in the resulting composts appeared to be minimal and comparable for the two mixes.

Phytotoxicity indices

The toxicity experiments carried out on plant species (Tomato and Sugar beet) allowed determining the quality of the compost as a soil amendment. Analysis of variance showed that there was a significant difference in GI and RL (Table 2) at each composting time, compost types tested and their interaction (p<0.001) for tomato. For sugar beet, when compost types and their interaction with the compost age were considered, no interaction was observed for both parameters.

The GI calculated for each of the 96 runs is included in the boxplot of Figure 1. The seed germination test identified potential phytoxicity of two mixtures (C1 and C2), after 15 days curing. In this day, GI values were zero in the extract concentration of composts C1 and C2 for tomato and sugar beet.

According to Figure 2 and Figure 3, there is a large variance of GI for the same time of sampling. The germination index of sugar beet on the other hand, was significantly inhibited by the immature compost and had germination index percentage around (37–49%) after stabilizing phase of composting day 15 (Table 3).

The germination index of tomato increased very rapidly and reached more than 50% by day 35 (Table 3), whereas that of sugar beet, especially for compost C1, increased progressively and reached approximatly 50%, but only after composting for 80 days (Table 3). The GI of sugar beet was only about 37% and 46% by day

Table 2. Analysis of variance of the effect of the type and age of the compost on the parameters of germination of two plant species

Source of variation	Germination index		Root longth	
	Tomato	Sugar beet	Tomato	Sugar beet
Age	143.26***	48.35 ***	175.04***	63.8 ***
Type	387.96***	0.04 NS	237.87***	1.69 NS
Age-Type	531.33***	1.16 NS	8.23 ***	1.51 NS

Note: *** – significant différences at p<0.001, ** – significant différences at p<0.01, * – significant differences at p<0.05, NS – not significant. Least significant difference (LSD) at 5%.

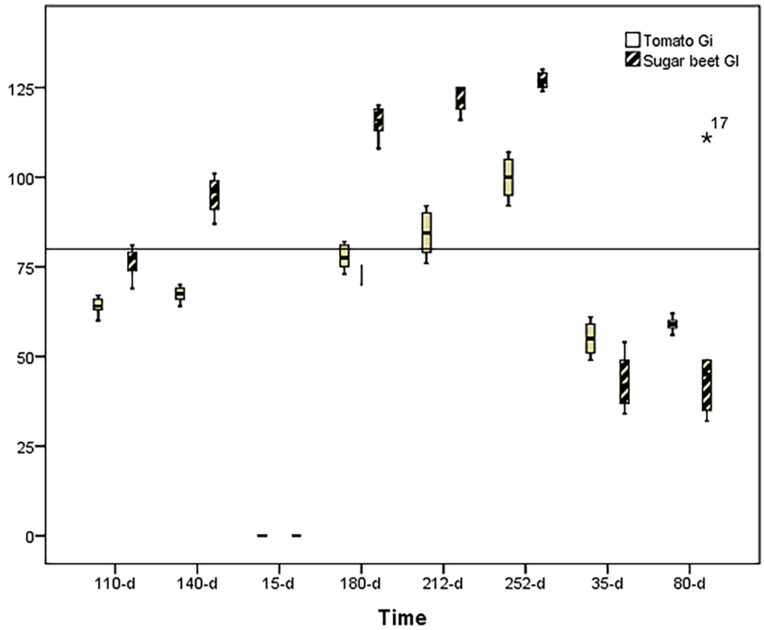

Figure 1. Boxplot of GI calculated from two seeds and two composts (indicates mean values)

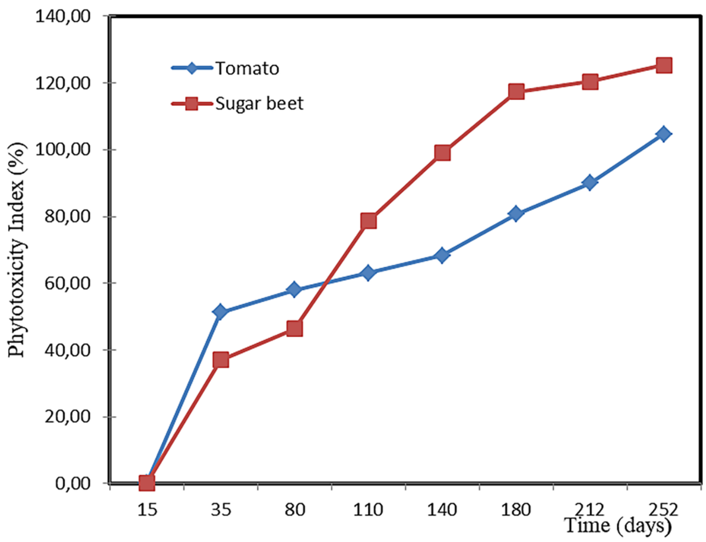

Figure 2. Average values of the phytotoxicity indexes measured during the composting period of compost C1

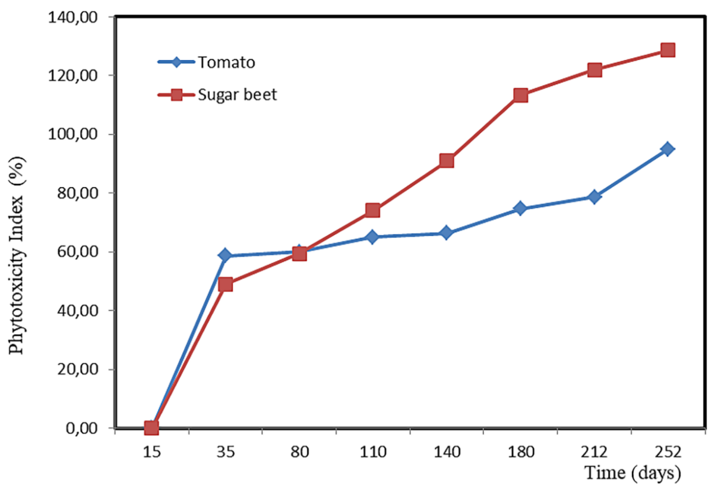

Figure 3. Average values of the phytotoxicity indexes measured during the composting period of compost C2

Table 3. Average values (±standard error) of the phytotoxicity indexes (GI) and Root elongation (RL) measured during the composting period

Species	Compost age	aC1		C2	
		GI (%)	RL (cm)	GI (%)	RL (cm)
Tomato	Control	100	3.9945c	100	3.9945c
	15	0.00	0.00	0.00	0.00
	35	51±1.15h	2.93±0.06i	59±1.45gh	3.47±0.06hg
	80	58±1.15gh	3.14±0.06h	60±1.15fg	3.49±0.12hg
	110	63±1.73ef	3.18±0.04h	65±1.15efg	3.57±0.23ef
	140	68±1.20	3.25±0.06h	66±1.45de	3.57±0.06 ef
	180	81±0.88bc	3.33±0.23h	75±0.88d	3.71±0.23d
	212	90±1.15b	3.91±0.23c	79±1.45cd	3.89±0.01c
	252	105±1.45a	4.75±0.12b	95±1.73b	5±0.23a
Sugar beet	Control	100	1.624a	100	1.624a
	15	0.00	0	0.00	0
	35	37±0.88d	0.6±0.06d	49±2.89d	0.52±0.06d
	80	46±2.60d	0.62±0.01d	59±2.89d	0.63±0.02d
	110	79±1.45d	0.85±0.01c	74±2.89d	0.76±0.01c
	140	99±1.15c	1.2±0.12b	91±2.31c	1.2±0.12b
	180	117±1.45b	1.3±0.06a	113±3.18b	1.5±0.12a
	212	120±2.60a	1.3±0.06a	122±1.73a	1.6±0.23a
	252	125±0.88a	1.41±0.06a	129±0.88a	1.65±0.06a

Note: (a) C1 – mixtures of separated municipal solid wastes (SMSW) and poultry manure (PM) at the ratio of 3:2 ww^{-1}. C2 – mixtures of SMSW and PM at the ratio of 2:3 ww^{-1}; (b) mean ± standard deviation of three replicates; (c) – values followed by the same letters in two column (C1 and C2) of each parameter are not significantly different among sampling times at p = 0.05 according to LSD; age – days of sampling from the start of the composting process.

35 and 80 respectively, for compost C1 while for C2 it was 49% and 59%. For the tomato, a slight difference in the GI between the two composts was observed, (59% and 60%) for compost C2 and (51% and 58%) for C1 at days 35 and 80, respectively. For both treatments, the GI levels increased between the initial and final sample times, for tomato from 0 to 105% and for sugar beet from 0 to 129% (Table 3).

The GI of tomato and sugar beet changes from 0% to about 59% by day 35 then increased slightly to (60–68%) for tomato and increased sharply to (59–99%) for sugar beet by days 80, 110 and 140 (Fig. 2).

In this study, the *Beta vulgaris L* GI values were observed to be 79% and 74% at day 110 and 99% and 91 % at day 140, with the samples prepared by extract concentrated of composts C1 and C2 respectively (Table 3), which suggests that the investigated materials can have an inhibitory effect.

The results of GI values showed that compost C2 (combination of 40% MSW and 60% PM), was different from compost C1 (produced by 60% MSW and 40% PM) on tomato only from day 180 to day 252 of composting and on sugar beet the difference was observed at day 35, 80 and day 110 of composting (Fig. 2).

The root elongation of sugar beet was significantly inhibited by the compost water-extracts at days 35 and 80 (Table 3). The RL of this plant species was only approximately 0.6 cm for C1 and 0.52 cm for C2 on day 38, but it gradually increased to around 1.2 cm for both composts by day 140 (Table 3). For sugar beet both root elongation and seed germination index was affected by the toxic compounds at 35 and 80 days. Compared to the control, the decreases for sugar beet RL were 0 to 68% and for tomato RL were 0 to 27% for all treatments (Table 3). The decreases for tomato RL were 0 to 13% for C2 and for C1 were 0 to 27% for all treatments, if compared with the control.

The GI of two plant species tested in the present study, increased to over 80% by day 140 for sugar beet and day 180 for tomato. The GI value was maximal with 252 day-old compost extracts in the two species. This maximal value was 129% for sugar beet using the extract of compost C2 (Fig. 3) and for tomato was 124%, using the extract of compost C1 (Fig. 2).

At 252d, there was a clear difference in tomato RL between the control and the compost extract-treated seeds (Table 3). RL increased with compost, reaching 119% and 125% of the control values for compost C1 and C2, respectively.

The data obtained allowed to classifing, according to the test of Tukey-HSD ($p<0.05$), composting times for GI into six homogeneous groups (252 > 212 > 180 > (140 and 110) > 80 > 35) for Tomato and four homogeneous groups (252, 212 and 180)>140> 110 > (80 and 40) for Sugar beet. The length of the root has been classified, according to this test for all ages, in six homogeneous groups (252 > 212 > 180 > 110> 80 > 35) for tomato and in four homogeneous groups (252 > (212 and 180)> 140> 110> (80 and 35) for sugar beet.

The classification according to the Tukey-HSD ($p<0.05$), showed that the highest GI and RL values occurred in the extract concentration of compost C2 for tomato. The compost type did not show any significant difference in seed germination bioassay for sugar beet for both parameters, except for GI, the difference was observed at day 35 and day 80 of cornposting. At these days, the GI of sugar beet was more inhibited by compost C1 than C2.

Evolution of seed germination of sugar beet

After 246 days of composting, the physico-chemical and phytotoxic tests showed that the composts tested are stable and mature. For this, the authors deemed it necessary to study the effect of the aqueous extract of the studied composts on the evolution of the germination of sugar beet. The results obtained show that germination is delayed by one day on the control medium compared to the germination of seeds irrigated with the aqueous extract of the compost. On the control medium, the average germination time is 7 days, whereas it is 6 days for the seeds treated with the extract of compost C1 and C2 (Fig. 4). The GI was larger than the control (>100) after incubating 4, 5, 6 and 7 days of germination (Fig. 4). At the start of germination (4 days), the length of the root was greater than that of the control, it was130.5% compared to the control for C1 and 125% for C2 (Fig. 5).

DISCUSSION

At the end of the process, the pH was reaching subalkaline values. Authors reported similar pH values using passive and active aeration systems [Bustamante et al, 2008; Ogunwande and Osunade, 2008; Rizzo et al. 2013; Wang et al 2022]. Composting yields an end product with a stable pH that is close to neutral, which indicates their maturity [Epstein 1997; Ogunwande and Osunade 2008]. Although EC parameters affect compost quality, due to the synthesis of ammonia as well as the increasing concentration of mineral salts brought on by the mass loss of compost, EC parameters increased in both composts, when the anaerobic digestion of PM was assessed. Guo et

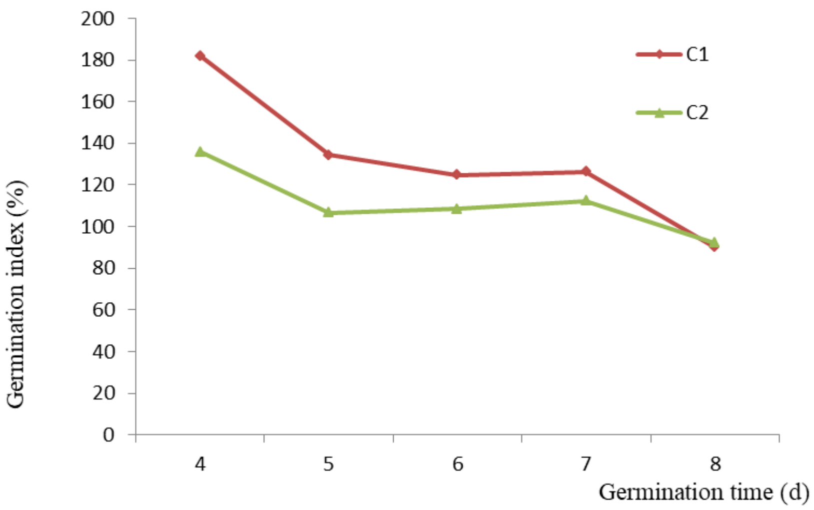

Figure 4. Evolution of seed germination index of sugar beet as affected by water extract from 252 days old co-composted municipal solid waste and poultry manure

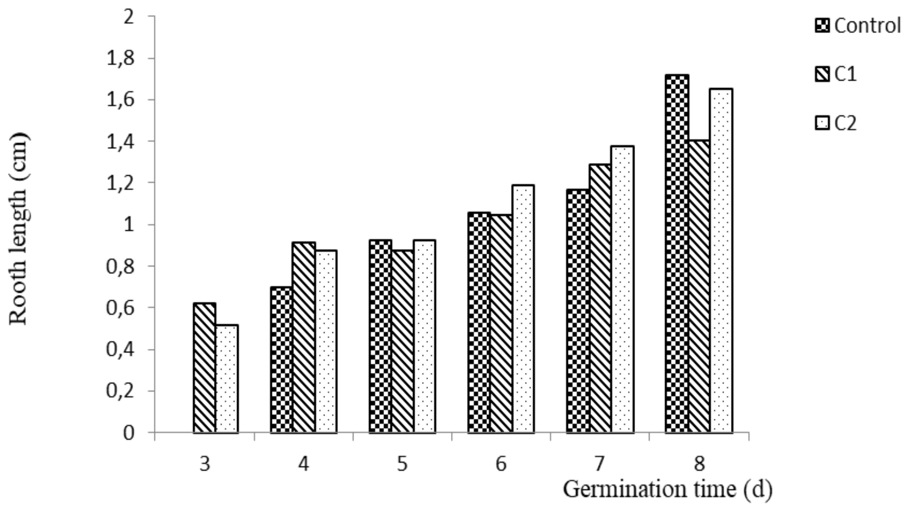

Figure 5. Evolution of root length of sugar beet as affected by water extract from 252 days old co-composted municipal solid waste and poultry manure

al. (2020), observed a positive association between EC and total ammonia nitrogen. The EC in compost C2 was significantly higher than in compost C1, probably due to the higher proportion of PM in the mixutre of compost C2. During the composting, water evaporation [Lhadi et al., 2004] led to a lessening in moisture content that exists in the composts and enhances microbial activity [Adani et al., 2004].

After 252 days of composting, the compost had final values of TOC higher in compost C1 than compost C2, due to the higher proportion of MSW in the mixutre of compost C1.

The TKN concentrations were similar for both composts at the end of the process. Final values of C/N ratio were lower in compost C2 than compost C1. Both composts had reached an acceptable degree of maturation, since their C/N ratios were <20. The N dynamics reflected the different proportion of original wastes. Compost C2 with more PM (2:3) had higher initial total N content, thus lower C/N ratios. Carbon mineralization to CO_2 tends to decrease the C/N ratio during the active phase and slows down during the curing stage [Zhou et al. 2018].

The NH_4^+-N concentration decreased and nitrate concentration increased at the final process. The highest values of NH_4^+-N and NO_3^--N corresponded to treatment C2. NH_4^+-N losses due to volatilization and transformation into NO_3^--N outpace ammonification rates, and NH_4^+-N concentrations decline as degradation rates slow [Liu et al., 2020a, 2020b].

Substrate pH increases mainly because of the degradation of the organic nitrogen and ammonium accumulation [Shan et al., 2021]. Several dependent factors take place to identify the transformation of N during aerobic biological processes, counting the substrate characteristics [Zhou et al. 2018] likewise operating conditions, such as temperature and aeration rate [Cesaro et al. 2015]. As in the case of the CE, the final macronutrient composition of the C2 mixtures was slightly higher than that of C1. Nutritive values of the compost are added from the macronutrient content. Although the heavy metal concentration of finished composts (Table 1) appeared to be low compared to international standards [CCQC 2001], the compost appears to be of high quality [Bernal et al. 2017].

Low germination index are often observed during the start of a biostabilization process due to the rapid start of biological activity and the synthesis of germination inhibitory chemicals, such as phenolic compounds, alcohols, and organic acids [Zhang et al., 2019; Wang et al., 2021a]. Taking into consideration the proprieties of the composts C1 and C2, no direct relationship of phytotoxicity with that could be related, in any case, it could be a clear conclusion that it is a direct relationship with the material samples. Compost 15 d old was being more phytotoxic than all other compost samples. According to the findings of this study, the inhibitory effect of compost C1 and C2 looked to decrease as the compost matured, but the real response relied on the plant type. The tomato and sugar beet germination index values increased with composting time (Fig. 2). Tomato, on the other hand, exhibited behavior distinct from the sugar beet test (Fig. 1). The sugar beet seed was highly sensitive than tomato seed to the toxicity of composts separated municipal solid waste and poultry manure at day 35 and 80 of composting. It is noticeable that statistically significant differences have been found to exist for GI for sample 140, 180 and 212 between both species, the compost could stimulate sugar beet germination. It is clear for samples 35d and 80d old that the investigated material could significantly inhibit sugar beet GI. In this study, the *Beta vulgaris L* GI values were observed to be 79% and 74% at 110 day and 99% and 91% at 140 day, with the samples prepared by extract concentrated of composts C1 and C2, respectively (Table 3), which suggests that the investigated materials can have an inhibitory effect. This potential effect is reducing with time as GI increases, which could be attributable to the low biological degradation processes throughout the maturation period. The maximal GI values of two species, however, were greater than 100%. As a result, the composting processes studied in this work reach full maturity.

Between the initial and final sample times, the RL values increased for both treatments, ranged between 0–5 cm for tomato and 0–1.64 cm for sugar beet (Fig. 3). These results show that composting reduced toxicity. Analysis of the root growth and seed germination results indicate that the phytotoxic effects of composts C1 and C2 were on both root growth and seed germination. However, root growth of sugar beet was more inhibited than RL of tomato. Indeed, after 110 days curing the seed germination index of tomato was inhibited while GI of sugar beet was not affected (Fig. 2 and Fig. 3).

For tomato both root elongation and seed GI was unaffected by the phytotoxic compounds at 35 days, as compared to the sugar beet GI and RL. In terms of relative root elongation, the two plant species responded differently to the toxicity of the compost water extracts (Fig. 3). Tomato root length was less impacted by the presence of toxic components in the compost extract than the germination index. Radical length of tomato seeds was affected only at 15 days, and then it had greater radical length in comparison with that of the second species (Table 3). For sugar beet, both root elongation and seed germination index was affected by the toxic compounds at 35 and 80 days. Compared to the control, the decreases for sugar beet RL were 0 to 68% and were 0 to 27% for tomato RL for all treatments.

Results from the sugar beet test highlighted that root elongation was a more sensitive test than GI. These results, suggested that seed germination test can be used to analyze high toxicity compost, as opposed to radicle growth, which may be used to examine low toxicity compost [Zucconi et al. 1981 and Tiquia et al. 1996]. Tomato seeds were not sensitive enough to detect the differences between mature and immature composts of separated municipal solid waste and poultry manure. In adition, a clear difference in RL between tomato and sugar beet seeds treated with 35 and 80 day-old compost extracts was evident. Tomato seeds presented a higher RL for these extracts, as compared to sugar beet. In particular, the decreases for tomato RL were 13 to 27% and 61 to 68% for sugar beet using the extracts of compost 35 and 80 day-old, as compared to the control. In addition, tomato root elongation was more affected by phytotoxic compounds in compost C1 than C2. This can be explained by the nature of the substrat used. Indeed, C2 compost is richer in poultry manure than C1. The final TOC content was higher for the compost C1 than for the C2.

The GI of two plant species tested in the present study, increased to over 80% by day 140 for sugar beet and day 180 for tomato. These findings reveal that the compost did not reject any toxicity on the plant growth, because phytotoxic inhibitors were removed. They also indicated a maturity level of the compost at day 140 and that the final composts were mature by day 180.

A GI > 80% demonstrates that the compost is mature [Luo et al. 2018] and a GI < 50% demonstrates high phytotoxicity [Barral and Paradelo 2011]. GI expanded to over 50% at day 35 for tomato. At this day, the GI of sugar beet was less than 50%. The results confirm a serious inhibition potential of these two composts to sugar beet and possibly to other plants. Therefore, the conducted indicates that composts C1 and C2 might not be phytotoxic to sugar beet after days 110. This evidence could be only related that seed germination of sugar beet is more sensitive to the salinity and other phytotoxic compounds than tomato. Seed germination and hypocotyls lengths of sugar beet were affected negatively and delayed with salt stress [Santos et al., 2021]. The GI of the sugar beet can use it to be a very sensitive index indicating, when greater than 90%, the disappearance of the phytotoxicity of the compost.

Incomplete composting has been shown to limit the degradation of phytotoxic compounds [Zhang et al., 2019, Wang et al., 2021a]. B. vulgaris L and L. esculentum L tests show that the freshly compost (sample 15 day] was noted a GI lower than 30%, which is representative of a compost inducing sensible inhibition on crops growth. Pursuant to WRAP 2011 and Chen et al., 2021, this product must not be used as an amendment. However, during curing phase developed inside a plastic container, even without an aeration process, the compost modified its characteristics, reducing its inhibition capacity (Fig. 1).

Interestingly, when the seed of sugar beet were incubated with extracts of the final composts (day 180), the GI increased to over 100% of the control (Table 3), precisely due to improved growth of the radical. The high germination index marks the stimulating effect of chemical compounds present in the extracts of compost [Kebron et al. 2019; Wei et al., 2020; Jiang et al., 2020]. Nonetheless, this stimulatory effect of compost C1 at day 180 for tomato seeds was not only absent, but also the GI was less than 80%.

Soil salinity significantly inhibits seed germination and seedling growth [Santos et al., 2021]. The sodium concentration in poultry manure was higher than in MSW. Meanwhile, as suggested by Meng et al (2019a) there is a relationship between EC and toxicity. The phytotoxicity in poultry manure may not be solely attributable to salts. The author's experience shows an increase in the index of germination and root length of the seed at the end of maturation, even if the compost has a high salinity. Komilis and Tziouvaras (2009) showed a negative statistically significant correlation between the electrical conductivity of the compost filtrates with the germination of two types of seeds.

The increase in seed germination and root elongation of the two plant species through composting occur simultaneously with the low concentration of ammonium. As a result, the composting process in this study reached complete maturity. The findings demonstrate that the phytoxicity of compost was influenced not only by the degree of stability and maturity, but also by the plant of seed studied. Despite the fact that only little variations can be observed for samples 110, 140, 180, and 212 days old, it is clear for the samples 35d and 80d old that the tested product might severely restrict sugar beet germination while stimulating tomato germination. These findings suggested that the maturity assessment should be performed concurrently with the stability evaluation and should be based on a uniform approach to ensure the reproducibility of the test results. The seed germination test is a practical and economical bioassay for determining the possible phytotoxicity of compost before it is used.

A GI result greater than 85 to 90% suggested that this phytotoxicity has disappeared in the compost. As a result, the removal of phytotoxicity from sugar beet may be used as an indicator of compost stability, whereas tomato bioassay could be utilized as an indicator of compost maturity.

Evolution of seed germination of sugar beet

Germination was delayed by one day for the control; the average time of germination was 7 days. However, 6 days were not enough for complete germination for control seeds. On the other hand, it was found that the germination of sugar beet seeds exceeds that of control seeds (Fig. 2). The highest GI acheived was 182 found for compost C1 treatment (Fig. 4). This is consistent with the work of Mazumder et al. (2020) who found that germination index was highest (183.74) at 100 g/L of compost extract for L. esculentum. These outcomes also indicated that mean germination time values of L. esculentum and B. oleracea decreased as the compost concentration increased. This increase of GI is mainly seen in compost rich in elements necessary for plant nutrition and with low content of phytotoxic substances. The C1 and C2 Composts used in this experiment retain low values NH_4^+-N concentration and high values of nitrate (Table 1).

Root length was also increased by compost about 30% with respect to the control (Fig. 5). Root length was increased most of the time by compost C1 than by compost C2 after incubating of 3 and 4 days. Over this phase, water absorption is crucial in seed germination and may be also affected by high salt concentrations of compost. Compost C1 showed a lower decrease in EC than C2 after 252 days of composting.

The roots are in charge of uptake and accumulation of metals so the root lengths were more affected by the concentration of the compost [Araujo and Monteiro 2005]. The heavy metal content in the compost may likewise be phytotoxic. The heavy metal level (Table 1) in the final composts in this investigation appeared to be minimal and comparable for both mixes. Therefore, it appears that the mature compost has a stimulating effect on the formation and growth of roots [Li et al., 2020a] and the stimulation of germination index [Mazumder et al., 2020].

CONCLUSIONS

The germination indices of phytotoxicity tests are significantly reliant on the type of seed utilized. Composts appear to have varying impacts on different types of seeds. Phytotoxic compost for sugar beet seeds could, on the contrary, in some cases, help the growth of tomato seeds. The results of GI values showed that compost C2 with high percentages of PM (60%) was different from compost C1 produced by high percentages of MSW (60%), on both sugar beet and tomato. The difference was observed only during the first 35 and 80 days of composting for sugar beet and at the end of process for tomato. After 35 days, the study demonstrates the greater phytotoxicity of C1 and C2, to sugar beet than for tomato and possibly for other crops. It appears clearly, in this study, that the sugar beet is the species most sensitive to phytotoxicity compost at the early stage of composting. Statistical analysis of germination index trials using tomato and sugar beet seeds demonstrated that only the compost produced after 180 days of composting was stable, mature and free from any toxicity. The two kind of seeds showed GI>80%. For the C1 compost, this GI threshold was reached on day 110 for sugar beets, while it took until day 180 for tomatoes. These dates changed when the C2 compost was used. Additionally, it was difficult to assign a single threshold GI value to indicate compost maturity and cannot be applied to different types of composts because different seeds reacted differently to the same compost. In any case, the conducted showed that MSW and PM may be composted effectively and increase their mineralized elemental compound. This can contribute to improving the soil properties as well as economical farming. These outcomes suggested that sugar beet seeds germination bioassay could be used to evaluate biotoxicity from complicated samples or could be utilized in observing procedures as a useful phytotoxicity test. Toxicity testing of compost, before its application by farmers, with training programs can aid in increasing the usage of these beneficial products.

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