Ecological And Morpho-Physiological Characteristics Of Corn (*Zea Mays* L.) Associated With Compost Curing

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Abstract: Municipal solid waste (MSW) compost is an 'organic' amendment that can act like inorganic fertilizers. This study aimed at evaluating the effect of further cured MSW compost on the growth and development of Zea may L. and characterizing the effect of curing on the soil microbial populations and enzymatic activities. The experimental design was a completely randomized block design with six treatments, the plant's morpho-physiological characteristics were studied, and the microbial analyses were done for three different soil layers 0-10, 10-20 and 20-30 centimeter as well as for the rhizosphere. Data was submitted to statistical analysis using SPSS 17, where treatments with further cured compost showed a significant (P<0.05) increase in all the parameters investigated, and the level of 2.5% had the highest values, except for fungal populations, for both the microbial and enzymatic activities.

Index Terms: Compost curing, enzymatic activity, morpho-physiological characteristics, microbial numbers, MSW compost, organic matter, *Zea mays* L.

1 Introduction

Organic manures and tillage systems are considered to improve soil properties and thus increase the crop yield by increasing the content of organic carbon, and available N, P and K in soil. Hence, placing compost recovers the soil physical properties such as bulk density and porosity, which in turn positively affects the yield components and the dry matter accumulation [1]. Bulky organic materials applied to soil may directly increase soil porosity, rates of infiltration and water holding capacity and aggregation [2], which may promote sufficient soil aeration and water for soil microorganisms and plants.

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The use of municipal solid waste (MSW) compost, an environmentally favorable waste management strategy, enhances soil quality by increasing the amounts of organic matter present and humus levels [3]. In addition, compost amendment reduces erosion losses and improves structural stability [4]. Regardless of the risks of heavy metal pollution, if applied responsibly, MSW compost improves nutrients availability to agricultural soils and their uptake by plants. Moreover, the addition of compost has been found to increase their water holding capacity and raise their pH [5]. The specific objectives of this study were to evaluate the effect of various application rates of MSW compost on the morphophysiological characteristics of the corn crops and on the soil microbial population and enzymatic activity.

2 Materials and Methods

2.1 Soil Analysis

The natural soil used in this study was brought form Ainata (South Lebanon) and selected at approximate 40cm depth. Soil texture, pH, nutrient concentrations and other physical and chemical characteristics were studied in the Pedology laboratory at the Faculty of Sciences and the DSST (Doctoral School of Sciences and Technology) in the Lebanese University, Rafic Hariri Campus, Hadath, Lebanon according to Kobaissi et al. (2013) [6].

2.2 System Preparation

PVC columns were used to prepare the system (60cm high cylindrical PVC tubes of 16cm diameter (15.6cm internal diameter) with a bulk density level of 1.25g.cm-3 [7]. The organic fertilizer, compost, used in this study was provided by the laboratory of Plant Biology and Environment [8]. The soil was mixed with two different compost percentages (2.5% and 5% of the total soil volume, mature or cured and immature or non-cured) before filling in pots along with the control without compost, with three replicates each. This experiment was done under controlled conditions at the laboratory of plant biology and environment in the Lebanese University between February and July 2013. Corn (Zea mays) was sown under conditions of 12/12h day/night period, 18/22°C day/night temperatures and 40/60% air moisture. By the end of the experiment, the plants were collected and several morphological parameters were measured.

2.3 Physiological Parameters
Total Chlorophyll concentration of these leaves, were determined using spectrophotometry at 645 and 663nm and the calculations was effectuated according to Arnon (1949) [9]. Nitrate reductase activity was estimated in fresh leaves of the plants according to Jaworski (1971) [10].

2.4 Soil Collection
Soil samples were taken from three soil layers (a, b and c) corresponding respectively to 0-10, 10-20 and 20-30 centimeters (cm) plus the rhizosphere (R). For the microbial and enzymatic study, 100% cured and non-cured compost treatments, were eliminated, since they were used as a preliminary study to investigate their effects on the plant morphology.

2.5 Microbial Culture and Enumeration
Microbial tests were done for the previously mentioned soil layers. Microbes were allowed to grow on three different media, Martin medium for fungi culture [11], PikovsKaya's (PVK) agar medium for phosphate solubilizing micro-organisms culture [12] and nutrient agar medium (N.A.) for total bacterial culture. 10g of each soil sample was dissolved in 100 ml sterile distilled water. Then, they were serially diluted up to 10-6 dilution. The dilutions of each of the soil samples were taken for spread plate technique followed by microbial incubation at 37ºC for about 1 week. Then the number of the grown bacteria and fungi was counted and recorded in terms of colony forming units per gram of dry soil (C.F.U. / g dry soil) for further analysis.

2.6 Microbial Enzymatic Activity
Two enzymes were tested, dehydrogenase (DHA) [13] and acid and alkaline phosphatases enzymes [14].

2.7 Statistical Analysis
The obtained data were submitted to statistical analysis using Duncan's multiple range test and standard error of mean using SPSS 17.0 with significance at α=5%.

3 RESULTS

3.1 Soil Preliminary Tests
The soil used was analyzed in the Pedology lab at the Lebanese University. Results obtained are shown in Table 4. The soil is clayey (Clay: 61.25%, Sand: 23.43% and Silt: 15.31%) and slightly alkaline (pH = 7.96), suitable for the corn growth. The porosity is acceptable (48.68%) for a heavy soil, it permits root growth and development. As expected, total calcareous is low (0.33%), due to the poor presence of stones and gravels. Electrical conductivity is (0.72 $mS.cm^{-1}$), acceptable for corn growth. Also, the soil has low organic matter (0.78%), as it resembles virgin soil with no cultivations and plant residues, therefore the effects of the treatments (i.e. fertilizer addition) will be effective and a significant on the plant development.

3.2 Effect of Compost Curing on Plant's Growth and Development
The compost used in this study originated from Ain Baal compost facility, and it was further cured in the Faculty of Sciences of the Lebanese University by Kobaissi et al.(2013) [8]. The further cured compost will be referred as cured, while the initial compost sample taken from the facility will be referred as non-cured.

3.2.1 Influence of Curing on the Plants' Leaves
Concerning leaf number (Table 1), there is no difference between control (S), 2.5% cured and non-cured compost (C2.5% and nC2.5% respectively) and 5% cured compost (C5%). However, 5% non-cured compost (nC5%) showed a significant reduction of 16.66% with respect to the cured compost treated plants (i.e. C5%). In addition, 100% cured or non-cured compost treated plants (C100% and nC100% respectively), showed a significant reduction of the leaf number. Leaf dry weight and area (Table 1) significantly

TABLE 1
EFFECT OF FURTHER CURING ON THE LEAVES' CHARACTERISTICS

Treatments	Leaf Number		Leaf Dry Weight (g)		Leaf Area (cm^2)	
S	12±0.0	d	0.72±0.04	b	248.43±0.29	c
$C_{2.5\%}$	12.33±0.47	d	1.89±0.06	d	745.71±0.20	e
$nC_{2.5\%}$	11.33±0.47	cd	0.97±0.13	c	403.29±0.54	d
$C_{5\%}$	12±0.82	d	1.84±0.12	d	721.69±0.20	e
$nC_{5\%}$	10±0.82	b	0.61±0.13	ab	170.18±0.18	b
$C_{100\%}$	9±0.0	ab	0.45±0.08	a	88.81±0.07	a
$nC_{100\%}$	8.33±0.47	a	0.4±0.06	a	75.36±0.33	a

Note: Means within columns followed by the same letter do not differ significantly according to Duncan's multiple range test (α=0.05).

increase by 163.72% and 200.16%, respectively, between S and C2.5%, where C2.5% and C5% showed the highest values with respect to all other treatments. Table 2 shows the variation of the total chlorophyll content and the nitrate reductase activity in the leaves. It indicates that there is no significant difference in chlorophyll content between S, C2.5%, nC2.5% and C5%. However, an evident effect of curing is significantly clear at 5% non-cured compost level with a decrease of 33.74% of the chlorophyll content. The nitrate reductase activity of the control plants is significantly different from all the other treatments. A significant increase of 55.54% is observed with 2.5% cured with respect to the control, which do not differ from the nC2.5%. Yet, the effect of curing is clear at the rate of 5% with a significant reduction of 28% between C5% and nC5%. C100% and nC100% have the lowest values in comparison to all the other treatments.

TABLE 2

EFFECT OF CURING ON NRA AND THE CHLOROPHYLL CONTENT IN THE LEAVES

Treatments	Nitrate Reductase Activity (µmol NO2-g-1 h-1)		Total Chlorophyll (µg mL-1)	
S	151.25±23	a	9.27±0.62	cdef
$C_{2.5\%}$	235.25±20.9	ef	10.54±1.28	ef
$nC_{2.5\%}$	211.25±18	de	10.05±0.45	def
$C_{5\%}$	257.5±24.7	fg	11.2±0.5	f
$nC_{5\%}$	184.75±3.89	cd	7.42±0.99	bc
$C_{100\%}$	111.25±14.8	a	3.86±0.47	a
$nC_{100\%}$	106.5±6	a	2.08±1.2	b

Note: Means within columns followed by the same letter do not differ significantly according to Duncan's multiple range test (α=0.05).

3.2.2 Stem's parameters affected by curing

Table 3 shows the plant height which is negatively affected in case of the non-cured compost, whatever its concentration was. In addition, no significant difference is found between C2.5% and C5%, and between nC2.5% and nC5%. Nevertheless, the use of low concentration of compost will increase significantly the height of the plant by 37% in comparison with the control S. In case of nC100%, the reduction of the plant height is significant with respect to all other treatments. The stem's length and dry weight shown in the table 3 show a strong positive correlation (r2= 0.972). Furthermore, C100% and nC100% have the lowest stem's length and dry weight, and C2.5% and C5% significantly have the highest values. However, the effect of curing is obvious at the level of 2.5% and 5%, table 3 shows that there is no significant difference between nC2.5%, nC5% and the control S. Still, the stem dry weight of C2.5% is significantly higher than C5% by 21%.

3.2.3 Outcomes of Compost Curing on the Root System

Table 4 shows the effect of the compost curing on the root system characteristics. In case of 2.5% and 5% compost, the

TABLE 3

EFFECTS OF CURING ON PLANT HEIGHT, STEM'S LENGTH AND DRY WEIGHT

Treatments	Plant Height (cm)		Stem Length (cm)		Stem Dry Weight (g)	
S	76.53±2.65	bc	31.67±2.87	bc	0.32±0.06	ab
$C_{2.5\%}$	105.2±2.34	f	68.5±2.15	e	2.42±0.08	e
$nC_{2.5\%}$	83.17±1.88	de	33.17±3.47	cd	0.43±0.08	abc
$C_{5\%}$	104.5±4.97	f	64.4±3.37	e	2.00±0.2	d
$nC_{5\%}$	83.83±2.09	de	27.83±1.03	b	0.35±0.2	ab
$C_{100\%}$	73.1±0.80	b	21±1.63	a	0.28±0.12	a
$nC_{100\%}$	60.13±0.66	a	20.33±1.25	a	0.21±0.08	a

Note: Means within columns followed by the same letter do not differ significantly according to Duncan's multiple range test (α=0.05).

effect of curing. In addition, the highest root length is observed in C2.5%, followed by nC2.5% and C5% (39.3>31.8>31.63cm). At the concentration of 100% compost, no effect of the curing is observed, and C100% and nC100% are significantly less than the control's S root length.

The root dry weight present in table 4 shows no significant difference between the control S, nC5%, C100% and nC100%. Treatments with cured compost showed highest roots dry weight, with superior values in those containing 2.5% compost.

3.2.4 Plant Growth Performance influenced by Curing

LMR, SMR, RMR, SLA and LAR are represented in fig.1 as percentages of leaf, stem, and root of total dry weight. The ratios (LMR, SMR and RMR) represent the proportion of the dry weight, and how it is distributed between the plant parts for each treatment. LMR is strongly negatively correlated with SMR (r^2= -0.998). Therefore, for all the treatments, when LMR increases SMR reduces and vice versa. LMR increases with the non-cured treatments, while SMR rises with the cured

TABLE 4

VARIATION OF THE ROOT'S LENGTH AND DRY WEIGHT WITH CURING

Treatments	Root Length (cm)	Root Dry Weight (g)

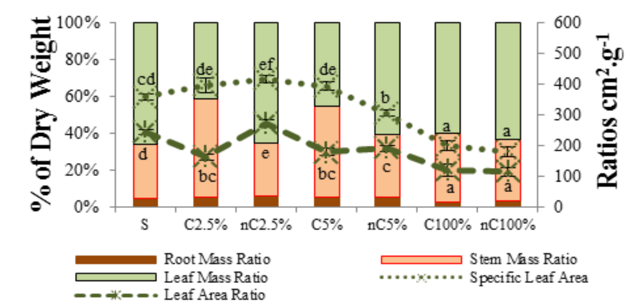

Fig.1. Influence of curing on plant's performance. Note: Means within columns followed by the same letter do not differ

ones. In addition, SLA and LAR are strongly positively correlated (r^2= 0.739). The highest SLA performance is observed with C2.5%, nC2.5%, and C5%. Significant effect of curing is detected at 5% compost level. The highest LAR is for nC2.5% followed by S, then nC5% (272.4<243.09<191.51cm^{2}g^{-1}). No significant difference betweenC2.5% and C5%. The treatments with 100% compost had lowest SLA and LAR. RMR is approximately the same for all treatments. Fig.2 shows the variation of RLR (Fig.2.a) and SRL (Fig.2.b). Moderate positive correlation links RLR and SRL (r^2= 0.570), clearly appeared by the linear lines on the graphs. On the other hand they are negatively correlated with the root dry weight. No significant difference between C2.5% and C5% and between nC2.5% and nC5% was detected. The control S is similar to nC2.5% and the treatments with 100% compost in case of RLR. But in case of SRL the 100% non-cured compost nC100% has the highest value followed by C100%.

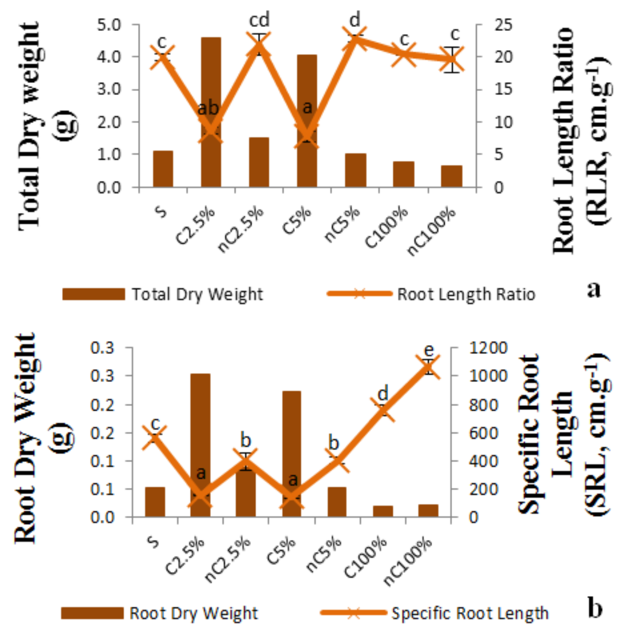

Fig.2. Effect of curing on RLR (a) and SRL (b). Note: Means within columns followed by the same letter do not differ significantly according to Duncan's multiple range test (α=0.05).

3.3 Effect of Curing Compost on Micro-Organisms

The study showed that the cured treated samples enhanced the bacterial populations' growth, while the non-cured treated samples facilitate the growth of fungi. In nutrient agar medium, the total bacterial numbers (Table 5) at C2.5% in the 3 layers and the rhizosphere was 2 to 5 times greater than those in the nC2.5%. Similarly for C5% and nC5%. The phosphate solubilizing bacteria (Table 5) showed a boosting increase in the 2.5% cured compost samples over the non-cured at R, a and c levels with a slight increase at the b layer; while a similar increase in a, b, and c layers was realized in the C5% samples. The phosphate solubilizing Fungi (Table 5) showed higher numbers in 2.5% cured samples over non-cured ones in all layers. At C5% their growth was slightly higher than nC5% in all layers except for b layer in which the numbers showed high preference for non-cured sample over the cured one. On the other hand, fungal populations (Table 5) proliferated highly in the non-cured samples. The nC2.5% was higher than the C2.5% by 29.7%, 676%, 408.8% and 111.8% at a, b, c and R layer respectively and an increase of 17.5%, 129%, 44.8% and 163.7% in the same subsequent layers for C5% and nC5%.

3.4 Enzymatic Activity in Compost.

At C2.5% (cured and non-cured), dehydrogenase activity (Table 6) was higher than that of the control. But at 5% cured and non-cured compost treatments this activity was lower compared to the control in layer a. In contrast, at 5% cured compost in layer c the activity was higher compared to S. Regarding the rhizosphere R, the cured 2.5% treatment had a higher enzymatic activity than that of the control, but the non-cured one, C5% and nC5% possessed a lower one. At layer b, dehydrogenase activity was highest at C5% and nC5%. The acid phosphatase activity (Table 6) was higher in cured 2.5% and 5% and non-cured 2.5%; much important at C2.5% followed by C5%. In layer b and c, the compost treatments showed a lower enzymatic activity than the control ones, and in layer c, the C5% and nC5% activity was higher than the C2.5% and nC2.5% samples. At the rhizosphere all the compost treatments (with 2.5%>5%) had higher phosphatase activity. The alkaline phosphatase activity (Table 6), in all layers (except for b) and R, the 2.5% compost treatments (which had lower enzymatic activity than 5%) and the 5% samples had higher activity than the control. Almost in the 3 studied enzymes, the highest enzymatic activities were obtained in the rhizosphere R.

4 Discussion

The results obtained confirm the beneficial action of the organic compost on the plant development. The plants that received 2.5% and 5% compost levels matured sooner than the others. They are similar to those previously obtained by [15], who concluded that the MSW application contributes to increase the growth of corn plants. The application of 2.5% cured compost gave the highest values for all parameters studied. However, treatments with 5% cured compost showed for many factors similar records as 2.5%, except for the dry weight of the shoot and roots. So it can be suggested that with 2.5% cured compost provide the soil with enough organic matter to support the growth [16], and an additional quantity of compost (5%) may set the plant in stress. This is obvious in the fresh weight, demonstrating that the plant stored more water to equilibrate its internal salt's concentration, due to high level of heavy metals that the plant can't tolerate [17]. Nevertheless, the compost quality influences the growth and the development of plants [15]. In our study, the organic compost further cured by Kobaissi et al [8] enhanced the corn plant's development, due to higher availability of nutrients caused by further decomposition of the organic matter [8]. Furthermore, compost physiological effect is reflected by the chlorophyll content, where a slight decrease in the chlorophyll concentration was observed in the 2.5% non-cured compared to 2.5% cured treatments, which may be a toxicity indicator, evident at the 5% level [18]. This toxicity is due to the high level of heavy metals in the non-cured compost [8] and its

TABLE 5

EFFECT OF CURING ON THE BACTERIAL, PHOSPHATE SOLUBILIZING MICROBES AND FUNGAL POPULATION

	a		b		c		R	
Bacterial Populations (NA)								
S	894466±145744	c	506887±80858	c	449393±16194	b	687234±19148	b
C2.5%	1222734±31330	d	311847±15679	b	619975±39664	b	983269±192543	c
nC2.5%	84816±1210	a	92130±5426	a	44006±5364	a	85897±3886	a
C5%	570976±34373	b	60417±32639	a	3623188±538219	c	1705021±31381	d
nC5%	86211±2262	a	85992±2924	a	38053±637	a	71017±1864	a
Phosphate Solubilizing Bacterial Populations (PVK)								
	a		**b**		**c**		**R**	
S	492278±21235	b	369835±2066	cd	439595±51903	c	445390±75511	b
C2.5%	3087558±65171	d	255517±43457	bc	235440±92730	b	2908623±110712	c
nC2.5%	56939±10969	a	147801±1561	ab	35088±3060	a	35781±1475	a
C5%	877060±160609	c	796296±148464	e	484299±41872	c	64156±26148	a
nC5%	65690±1075	a	43251±20002	a	14454±4130	a	79774±9996	a
Phosphate Solubilizing Fungal Populations (PVK)								
	a		**b**		**c**		**R**	
S	6435±1820	a	4132±0.00	b	4049±0.00	a	14894±2128	b
C2.5%	47045±1907	b	11574±996	c	25658±1096	c	17599±3132	c
nC2.5%	7710±1433	a	1274±107	a	4298±2121	a	15385±0.00	b
C5%	8872±1792	a	4630±1637	b	14058±3188	b	8474±1107	a
nC5%	6352±163	a	22904±2793	d	12979±885	b	7797±678	a
Fungal Populations (Martin)								
	a		**b**		**c**		**R**	
S	40745±558	a	3777±605	a	4993±688	a	4645±885	ab
C2.5%	6889±596	b	5387±654	ab	6534±848	a	11390±1737	c
nC2.5%	8541±1006	c	10764±1724	d	23538±3230	c	19347±3406	d
C5%	16539±2091	d	6829±1073	bc	5314±2078	a	2314±895	a
nC5%	19435±2965	e	15644±1534	e	7696±1375	ab	6102±479	ab

Note: Means within columns followed by the same letter do not differ significantly according to Duncan's multiple range test (α=0.05).

TABLE 6

ENZYMATIC ACTIVITY INFLUENCED BY COMPOST CURING

	a		b		c		R	
Dehydrogenase Activity								
S	7.55±1.13	b	4.48±0.95	a	8.406±1.78	b	17.09±1.50	c
C2.5%	14.95±0.55	d	6.033±1.17	ab	12.75±0.93	d	17.60±0.41	c
nC2.5%	9.97±1.41	c	4.78±0.58	a	11.71±1.44	cd	7.47±1.09	a
C5%	6.13±1.27	ab	9.83±0.26	c	9.93±0.56	bc	11.4±0.74	b
nC5%	4.96±0.04	a	8.45±0.0	bc	5.61±0.29	a	10.13±0.62	b
Acid phosphatase								
	a		**b**		**c**		**R**	
S	420.57±156.05	a	1793.38±00	b	1757.08±00	d	747.11±202.5	a
C2.5%	2000±0	d	1339.71±140.82	ab	1272.645±54.04	bc	1531.24±32.26	c
nC2.5%	1042.7±186.8	bc	1304.63±165.18	ab	908.97±286.94	a	1267.48±204.12	bc
C5%	1146.4±60.53	c	1108.03±109.52	a	1572.46±00	cd	1257.94±40.82	bc
nC5%	832.5±136.4	b	1079.095±196.97	a	1133.355±119.92	ab	1145.755±98.05	bc
Alkaline phosphatase								
	a		**b**		**c**		**R**	
S	843.07±198.83	a	1302.295±123.34	a	1265.46±192.67	ab	1575.07±150.89	c
C2.5%	1615.865±313.64	b	1369.33±195.91	a	1464.6±49.37	b	1588.465±18.29	c
nC2.5%	1390.44±4.98	ab	1159.435±138.29	a	1382.2±113.57	ab	1517.48±0.0	c
C5%	1391.81±210.81	ab	1362.845±73.02	a	1151.91±116.01	a	1290.015±41.68	b
nC5%	979.75±304.14	a	1266.435±46.51	a	1106.82±35.27	a	770.455±27.68	a

Note: Means within columns followed by the same letter do not differ significantly according to Duncan's multiple range test (α=0.05).

accumulation in the leaves [19]. Also, the nitrate reductase activity increased in the cured compost treatments indicating that this quality of compost could be a good source of nitrates [8] for corns. Increasing compost's level may import harmful effects on the plant growth and delay corn's maturity. And that was obvious at the level of 100%, where lowest values for all the parameters studied were found. Concerning the microbial population, Lauber et al. (2009), Nilsson et al., (2007) and Baath and Anderson (2003) had shown that bacterial populations prefers cured samples over non-cured ones because, bacteria are highly sensitive to optimum conditions needed for their growth [20,21]. Non-cured compost has a pH value and moisture content higher than that needed for bacterial growth. While fungal populations tend to a slight preference for cured compost samples and a higher preference for non-cured compost samples. In fact, fungi prefer the non-cured sample because they are less sensitive to pH [20]. In addition, the non-cured sample contains more total organic matter; it includes more pores that are needed for fungal growth and higher water holding capacity than the cured one [8]. The previous studies are compatible with our results. Concerning the high enzymatic activity obtained in cured treatments, it is also due to higher microbial numbers. Both microbial numbers and enzymatic activities are affected by soil depth. Dehydrogenase and phosphatases, in rhizosphere, were higher than in bulk soil. This may be attributed to relatively longer time of root growth in the bulk soil. Similar results were obtained by Nosalewicz (2010) in which the average value of these enzymes in the rhizosphere soil was more than twice higher than in the bulk soil due to higher numbers of microbes. Moreover, in general, the highest microbial numbers and thus enzymatic activity were obtained in layer a (after R), and then an alteration between b and c due to the affection of chemical and physical soil properties on microbial growth.

5 Conclusion

The application of mature MSW compost improved the growth and development of corn. The use of cured compost at 2.5% level improved the corn development in comparison to the control and other levels and types of compost. But, increasing the compost level above 5% negatively affected the studied parameters due to metal toxicity and stress conditions. The presence of compost also enhanced the microbial populations' growth, where cured one facilitates bacterial growth while the non-cured the fungal ones. Finally, the production of MSW compost fertilizer by composting solid wastes could be a possible solution for the problem of solids wastes in a country facing this major problem as in Lebanon.

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