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Potential Usage of Food Waste as a Natural Fertilizer after Digestion by *Hermetia illucens* (Diptera: Stratiomyidae)

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The black soldier fly larvae are able to decompose various organic wastes such as livestock manures and food wastes. We tested whether the quality of the insect derived compost, i.e. larval feces, was comparable to that of a commercial fertilizer. The results show that the chemical composition and the growth rate of cabbages grown on the insect derived compost are virtually identical to those on the commercial fertilizer. Therefore the insect derived compost will be an ideal substitute to commercial fertilizers.

Key words: Insect derived compost, Chemical compound composition, Commercial fertilizer, Cabbage growth rate

Introduction

With the elevated living standard, food is in excess at least in some wealthy countries. Excessive food is normally wasted and claims budget to treat it. In Korea 698 metric tons of food are wasted daily (Ministry of Environment, 2008). Monetary loss by the food waste is expected to be more than 8 trillion Korean Won (app. 800 million US dollars) and additional 2 trillion Korean Won (app. 200 million US dollars) is required to manage the waste per year (Ministry of Environment, 2003). Up until now the most common ways to clean up food waste are to perform landfill, and to dump it in the sea. Landfill is the cheapest way to remove food waste. This has caused soil contamination and aquifer pollution and also hygienic issues (Benfetnati *et al.*, 1996). Nevertheless is the second method also very cheap, it has caused the severe water pollution and the maritime ecosystem disruption. As of 2013, dumping food waste in the sea will be completely banned (International Maritime Organization, 1991).

Various methods have been proposed or already in use to treat the waste in a more efficient way such as using earthworms, bacterial digestion and dry-burning at a power plant (Bansal and Kapoor, 2000; Ministry of Environment, 2008; Sahlström, 2002).

An earthworm was also tested to manage municipal wastes i.e. organic wastes and cow manure (Atiyeh *et al.*, 2000; Elvira *et al.*, 1997). The earthworm is susceptible to salinity probably to chloride ion (Owojori *et al.*, 2008; Schrader *et al.*, 1998). Therefore prior de-salinity is required, which should claim extra budget and may cause potential soil and water pollution by salines. At a power plant, dried food waste can be converted into electricity and/or heat. However it emits a huge amount of greenhouse gases that are the deterministic culprit of recent global climate change (Lackner, 2003).

An alternative is to use an insect decomposer. Since its first description in Korea (Kim, 1997), the black soldier fly (*Hermetia illucens*) has been paid much attention with its ability to managing manures from livestock and decomposing food wastes. In the field the insect can be found near cattle sheds, manure sheds, food waste dump grounds (Kim *et al.*, 2008). We have investigated potential utilization of the insect especially at the larval stage in a range of ways (unpublished). One of them is conversion of food waste to the natural compost by the insect. Here we present that the compost produced by the insect is equivalent to a commercial fertilizer in quality. Therefore it is a promising option to substitute a conventional chemical fertilizer.

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Materials and methods

To test the suitability of the insect derived compost, two subsets of tests were performed. First, chemical composition of the insect derived compost was compared with that of the commercial fertilizer. Second, by using the parameters of the growth rate and volume of Chinese cabbage, the nutrient availability of the insect derived compost was compared with that of the commercial fertilizer.

Analysis of compounds in the fertilizers and cabbages
Analysis of various minerals was performed by following the methods described in 'Soil and plant analysis' (Rural Development Administration, 2002). Therefore the methods are not described here in detail. For each analysis 5 g of the compost and the fertilizer were used. The methods for analyzing the compounds in the cabbages grown on the two fertilizers are as almost identical as for analyzing the fertilizers. The amount of cabbage for each analysis varied from 0.5 g to 2 g biomass depending on the target compound to be analyzed.

Growth parameters of cabbages
The seeds of the cabbage variety (common name: Ssam-mat) were planted on pots. As soon as the seeds of the variety were budding, they were transplanted to the experimental grids (1.7×1.7 m) in NAAS. In each plot (~ 2.9 m^2) of the two treatments where the cabbages were transplanted at every 30 cm, 3.5 kg (25% moisture) of the fertilizer or the insect derived compost was applied following the fertilizer manufacturer's instruction. For measuring the leaf length and width, 3 outermost leaves were chosen and examined once a week for 4 weeks. The number and size of leaves of the cabbage were recorded once every week for 4 weeks. After completing the 4 week examination, they were harvested for analyzing their biomass and dry mass.

Statistics
By using SPSS (version 11.0), student-t tests were performed to determine if there were differences in chemical composition between the two fertilizers and in the growth parameters and the biomass and dry mass of the cabbages grown on the two fertilizers.

Results

Chemical compound composition of the two fertilizers
The analyses show that there is virtually no difference in the amount of chemicals between the two fertilizers. This indicates that the insect derived compost can be practiced immediately. The insect derived compost contained slightly more Electrical conductivity (Ec) (Table 1). This may be caused by the relatively high amount of Sodium (Na) in the insect derived compost (Table 1).

Table 1. Chemical composition of the insect derived compost (A) and the commercial fertilizer (B)

Compounds \ Group	unit	N[1)]	A	B	P-value
pH		3	7.0±0.2	7.1±0.2	
Ec	dS m^{-1}	3	0.5±0.1	0.3±0.0	<0.05
Om	g kg^{-1}	3	33.2±1.5	31.3±2.8	
K[2)]		3	0.1	0.1	-
Ca	$cmol_c$ kg^{-1}	3	8.8±0.4	8.7±0.5	
Mg		3	1.7±0.1	1.7±0.1	
Na		3	0.4±0.1	0.2±0.0	<0.05
P_2O_5	mg kg^{-1}	3	207.5±23.2	182.0±21.8	
NO_3-N		3	8.7±2.0	5.7±1.3	
NH_4-N		3	186.7±63.7	117.8±68.1	

[1)]Number of replicates
[2)]t-test can not be computed because the standard deviations of both groups are 0 since the exact values were all 0.08.

Table 2. Chemical composition of chinese cabbage grown on the insect derived compost (A) and the commercial fertilizer (B)

Minerals \ Groups	unit	N[1)]	A	B	P-value
N	%	6	2.1±0.3	3.2±0.2	
P		6	0.42±0.0	0.48±0.1	<0.05
K		6	3.9±0.4	5.4±0.5	
Ca		6	2.5±0.2	2.7±0.2	
Mg		6	0.2±0.0	0.2±0.1	
Na		6	0.3±0.0	0.1±0.0	
Fe	mg kg^{-1}	6	345.0±15.0	399.7±23.9	
Cu		6	6.3±0.3	7.3±0.7	
Mn		6	22.3±1.2	28.7±0.9	
Zn		6	24.0±1.5	33.3±5.8	
B		6	16.0±1.5	18.3±0.7	

[1)]Number of replicates

Chemical composition of cabbages
The cabbages on the insect derived compost contained the comparable amount of chemical elements (Table 2), even though the amount of phosphate (P) in the cabbages was less than that in the cabbages grown on the commercial fertilizer.

Growth rate of cabbages
The cabbages grown on the commercial fertilizer had

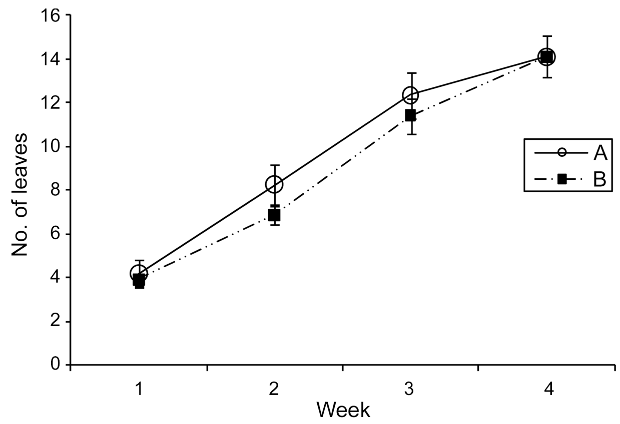

Fig. 1. Comparison of the number of leaves between the cabbages grown on the insect derived compost (○) and the commercial fertilizer (■).

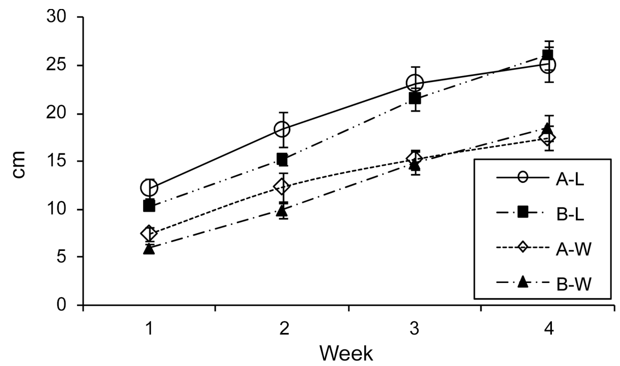

Fig. 2. Comparison of the leaf length and leaf width between the cabbages grown on the compost and the commercial fertilizer.
○(A-L) Leaf length grown on the compost
■(B-L) Leaf length grown on the commercial fertilizer
◇(A-W) Leaf width grown on the compost
▲(B-W) Leaf width grown on the commercial fertilizer

slightly fewer leaves on second and third week (Fig. 1). However this was not statistically significant (df=2, 4, P>0.1 at all check points).

Their growth patterns were almost identical (Fig. 2). There was no statistical difference in the leaf length and width of cabbages (df=2, 4, P>0.1 at all check points). The biomass and the dry mass between cabbages grown on the insect derived compost and the commercial fertilizer showed no statistical difference (df=2, 23, P>0.1) (Table 3). The results again confirm that the insect derived compost is as good as the commercial fertilizer in quality.

Table 3. Biomass dry mass of cabbages grown in the insect derived compost (A) and the commercial fertilizer (B)

Group	Biomass		Dry mass	
	N	Mean±S.E.	N	Mean±S.E.
A	12	279±43.4	9	0.16±0.02
B	13	288±41.3	10	0.19±0.02

Discussion

Chemical fertilizers have been sprayed in agricultural fields to increase soil fertility in the world since its invention in 19th century (Smil, 1999). However, the intensive use of chemical fertilizers has caused huge environmental and health issues (Ghosh and Bhat, 1998; Horrigan *et al*., 2002). To reduce such negative effects, some alternatives for chemical fertilizers have been practiced (Cucci *et al*., 2008). As a most inclusive concept, organic farming has gained popularity (Mäder *et al*., 2002). However some organic practices cause heavy metal accumulation in the agricultural fields (Baize, 2009; Valsecchi *et al*., 2004).

Large amount of insects play essential roles in stabilizing ecosystems, even though human beings have had little cognizance (Losey and Vaughan, 2006). There are advantages when considering using insects to treat organic wastes. For example, the house fly (*Musca domestica*) is also a powerful decomposer. However this insect is of huge medical importance and is found near human habitats. Dung beetles also consume organic matters, even though they are specialized in dung excreted preferentially by animals (Estrada *et al*., 1993; Losey and Baughan, 2006)

The black soldier fly has never been known to vector any pathogens. The insect seems not to be attracted to fresh food. This feature makes the insect an ideal alternative to the house fly. The larva of the insect is thought to consume decaying food more actively (Kim et al, unpublished). As seen in our results, the insect derived compost based on food consumable by human is free of heavy metal. It is possible that the chemical composition of the compost may be subject to that of the food waste the insect consumes. In the sense of quality control, this potential problem may be solved with pre- or post-processing of the food waste and the compost.

In conclusion, the insect derived compost can be an alternative to chemical fertilizers. It may be immediately applied in agricultural fields. The use of the black soldier fly can in part solve the food waste problem and the abuse of the chemical fertilizers. It is expected to see more green technologies. Using beneficial insects will be one of the technologies and one of good preparations for green future.

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