

# CO-COMPOSTING POTATO STARCH SLUDGE WITH SWINE MANURE

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## ABSTRACT

*This paper investigates the co-composting of pig manure and potato sludge left after the processing of potato starch, in Cheju island, Korea. Both potato production and pig raising are important economic activities on the island. Disposal of the wastes is a problem, since the island depends on groundwater for irrigation and drinking water. The need to protect groundwater from contamination has led to strong restrictions on landfill and other means of waste disposal. Co-composting produced a high-quality product that could be used as an organic fertilizer on potato crops. This technology has been successfully transferred to the private sector, and the compost is now commercially available.*

## INTRODUCTION

Large amounts of organic wastes are generated by households, agriculture and industry. Most of the wastes from industry and households in Korea are deposited in landfill. This is an undesirable solution, because landfills spoil the landscape and leach various pollutants into the groundwater. Because of the shortage of landfill sites in Korea, many organic wastes, especially hazardous ones, are incinerated. This can have a detrimental effect on the environment, in terms of air quality. Many agricultural by-products, including animal wastes are now being recycled through composting.

The number of livestock raised in Korea has been steadily increasing since 1985, due to the increasing consumption of meat. By 1999, the total

numbers of cows, pigs and poultry were about 2.7 million, 7 million and 110 million, respectively. These livestock generate about 35 million mt of wastes each year (Ministry of Environment 1999). The total amount of nitrogen, phosphorus and potassium in the wastes was nearly 700 mt. This exceeds the level in chemical fertilizers recommended for crop cultivation (Yang *et al.* 1999). The recent trend for livestock production in Korea is for feedlots, where livestock are raised intensively in a small area. The disposal of the animal wastes from these feedlots has become a difficult problem.

The most common method of disposing of animal wastes is to apply them to the soil. However, this causes many environmental problems. Composting the wastes is a promising alternative.

Keywords: Cheju Island, co-composting, compost, Korea, potato scab, potato sludge, swine manure

Several factors have contributed to the recent rapid promotion of composting, along with the decline in landfill treatment. The Korean government has been tightening the legislation to protect groundwater, and improve compost quality. This has created a favorable marketing environment for compost products. The number of compost plants in Korea using agricultural by-products increased from 353 in 1991 to 446 in 1997 (Kim 1998, Lee 1998).

In the composting process, sawdust is mostly used as the bulking agent. However, sources of sawdust are limited and the price is rising, especially in Cheju Island, the southernmost island of South Korea. An alternative bulking agent is needed.

Potato production in Cheju Island is around 24% of Korea's total commercial production. Potato is the second most important crop, after citrus. It is starch production which to large extent determines the price of potatoes in the market. Potato sludge is the main waste material left after starch processing. Most of the sludge is produced over the winter (November to April). It is rich in cellulose and has a high C/N ratio. Under natural conditions, it decomposes very slowly. Most of the starch extraction facilities are located along the coast, where there is access to water for the washing process. More than 40 factories making potato starch produce about 10,000 - 50,000 mt of sludge each year.

The sludge was used as landfill until the mid 1990s. However, this was then restricted, because of the threat of contamination to groundwater. The parent rock of Cheju Island is basalt. Most of the water used for drinking and irrigation is groundwater. Conservation of the groundwater is a top priority from both the environmental and the economic point of view.

The sludge was then dumped out at sea. However, this was costly, and also harmed the marine environment.

Recently, many countries have made an effort to recycle 15 - 50% of the wastes they generate (Diaz *et al.* 1993). To divert this quantity of wastes from landfills to compost heaps, it is necessary to plan and implement an overall waste management program.

Pig raising is also important on Cheju Island. Pork from the island is famous for its flavor. Currently, about 200,000 pigs are being raised on Cheju Island, generating about 150,000 mt of manure each year. The Provincial Government requires livestock producers to have some kind of animal waste treatment facility, and over 90% of the households are equipped with a septic tank or a

fermentation tank.

Sawdust is the primary bulking agent used in composting. The amount of sawdust used in Cheju Province is about 30,000 mt annually, but recently supplies of sawdust are getting scarcer, and the cost is high. Starch sludge cake with the excess water removed has the potential to be used as a bulking agent, in a sustainable recycling of organic resources. This would reduce costs, and promote both the potato and livestock industries.

### CO-COMPOSTING: A NEW APPROACH TO COMPOSTING

Co-composting is an interesting example of integrated waste management. Co-composting is a waste treatment method in which different types of waste are treated together (Ahring *et al.* 1992, Angelidaki and Ahring 1997). Co-composting is an attractive method of resource recovery and waste disposal, with many advantages. It costs less than separate treatment systems, mainly because of the lower cost per volume treated at large treatment plants. By diluting or concentrating materials to a suitable dry matter content, for instance by mixing solid wastes with more diluted wastes such as liquid manure, a better handling and digestibility of the solid waste is achieved. Furthermore, this dilutes or counteracts substances which inhibit fermentation, such as ammonia or inorganic compounds. It also gives the wastes a better nutrient balance.

The concept of co-composting was a natural consequence of composting municipal refuse (Diaz *et al.* 1993). Before 1975, the emphasis was on the refuse fraction of municipal solid wastes. Sewage sludge was regarded principally as a source of nitrogen and phosphorus, and to a lesser extent of potassium. These enriched the refuse and thus promoted the composting process. Thus, it might be said that co-composting was a means to an end, rather than an end in itself. After 1975, the emphasis in composting shifted from the refuse fraction to the sludge fraction.

The shift was largely a response to the need for a means of treating sludge other than incineration or landfill. Composting seemed to meet the need, especially since sludge treatment had advanced considerably, particularly in terms of reducing the water content. In composting, the water from sludge is removed to produce a solid substrate which can be composted, provided a bulking agent such as sawdust is used.

The steps involved in co-composting are

similar to those of ordinary composting.

- Collect and process the waste;
- Segregate and prepare the organic fractions;
- Mix the materials with sludge cake;
- Compost the mixture, *and*
- Prepare the compost product for storage, use or sale.

Diaz (1993) summarized the five most common problems in co-composting. They are:

- Inadequate mixing of the sludge and the wastes;
- Insufficient primary processing to the raw materials;
- Inadequate management of the moisture content (too wet or too dry),
- Tendency of the composting mass to arch or bridge over when mechanical mixing devices are used, *and*
- Lack of understanding of the composting process on the part of the operators.

We recently developed a co-composting technology using sludge cake produced from potato starch production, together with swine manure, in Cheju Island. The process is described in this paper, including reducing the water content, mixing and composting. We also analyze the effect of the applied compost on the growth and yield of potato crops.

### **CO-COMPOSTING OF POTATO STARCH SLUDGE WITH SWINE MANURE**

The process of co-composting is as follows:

- Excess water is removed from the potato starch sludge, using a pilot screw press.
- The sludge cake is mixed with swine manure (70%), sludge cake (5%, dry weight), seed oil cake (20%, dry weight), and zeolite (5%). The moisture content is adjusted to 50-55%.
- The mixture is left to ferment for two weeks.
- The compost is made into pellets, and packed into plastic bags perforated with small holes to allow aeration.
- The bags of compost are left in storage to allow the compost to cure for 2 months (10 or 12 bags per stack).
- The pellets are shipped to market and sold.

### **LOWERING THE WATER CONTENT OF THE POTATO STARCH SLUDGE**

Potato starch sludge contains carbohydrates such as cellulose, pectin and even residual starch, so that removing the excess water is not an easy task. Before the water is removed, the potato starch sludge has a moisture content of about 90%. With such a high water content, the sludge cannot be used as a bulking agent for livestock manure. Conventional methods of reducing the water content, such as a filter press, are not effective, especially if starch is present in the sludge, because it gelatinizes with moisture. While we do not yet have a press designed especially for starch sludge, we tested a pilot scale screw press and found the results satisfactory (Fig. 1 and Fig. 2). Adding calcium to the suspended colloidal sludge promoted the aggregation of particles, so that it was easier to press the water out of the sludge. Slaked lime at a rate of 0.5% was used as the main source of calcium.

### **Results**

The sludge contains about 92% moisture and 2% starch, and has a high C/N ratio. As a result, the sludge decomposes slowly under natural conditions. Because of the high moisture content, fermentation is anaerobic, causing an unpleasant odor. Apart from the water, the major components are carbohydrates such as cellulose, pectin and starch.

Generally, sludge is produced in November (autumn), stored over the winter in a storage tank, and treated in spring (March or April). The solids and water tend to separate out during storage, and the solids sink to the bottom. The efficiency of water removal was increased by a longer period of storage.

### **Efficiency of the pilot screw press in removing water from sludge**

When the compression ratio of inlet and outlet was 6:1, between 73 and 78% of the moisture remained in the sludge. Increasing the compression ratio might make water removal more efficient, but it complicates the mechanical design of the screw press and is not cost effective.

### **Conclusion**

Since the initial moisture content of the potato starch sludge was 92%, the sludge could not be used as a bulking agent in place of sawdust for co-



Fig. 1. Removing excess water from the starch sludge. (Clockwise, from top left); View of starch factory; Storage of sludge; Pilot screw press; Determining the water content by a far infrared moisture analyzer

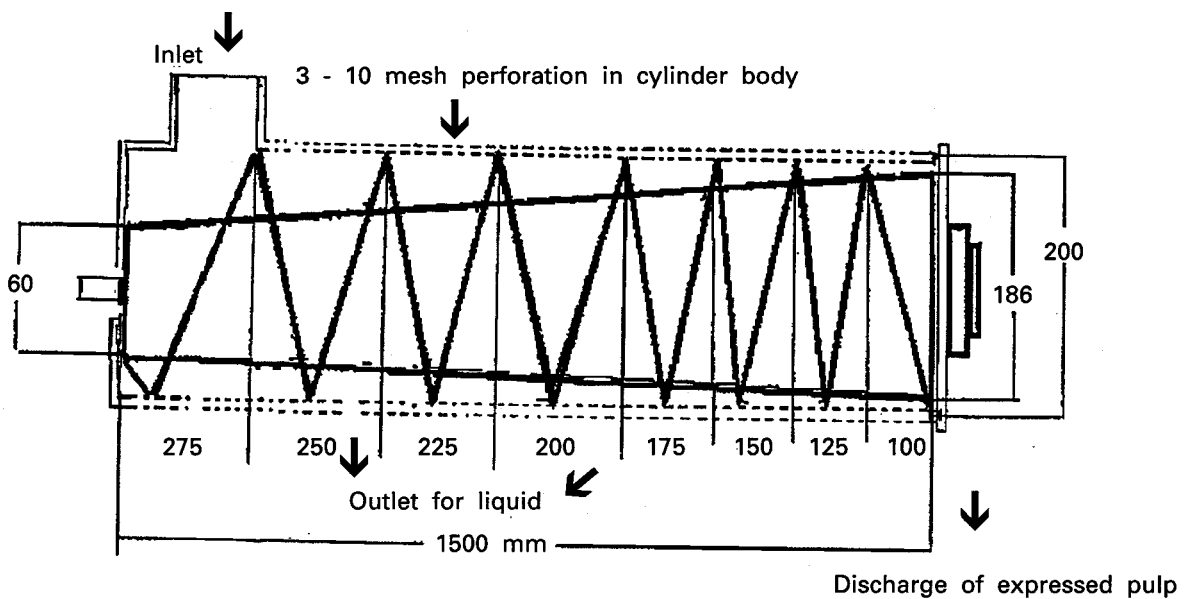


Fig. 2. Pilot screw press used to remove excess water from the starch sludge

composting swine manure. Removing the excess water was an essential preliminary step for the co-composting. We manufactured a pilot screw press for dewatering from the sludge and tested its efficiency. The longer the period of storage for the sludge, the higher the efficiency of water removal.

Treating the sludge with slaked lime was effective in increasing the efficiency of the screw press. Efficiency was increased with the amount of lime added, but 0.5% added lime was considered optimum considering the compression ratio (1:6) of the pilot screw press. Using this process reduced the moisture content of the cake to about 65%, which allowed it to be used as a bulking agent for co-composting with swine manure.

### **CO-COMPOSTING THE SLUDGE CAKE WITH SWINE MANURE**

We co-composted of swine manure and the sludge cake in an aerated pile in a shaded garage. The compost pile was thoroughly mixed before composting began, but was not mixed during the composting process. Sludge cake, the output from the pilot screw press, was used as the bulking agent. It had an initial moisture content of about 60%. Manure, sawdust and sludge cake were used at three different ratios: 1:1:0, 1:0.5:0.5, and 1:0.75:0.25. During the co-composting process, temperatures were monitored at a depth of 30, 45 and 90 cm inside the pile.

#### **Temperature changes during co-composting**

Temperatures in the compost with 1:0.5:0.5 manure, sawdust and sludge reached about 60°C after 8 or 9 days of composting (Fig. 3). This was a faster increase than was found in the compost with equal quantities of manure and sawdust (1:1:0). This trend continued into the curing stage, when the compost containing sludge maintained a temperature 10 - 20°C higher than the 1:1:0 compost.

This shows that the sludge cake is more efficient for co-composting with swine manure than sawdust. Temperatures at a depth of 90 cm were 25 - 30°C for all treatments (Fig. 3), suggesting that frequent mixing of the pile would give better composting.

#### **Moisture changes during co-composting**

The moisture content of the pile fell as composting proceeded. Compost with a manure:

sawdust: sludge ratio of 1:0.5:0.5 had a lower moisture content than the manure-sawdust mixture. The results indicate that the sludge cake is comparable with sawdust as a conditioner for compost.

#### **Changes in chemical properties during co-composting**

During the composting process, the chemical properties of the compost were monitored, including total nitrogen content, cations and anions. The total nitrogen content was maintained in the range of 0.5 to 1%, irrespective of the ratio of the materials. The nitrite (NO<sub>2</sub>) content was higher towards the top of the pile at the initial stage of composting, but in the later stages gradually increased deep inside the pile. Compost made only of manure and sawdust had a lower level of potassium and calcium than compost which included sludge cake as a raw material.

#### **EFFECT OF THE EXPERIMENTAL COMPOSTS ON POTATO GROWTH**

We evaluated the effect of the co-composted fertilizer on the growth and yield of potato grown in a plastic greenhouse. We also monitored the occurrence of the common scab disease of potato caused by *Streptomyces scabies*, to cross check the safety of the compost fertilizer. One plot was treated with compound chemical fertilizer recommended for potato (NPK: 10-9-12), applied as a basal fertilizer. Compost was applied at a rate of 20 mt/ha, and chemical fertilizer at a rate of 1.5 mt/ha.

We found that after 40 days of growth, the potato plants were taller in the compost treatments than in the chemical fertilizer treatment. However, there was no significant difference between the different kinds of compost.

The number of tubers and stems was highest in the plots to which was applied compost containing potato starch sludge. However, they were higher in all plots given compost treatments than in plots treated with chemical fertilizer (Fig. 4). The diameter of the tubers followed the same trend.

#### **Effects of the experimental compost on potato yield**

The percentage of potato tubers heavier than 50g were about 86% in plots given compost containing potato starch sludge. This can be compared to 82% in the plot given chemical fertilizer,

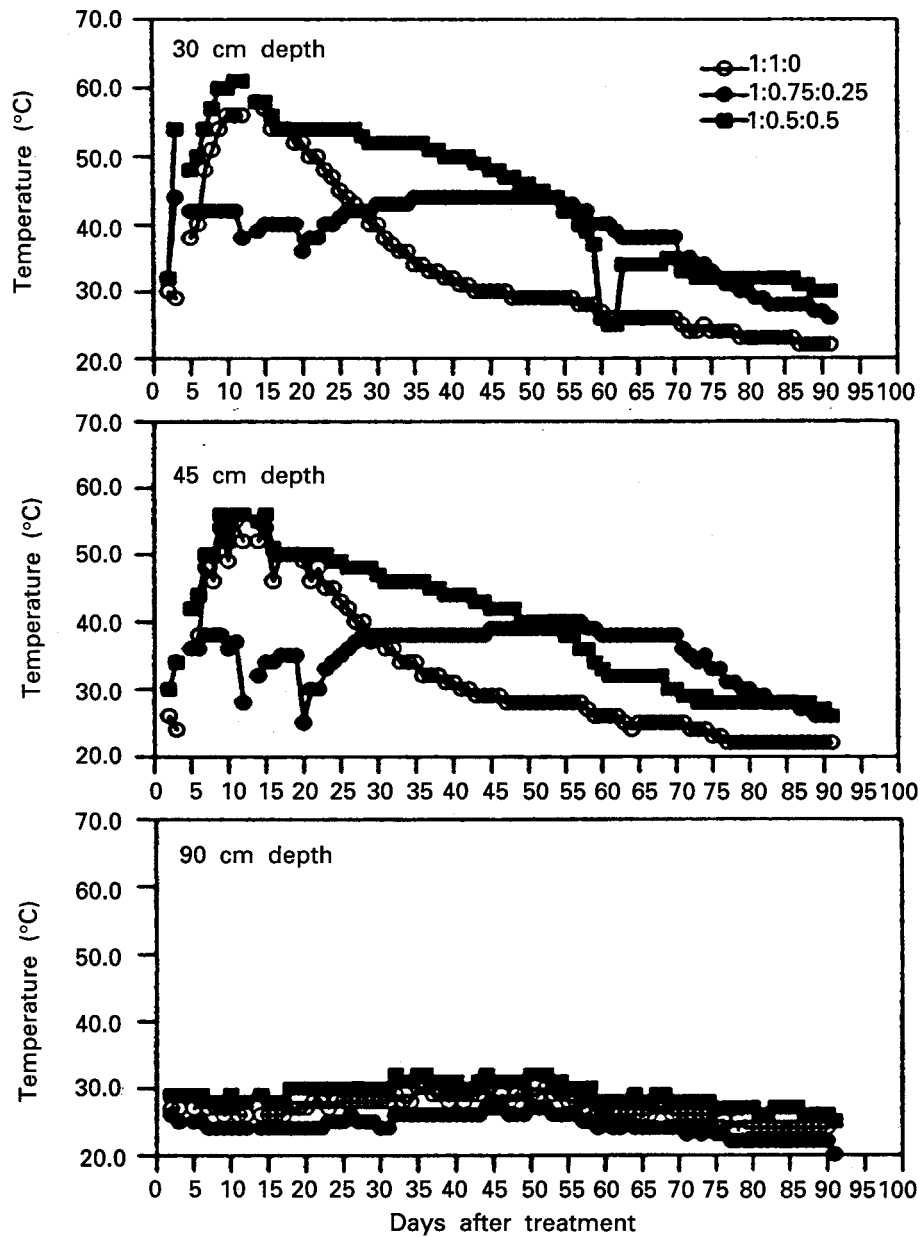


Fig. 3. Changes in temperature during the period of composting

and 81% in the manure-sawdust compost plot. This indicates that the compost from starch sludge cake had a beneficial effect on potato yield.

Common scab is a widespread disease of potato in Korea. We found that the incidence was higher in plots treated with compost containing sludge compost (Table 1). The incidence was highest in plots given compost with the highest percentage of potato starch. It is possible that scab pathogens may have been transmitted in the composted sludge to plants in the field. However, the percentage of

marketable tubers was still highest in the plots given composted sludge.

#### Effects of the compost on nutrient uptake by potato

Application of the sludge-amended compost enhanced the uptake of nutrients such as nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca), compared to the chemical fertilizer. No significant difference was found between the

different kinds of compost. Table 4 shows the nutrient content of potato tubers at harvest. The uptake of both macronutrients and micronutrients by the potato tubers was generally enhanced by compost application.

### CONCLUSIONS

In the potato starch manufacturing plant, it was cost effective to install the pilot screw press for the dewatering process. The screw press can remove the surplus water from about 75 mt of sludge per

day. The residue can then be made into compost. The net cost of pressing and composting was lower than the cost of disposal by landfill or dumping at sea.

The starch sludge cake left after pressing was successfully used as a bulking agent for co-composting with swine manure. The physical and chemical quality of the compost was comparable to, or even better than, compost made from a mixture of sawdust and manure. Judging from changes in the temperature, moisture content and chemical properties of the compost, as indicators of compost

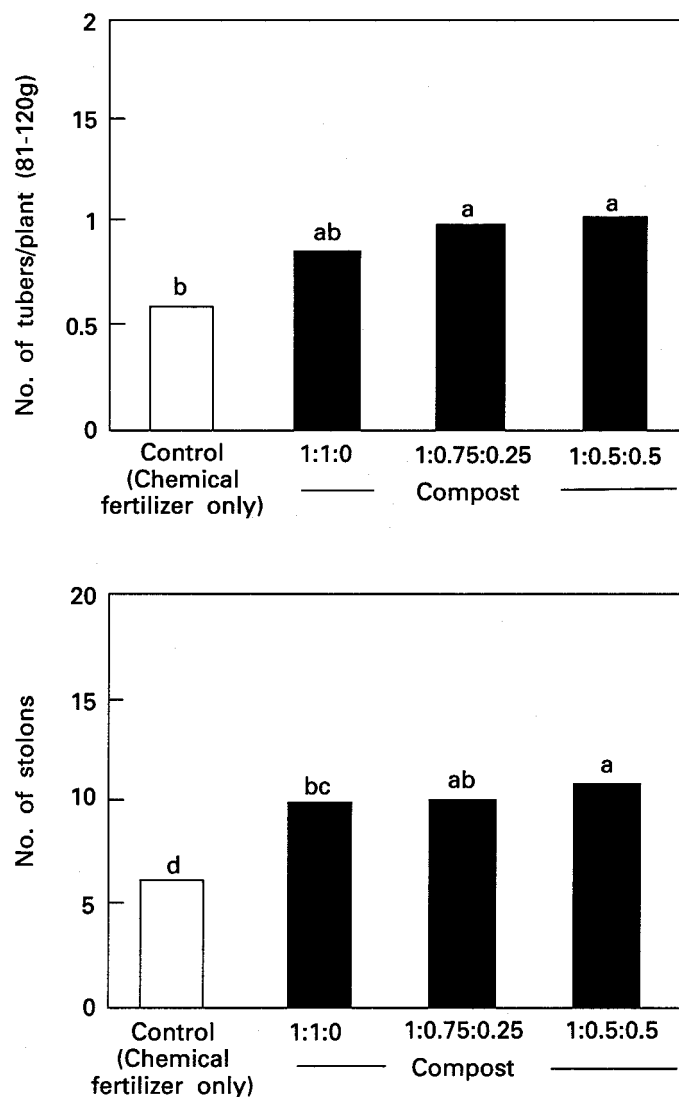


Fig. 4. Effects of the experimental compost on potato yield

quality and maturity, the best ratio of manure, sawdust and potato sludge was 1:0.5:0.5.

Application of compost made from manure and potato starch sludge enhanced the growth and yield of potato better than the application of chemical fertilizer. The effect was the same as from compost made from sawdust and manure. However, the occurrence of common scab disease was slightly higher in plots treated with the composted sludge than in those given chemical fertilizer. Further research is needed on this point.

Currently, the co-composting technology is being carried out by a private commercial company. The compost has been introduced onto the market, and is making a profit. In 2000, about half a million packages were sold for a total of US\$ 2 million. This year, the company plans to sell about 1.5 million packages. Compost of this kind facilitates the recycling of residues from starch production, and increases the profitability of both potato production and starch processing. It is also a great benefit to the environment, since it represents an improved form

Table 1. Effect of the compost application on the marketable potato yield and the occurrence of the common scab.

Fertilizers	Ratio of marketable tubers <sup>1)</sup>	Percentage of potato tubers infected by the common scab <sup>2)</sup>	Percentage of occurrence of common scab <sup>3)</sup>
Chemical fertilizer (control)	82.16 <sup>ab 4)</sup>	17.79 <sup>ab</sup>	6.48 <sup>ab</sup>
Compost (1:1:0)	80.97 <sup>ab</sup>	21.81 <sup>ab</sup>	7.59 <sup>ab</sup>
Compost (1:0.75:0.25)	85.55 <sup>a</sup>	17.83 <sup>ab</sup>	6.45 <sup>ab</sup>
Compost (1:0.5:0.5)	86.42 <sup>a</sup>	37.61 <sup>ab</sup>	14.00 <sup>ab</sup>

1. (Potato weight greater than 50g) \*100/(total weight of potato harvest)

2) (Number of infected tubers \*100/total number of tubers)

3)  $[(I*n+II*n+III*n+IV*n)/(\text{Number of tubers investigated}*4)]*100$ . I: no infection; II: less than 5% of surface infected; III: 5.1 to 10% of surface infected; IV: 10.1 to 20% of surface infected; V: more than 20% of surface infected.

4) The same letter in the column indicates no significant difference

Table 2. Effect of the compost applications on nutrient uptake by potato tubers at harvest

Fertilizers (%)	Total N (%)	K (%)	Ca (%)	P (%)	Mg (%)	Na %	Mn (mg/kg)	B (mg/kg)
Chemical fertilizer (control)	1.22 <sup>a 1)</sup>	1.27 <sup>a</sup>	0.04 <sup>b</sup>	0.13 <sup>a</sup>	0.08 <sup>a</sup>	0.02 <sup>b</sup>	69.78 <sup>a</sup>	16.72 <sup>b</sup>
Compost (1:1:0)	1.35 <sup>a</sup>	1.31 <sup>a</sup>	0.04 <sup>b</sup>	0.16 <sup>a</sup>	0.07 <sup>a</sup>	0.03 <sup>ab</sup>	53.29 <sup>a</sup>	20.44 <sup>ab</sup>
Compost (1:0.75:0.25)	1.27 <sup>a</sup>	1.36 <sup>a</sup>	0.03 <sup>b</sup>	0.14 <sup>a</sup>	0.07 <sup>a</sup>	0.03 <sup>ab</sup>	52.14 <sup>a</sup>	16.57 <sup>b</sup>
Compost (1:0.5:0.5)	1.29 <sup>a</sup>	1.56 <sup>a</sup>	0.07 <sup>a</sup>	0.13 <sup>a</sup>	0.08 <sup>a</sup>	0.05 <sup>a</sup>	70.95 <sup>a</sup>	27.37 <sup>a</sup>

1) The same letter in the column indicates no significant difference.

of waste management through nutrient recycling.

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