A THESIS FOR THE DEGREE OF MASTER OF SCIENCE

Composting of Citrus Industrial Waste and Effects of the Compost on Soil Properties and Potato Growth

DAO QUOC HUNG

DEPARTMENT OF AGRICULTURAL CHEMISTRY
GRADUATE SCHOOL
CHEJU NATIONAL UNIVERSITY

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Dao Quoc Hung
(Supervised by Professor Hae-Nam Hyun)

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This thesis has been examined and approved.

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Thesis director, Chan-Shick Kim, Professor of Agricultural Chemistry

…………………………………………………………………………………

So-Mi Kim, Professor of Agricultural Chemistry

…………………………………………………………………………………

Hae-Nam Hyun, Professor of Agricultural Chemistry

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Department of Agricultural Chemistry
GRADUATE SCHOOL
CHEJU NATIONAL UNIVERSITY

CONTENTS

LIST OF TABLE

LIST OF FIGURES

ABSTRACT

감귤박은 감귤 가공과정에서 발생하는 폐기물로 탄질비가 80 내외로 매우 높으며, 수분이 함유되어 있기 때문에 자연분해가 어렵다.

본 연구는 감귤박을 퇴비원료로 사용하기 위한 것으로, 감귤박에 돈분, 채종유박을 혼합하여 부숙 요인을 조사하고 토양에 처리하여 토양성질의 변화 및 감자재배에 미치는 영향을 조사하였다. 감귤박에 돈분을 혼합하여 수분을 60% 내외로 조절했을 때 온도변화 및 성분의 변화가 없었으며, 부숙이 진행되지 않았다. 이는 감귤박 중의 유기산에 의해 pH 가 급격히 낮아지기 때문으로 보인다.

감귤박에 생석회를 5%를 처리하고 돈분, 채종유박을 혼합했을 때 2 주일 이내에 온도가 70℃까지 높아졌으며, pH 는 7 내외를 나타냈다. 부숙이 진행되면서 인산, 칼리, 칼슘 및 마그네슘의 함량은 많아졌으며, 수용성 불소 및 아질산의 함량은 감소하였다.

감귤박 퇴비를 감자재배 토양에 처리했을 때 치환성 칼슘함량이 높아졌으며, 퇴비 처리량이 많을수록 토양의 치환성 칼슘함량도 많아졌다. 유기물함량도 소량 증가하였으나 그 외의 성분은 큰 변화가 없었다.

감귤박 퇴비 400kg/10a 처리구의 수량은 2,131 kg/10a 로 무처리구에 비해 22% 증수되었다. 또한 상서율(rate of marketable tuber)은 61.8%로 무처리 49.7%에 비해 12.1% 높아졌다. 그러나 감귤박 퇴비의 더뎅이병 이병율은 무처리에 비해 6.2% 높았다.

Keywords: Compost, Pig manure, Citrus waste, Rape oil waste

ABSTRACT

Citrus industrial waste was discarded from citrus factories after extracting juice of non-marketable citrus fruits. The carbon/nitrogen ratio of the waste was high in 80. It also contains high amounts of oils and pectin which limits the composting process. This research was conducted to find the mixing condition of better composting and to investigate the effects of citrus waste compost on soil properties and potato growth.

When pig manure, rape oil waste and citrus waste were mixed without lime, there were not any composting symptoms like changes in temperature and chemical components. However, pH was rapidly decreased to around 4. While citrus waste was mixed with pig manure and rape oil waste after being treated with 5% of quicklime, occurred as temperature reached to about 70°C in two weeks; water content was reduced; content of organic matter, K_2O, CaO and MgO were increased and pH was changed to around 7. Organic matter content of the final product was little higher and concentration of heavy metals of the compost was 5~10 times lower than that of Korean criteria of compost. This compost was applied to experimental field at rate of 0, 200, 400 and 600 kg/10a in various plots; each fertilization rate was replicated 3 times. Soil properties in the compost treatments were improved better than that in no-compost treatment. The growth and yield of spring-potato was increased with the citrus waste compost treatments and the optimum fertilization rate is considered to be 400 kg/10a.

Keywords: Compost, Pig manure, Citrus waste, Rape oil waste

I. 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 (Yang et al., 2001).

The number of livestock raised in Korea has been steadily increasing since 1985. 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).

Pig raising is a major agricultural industry in Jeju-do, Korea. The number of pig was increased continuously from about 300 thousand of pigs in 1999 to nearly 400 thousand of pigs in 2003 due to the increasing consumption of pork. In 2004 more than 1.2 million tons of pig manure was generated, made up more than 83 % of total livestock waste in more than 1.5 million tons (Jeju-do annual statistics, 2004). The Provincial government requires livestock producers to have some kinds of animal waste treatment facility, and over 90% of the households are required with a septic tank or a fermentation tank.

The most common method of disposing of animal wastes is to apply them to soil. However, this causes many environmental problems. Composting the wastes is a promising alternative. 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 1977 (Kim, 1988, and Lee, 1998).

General method for utilization of pig manure, which used for making compost by many companies, is to mix pig manure with saw dust. So 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. An alternative bulking agent is needed (Yang et al., 2001).

Citrus is one of the most important crops in Jeju-do. Citrus fruits contain about 35% to 55% of juice (Sinclair., 1984). After extracting juice, the remainders of fruits, like peel, membranes, juice vesicles and seed, are discarded as wastes. Citrus waste has many applications (Sinclair., 1984), e.g., as fibre (Braddock and Graumlich, 1981), pectin (Ma et al., 1993) and flavonoid source, binding agent in food technology (Lo curto et al., 1992), fermentation substrate for single-cell protein (Vaccarino et al., 1989), silage (Ashbell and Weinberg, 1988) and mosquito re-pellant (Anaso et al., 1990). However, most of these conversions require advanced technology or facilities (Van Heerden et al., 2002).

Citrus waste 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 citrus and pig industry. Citrus waste can be composted to convert into a value-added commodity without specialized equipment or facilities. Composting converts organic matter into the stable substance which can be handled, stored, transported and applied to a field without adversely affecting the environment (An Heerden et al., 2002). Further, C/N is one of the important factors affecting compost quality (Golueke., 1977, and Michel et al., 1996). Citrus industry waste produced from citrus factory after extracting juice from non-marketable citrus. The carbon/nitrogen ratios of the waste was as high as 80. It also contains high amounts of oils and pectin which limits the composting process. Hence rape oil waste in low C/N ratio was also added into composting process.

Thus, this research was conducted to find the mixing conditions of better composting for citrus industrial waste, rape oil waste and pig manure; and to investigate the effects of the citrus waste compost on soil properties and potato growth.

II. MATERIALS AND METHODS

1. Composting method

Materials were used to make a compost include pig manure, citrus waste, rape oil waste and lime. Of which, C/N ratio of pig manure and citrus waste are very high in 48.04 and 77.30, respectively; meanwhile that of rape oil waste is very low in 8.94 (Table 1).

Table 1. C, N, and C/N ratios of mixing materials

	Carbon content (%)	Nitrogen content (%)	C/N ratio
Pig manure	54.24	1.13	48.04
Citrus waste	52.60	0.66	77.30
Rape oil waste	51.88	5.93	8.94

To find out the better composting condition, 2 treatments were experimented with mixing ratios of these materials as the following:

Pig manure : Citrus waste : Rape oil waste : Lime

Treat-A: 1:0.50:0.50:0.00

Treat-B: 1:0.50:0.25:0.25

These treatments were investigated the changes of the factors in the composting process: temperature was measured everyday; and the other factors like moisture content, organic matter content, pH, K_2O, CaO, MgO and P_2O_5 were analyzed every week.

2. Experimental field, fertilization of compost and potato plantation

After composting experiment, there was the best composting condition was selected to make compost. It was named "citrus waste compost". Before applying this compost and sowing potato, soil field was ploughed carefully.

This field was in greenhouse condition. It was divided into 12 plots, which was 1-m width x 1.5-m length and separated by the 15-cm width and 20-cm depth furrow drain, for 4 formulas of applied fertilizer. Each formula was replicated 3 times or 3 plots.

Two fertilizers were basically applied to soil. 10%N – 14%P_2O_5 – 11%K_2O fertilizer was fertilized at rate of 120 kg/10 for all plots or formulas as a background; and citrus waste compost was fertilized as the 4 following formulas (Table 2).

Control: no compost was applied.

Treat-1, Treat-2, and **Treat-3:** citrus waste compost was applied at rate of 200, 400, and 600 kg/10a, respectively.

Finally, potato (*Solanum tuberosum L.*), which is grown widely in Jeju-do, was sowed.

Table 2. The arrangement of the experimental formulas

Control	Treat-1	Treat-2	Treat-3
Treat-2	Treat-3	Control	Treat-1
Control	Treat-1	Treat-2	Treat-3

3. Soil sampling

Soil samples were collected once a month since one day before applying fertilizers and sowing potato.

4. Methods of soil analysis

After sampling soil, the soil samples were naturally dried for 3 days in room temperature, and sieved through 1-mm sieve before analyzing. Elements in the soil were selected to analyze included soil pH, soil electronic conductivity (EC), soil organic matter content, soil total nitrogen, soil available phosphorus (P_2O_5), exchangeable cations (Ca^{++}, Mg^{++}, K^+, and Na^+), heavy metals (Cu, Zn, Pb, Cr, and Cd), soil moisture content, soil bulk density, and soil porosity.

1) Procedure of soil pH and soil electrical conductivity analysis

Soil pH and EC was determined by 1:5 soil to water methods (Rural Development Administration, 1998b). Add 5 g of air-dried soil and 25 ml of distilled water into a 125-ml conical flask. Shake the mixture continuously for 30 minutes. And then pH of this suspension was measured by glass electrode pH meter (*EN 50082-1, Sentron, Netherlands*); and its electrical conductivity was measured by electrical conductivity meter (*MC126, Mettler toledo, Switzerland*).

2) Procedure of soil organic matter content analysis

Soil organic matter content was determined by Walkley-Black method (Walkley A. et al., 1933). Add 0.1 g of air-dried soil, 10 ml of 1N $K_2Cr_2O_7$, and 20 ml of conc. H_2SO_4 into a 500-ml conical flask. Stand for about 30 minutes. And then add 200 ml of distilled water and 0.4 ml of indicator into the flask. Finally, the solution was titrated by 0.5 N $FeSO_4.7H_2O$ for determining and calculating organic matter content.

3) Procedure of soil total nitrogen analysis

Soil total nitrogen content was determined by regular kjeldahl method (Bremner J.M. et al., 1982). Add 0.5 g of air-dried soil, 1 tablet of catalyst, and 6 ml of conc.H_2SO_4 into a kjeldahl flask. Digest the flask continuously at 400^{o}C for 30 minutes. And then the digested product was automatically distilled and titrated by kjeldahl auto-analyzer (*2300 kjeltec analyzer unit, Foss tecater, U.S.A*).

4) Procedure of soil available phosphorus analysis

Soil available phosphorus was determined by Lancaster method (Rural Development Administration, 1998a). Add 5.0 g of air-dried soil, and 20 ml of phosphorus extraction solution. Shake the mixture for 10 minutes. And then the suspension was filtrated through the filter paper (*Whatman N^{o}. 2*). Finally, absorbance of phosphorus was measured by spectrophotometer (*Genesys 5, Spectronic instruments, U.S.A*) and calculation.

5) Analytic procedure of exchangeable cations in soil

Exchangeable cations in soil were determined by 1N ammonium acetate method (Grant W. Thomas., 1982). Add 5.0 g of air-dried soil, and 50 ml of 1N CH_3COONH_4 (pH = 7). Shake the mixture for 30 minutes. And then the suspension was filtrated through the filter paper (*Whatman No. 2*). finally, these cations, $K^{+,}$ Ca^{++}, Mg^{+}, Na^{+}, were automatically determined by atomic absorption spectrophotometer (*SpetraAA 220 FS, Verian, Australia*).

6) Analytic procedure of heavy metals in Soil

Heavy metals in soil were determined by diethylenetriaminepentaacetic acid (DTPA) method (Dale E. Baker and Michael C. Amacher., 1982). Add 10 g of air-dried soil, and 20 ml of DTPA into a 125-ml conical flask. Shake the mixture continuously for 2 hour. And then the suspension was filtrated through the filter paper (*Whatman N^{o}. 42*). Finally, the heavy metals, Cu, Zn, Pb, Cr, and Cd, were automatically determined by atomic absorption spectrophotometer (*SpetraA 220 FS, Verian, Australia*).

7) Procedure of soil moisture content, soil bulk density and soil porosity analysis

Soil moisture content was determined by gravimetric method with oven drying (Topp, G. C., 1993) and soil bulk density and soil porosity were determined by core method (Cully, J.L.B., 1993). Soil samples were sampled in 100-cm^3 cylinder. Its mass was weighed immediately after sampling soil. And then the sample was dried in a drying oven at 107^o C for about 24 hours and its mass was weighed again. Soil moisture, bulk density, and porosity, therefore, were calculated.

5. Methods of compost analysis

Elements in the compost were selected to be analyzed consisted of moisture content, organic matter content, total nitrogen, available phosphorus (P_2O_5), and metal elements (K_2O, CaO, MgO, NaCl, Cu, Zn, Pb, Cr and Cd).

1) Procedure of moisture and organic matter content analysis

Moisture and organic matter content analysis were determined by a drying oven method. Add 1 g of compost into a small china-cup. Dry the cup continuously at 105^{o}C for 12 hours in the furnace (*F6730-80 Thermolyne, USA*). After drying, weigh its mass to determine moisture content. And then burn the cup once again at 600^{o}C for 5 hours in the furnace. After burning, weigh its mass to determine organic matter content.

2) Procedure of total nitrogen, available phosphorus and metal elements analysis

To determine these elements, there are two steps (digestion and determination) as the following:

Step 1, Digestion

Add 0.2 g of compost and 10 ml of conc.H_2SO_4 into a kjeldahl flask. Heat the flask continuously at 300^oC for about 3 hours. Then cool to room temperature. After that add 1 ml of 70% $HClO_4$ and heat the flask again at 300^oC for about 1 hour. Allow the flask to cool and move the digested solution into a 100-ml volume flask and make it to 100 ml by addition of distilled water. Finally, swirl the 100ml-flask vigorously to mix the contents to determine the elements.

Step 2, Determination

a) Metal elements

K_2O, CaO, MgO, NaCl, Cu, Zn, Pb, Cr and Cd were measured by atomic absorption spectrophotometer (*SpetraA 220 FS, Verian, Australia*).

b) Total nitrogen

Total nitrogen was determined by a regular kjelhdan method (Bremner, J.M., and C.S. Mulvaney., 1982). Move 10 ml of the digested solution to a kjelhdan flask. And then distilled and titrated automatically by Kjelhdan auto-analyzer (2300 kjeltec analyzer unit, Foss tecater, U.S.A).

c) Available phosphorus

Available phosphorus was determined by ammonium vanadate method (Olsen, S.R., and L.E. Sommer., 1982). Move 10 ml of the digested solution into a 125-ml conical flask, and adjust its pH range 6-8 by addition of NH_4OH. After that it is moved to a 100-ml volume flask. And then add 20 ml of indicator and bring to 100 ml by addition of distilled water. Finally, absorbance of phosphorus was determined by spectrophotometer (*Genesys 5, Spectronic instruments, U.S.A*).

III. RESULTS AND DISCUSSION

1. Changes in factors during composting process

1) Changes in temperature

Temperature in Treat-A (treated without lime) was not changed during composting process because there were not microbial activities in condition of very low pH, while in Treat-B (treated with lime), during composting, the degradable organic matter and nitrogenous compound were being broken down by microbial. This process resulted in the release of heat and so, the temperature increased to 70^{o}C in two weeks; by the end of composting, no more further decomposition is taking place, no more heat would be released and the temperature dropped to ambient level (Fig. 1). A similar result was reported by Yang et al., (2001) that manure mixed with sawdust and sludge showing temperature was reached about 60^{o}C after 8 or 9 days and then dropped to ambient level. This indicated that there was not composting symptom when pig manure, citrus waste and rape oil waste were mixed without lime; on the contrary, addition of 5 % of lime helped composting symptom to be occurred.

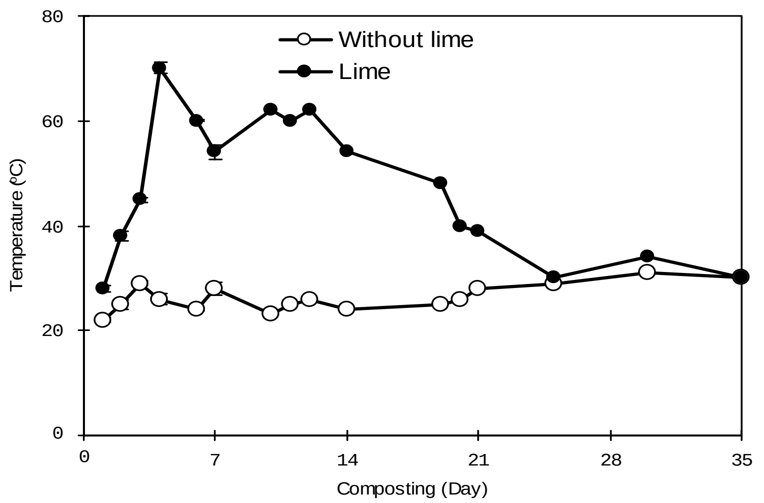

Figure 1. Changes in temperature during composting process

2) Changes in moisture content

Moisture content in Treat-A was slightly decreased because there is not composting symptom, but water content was evaporated due to ambient temperature, while that in Treat-B was rapidly decreased as temperature of this treatment was rapidly increased until 70°C (Fig. 2). Yang et al., (2001) reported similar investigation showing moisture content was also fallen as composting process. Thus, when there was composting symptom, moisture content of the compost was decreased rapidly and reached to about 30% in four weeks.

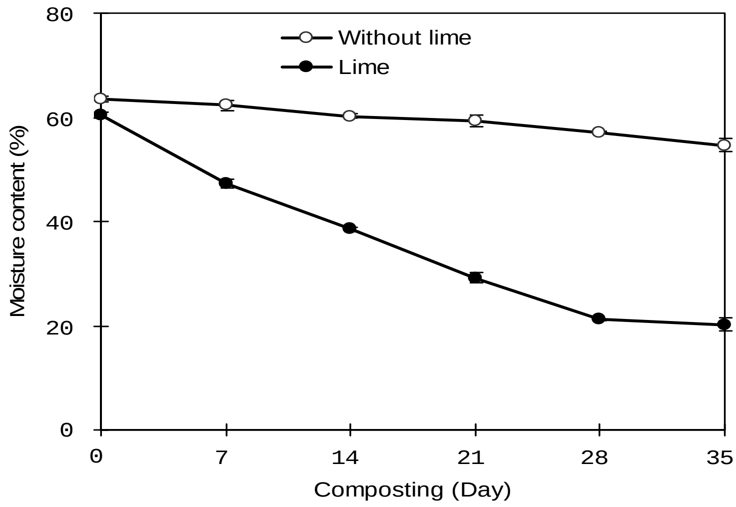

Figure 2. Changes in moisture content during composting process

3) Changes in calcium, magnesium, potassium, available phosphorus, total nitrogen and organic matter

Contents of calcium oxide, magnesium oxide, potassium dioxide, available phosphorus, total nitrogen and organic matter in the Treat-A was not changed because there not composting symptom in this treatment, while that in Treat-B was rapidly increased in composting process as these elements were released from citrus waste and rape oil waste during composting and a large amount of water was evaporated due to high temperature (Fig. 3a, b, c, d, e, f). Tiquia et al., (1998) reported investigation of composting of spent pig litter at different moisture contents showing total nitrogen, available phosphorus and ashes content increased in composting process, even if total carbon was decreased due to the nitrification process and the oxidation of C to CO_2 by the micro-organisms during composting. Thus, contents of chemicals in compost, such as CaO, MgO, K_2O, P_2O_5, total nitrogen and organic matter, were increased as there was composting symptom.

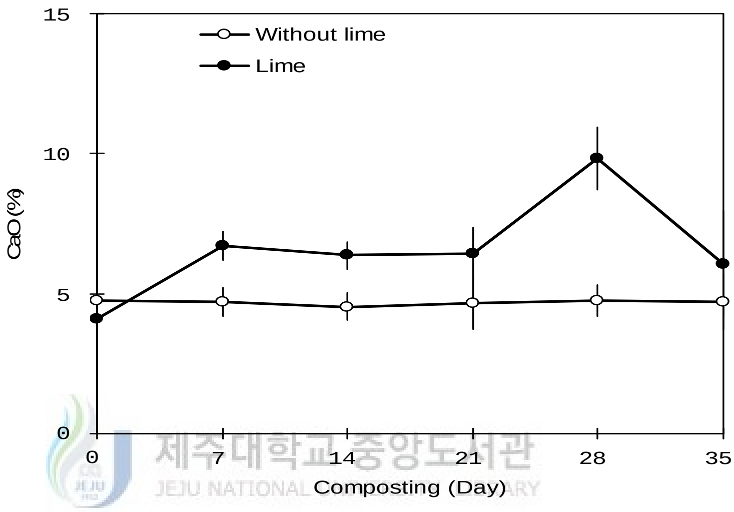

Figure 3a. Changes in amount of calcium during composting process

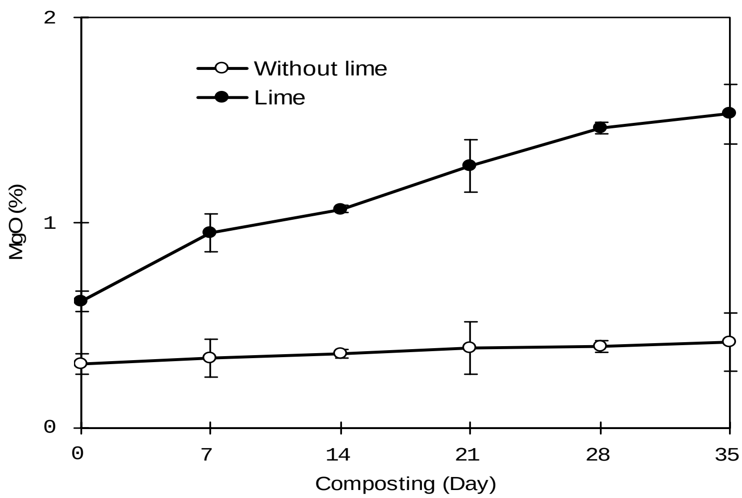

Figure 3b. Changes in amount of magnesium during composting process

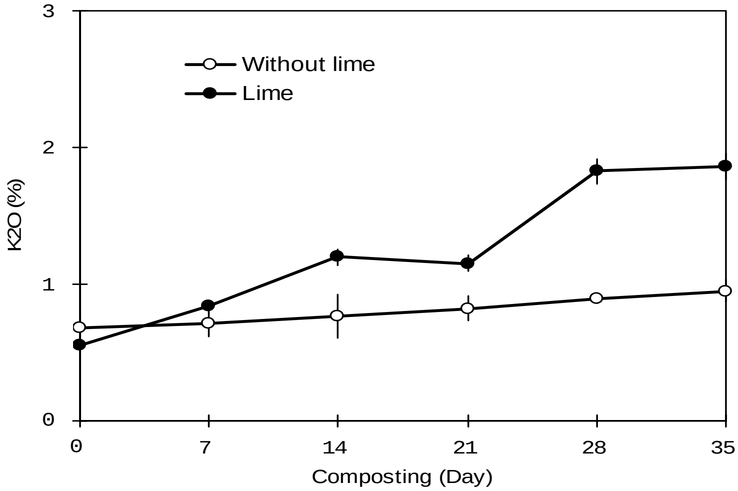

Figure 3c. Changes in amount of potassium during composting process

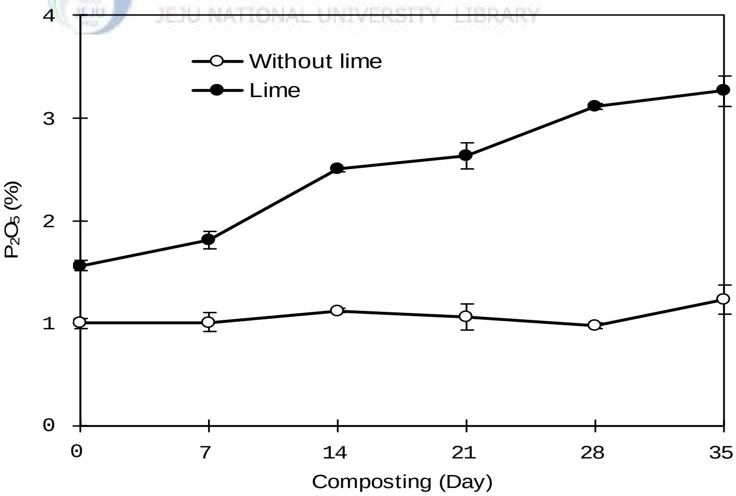

Figure 3d. Changes in total nitrogen content during composting process

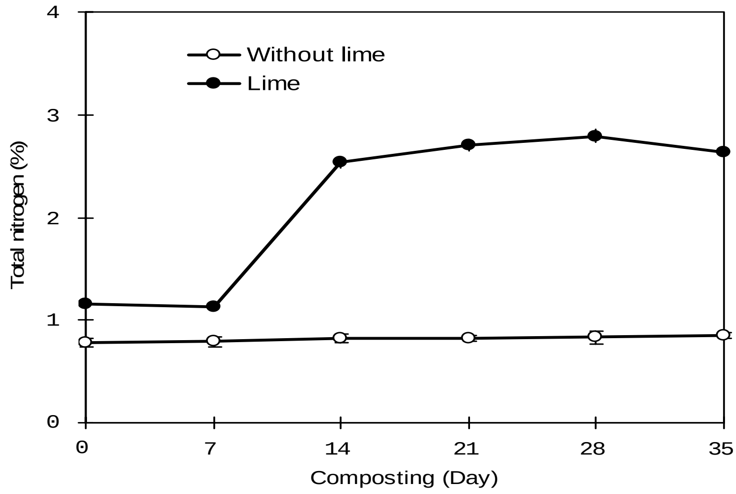

Figure 3e. Changes in total nitrogen content during composting process

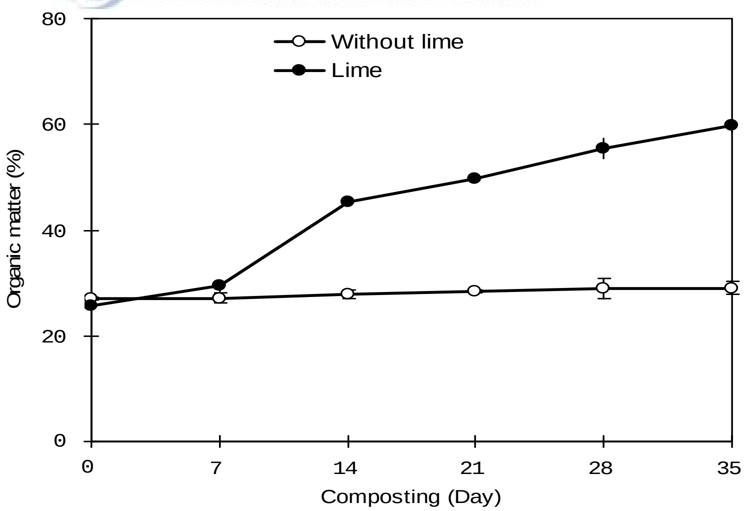

Figure 3f. Changes in organic matter content during composting process

4) Changes in C/N ratio

C/N ratio in both Treat-A and Treat-B was slightly decreased to around 30 and 10, respectively (Fig. 4). The decreasing of these C/N ratios was due to total carbon content was decreased because of the nitrification process and the oxidation of C to CO_2 by the micro-organisms during composting (Golueke, 1977, Riffaldi et al., 1986. and Tiquia et al., 1996a). Thus, C/N ratio had trend to decrease slightly in composting process because of a small amount of Carbon released.

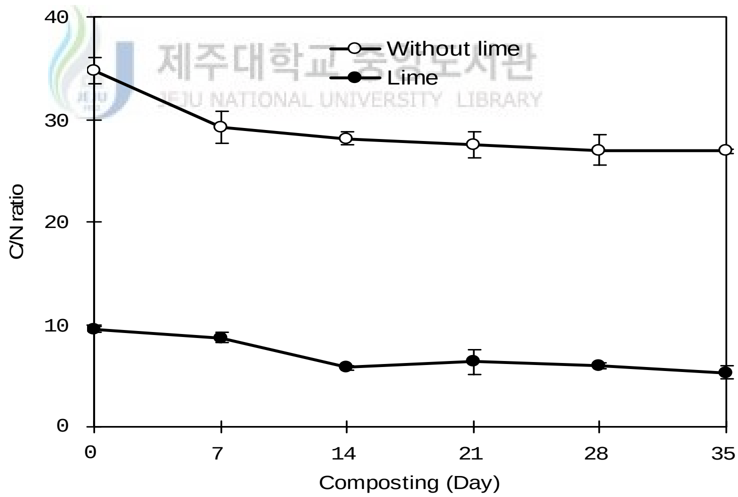

Figure 4. Changes in C/N ratio value during composting process

5) Changes in pH

pH in both Treat-A and Treat-b was rapidly decreased to around 4 and 7, respectively because H^+-released as a result of microbial nitrification process by nitrifying bacteria (Eklind and Kirchmanm, 2000). The deomposition of organic matter and production of organic and inorganic acids by microbial activities in composting would also be responsible for the decrease (Mathur, 1991). However, pH in treatment with lime was much higher than that in treatment without lime because 5 % of lime was added to the treatment with lime (Fig. 5). Tiquia et al., (1998) reported similar investigation in composting of spent litter at different moisture content showing pH decreased during composting process. Thus, though there was composting symptom or not, pH was always decreased; however, addition of lime increased pH value in compost depending on amount of lime added.

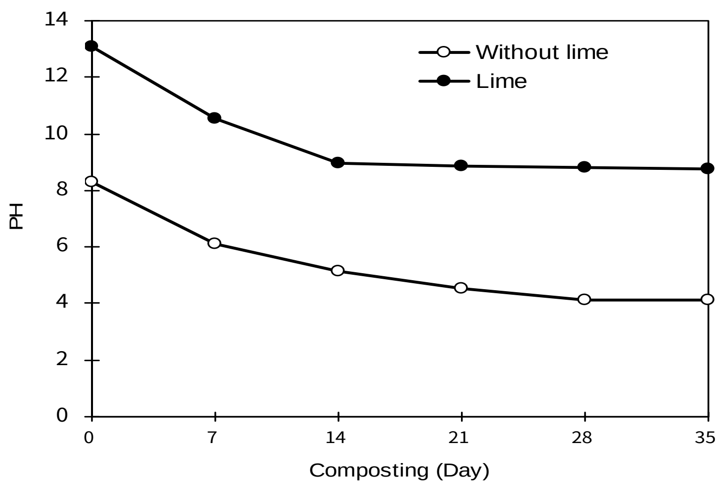

Figure 5. Changes in pH value during composting process

11) Nutrient content of the final composting product

After experiment, there was the final composting product of treatment with lime named “citrus waste compost”. Moisture content of citrus waste compost, 30.87 %, was much lower than that of Korean criteria of compost, 50%. Concentration of heavy metals (Cu, Zn, Pb, Cr and Cd) in citrus waste compost was also 5 to 10 times lower than that in Korean criteria of compost. And organic mater content of citrus compost, 26.86 %, was little higher than that of Korean criteria of compost (Table. 3).

Table 3. Content of elements of the citrus waste compost and Korean criteria

Content	*Citrus waste compost*	*Korean criteria of compost*
Moisture content (%)	30.87 (±0.17)	maximum 50.00
Organic matter content (%)	26.86 (±0.23)	minimum 25.00
N (%)	1.51 (±0.16)	
P_2O_5 (%)	2.17 (±0.10)	
K_2O (%)	0.54 (±0.01)	
CaO (%)	10.86 (±0.96)	
MgO (%)	0.65 (±0.01)	
NaCl (%)	0.64 (±0.04)	
Cu (mg/kg)	104.50 (±8.74)	maximum 300.00
Zn (mg/kg)	127.45 (±3.86)	maximum 900.00
Pb (mg/kg)	0.00 (±0.00)	maximum 150.00
Cd (mg/kg)	0.00 (±0.00)	maximum 5.00
Cr (mg/kg)	64.00 (±7.67)	maximum 300.00

2. Effect of the citrus waste compost on soil properties

1) Effect of the compost on soil pH

The values of soil pH after harvesting potato did not show any effect caused by the application of composts. As organic matter of the compost decomposed, both organic and inorganic acids were formed caused soil pH decrease. The exchangeable base-forming cations, such as Ca^{++}, Mg^{++}, K^{+}, and Na^{+}, in the compost, contributed toward a reduction in acidity and an increase in alkalinity (Nyle C. Brady, 1990). However, soil pH of Control was slightly decreased, while pH of the compost treatments was slightly increased and higher than that of Control because the compost had a large amount calcium supplement to soil (Fig. 6). This indicated that this compost contributed to increase soil pH value.

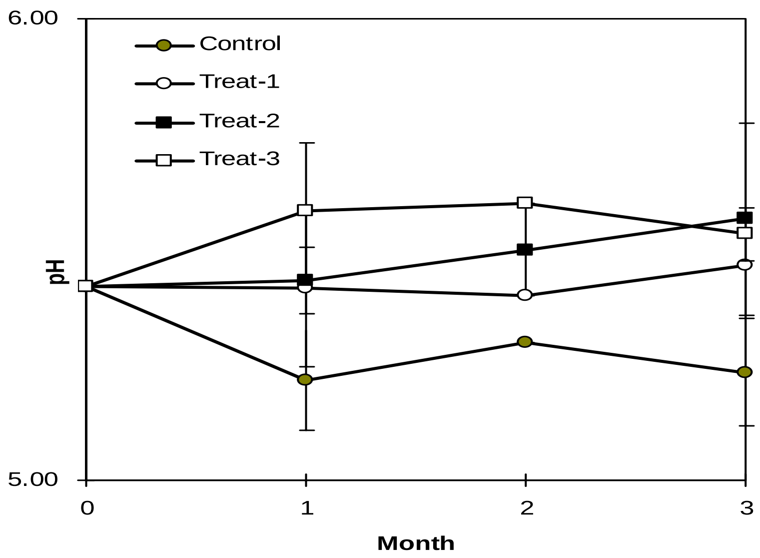

Figure 6. Effect of the compost treatment on soil pH

2) Effect of the compost on soil electrical conductivity

Soil electrical conductivity was increased in the first period after applying the fertilizers. A large amount of mineral salt ions, such as Ca^{++}, Mg^{++}, K^{+}, Na^{+}, Cl^{-} ..., in the fertilizers, were dissolved and presented more in soil after applying the fertilizers. Otherwise, mineral salt ions like the nutrient elements were absorbed by potato for its growth and development, some were digested by microbial in soil and the others were leached. Therefore, soil electrical conductivity was gradually decreased in the last period. However, soil electrical conductivity of the compost treatments was higher than that of Control (Fig. 7).

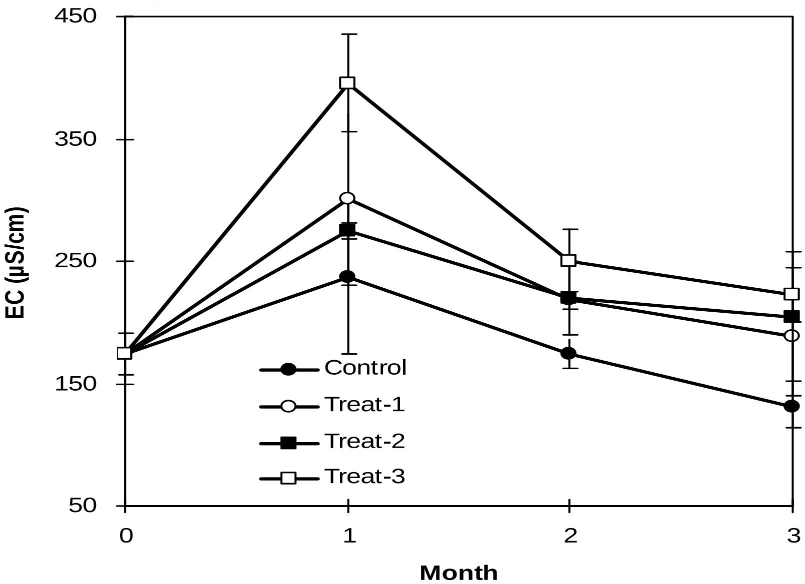

Figure 7. Effect of the compost treatment on soil electrical conductivity

3) Effect of the compost on soil organic matter content

Soil organic matter content was slightly increased because the compost contained amount of organic matter was added to soil. Organic matter content in the compost treatments was higher than that in Control (Fig. 8). Celik et al., (2004) found that soil organic matter content was higher in the compost and manure plots than in Control plots. Thus, the application of this citrus waste compost increased soil organic matter content.

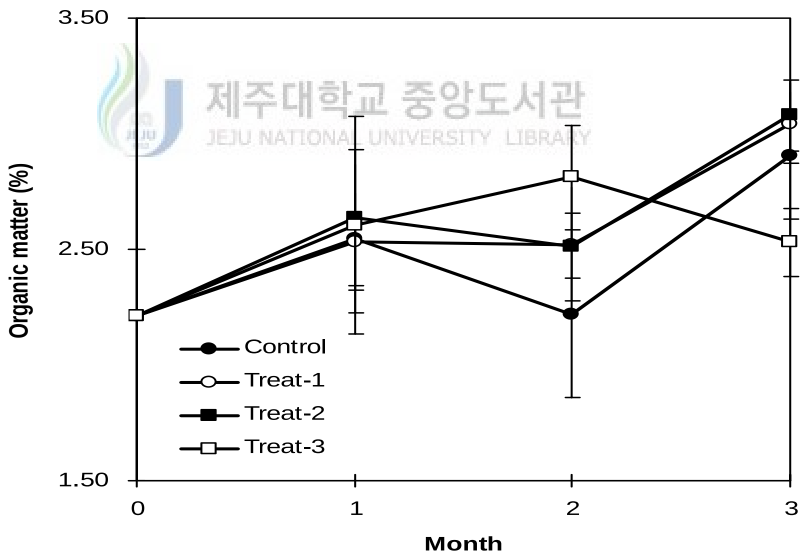

Figure 8. Effect of the compost treatment on soil organic matter content

4) Effect of the compost on soil total nitrogen

Total nitrogen in Control was slightly decreased because of absorption of potato, while that in compost treatments was slightly increased as a small amount of nitrogen in the compost was added to soil. However, total nitrogen in the compost treatments was little higher than that in Control (Fig. 9). This indicated that the application of the compost supplemented a small amount of total nitrogen in soil.

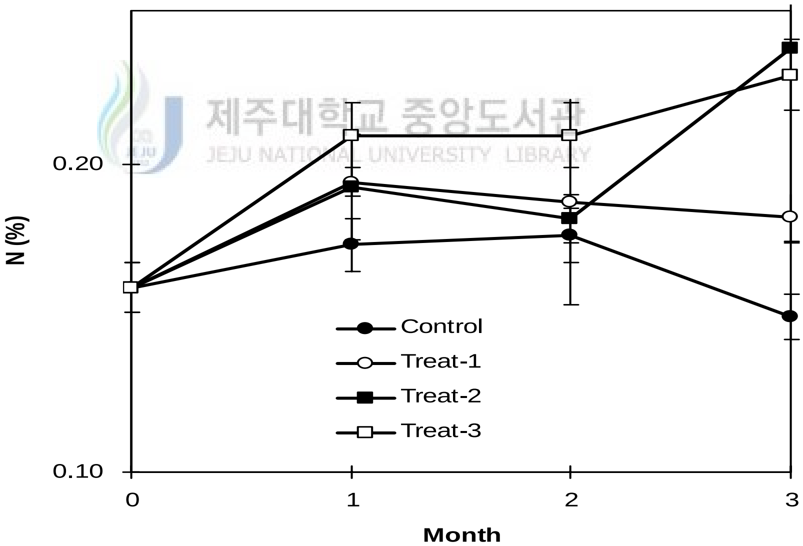

Figure 9. Effect of the compost treatment on soil total nitrogen

5) Effect of the compost on soil available phosphorus

Soil available phosphorus was low and after harvesting potato it did not show much change caused by applying the compost. However, available phosphorus content in the compost treatments was little higher than that of Control as the compost contained a small amount of available phosphorus was added to soil (Fig. 10). Thus, the application of the compost slightly increased available phosphorus content in soil.

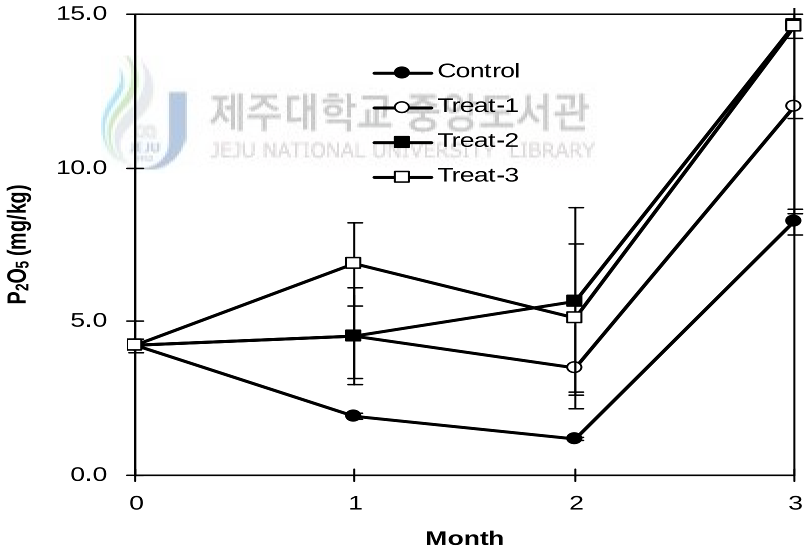

Figure 10. Effect of the compost treatment on soil available phosphorus

6) Effect of the compost on exchangeable potassium cation in soil

In the first period exchangeable potassium cation in soil were increased, and then decreased in the last period. Because in the first period, amount of potassium in the fertilizers was added to soil, then potato absorbed these potassium cations in the last period. However, amount of potassium cations in the compost treatments was higher than that in Control (Fig. 11). This indicated that the application of the compost contributed to increased amount of potassium cations in soil.

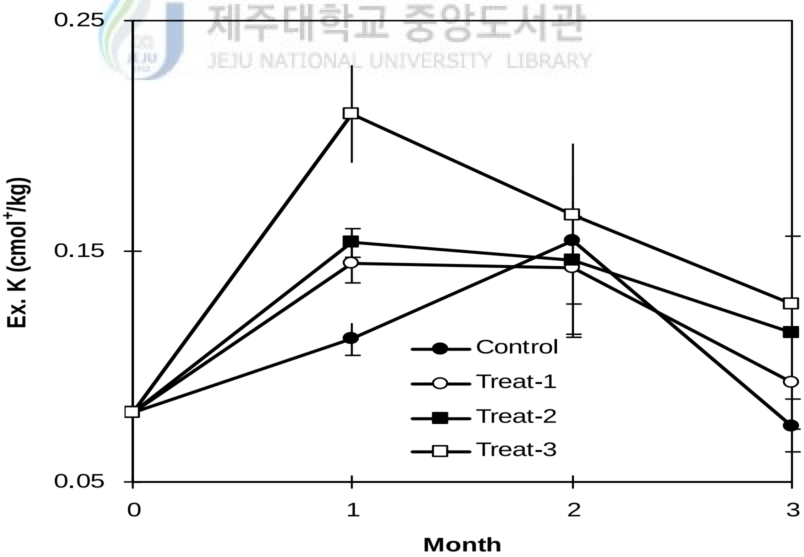

Figure 11. Effect of the compost treatment on potassium cation in soil

7) Effect of the compost on exchangeable calcium cation in soil

Amount of calcium cations in soil in Control was not changed after harvesting potato, while that of the compost treatments was rapidly increased because the compost contained a large amount of calcium was added to soil (Fig. 12). Thus, the application of this citrus waste compost supplied a large amount of calcium cations to soil.

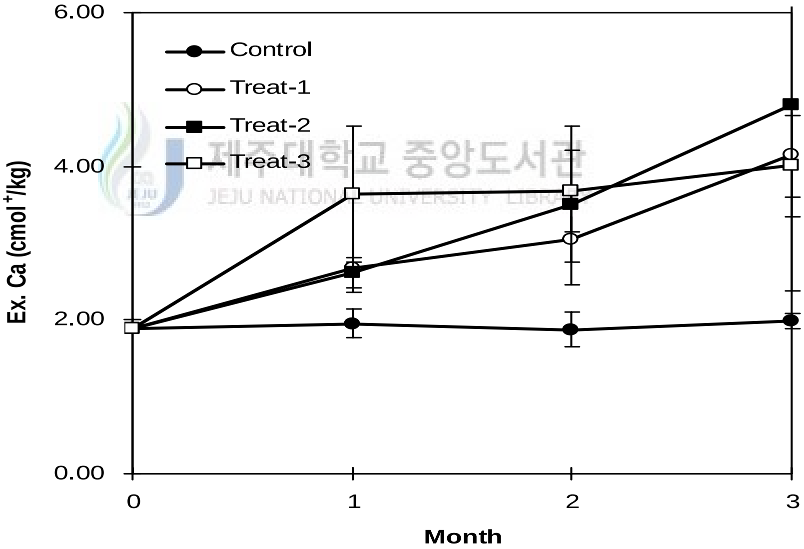

Figure 12. Effect of the compost treatment on calcium cation in soil

8) Effect of the compost on exchangeable magnesium cation in soil

Amount of magnesium cations in soil in Control was not changed after harvesting potato, while that of the compost treatments was rapidly increased because the compost contained a large amount of calcium was added to soil (Fig. 13). Thus, the application of this citrus waste compost supplied a large amount of calcium cations to soil.

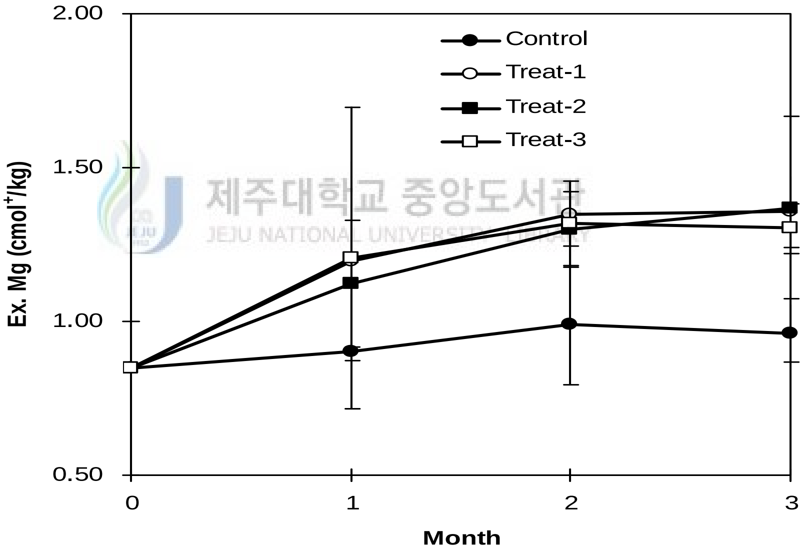

Figure 13. Effect of the compost treatment on magnesium cation in soil

9) Effect of the compost on exchangeable sodium cation in soil

Concentration of sodium cations in soil was very low and after harvesting potato it did not show much change caused by applying the compost (Fig. 14). This indicated that the application of the citrus waste compost did affect inconsiderable amount of sodium cations in soil.

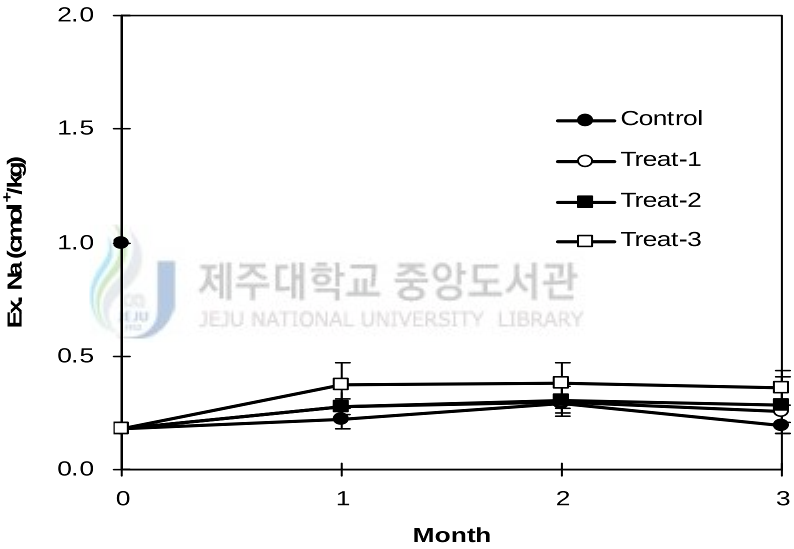

Figure 14. Effect of the compost treatment on sodium cation in soil

10) Effect of the compost on heavy metals in soil

The concentration of heavy metals, such as Cu, Zn, Pb, Cr, Cd, in the soil were very low because these heavy metals contents in the citrus waste compost applied were much low comparing to Korean criteria of compost (Fig. 15 a, b, c, d, e and table 1). Thus, the application of this citrus waste compost did affect inconsiderable amount of heavy metals in soil.

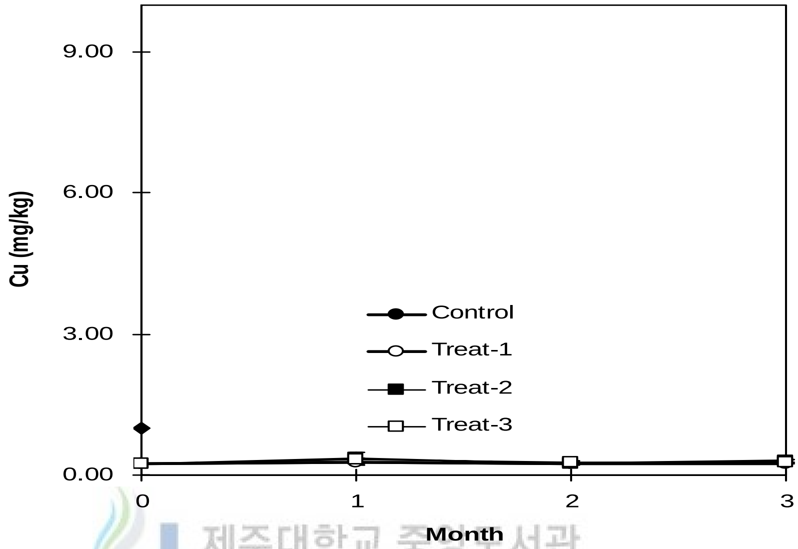

Figure 15a. Effect of the compost treatment on the conc. of copper in soil

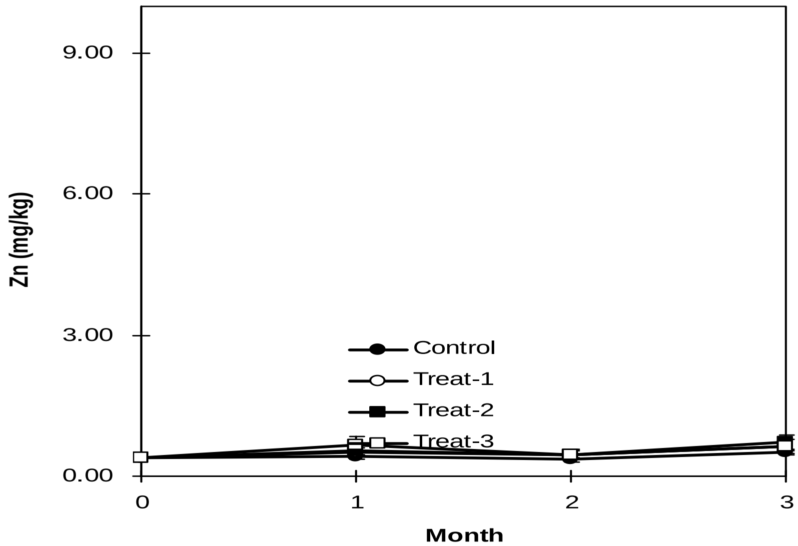

Figure 15b. Effect of the compost treatment on the conc. of zinc in soil

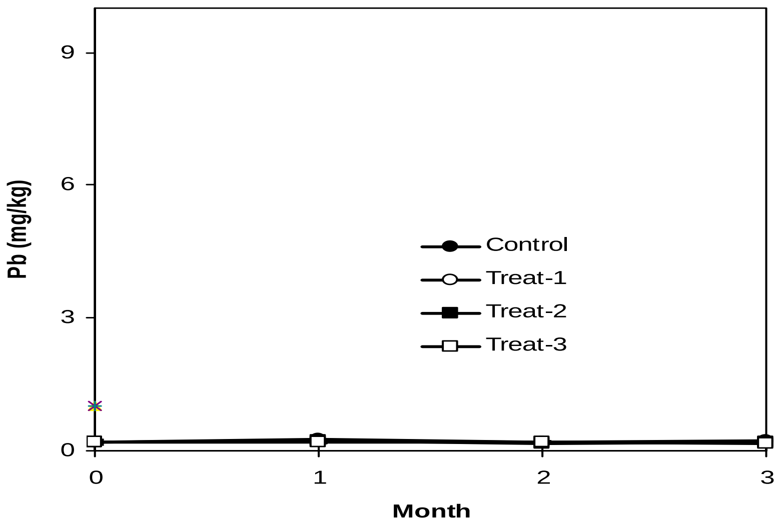

Figure 15c. Effect of the compost treatment on the conc. of lead in soil

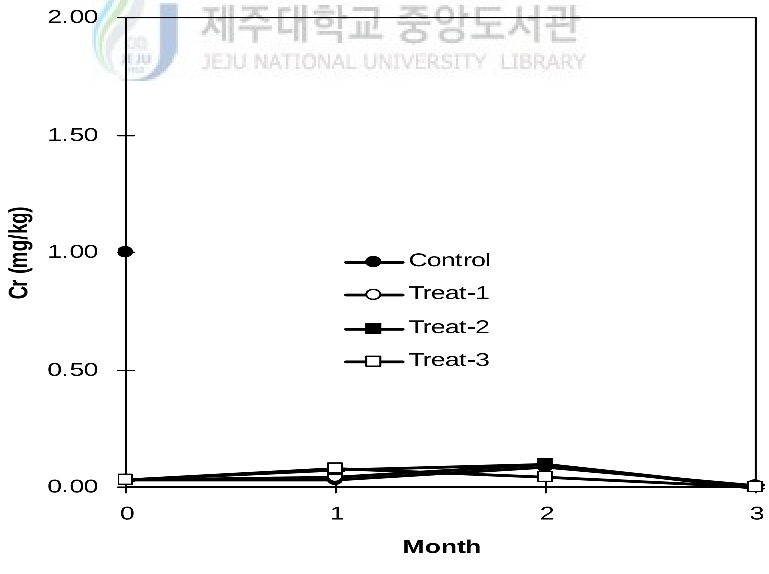

Figure 15d. Effect of the compost treatment on the conc. of chrome in soil

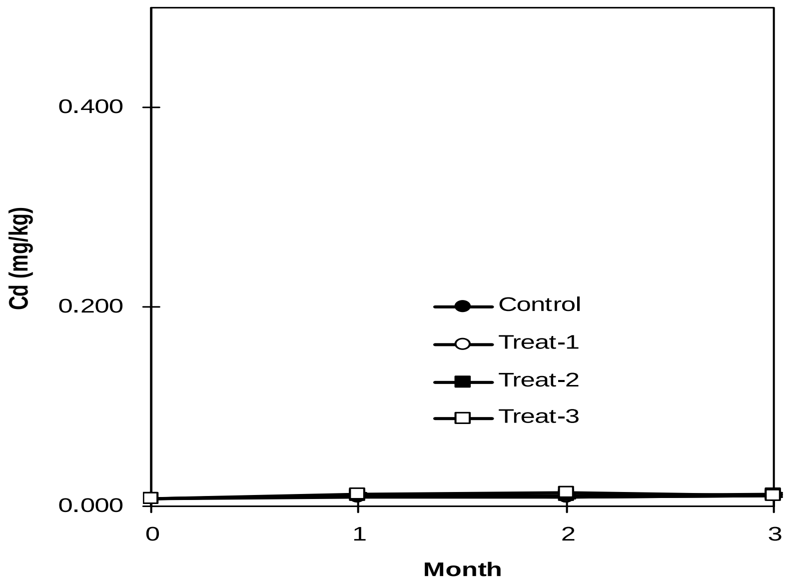

Figure 15e. Effect of the compost treatment on the conc. of cadmium in soil

11) Effect of the compost on soil bulk density

Soil bulk density of Treat-1, Treat-2 and Treat-3, 1.01, 1.08, and 1.07, respectively, was little lower than that of Control, 1.30 (Fig. 16). A small amount of organic matter in the compost was added to soil. Celik et al., (2004) reported that statistically significant lower bulk density was found in compost and manure plots compared to fertilizer and control treatments. This indicated that soil bulk density was increased with amount of compost application.

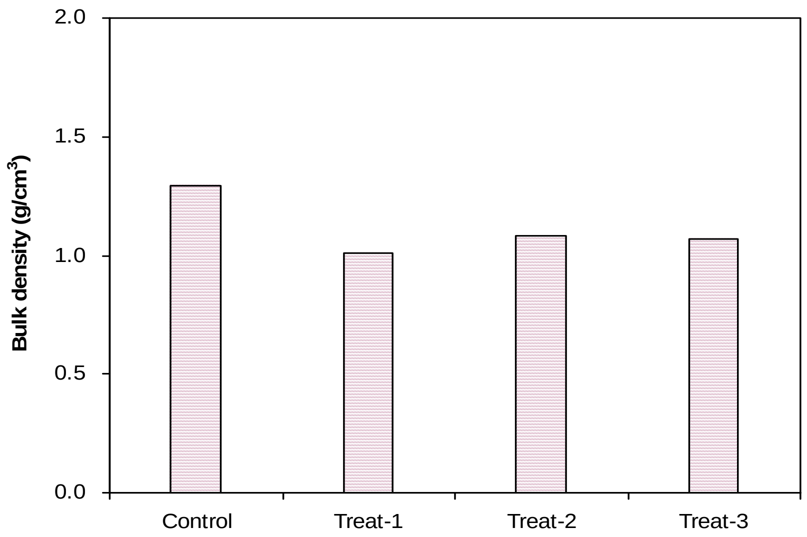

Figure 16. Effect of the compost treatment on soil bulk density

12) Effect of the compost on soil porosity

Soil porosity of Treat-1, Treat-2 and Treat-3, 63.21%, 61.46%, and 58.74%, respectively, was little higher than that of Control, 51.95% (Fig. 17). A small amount of organic matter in the compost was added to soil. Marinari et al. (2000) found that total soil porosity increased with organic fertilizers and compost, depending on the amount of materials applied. Thus, soil porosity had trend to increase according to increasing of amount compost application.

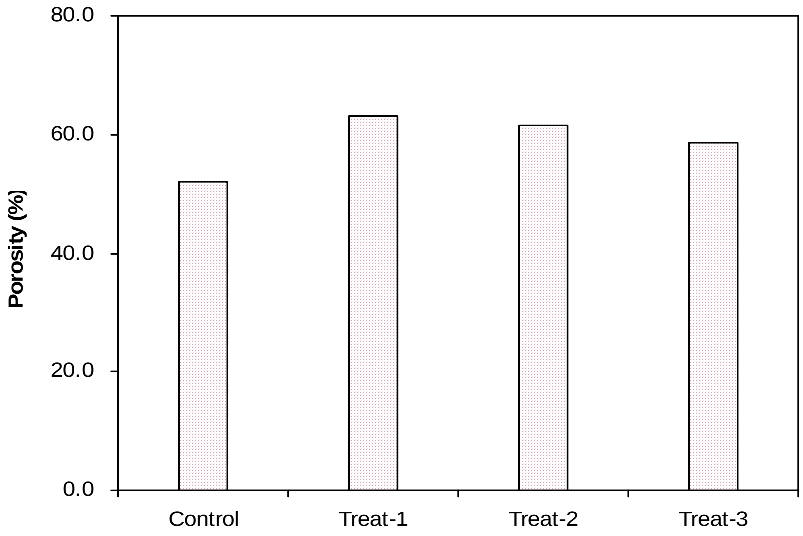

Figure 17. Effect of the compost treatment on soil porosity

3. Effect of the citrus waste compost on potato growth

1) Effect of the compost on potato height

Potato height of Treat-1, Treat-2 and Treat-3, 54.53, 55.77 and 56.10 cm, respectively, was higher than that of Control, 51.10 cm (Fig. 18). This indicated that the application of compost increased the height of potato.

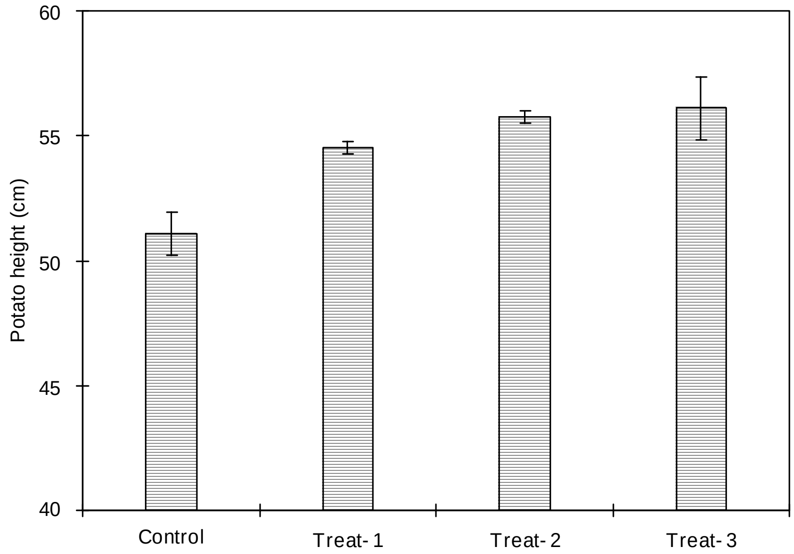

Figure 18. Effect of the compost treatment on potato height

2) Effect of the compost on total and marketable potato tuber yield

Total and marketable potato tuber yield of Treat-2, Treat-3, 2134 and 1320, 2138 and 1353 kg/10a, respectively, was higher than that of Control and Treat-1, 1749 and 866, 1829 and 1012 kg/10a, respectively (Fig. 19a, b). This indicated that total and marketable potato tuber yields were increased with amount of compost application.

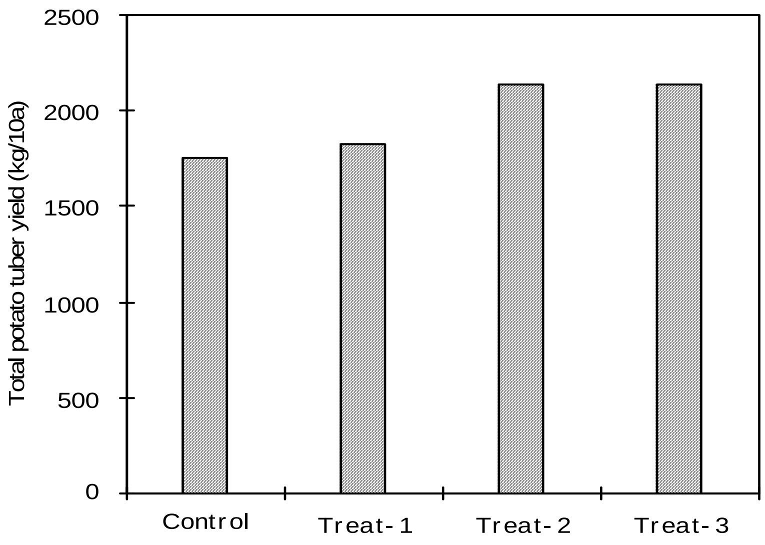

Figure 19a. Effect of the compost treatment on total potato tuber yield

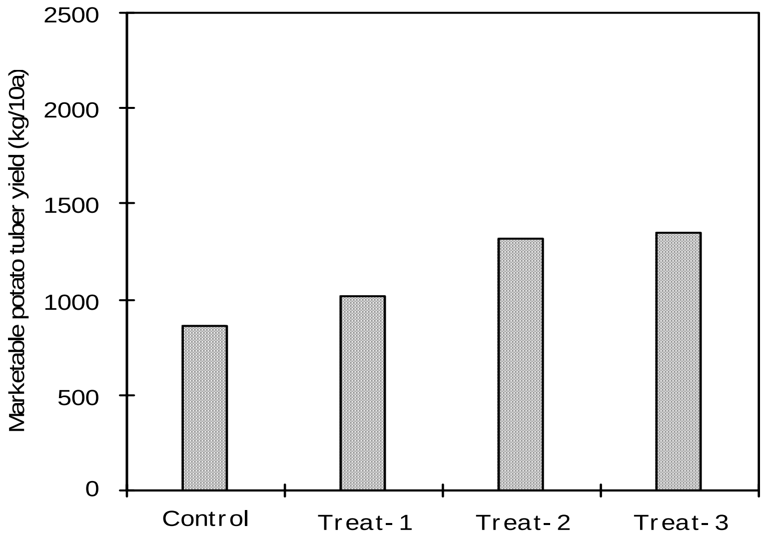

Figure 19b. Effect of the compost treatment on marketable potato tuber yield

3) Effect of the compost on rate of marketable potato tuber

Rate of marketable potato tuber in Treat-1, Treat-2 and Treat-3, 55.3, 61.8 and 63.2%, respectively, was higher than that of Control, 49.7% (Fig. 20). So rate of marketable potato tuber was also increased by compost treatments.

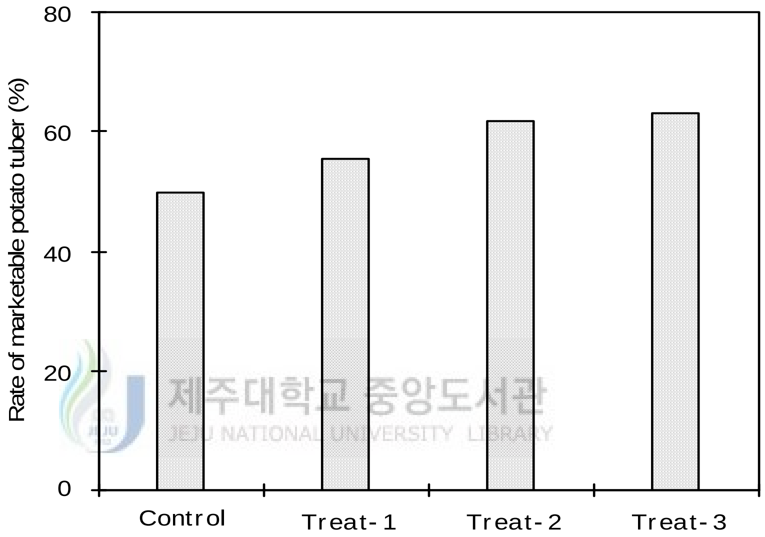

Figure 20. Effect of the compost treatment on rate of marketable potato tuber

4) Effect of the compost on infected rate of potato tuber scab

Infected rate of potato tuber scab in Treat-1, Treat-2 and Treat-3, 13.9, 16.4 and 18.6%, respectively, was higher than that of Control, 10.2% (Fig. 21). Similar result was found by Yang et al., (2001) showing the occurrence of common scab disease was slightly higher in plots treated with the composted sludge than in those given chemical fertilizer. This indicated that infected rate of potato tuber scab had trend to increase according to increasing of amount of compost application.

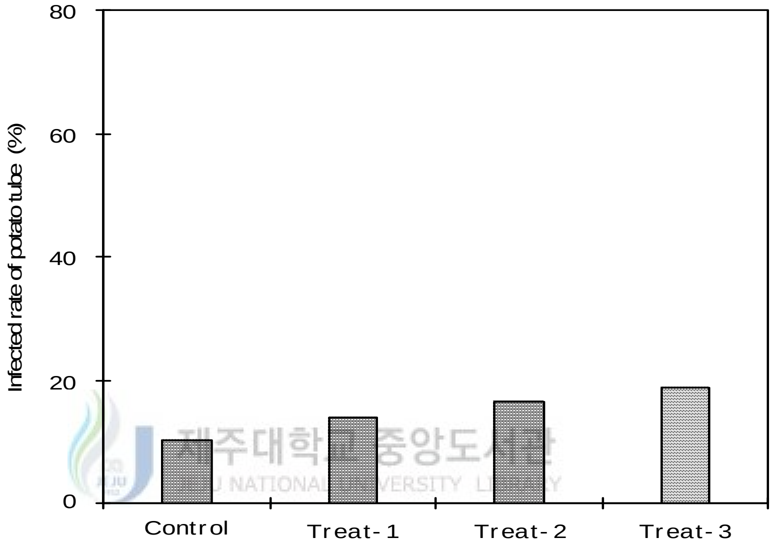

Fig 21. Effect of the compost treatment on infected rate of potato tuber scab

5) Optimum fertilization rate of the compost for spring-potato

Marketable spring-potato yields were gained the same statistically significant, 1320 and 1353 kg/10a in compost application rate of 400 and 600 kg/10a, respectively, were higher than that in compost application rat of 0 and 200 kg/10a. Thus, the optimum fertilization rate of citrus waste compost for spring-potato is considered to be 400 kg/10a (Fig. 22).

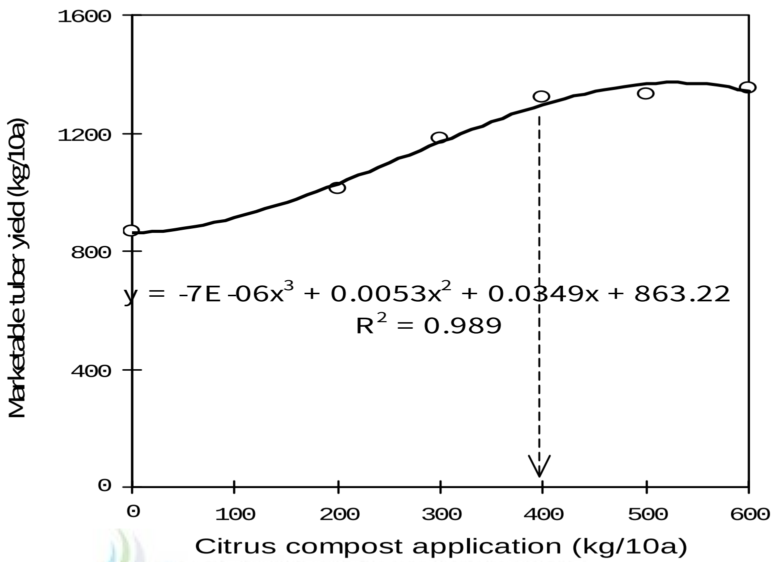

Figure 22. Relationship between compost application and marketable potato tuber yield

IV. CONCLUSION

When the citrus waste mixed with pig manure and rape oil waste without lime, there were not any symptoms like changes in temperature and chemical components. However, pH was rapidly decreased to around pH 4.

Citrus industry waste mixed with pig manure and rape oil waste after treating 5% of quicklime, temperature was reached to about 70℃ in two weeks, water content was reduced, organic matter content, K_2O, CaO, and MgO were increased and pH was changed to around 7. Concentration of heavy metals of the final product was 5 ~ 10 times lower than that of Korean criteria of compost. Organic matter content of the compost was also little higher than that of the criteria.

Soil properties of the application of the compost, which was made from citrus industrial waste, pig manure and rape oil waste, were improved better than that of the application of only chemical fertilizer (Control). pH, electrical conductivity, organic matter content, total nitrogen, exchangeable cations (K^+, Ca^{++}, Mg^{++}, Na^+), available phosphorus and porosity were higher than that of Control.

The growth and yield of spring-potato in the plots treated by the citrus waste compost were enhanced better than that of only chemical fertilizer. Height as well as total and marketable tuber and rate of marketable tuber of potato was higher than that in Control. The optimum fertilization rate is considered to be 400 kg of citrus waste compost/10a. However, the occurrence of common scab disease in the compost treatments was slightly higher than that in Control. Further research should be needed on this point. The effects on soil properties and potato growth were the same as the composts, which made from sawdust and pig manure.

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DEPARTMENT OF AGRICULTURAL CHEMISTRY

GRADUATE SCHOOL

CHEJU NATIONAL UNIVERSITY

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