Korean J. Crop Sci. 49(4) 305~308(2004)

Effects of Vermicompost on Growth of Fall-Cropping Potato in Volcanic Ash Soil

Bong Kyoon Kang†

The Research Institute for Subtropical Agriculture and Biotechnology, Cheju National Univ., Jeju 690-756, Korea

ABSTRACT: Recently, with increasing concern for sustainable agriculture and safe agricultural products, organic farming has become widely adapted as an alternative to conventional farming. This study was conducted to investigate the effects of earthworm casts (EWC) with 100% organic compost on the growth and yield characteristics of fall-cropping potato (*Solanum tuberosum* L. cv. Dejima) in Jeju. The treatments consisted of seven plots: 2-, 4-, 6-, 8-, and 10-ton ha^{-1} EWC-treated plots, 1.2-ton ha^{-1} complex fertilizer (N-P_2O_5-K_2O, 10-10-14)-for-potato (CFP)-treated plot as conventional practices, and a control plot. The plant heights were greater in the plots where EWC and CFP were applied than in the control plot. Tuber diameter, number of stems per plant, and chlorophyll level tended to increase in the plots where 8-10 tons ha^{-1} of EWC were applied. The application of CFP and EWC showed an increment in the average tuber weight per plant, but there was minimal significant difference. The application of 8-10 tons ha^{-1} of EWC resulted in an increase in the total tuber yield (21.61-21.87 tons ha^{-1}) as compared to the other plots. The highest yield of marketable tubers was 69.8% of the total yield from the 10-ton ha^{-1} EWC-treated plot. Consequently, with regard to the growth and yield characteristics of fall-cropping potato, the effects of EWC application were more favorable than the effects of the application of a chemical fertilizer.

***Keywords*:** earthworm cast, earthworms, organic compost, fall-cropping potato

Gaddie & Douglas (1975) identified the scientific availability of earthworm farming. Since they did so, many scientists have developed an interest in earthworm casts (Loehr *et al.*, 1985; Kim & Joo, 1990; Song *et al.*, 1993). Although researches on fertilizing animal manure and industrial waste have been continued in the hope of paving the way for the recycling of resources and of addressing the problem of environmental pollution (Willson *et al.*, 1980; Kiysoshi, 1982), a great deal of effort and resources is needed to establish organic composts. In an ecosystem, earthworms decompose many kinds of organic waste, like agricultural by-products and animal manure, into easily usable materials for growing crop plants. With these agronomical features, earthworm technologies of culture, composting, and stabilization have become available. Advanced countries, including the USA, Japan, and Canada, put vermi-composting into practice in discomposing livestock manure and industrial waste.

In addition, side-produced earthworms are used as a feed for domestic animals, and earthworm casts are used as an organic compost (Gaddie & Douglas, 1975). Camp & Mikee (1981) reported a new concept of the vermi-composting method by which urban waste sludge was processed using the earthworms ingesting ability. Bender (1992), analyzing and evaluating the physiochemical characteristics of soil conditioners, organic fertilizers, and earthworm casts available in the US market, announced that earthworm cast-treated soil had shown the most affirmative result. But most researches only mentioned the efficiency of earthworm casts produced by vermi-composting and vermi-stabilization as compost or deodorant.

Therefore, the outcomes of researches have not been favorable to the application of the method to crop cultivation. Thus, these experiments were conducted to estimate the effects of the earthworm casts (EWC) on the growth and development of fall-cropping potato in the volcanic ash soil of Jeju.

MATERIALS AND METHODS

Experimental Materials

This study was conducted in the greenhouse of the Experimental Farm of the College of Agriculture, Cheju National University (33°27'20"N latitude, 277 m altitude). The chemical properties of the topsoil (0 to 15 cm) were measured before the experiment was conducted (Table 1). The farm soil was a volcanic ash of silty clay loam soil, with fertility

Table 1. Chemical properties of soil used in the experiment

pH (1:5)	Organic matter (%)	Available P_2O_5 (mg kg^{-1})	Exchangeable cations (cmol$^+$kg^{-1})				EC (dS m^{-1})
			K_2O	CaO	MgO	Na	
5.30	5.24	120	0.91	4.54	1.01	0.22	1.12

†Corresponding author: (Phone) +82-64-754-3391 (E-mail) kangbong@cheju.ac.kr <Received March 22, 2004>

that was common. Potato (*Solanum tuberosum* L. cv. Dejima) tubers used in this study were produced by recycling a wick culture system in a glasshouse in the spring of 2003. The seed tubers were planted into 60-cm rows with 20-cm spacing in the greenhouse, with no heating, during the 2003 fall season.

Cultivation and Investigation Items

The mineral content of the testing compost, earthworm casts from cattle manure gathered through earthworm-rearing (Modoagi Co., Ltd , Japan), is shown in Table 2 The treatments consisted of seven plots: 2-, 4-, 6-, 8-, and 10-ton ha^{-1} EWC-treated plots, a 1.2-ton ha^{-1} complex fertilizer (N-P_2O_5-K_2O, 10-10-14)-for-potato (CFP)-treated plot as conventional practices, and a control plot. The experiment was conducted in a randomized complete block design with three replications, and the size of each experimental unit was 6.6 m^2 Growth characteristics were determined 70 days after planting, and yield-related characteristics were determined 100 days after planting, in accordance with the examination guide of the Rural Development Administration of Korea Chlorophyll content was measured with the use of a portable chlorophyll meter (SPAD-502, Minolta Co., Japan), with 10 replications.

Chemical and Statistical Analysis

The chemical properties of the experimental soil and EWC were analyzed as follows: pH and EC (1 : 5 water extraction), content of organic matter (Wakley and Black method), content of total nitrogen (micro-Kjeldahl digestion method), content of available P_2O_5 (Lancast method; NIAST, 2000), and contents of exchangeable Ca, Mg, K, and Na (1M NH_4-acetate pH 7). The data were statistically analyzed using PROC (ANOVA) of the SAS (2000) program. The differences between the treatment means were compared with the use of Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Top Growth Characteristics

The effect of EWC application on the growth and development of fall-cropping potato is presented in Table 3. As regards plant height, the EWC-treated plots and the CFP-treated plot showed better growth of the potato plant as compared to the control plot. As the application rate of EWC increased, the plant height of the potato also increased The application of 10 tons ha^{-1} of EWC showed a significant increase in the stem diameter, compared to other plots Of all the plots, the 8- to 10-ton ha^{-1} EWC-treated plots showed the greatest number of stems per plant, followed by the 2- to 6-ton ha^{-1} EWC-treated plots and the CFP-treated plot. The control plot had the lowest number of stems per plant. Chlorophyll content was low in the control plot, the CFP-treated plot, and the 2-ton ha^{-1} EWC-treated plot (39 61-40.21), and was highest in the 10-ton ha^{-1} EWC-treated plot (42.81).

The earthworm-organizing cast recognized the physics

Table 2. Chemical properties of earthworm casts used in the experiment

pH (1.5)	EC (dS m^{-1})	Moisture	Organic matter	T-N	P_2O_5	K_2O
		(%)				
6.75	15 82	21 43	19 75	0 87	1 99	1 32

Table 3. Effects of EWC application rate on growth characteristics of fall cropping potato at 70 days after planting

Treatment		Plant height (cm)	Stem diameter (mm)	No. of stems $plant^{-1}$	Chlorophyll[§]
Control		63.97^c	9 46^c	3 13^c	39 61^c
[†]CFP (tons ha^{-1})	1.2	65.96^b	10 32^{ab}	3 42^{ab}	40 46^c
[‡]EWC (tons ha^{-1})	2	65 61^b	10 14^{bc}	3 31^{bc}	40 21^c
	4	66.44^b	10.63^{ab}	3 34^{bc}	41 67^b
	6	68 27^a	10.75^{ab}	3.43^{ab}	42 10^{ab}
	8	69 28^a	10.63^{ab}	3 63^a	42 45^{ab}
	10	69.48^a	10 88^a	3 64^a	42 81^a

[†]CFP : Complex fertilizer (N-P_2O_5-K_2O, 10-10-14) for potato
[‡]EWC · Earthworm casts
[§]SPAD value
Mean separation within columns by DMRT at 5% level

and chemistry of superiority, and has been used with soil improvement resources (Brady, 1974; Harris *et al.*, 1990). Having a high water-retention capacity and proper nitrogen-releasing activity in soil, earthworm casts are a good soil conditioner. In addition, vermi-composting is a good heavy metal reductioner (Harris *et al*, 1990). In this study, EWC applied to potato accelerates sprout elongation and, therefore, has a good effect on top growth (Harris, 1978).

Yield Characteristics

The number of tubers per plant was linearly increased as the application rate of EWC was increased from 2 tons ha^{-1} to 10 tons ha^{-1} (Table 4). Average tuber weight per plant ranged from 40.65 to 43.04, showing minimal difference among plots The application of 8-10 tons ha^{-1} of EWC resulted in an increase in total tuber yield (21.61-21.87 tons ha^{-1}) as compared to the other plots.

The relationship between the earthworm cast application rate and the total tuber yield was expressed as $Y = -0\ 0354X^2 + 0.6218X + 19.081$ ($R^2 = 0.89$). According to the equation, the EWC optimum application rate showing a maximum yield of fall-cropping potato in the volcanic ash soil of the Jeju region was around 8 tons ha^{-1}. Marketable tuber (larger than 50g of tuber) yield was 15 27 tons ha^{-1} in the 10-ton ha^{-1} EWC-treated plot (the proportion of marketable tuber was 69.8%) > 13.42 - 14.85 tons ha^{-1} in the CFP-treated plot and the 2- to 8-ton ha^{-1} EWC-treated plots (64.76-68.72%) > 12 46 tons ha^{-1} in the control plot (64.29%). The relationship of the earthworm cast compost rate with the marketable tuber yield was expressed as a simple regression equation, $Y = 0\ 2497X + 2.785$ ($R^2 = 0.96$) (Fig. 1)

Collier (1978) reported that the weight of plants in earthworm casts of sludge lagoons was 4 times more than the weight of plants in common soil. Organic composts applied on soil are immobilized by soil microbes to supply plants with nutrients, taking on the role of a deposit of these nutrients (Coleman *et al.*, 1983; Paul & Vorony, 1980). Through this procedure, organic composts are known to have a great influence on the enhancement of crop productivity (Dux-

Table 4. Effects of EWC application rate on tuber yield, average tuber weight per plants and marketable yield of fall-cropping potato at 100 days after planting.

Treatment[f]		No of tubers $plant^{-1}$	Aver tuber weight per plant (g)	Total Tuber yield	Marketable tuber yield[z]	Rate of Marketable tuber (%)
				(tons ha^{-1})		
Control		8 83[d]	40 65[a]	19.38[d]	12 46[e]	64 29[c]
[f]CFP (tons ha^{-1})	1 2	8 98[cd]	42 29[a]	20.71[bc]	13 42[dc]	64 76[c]
EWC (tons ha^{-1})	2	8 95[cd]	42 22[a]	20.03[cd]	13 18[de]	65 80[bc]
	4	9 26[bc]	42 32[a]	21 35[ab]	14.03[c]	65.72[bc]
	6	9 58[ab]	42 76[a]	21 41[ab]	14 09[bc]	65 79[bc]
	8	9 71[a]	42 92[a]	21 61[a]	14 85[ab]	68 72[ab]
	10	9 76[a]	43 04[a]	21 87[a]	15 27[a]	69 80[a]

[f]See Table 3
Tuber > 50 g
Mean separation within columns by DMRT at 5% level.

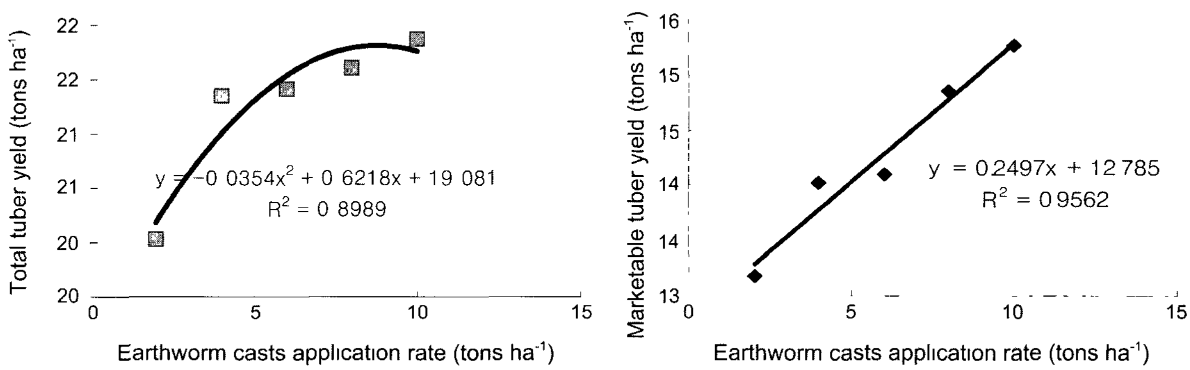

Fig. 1. Relationship between earthworm casts application rate and total tuber yield and marketable tuber yield of fall-cropping potato at 100 days after planting

bury *et al.*, 1989). In addition, EWC is known to carry a higher level of Bacillus, organic matter, total nitrogen, available phosphorus, potassium, and cation exchange capacity than earthworm living soil, making soil productivity better when it is applied (Brady, 1974). The sludge vermi-compost improves the physiochemical properties of soil, promoting the root growth of crops (Yoon *et al.*, 2001).

In summary, EWC application in a fall-cropping potato field in the Jeju region was found to have a positive effect on the growth and yield characteristics of the soil. The optimum application rate for the potato field in the volcanic ash soil of Jeju was determined to be around 8 tons ha^{-1}.

REFERENCES

Bender, G 1992 Vermigro Fallbrook Sanitary District Quality testing pp 7 USA

Brady, N. 1974 The nature and properties of soils. MacMillan Publishing Co Inc New York

Camp, D and Mikee 1981. Engineering assessment of vermicomposting municipal wastewater sludges EPA 600/2-81-075 Cincinnati, Ohio

Coleman, D C., C P Reid, and C. Cole 1983 Biological strategies of nutrient cycling in soil systems Adv. Eco Res 13 1-55

Collier, J 1978. Use of earthworms in sludge lagoons In "Utilization of Soil Organisms in Sludge Management" (R. Hartenstein, ed) pp 131-133 Natl Tech Inf. Services. PB 286932. Springfield, Virginia

Duxbury, J M , M S. Smith, and J W Doran 1989 Soil organic matter as source and a sink of plant nutrients In Dynamics of Soil Organic Matter in Tropical Ecosystems pp 33-68 Univ of Hawaii Press Honolulu

Gaddie, R E and D. E Douglas 1975 Earthworms for ecology and profit. North American Bait Farms. INC. 1207 South Palmetto Ontario, California 91761

Harris, G D., L. P Weldon, and C. P. Benton. 1990 Vermicomposting in a rural community Biocycle. 31(1). USA.

Harris, P. M. 1978. Water. In P M Harris (Ed) The potato crop. Chapman and Hall London. pp 244-277.

Kim, S P and Y. H. Joo 1990. Study on properties of pot media under controlled horticulture for compost from agro-industrial wastes by earthworm (*Lumbricus rubellus*) J Kor. Soc Soil Sci Fert 23(2) · 140-145.

Kiysoshi, K. 1982 Urban and industrial wastes as fertilizer materials International conference on organic matter and rice. The international rice research institute, Los Banos, Lagana, Philippines 9 27-10.1.

Loehr, R. C., J. H. Neuhauser, and E F. Martin 1985 Liquid sludge stabilization using vermistabilization. J. Water Pollution Control Federation 57(7) : 817-826

NIAST 2000. Method of soil and crop plant analysis National Institute of Agricultural Science and Technology Suwon, Korea.

Paul, E A. and R P Vorony 1980. Nutrient and energy flows through soil biomass. In Contemporary Microbial Ecology pp 197-207 Academic Press. London.

Song, J. S , K C Lee, S. H Chun, M D Lee, and K H Cho 1993 The effects of earthworm casts on growth of plants J Kor Org Waste Recycling Council 1(2) 237-258

Statistical Analysis System 2000 SAS/STAT Users Guide Ver 7 Statistical Analysis Systems Institute, Electronic Version Cary, NC, USA

Yoon, O S , B J Lee, and B S. Yoon 2001 The effects of sludge vermicompost on growth and yields of crop (chinese cabbage) and soil fertility. J. Kor Solid Waste. Engi Soci. 18(5) 427-433

Willson, G B , J F Parr, and E Epstein 1980 Manual for composting sewage sludge by the Beltsville aerated-pile method Environmental Protection Agency. pp 65 Cincinnati, Ohio