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# Sodicity Difference between Paddy and Upland Soil as Affected by Food Waste Compost Application

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## ABSTRACT

To compare the effect of food waste compost(FWC) application on the sodicity of paddy and upland soil, laboratory experiment was conducted. Six kinds of FWC made of various mixing ratio of food waste and pig slurry as raw material were applied to paddy soil under submerged condition and to upland soil in field water capacity, and were kept at 25℃ under laboratory incubation. The higher the mixing ratio of food waste on making FWC, the higher the FWC showed Na content and EC. Mineralized ratio of cations in FWC during incubation showed no difference between paddy and upland soil. It was high in the order of Na>K>Mg>Ca as 99, 94, 71, and 71%, respectively. NaCl contents of FWC applied to soils against SAR and ESP were fitted well to first linear regression with extremely high significance($R^2$=0.99). Increasing rate of SAR and ESP was higher in upland soil than paddy soil by 2.3 times. The difference was considered to be caused by dilution effect which was exerted by the application of more soil to water ratio to paddy soil than to upland soil on SAR analysis in consideration of cultivating condition. The calculated values of $([Ca^{2+}+Mg^{2+}]/2)^{1/2}$ used as a denominator on SAR calculation showed a little difference among FWC treatments by 2.1~2.4, while $[Na^+]$used as a numerator showed much variance by 3.1~9.5. Therefore, as a parameter for the assessment of FWC quality affecting soil sodicity, the use of only Na content in FWC was proposed without regarding Ca and Mg contents. Soil Ex. Na contents showed extremely high correlation($R^2$=0.99) with ESP. Moreover, because the former can be more easily determined than the latter, soil Ex. Na content was proposed as a new sodicity index.

**Key words** : Sodicity, FWC, SAR, ESP, Paddy and upland soil.

## Introduction

The most environmentally sound management of putrefied food waste has been reported as composting. However, FWC(food waste compost) application in Korea has the problem of its high content of NaCl due to the salt-favored cooking(Chang et al. 1996). When the $Na^+$ is accumulated in the soil, physical properties of the soil is worsen by structural destruction, and the soil becomes open to erosion by rain(Rowell 1994).

Dispersion and swelling of clay particles are the major factors on the destruction. When the diffuse double layer is thicken, the Van der Waals force becomes weaken making the clay particles disperse(Rhodes & Miyamoto 1990), and when $Na^+$ is inserted into the smectite layers it makes the structure swell out(Shainberg & Letey 1984). On the other

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hand, the increase of electrolytes in the soil alleviates the $Na^+$-caused dispersion and swelling of clay particles. Therefore, the interrelation between salt deposition and $Na^+$ accumulation is known to be a basal factor on the physical property of soil(Sumner 1993)

The parameter used for estimation of $Na^+$ accumulation affecting plant growth has been ESP(exchangeable sodium percentage). When ESP is over 15, the soil is defined as sodic soil whose structure and hydraulic conductivity is not ideal for cultivation(U. S. Salinity Laboratory Staff 1954). However, some soil scientist did not agree with the critical ESP, for even in low ESP the physical property of soil could go bad when the salt concentration is low(Quirk & Schofield 1955, Shainberg et al. 1981). McIntyre(1979) suggested the critical ESP as 5, and Northoote and Skene(1972) as 6. The reason of these different definitions is explained by Sumner(1993) who said that those disagreements were caused by different concentration of experimental solution, and the hydraulic conductivity as a multi-function of ESP and salt concentration, decreases when the ESP is high and the salt concentration is low.

Besides ESP, SAR(sodium adsorption ratio) is being used as a indicator of $Na^+$ accumulation in irrigation water and soil solution. In most soils there is high correlation between SAR and ESP, and some equations have been known(U. S. Salinity Laboratory Staff 1954, Somner 1993, Rengasamy et al. 1984). In normal soils, the ESP shows approximately same figure with SARe(SAR in saturated extracts) in the range below about 30.

The SAR of soil solution is decreased when the water/soil ratio is increased, which caused by dilution effect and dissolution of $Ca^{2+}$-containing soil minerals such as calcite and gypsum. Therefore, the SAR measured in lowly diluted soil extracts like saturated extracts should be favored(Rhodes & Miyamoto 1990). Although SAR shows inverse proportion to square root of dilution rate in the absence of mineral dissolution, its decreasing rate by dilution in normal soil marks a lot smaller range, for the substitution reaction in normal soil plays a buffering role for the SAR change(Oster & McNeal 1971).

In general, the rice plants grown in flooding field are not affected much by physical property of the soil(De Datta 1981). Therefore, FWC containing high content of $Na^+$ is better to be applied in paddy rice field than in upland field.

In this study, the effects of FWC application both on the paddy and upland soil were compared by laboratory incubation at constant temperature to gain the basic data for FWC application.

## Materials and Methods

### 1. Treatment

Soil series used were Chisan(paddy soil) and Sangju(upland soil). The soil samples were air-dried and meshed by 2mm sieve. Physicochemical characteristics of both soils were shown in Table 1.

FWCs were made by mixing the food waste and pig slurry with various mixing proportion of food waste(0, 20, 40, 60, 80, 100%) and decomposed for 2 months with the same volume of saw dust. Application treatments were control, NaCl 200g $Mg^{-1}$, and 20kg $Mg^{-1}$ of six kinds of FWCs. The total 8 treatments were performed with three replicates.

Each 42g of Chisan series was added in test-tube(30 × 150mm) and mixed with FWC for each treatment and 52ml of distilled water was added. After these treatment, the heights of covering water above soil were

**Table 1. Some chemical properties of used soils**

| Soil series | pH (1:5) | EC (dS $m^{-1}$) | OM (g $kg^{-1}$) | T-N (g $kg^{-1}$) | Av. $P_2O_5$ (mg $kg^{-1}$) | Exch. cations (cmol⁺ $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | K | Ca | Mg | Na |
| Jisan | 5.7 | 0.5 | 24 | 1.7 | 81 | 0.54 | 3.5 | 1.3 | 0.18 |
| Sangju | 5.7 | 3.0 | 18 | 1.2 | 551 | 0.38 | 4.4 | 1.3 | 0.06 |

6.5cm. The tube was blocked by rubberstopper(#6) whose center was passed by 8mm glass tube tied with stop-cocked rubber hose. Each treated soil was incubated at 25±0.1℃ for 6 weeks. During incubation, the soils were sampled weekly and analyzed. The stop-cock was opened daily lest the cover should open due to the gas emission.

Upland soils each 60g of Sangju series were added in 100ml plastic beakers. After each treatment, distilled water whose amount corresponded to the field moisture capacity was added and the beaker was covered. For ventilation, the cover was perforated by a pin. Each soil was incubated at 25±0.1℃ for 8 weeks. During incubation, the soils were sampled weekly and analyzed. Supplemental water whose amount was calculated by measuring was added to the soil weekly.

## 2. Analysis of FWC, soil, and soil solution.

pH and EC of FWC were measured with five volume of water. T-C was measured by weight method and T-N was by Kjeldahl method after wet degradation with $H_2SO_4$ added by $K_2SO_4$ and $CuSO_4$. Total phosphate and cations were measured by ICP(GBC Integra XM) after wet degradation with $H_2SO_4$ and $H_2O_2$. Exchangeable cations were analyzed by ICP after 1M ammonium acetate extraction(Institute of Agricultural Science 1988).

For analysis of cations($Ca^{2+}$, $Mg^{2+}$, $K^+$, and $Na^+$), Chisan soil was filtered through No.2 Whatman filter paper. After filtering, the water content in the soil residue was quantified for analysis of exchangeable cations. Water content of Sangju soil was also quantified in each incubation stage. After 24hour of water-saturation the soil solution was collected with Buchner funnel and Na, Ca and Mg were measured by ICP to gain SAR and ESP.

## 3. Data analysis

After incubation, the mineralization rate(MR) of cations in FWC was calculated by equation (1).

$$MR(\%) = \frac{\text{exchangeable cations - control}}{\text{total cations}} \times 100 \quad (1)$$

As an indirect indicator of soil sodicity, SAR(sodium adsorption ratio) was gained with equation (2).

$$SAR = \frac{[Na^+]}{\sqrt{[Ca^{2+} + Mg^{2+}]\ /2}} \quad (2)$$

In the equation (2), parentheses mean mmol$_c$ $L^{-1}$.

As a direct indicator of soil sodicity, ESP(exchangeable sodium percentage) was computed by equation (3) (Sumner & Miller 1996).

$$\frac{ESP}{100 - ESP} = 0.0145SAR \quad (3)$$

# Results and Discussions

## 1. Chemical characteristics and mineralization rate of FWC

As shown in Table 2, the higher the ratio of food waste content, the higher were the Na concentration and EC, while the lower were the others.

The higher the mixture ratio of food waste, the higher was the Ex. Na concentration(Figure 1). This result agreed with Na concentration variation shown in table 2. Ex. Na contents reached continuous level after 2 weeks in paddy soils and after first week in upland soils. On the other hand, the Ex. Ca in soils mixed with high content of food waste kept low level during whole incubation period agreeing with table 2. The changes of Ex. Mg and K were similar to that of Ca(data not shown).

There was no significant difference in mineralization rate of cations between paddy soil and upland soil, and the order of cation contents was as Na>K>Ma>Ca(Table 3). Among the cations, sodium was mineralized in whole suggesting that Na in FWC exist as a free ion which can be extracted with ammonium acetate. Over 90% of potassium was mineralized supposedly existing as free ions. Calcium and magnesium

**Table 2. Some chemical properties of different kinds of food waste compost in the experiment**

| Kinds of FWC* | pH (1:5) | EC (dS m$^{-1}$) | OM | T-N | $P_2O_5$ | $K_2O$ | CaO | MgO | $Na_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | | | | | | |
| FWC 0% | 7.8 | 27 | 41 | 2.2 | 3.3 | 1.02 | 1.35 | 0.53 | 0.21 |
| FWC 20% | 8.0 | 28 | 41 | 2.1 | 3.3 | 0.83 | 1.32 | 0.54 | 0.34 |
| FWC 40% | 7.9 | 35 | 39 | 2.0 | 2.9 | 0.70 | 1.14 | 0.35 | 0.46 |
| FWC 60% | 7.9 | 40 | 44 | 1.9 | 2.5 | 0.60 | 1.16 | 0.33 | 0.65 |
| FWC 80% | 7.8 | 51 | 43 | 1.7 | 1.7 | 0.56 | 1.01 | 0.27 | 0.65 |
| FWC 100% | 7.8 | 45 | 41 | 1.6 | 1.4 | 0.35 | 0.85 | 0.08 | 1.00 |

* FWC : food waster compost. Percentage beside FWC represents the ratio of food waste to the total amount of food waste and pig slurry used as compsting material on making FWC.

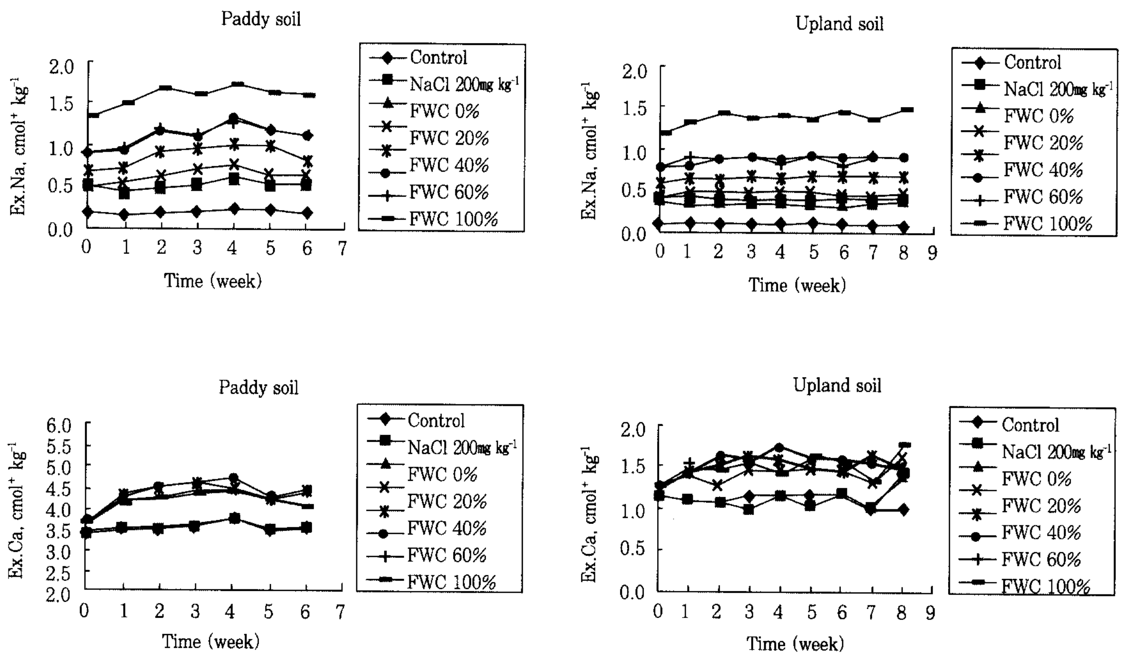


**Fig. 1. Periodical change of EX. Na and Ca in paddy and upland soil applied with different kinds of food waste compost(FWC) under laboratory incubation. Full description of legend contents is referred to the footnote of Table 2.**

were known to exist as bound forms such as cell wall-bound calciums(Marshner 1995). That may be the reason of the low mineralization rate of them in this experiment.

## 2. Differences in sodium accumulation between paddy and upland soil responding to FWC.

As shown in figure 2, the higher the level of NaCl in FWC, and the more the applied FWC, the higher were the SAR and ESP with high level of significance. It can be inferred from the linear regression that NaCl in FWC is able to be regarded as pure NaCl, for NaCl(200g Mg$^{-1}$) used in this experiment agreed with it in FWC. This agreement was thought to be resulted from the high mineralzation rate of sodium(Table 3).

In the linear regression, the slopes were severer in upland

**Table 3. The ratio of mineralized cations extractable by 1 M Ammonium acetate to the total amounts contained in food waste compost applied to paddy and upland soil under laboratory incubation**

| Treatment* | Ratio of mineralized cations(%)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | K | | Ca | | Mg | | Na | |
| | P | U | P | U | P | U | P | U |
| FWC 0% | 91 | 85 | 54 | 42 | 96 | 80 | 100 | 93 |
| FWC 20% | 93 | 91 | 54 | 37 | 62 | 54 | 98 | 98 |
| FWC 40% | 95 | 92 | 54 | 56 | 56 | 75 | 100 | 100 |
| FWC 60% | 92 | 94 | 56 | 57 | 55 | 72 | 100 | 99 |
| FWC 80% | 97 | 89 | 65 | 58 | 78 | 77 | 100 | 99 |
| FWC 100% | 99 | 100 | 47 | 71 | 66 | 83 | 100 | 100 |
| Average | 95 | 92 | 55 | 54 | 69 | 73 | 100 | 98 |

* Full description of treatment contents is referred to the footnote of Table2.
** P : paddy soil, U : upland soil

soil than in paddy soil. When 2%(w/w) compost was applied in soil as in this experiment, 1% increase of NaCl resulted in the ESP increase as 1.5% in paddy soil and 3.5% in upland soil. 2.3 fold higher rate of increase in upland soil was also investigated in the computation which was standardized by contents of added NaCl within the applied compost. On the regression line, 1mg $kg^{-1}$ increase of NaCl caused the ESP increase as 0.017% in upland soil and 0.0074% in paddy soil. The concentrations of NaCl within the FWC and applied compost which brought out the critical ESP(15%) were 9.6%(1,919mg $Kg^{-1}$) in paddy soil and 4.3%(876mg $Kg^{-1}$) in upland soil proposing 2.2times higher probability of

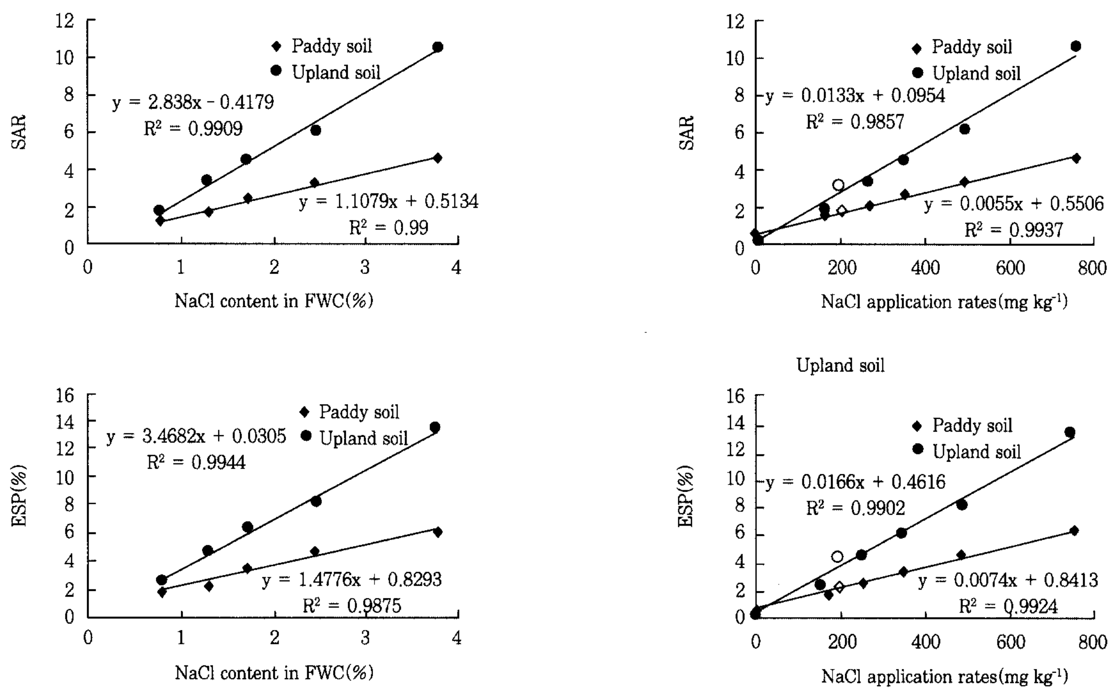


**Fig. 2. Susceptibility difference between paddy and upland soil to the ESP increse as affected by the application of food waste composts varying NaCl content and subsequently by NaCl application rate. Emrty symbols(○ and ◇) in right-hand figures represent the data points of NaCl 200g $Mg^{-1}$ application.**

sodium accumulation in upland soil.

However, when the paddy soil is compared to upland soil on its sodium-accumulating properties, Figure 2 can not be an exact reference. It should be noted that flooding solution was used for SAR of paddy soil and saturated extract was for that of upland soil resulting in the discrepancy in dilution ratios. It has been known that when the soil/water ratio increases calcium in minerals such as calcite and gypsum is dissolved to decrease the SAR, and in the absent of calcium SAR shows inverse proportion to the square root of soil/water ratio(Rhoades & Myamoto 1990). It is known to be 'valence dilution effect', increasing the ratio of soil/water make the high valency cation bind more easily to soil surface(Bohn 1979).

## 3. A proposal of sodium contents as a criteria of FWC estimation

The major factors on SAR in FWC-applied paddy soil were investigated to gain the proper methods for FWC estimation. The square root of (Ca+Mg)/2, which denominator of SAR was highest in pig slurry(FWC 0%) as 2.4 and lowest in FWC(100%) as 2.1%, which marked a little difference. However, $Na^+$, the numerator, marked the range of 3.1~9.5 suggesting that SAR depends on the $Na^+$ content(Table 4). The reason seems to be the high mineralization rate of sodium and the necessarily low variation in the denominator in computation.

Therefore, without Ca and Mg, Na content alone could be used when the salt involved-quality of FWC is estimated

## 4. A proposal of Ex. Na as a new indicator of sodium accumulation.

As an indicator of sodium accumulation, Ex. Na was investigated. In the test of significance, Ex. Na of paddy and upland soils showed strict linear relationships with ESP. After the investigation into the earlier study on estimation of soil structure, Cook and Muller(1997) reported that Ex. Na is more available than ESP. Sumner(1993) said that ESP analysis is laborous and erroneous. However, many studies on the relationships among the Ex Na in various soils,

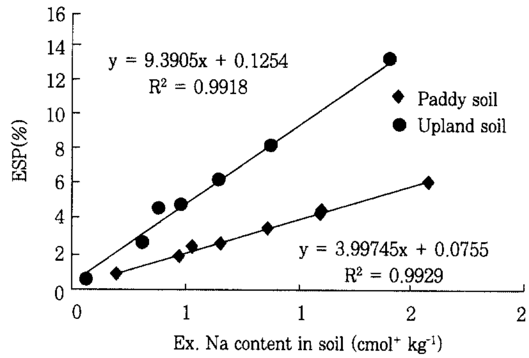


**Fig. 3. Relationship between ESP and soil Ex. Na in paddy and upland soil applied with food waste composts varying NaCl contents.**

**Table 4. Prevailing effect of Na concentration in soil solution of paddy soil applied with various food waste composts on the determination of SAR, compared with Ca and Mg concentration**

| Treatments* | $[Ca^{2+}\ Mg^{2+}]$ ** (cmol⁺ kg⁻¹) | $([Ca^{2+}\ Mg^{2+}]/2)^{1/2}$ (cmol⁺ kg⁻¹)$^{1/2}$ *** | $[Na^+]$** (cmol⁺ kg⁻¹) | SAR |
|---|---|---|---|---|
| Control | 6.0 | 1.7 | 1.0 | 0.6 |
| NaCl 200mgkg⁻¹ | 6.3 | 1.8 | 3.0 | 1.7 |
| FWC 0% | 11.3 | 2.4 | 3.1 | 1.3 |
| FWC 20% | 10.3 | 2.3 | 4.2 | 1.9 |
| FWC 40% | 11.1 | 2.4 | 5.9 | 2.5 |
| FWC 60% | 10.3 | 2.3 | 7.4 | 3.3 |
| FWC 80% | 9.4 | 2.2 | 7.3 | 3.4 |
| FWC 100% | 9.2 | 2.1 | 9.5 | 4.6 |

* Full description of treatment contents refers to the footnote of Table 2.

** [ ] represents concentration

*** Na and $([Ca^{2+}\ Mg^{2+}]/2)^{1/2}$ are used as a numerator and a denominator, repectivity, in SAR calculation physicochemical properties of soils, and their nutritional value should be carried out. that Ex. Na could be established as a new parameter for sodicity

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# Sodicity Difference between Paddy and Upland Soil as Affected by Food Waste Compost Application

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# 음식물쓰레기 퇴비 시용에 따른 논 토양과 밭 토양의 Na 집적 차이

이상은*

음식물쓰레기 퇴비 시용이 논 토양과 밭 토양의 Na 집적에 미치는 영향을 비교하고자 실내 항온 실험을 하였다. 음식물쓰레기 혼합비율을 달리하여 부숙시킨 6종의 음식물쓰레기 퇴비를 처리하여, 논 토양은 담수조건으로, 밭 토양은 포장용수량 상태로 25℃에서 항온시켰다. 음식물쓰레기 혼합비율이 높은 퇴비일수록 Na 함량과 EC가 높았다. 음식물쓰레기 퇴비의 양이온 무기화 율은 논과 밭 토양 간에 차이가 없었으며, Na, K, Mg 및 Ca가 각각 99, 94, 71 및 55%로서 Na>K>Mg>Ca 순으로 높았다. NaCl 함량이 높은 퇴비를 시용할수록, 논과 밭 토양에서 공히 SAR과 ESP가 고도의 유의성($R^2=0.99$)을 가지고 직선적으로 증가하였다. SAR과 ESP 증가율은 논 토양에 비해 밭 토양에서 2.3배 높았다. 이 차이는 SAR 분석 시, 실제 상황을 감안하여 논 토양은 담수 상태의 토양용액을 사용하였던 반면, 밭 토양은 포화추출용액을 사용하므로써, 토양:물 비가 크게 달라서 일어나는 희석효과 때문으로 판단되었다. SAR 계산 시 분모로 사용되는 논 토양의 $([Ca^{2+}+Mg^{2+}]/2)^{1/2}$은 음식물쓰레기 퇴비 처리들 간에 2.1~2.4로 별 차이가 없었 던 반면, 분자로 사용되는 $[Na^{+}]$는 3.1~9.5로 편차가 컸다. 따라서 토양 Na 집적을 고려한 음식물쓰레기 퇴비 품질 평가 시, Ca와 Mg 함량을 무시하고 Na 함량 만 사용할 것을 제안하였다. 토양 Ex. Na 함량은 ESP와 고도의 유의성이 있는 직선관계를 보여, 새로운 토양 Na 집적 지표로 토양 Ex. Na 함량을 제안하였다.

**Key words** : Sodicity, FWC, SAR, ESP, Paddy and upland soil.

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