Nutrient Supplying Potential of Different Spent Mushroom Substrate Preparations as Soil Amendment in a Potting Media

VU Ultra, Jr. 1, JME Ong Sotto2 and MR Punzalan.2

1 Department of Earth and Environmental Sciences, Faculty of Science, Botswana
International University of Science and Technology, Palapye, Botswana
2 College of Agriculture, Fisheries and Natural Resources, University of Eastern Philippines, Catarman, Northern Samar, Philippines
E-mail: mropunsalan_09@yahoo.com.ph

Abstract. A three consecutive cropping experiment was conducted to evaluate the nutrient supplying potential of different preparations of the spent mushroom substrate as an amendment of growing media for potted plants using pechay as test plant. There are 12 treatment combinations consisted 4 types of growing media containing soil alone and mixtures of soil with fresh SMS (FSMS), weathered SMS (WSMS) and carbonized SMS (CSMS) in combination with 0%, 50% or 100% recommended rate (RR) of nitrogen fertilizer. Succeeding two trials were conducted on the same pots and treatment assignments. The high yield of pechay during the first and second crop was observed on WSMS and CSMS treatments FMS media produced high yields only during the 3rd crop. Yield was increased by N fertilizer in WSMS and CSMS treatments but not in FSMS. The growth differences is attributed to differences in available nutrients and C/N ratio between treatments. WSMS and CSMS increased the available N while FSMS immobilized N and other nutrients indicting that weathered SMS and carbonized SMS are more suitable as a component of potting media or as soil amendments without detrimental effect on immobilization and availability of nutrients.

1. Introduction
Nurseries and the emerging popularity of urban agriculture/containerized crop production resulted in high demands of growing medium for potted plants. Currently, peat is utilized as the main component of the growing media [1] and depleted the peatlands [2]. In agriculture, alternative sources of nutrients and soil amendments is needed to combat land degradation due to excessive chemical fertilizer application that utilization organic wastes into soil amendments or as a substrate component for nursery potting media instead of peat will provide solutions for waste disposal and conserve peat areas [3].

The boom of the mushroom industry is a global phenomenon with the market value of $35 billion in 2015 [4]. The production is 6,535,542 tons in 2009 and still increasing annually at 9.2% between 2002 to 2016. However, mushroom production system is accompanied with the generation of millions of tons of residue referred to as spent mushroom substrate (SMS) [5], [6]. The SMS by-product in mushroom cultivation amounts to 5 kg of SMS generated from the production of 1 kg of mushrooms [7]. It has high levels of residual nutrients which may result in environmental pollution if it is dumped as waste [6], [8]. Thus, if properly utilized, SMS could serve as an important agricultural resources that would increase farmer's productivity and at the same time protect the environment.
Current practices in the different production area are carried out on substrates formulated with lignocellulosic materials from different sources (such as wheat, rye or rice straw, sawdust and corn cobs), either alone or mixed with supplements to overcome nutritional limitations and to provide suitable substrate structure and pH [7]. The SMS by-product from these processes have a stabilized organic matter that make them a potential candidate as soil amendments or as a substitute for peat for horticultural growing media. Previous studies have shown some benefits of using SMS in several agricultural applications such as soil amendment which increased the organic matter, improved soil structure and provided plant-available nutrients [9]; while as surface mulch controlled the weeds [10]. Therefore, this study evaluated the potential of different preparations of SMS as soil amendments or component of a growing medium in horticulture by evaluating the growth of pechay grown in the different combination of SMS preparation, nutrient availability and nutrient supply/retention capacity in the presence of different N levels of fertilization.

2. Materials and methods

2.1. Treatment description and experimental design
Using pechay as test plant, a two-factorial experiment consisted of four kinds of growing media and three levels of N fertilization was laid out following complete randomized design with three replications. The 12 treatment combinations include: T1 - Garden soil (GS) only, T2 - GS + FSMS (1:2), T3 - GS + WSMS (1:2), T4 - GS + CSMS (1:2), T5 - GS only + 50% RR of N, T6 - GS + FSMS (1:2) + 50% RR of N, T7 - GS + WSMS (1:2) + 50% RR of N, T8 - GS + CSMS (1:2) + 50% RR of N, T9 - GS only + 100% RR of N, T10 - GS + FSMS (1:2) + 100% RR of N, T11 - GS + WSMS (1:2) + 100% RR of N, T12 - GS + CSMS (1:2) + 100% RR of N. Pots designated 100% GS only, 100% GS + C were fertilized with 7 g of urea, while 3.5 g for 50% RR of N.

2.2. SMS and growing media preparation
The garden soil in the experiment was collected from a surface soil of the UEP experimental station. The soil samples were sieved and heat sterilized prior to mixing. One (1) part of the soil was amended with two (2) parts of SMS (fresh, weathered or carbonized) by weight basis. The SMS was obtained from Volvariella volvacea grown in the Mushroom Production Project of UEP, Catamaran, Northern Samar, Philippines. One hundred twenty (120) kilos each of weathered and FSMS was mixed separately with sixty (60) kilos of sterile garden soil. Another 120 kg of fresh SMS was subjected to carbonization based on the method of Orge & McHenry [11] and after cooling was mixed with sixty kilos sterile garden soil. The different growing medium preparations were potted at 4 kg per pot using a 6 x 11 inches polyethylene bag. The CSMS amended medium which was potted at 3 kg per pot.

2.3. Seedling Preparation and plant establishment
Seedlings were germinated on a sterile mixture of garden soil, compost and carbonized rice hull (1:1:2) for 14 days before transplanting at the rate of one (1) seedling per pot. The plants were irrigated twice each day and maintained under screen house condition.

2.4. Plant yield measurements
Twenty-three days after transplanting, plants were harvested and the fresh weight (shoots and roots) was recorded after washing and subsequent blot drying.

2.5. Chemical analysis
Before and after the experiment during each cropping, soil and growing media samples were collected for chemical analysis. Samples were immediately frozen after sampling and maintained frozen while on transient for laboratory analysis. The samples were freeze-dried prior to analysis at the Laboratory of Environmental Science, Catholic University of Daegu, South Korea. The pH and electrical conductivity (EC) of the soil/growing media samples were measured on a 1:2.5 and 1:5 soil: water (w/v) ratio, respectively [12] while the oxidizable organic C (oxidizable OC) by the Walkley and Black modified method [13]. The total nitrogen by the Kjeldahl method while the available N (NH4-N
and NO3-N) was determined by 1N KCl extraction (1:5 w/v, 2 hours shaking) followed by close-system steam distillation. Available P was determined colorimetrically [14]. Exchangeable Na, K, Ca and Mg in soil were determined in the ammonium acetate extract [15] by flame photometry (Na, K) and atomic absorption spectrometry (Ca, Mg). Available Fe, Cu, Mn and Zn in soil were measured in the DTPA extract [16] by atomic absorption spectrometry.

2.6. Statistical analysis
Fresh yield and chemical properties data were subjected to 2-way analysis of variance followed by treatment mean comparison using Tukey’s Honesty Significant Difference (HSD) Test at 5% level of significance.

3. Results

3.1. Growth performance of pechay on different growing media preparations as affected by N fertilization

Table 1. Fresh weight, number of leaves and root length of pechay grown for 27 days after transplanting as affected by different growing media and N fertilization at different cropping period.¹

| Treatments          | 1st Crop | 2nd Crop | 3rd Crop |
|---------------------|----------|----------|----------|
| T1 –soil            | 14.96 d  | 20.12 e  | 47.83 c  |
| T2 –soil + F SMS    | 2.00 d   | 2.84 f   | b        |
| T3 –soil + WSMS     | 83.80 c  | 63.84 c  | 93.60 b  |
| T4 –soil + CSMS     | 20.20 d  | 35.27 e  | 91.63 b  |
| T5 –soil + ½ N      | 26.70 d  | 25.26 e  | 81.19 b  |
| T6 –soil +FSMS + ½N | 15.40 d  | 49.8 d   | 128.13 a |
| T7 –soil + WSMS + ½N| 182.30 a | 116.27 a | 117.70 b |
| T8 –soil + CSMS + ½N| 167.30 a | 147.34 a | 143.20 a |
| T9–soil + 100% N    | 60.50 c  | 17.85 e  | 36.50 c  |
| T10–soil + FSMS + 100% N | 20.80 d  | 44.4 d   | 144.97 a |
| T11 –soil + WSMS + 100% N | 214.60 a | 71.67 c  | 53.30 c  |
| T12 –soil + CSMS + 100% N | 140.00 b | 57.16 c  | 51.40 c  |

¹Means followed by the same letter(s) are not significantly different from each other based on Tukey's HSD test at 5% level of significance.

The fresh weight of pechay was significantly affected by different growing media and N fertilization at different cropping (Table 1). During the first crop, the average fresh weight of pechay from T11 was highest at 214.6 g while the lowest value of 2.0 g was from T2. Treatments with WSMS as soil amendments with 100% and 50% of urea added had higher yield compared to other treatments. Plants grown in CSMS + 100% RR of urea performed better than those with FSMS and pure soil but inferior to those with WSMS. N fertilization significantly enhanced growth in terms of average fresh weight since T3 (with WSMS) and T4 (with CSMS) which have 0% RR of urea added gave a significantly lower gross weight of 83.3 g and 20.2 g, respectively. Lowest yield was obtained in T2 which is composed of GS + FSMS only. During the second crop, significantly higher fresh yield was obtained in treatments with WSMS and CSMS at 1/2 RR of N fertilizer. Plants from treatments with FSMS are consistently inferior compared to other media regardless of the N fertilization. The full rate of N fertilization did not result in high yield as compared to 1/2 RR of N fertilizer. Lowest yields were observed from growing media in soil + FMS, soil alone at all levels of N fertilizer and soil + CSMS without N fertilizer. On the 3rd crop, plants grown in treatments with FSMS had higher or comparable...
yield to other treatments across different levels of N fertilizer application. A significantly lower yield was obtained from treatments with WSMS and CSMS with a full rate of N fertilizer and those from the control (soil alone) and soil + full RR of N fertilizer.

3.2. Chemical properties and nutrient availability of the growing media
The chemical properties of the different growing media were presented in Tables 2a, 2b, and 3a, 3b. Significance differences were observed on pH, EC, Total C, Total N, C/N ratio, available N and available P before and after cultivation of pechay for three cropping (Table 2). Before plant cultivation, the pH, electrical conductivity (EC), total C, total N, C/N ratio, available N and available P of growing media used in the experiments before planting and after the first cropping.

| Treatments          | pH   | EC  | Total C (g/kg) | Total N (g/kg) | C/N ratio | Avail. N (mg/kg) | Avail. P (mg/kg) |
|---------------------|------|-----|---------------|---------------|-----------|-----------------|-----------------|
| **Before planting** |      |     |               |               |           |                 |                 |
| Soil                | 5.92 c | 126 e | 42 c          | 1.44 c        | 28.82 c   | 12.00 e         | 62.00 a         |
| Soil + FSMS         | 7.02 b | 1021 b | 68 a          | 1.8 b         | 37.78 b   | 5.20 f          | 54.00 b         |
| Soil + WSMS         | 8.39 a | 2640 a | 62 b          | 2.7 a         | 22.96 c   | 14.85 d         | 65.00 a         |
| Soil + CSMS         | 8.02 a | 803 c | 78 a          | 1.1 d         | 70.91 a   | 6.80 f          | 32.00 c         |
| **After First Crop**|      |     |               |               |           |                 |                 |
| T1 –soil            | 6.54 c | 145 e | 42 c          | 1.6 c         | 26.25 c   | 4.20 f          | 59.00 b         |
| T2 –soil + F SMS    | 8.17 a | 466 d | 74 a          | 2.0 b         | 37.00 b   | 3.20 f          | 52.92 b         |
| T3 –soil + WSMS     | 8.68 a | 837 c | 67 a          | 2.6 a         | 26.15 c   | 12.80 e         | 63.70 a         |
| T4 –soil + CSMS     | 8.16 a | 417 d | 77 a          | 0.92          | 83.70 a   | 5.40 f          | 31.36 c         |
| T5 –soil + ½ N      | 5.83 c | 428 d | 42 c          | 2.3 b         | 18.26 c   | 18.20 d         | 58.00 a         |
| T6 –soil + FSMS + ½N| 7.85 b | 432 d | 66 a          | 1.8 b         | 36.67 b   | 6.24 f          | 53.13 b         |
| T7 –soil + WSMS + ½N| 8.44 a | 986 c | 60 b          | 2.9 a         | 20.69 b   | 28.00 c         | 63.95 a         |
| T8 –soil + CSMS + ½N| 8.05 a | 709 c | 76 a          | 1.5 c         | 50.67 b   | 26.80 c         | 31.49 c         |
| T9–soil + 100% N    | 6.00 c | 426 d | 41 c          | 2.1 b         | 19.52 c   | 19.52 c         | 42.00 a         |
| T10 –soil + FSMS + 100% N| 7.81 ab | 473 d | 70 a          | 2.2 b         | 31.82 c   | 8.42 ef         | 51.54 b         |
| T11 –soil + WSMS + 100% N| 8.29 a | 1037 b | 66 a          | 2.9 a         | 22.76 c   | 32.28 b         | 62.04 a         |
| T12 –soil + CSMS + 100% N| 7.88 ab | 744 c | 76 a          | 1.9 b         | 40.00 b   | 27.54 c         | 30.54 c         |

*Means followed by the same letter(s) are not significantly different from each other based on Tukey's HSD test at 5% level of significance.*
growing media. Consequently, highest C/N ratio was observed due to the addition of CSMS. The available N and P were significantly enhanced by WSMS addition but reduced due to FSMS and CSMS based on the control soil. After the first (Table 2a) and second crop cultivation (data not shown), the pH, EC, and total C followed the same trend to that observed before crop cultivation regardless of the N fertilization. On the other hand, the total N, C/N ratio, available N, and P showed considerable differences and patterns. The total N was increased due to N application that consequently decreased the C/N ratio. However, the available N levels showed greater variability and behave differently compared to total N (Figure 1). Addition of N fertilizer increased the available N concentration in growing media with WSMS and CSMS but not in growing media with FSMS. The available P followed the same trend with available N but of lower magnitude. In table 2b, noticeable increase EC, available N and P and the decrease in total C and C/N in FSMS amended treatments as compared to other treatments and to its previous values obtained after the first and second crop. On the other hand, the available N and P of treatments with WSMS and CSMS supplied with 100% RR of N fertilizer declined and the values were even lower compared to WSMS and CSMS treatments with 1/2 N fertilizer. Table 3a, showed a significant increased on the exchangeable K, Ca, Mg and Na and available Cu, Mn, and Zn due to mixing of different preparations of SMS before planting and after the first crop. Although the three preparations did not differ significantly, a higher concentration of exchangeable basis and available micronutrient was observed due to carbonized SMS. Only the available Fe were not altered significantly by mixing different SMS preparations with soil in the growing media. After the second crop (data not shown) and after the 3rd crop (Table 3b), a general decrease of the exchangeable K, Ca, Mg and Na and available Cu, Mn, and Zn were observed. However, after the 3rd

Table 2b. The pH, electrical conductivity (EC), total C, total N, C/N ratio, available N and available P of growing media used in the experiments.1

| Treatment                  | pH   | EC (uS/m) | Total C (g/kg) | Total N (g/kg) | C/N ratio | Available N (mg/kg) | Available P (mg/kg) |
|----------------------------|------|-----------|----------------|----------------|-----------|---------------------|---------------------|
| **After 3rd Crop**         |      |           |                |                |           |                     |                     |
| T1 – soil                  | 6.12 c | 146 d      | 42 c           | 1.5 b          | 28.00 c   | 4.38 e              | 32.28 b             |
| T2 – soil + F SMS          | 7.94 a | 824 a      | 52 b           | 1.7 b          | 30.23 b   | 38.28 b             | 64.22 a             |
| T3 – soil + WSMS           | 8.04 a | 423 b      | 61 a           | 1.6 b          | 38.13 b   | 16.28 d             | 36.12 b             |
| T4 – soil + CSMS           | 7.72 a | 386 c      | 76 a           | 0.8 c          | 90.48 a   | 12.18 d             | 21.48 c             |
| T5 – soil + ½ N            | 5.82 c | 468 b      | 41 c           | 1.8 b          | 22.78 c   | 19.22 c             | 32.18 b             |
| T6 – soil +FSMS + ½N       | 7.41  | ab         | 892 a          | 46 b           | 2.3 a     | 20.00 c             | 52.12 a             |
| T7 – soil + WSMS + ½N      | 7.88 a | 827 a      | 48 b           | 2.5 a          | 19.20 c   | 43.24 b             | 42.13 a             |
| T8 – soil + CSMS + ½N      | 7.62  | ab         | 726 a          | 74 a           | 2.4 a     | 30.83 b             | 24.18 c             |
| T9 – soil + 100% N         | 5.68 c | 548 b      | 42 c           | 1.8 b          | 23.33 b   | 24.12 c             | 24.17 c             |
| T10 – soil + FSMS + 100%N  | 7.54  | ab         | 926 a          | 48 b           | 2.3 a     | 20.87 c             | 58.34 a             |
| T11 – soil + WSMS + 100%N  | 8.00 a | 724 a      | 49 b           | 2.7 a          | 18.15 c   | 19.24 c             | 24.00 c             |
| T12 – soil + CSMS + 100%N  | 7.58  | ab         | 634 b          | 72 a           | 2.1 a     | 34.29 b             | 18.26 c             |

1Means followed by the same letter(s) are not significantly different from each other based on Tukey's HSD test at 5% level of significance.
crop, the amounts of exchangeable K and Ca in WSMS and CSMS in 1/2 RR and 100% RR N fertilized were significantly lower compared to other treatments. The exchangeable K and Ca in WSMS and CSMS in 1/2 RR and 100% RR N fertilized decreased in higher magnitude compared to others while those with FSMS had increased considerably.

4. Discussion
The variable growth based on the fresh yield of pechay grown in different growing media with different levels of N fertilization and at different successive cropping is an indication of the potential of different preparation of SMS as a component growing medium of potted plants. Our results showed how these different preparations would affect nutrient availability especially on N and P. The variable growth of pechay could be attributed to differences in the chemical properties of the different soil: SMS mixtures with different preparation as affected by time. Based on the initial chemical analysis

Table 3a. Exchangeable K, Ca, Mg and Na and the available Fe, Cu, Mn, and Zn of growing media used in the experiments after the first crop.

| Treatments and Soil Preparations | Exchangeable Bases | Available Micronutrients |
|----------------------------------|--------------------|--------------------------|
|                                  | K (g/kg)           | Ca (g/kg)                | Mg (g/kg) | Na (g/kg) | Fe (mg/kg) | Cu (mg/kg) | Mn (mg/kg) | Zn (mg/kg) |
| **Before planting**              |                    |                          |           |           |            |            |            |            |
| Soil                             | 0.38 c             | 3.67 b                   | 0.58      | 0.35      | 1.85 a     | 1.38 b     | 6.40 b     | 2.12 b     |
| Soil + FSMS                      | 0.43 b             | 4.11 a                   | 0.65 a    | 0.39 a    | 2.07 a     | 1.55 a     | 7.47 a     | 2.37 a     |
| Soil + WSMS                      | 0.45 a             | 4.32 a                   | 0.68 a    | 0.41 a    | 2.18 a     | 1.62 a     | 7.53 a     | 2.49 a     |
| Soil + CSMS                      | 0.46 a             | 4.80 a                   | 0.70 a    | 0.42 a    | 2.22 a     | 1.66 a     | 7.68 a     | 2.54 a     |
| **After First Crop**             |                    |                          |           |           |            |            |            |            |
| T1 – soil                        | 0.39 c             | 3.62 b                   | 0.58      | 0.34      | 1.70 a     | 1.43 b     | 6.24 b     | 2.18 b     |
| T2 – soil + FSMS                 | 0.42 c             | 4.03 a                   | 0.64 a    | 0.38 a    | 2.03 a     | 1.51 a     | 7.02 a     | 2.33 a     |
| T3 – soil + WSMS                 | 0.44 a             | 4.23 a                   | 0.67 a    | 0.40 a    | 2.13 a     | 1.59 a     | 7.38 a     | 2.44 a     |
| T4 – soil + CSMS                 | 0.45 a             | 4.70 a                   | 0.68 a    | 0.41 a    | 2.17 a     | 1.62 a     | 7.52 a     | 2.49 a     |
| T5 – soil + ½ N                  | 0.32 d             | 3.58 b                   | 0.59      | 0.36      | 1.78 a     | 1.39 b     | 6.45 b     | 2.01 b     |
| T6 – soil +FSMS + ½N             | 0.42 b             | 4.04 a                   | 0.64 a    | 0.39 a    | 2.04 a     | 1.52 a     | 7.05 a     | 2.34 a     |
| T7 – soil + WSMS + ½N            | 0.44 a             | 4.25 a                   | 0.67 a    | 0.40 a    | 2.14 a     | 1.60 a     | 7.41 a     | 2.45 a     |
| T8 – soil + CSMS + ½N            | 0.45 a             | 4.72 a                   | 0.68 a    | 0.41 a    | 2.18 a     | 1.63 a     | 7.55 a     | 2.50 a     |
| T9 – soil + 100% N               | 0.28 d             | 3.64 b                   | 0.52      | 0.42 a    | 1.68 a     | 1.32 b     | 6.14 b     | 2.21 ab    |
| T10 – soil + FSMS + 100%N        | 0.41 c             | 3.92 ab                  | 0.62 a    | 0.39 a    | 1.98 a     | 1.48 a     | 6.84 a     | 2.27 ab    |
| T11 – soil + WSMS + 100%N        | 0.43b              | 4.12 a                   | 0.65 a    | 0.39 a    | 2.08 a     | 1.55 a     | 7.18 a     | 2.38 a     |
conducted before cropping, SMS mixture would increase the pH of soil which could be attributed to the liming contents of SMS during its preparation. Calcium sulfate is added on the mushroom substrate during preparation to neutralize the pH of the composting mixture of residues and to supply the suitable level of Ca for mushroom [17]. The pH observed in the growing media is quite high than the normal pH for crops which is about 6.5 [18]. Increase in pH will affect nutrient dynamics especially the availability of P and other micronutrients (Table 2a and Table 3a). Similarly, the EC values in SMS amended growing media was increased due to SMS preparations indicating the capacity of SMS preparation to increase the soluble nutrients in the growing media. This is supported by a higher concentration of exchangeable basis and available micronutrients determined after crop cultivation. However, it should be noted that before crop cultivation, the EC of the growing media with different SMS exceed the suggested reference level (605 uS m\(^{-1}\)) [17].

Based on the data presented, the different preparations of SMS had greatly affected the N availability in the growing media. It appeared that FSMS will result to high N immobilization throughout the duration of the first and 2nd cropping period resulted in an inferior growth of pechay even in the presence of full rate of N fertilizer. This could be attributed to high C/N ratio and the nature of organic C present in the growing media containing FSMS (Figure 1). It should be noted that the N-immobilization in FSMS containing growing media was occurring at a very high rate because the added N fertilizer did not improve the growth of pechay (low fresh weight) and that the available N levels after crop cultivation remained low (Table 1, 2a, 2b). In contrast, WMS and CSMS showed higher N availability (Table 2a and 2b) which implied that net N mineralization takes place. Weathering of SMS prior to mixing in the growing media resulted to low C/N ratio that favored higher N availability (Table 2) [20]. In fact, the addition of WMS slightly increased the available N in the growing media indicating that WMS released some available N ready for plant uptake. Consequently, additional N fertilizer increased the available N for plant use resulted in enhanced growth of pechay during the first and second crop. On the other hand, carbonization process of SMS transformed the SMS-C into a non-bioavailable form that is not reactive to microbial attack [21], [22]. Even if the C/N ratio of the growing media containing CSMS is high, this did not result to biological N immobilization. Probably, CSMS had increase available N absorption into the C matrix that resulted to N-fixation (physical N-immobilization) as can be observed by low growth of pechay receiving half rate of fertilizer N [20]. During the 3rd crop, a considerable increased in the fresh yield of pechay in growing media containing FSMS while those plants grown in media containing WMS and CSMS had low fresh yield regardless of the N fertilizer level (Table 1). The increase in yield in FSMS containing growing media could be attributed to an increase in available N and P, and other nutrients as indicated in the residual nutrients after the 3rd crop. This would imply that at this stage, FSMS was able to reach a condition that promotes nutrient mineralization rather immobilization as observed during the 1st and 2nd cropping, hence an increase of nutrients occurred (Table 2c and 3c). In contrast, the decline in fresh yield of pechay from WMSMS and CSMS containing growing media despite the supply of N fertilizer would indicate that some other nutrient become limiting for optimal growth as indicated in lower K and Ca contents in these treatments. It appeared that at 3rd-crop, nutrient imbalance occurred in WMSMS and CSMS containing media causing slow growth of test plant. This nutrient imbalance could be due to previous nutrient uptake depleting some nutrients.

**Table 3b.** Exchangeable K, Ca, Mg and Na and the available Fe, Cu, Mn, and Zn of growing media used in the experiments after the third crop.

| Treatments       | Exchangeable Bases | Available Micronutrients |
|------------------|--------------------|-------------------------|
|                  | K      | Ca      | Mg      | Na      | Fe      | Cu      | Mn      | Zn      |
|                  | (g/kg) |         |         |         |         |         |         |         |
| After Third Crop |        |         |         |         |         |         |         |         |
| T1 -soil         | 0.35 c | 3.56 b  | 0.50 c  | 0.32    | 1.68    | 1.42    | 6.02    | 2.10 b  |
T2 –soil + F SMS 0.48 a 4.28 a 0.62 b 0.43 a 2.16 a 1.56 b 6.52 b 2.46 a
T3 –soil + WSMS 0.42 b 4.12 a 0.63 b 0.38 a 2.06 a 1.32 a 7.06 a 2.42 a
T4 –soil + CSMS 0.40 b 4.24 a 0.62 b 0.39 a 2.01 a 1.46 b 7.04 b 2.48 a
T5 –soil + ½ N 0.32 d 3.46 b 0.58 b 0.34 b 1.84 a 1.36 b 6.33 b 2.15 b
T6 –soil +FSMS + ½N 0.46 a 4.38 a 0.68 a 0.46 a 2.13 a 1.65 a 6.76 a 2.53 a
T7 –soil + WSMS + ½N 0.36 c 3.08 b 0.60 b 0.41 b 2.02 a 1.56 a 7.16 a 2.38 a
T8 –soil + CSMS + ½N 0.38 c 3.34 b 0.55 c 0.42 b 2.00 a 1.52 a 7.24 a 2.42 a
T9–soil + 100% N 0.31 d 3.64 b 0.51 c 0.40 a 1.79 a 1.34 a 6.14 a 2.22 a
T10–soil + FSMS + 100%N 0.48 a 4.53 a 0.69 a 0.44 a 2.56 a 1.64 a 6.96 a 2.48 a
T11 –soil + WSMS + 100%N 0.32 d 3.20 b 0.57 c 0.37 a 2.19 a 1.48 a 6.88 a 2.30 a
T12–soil + CSMS + 100%N 0.31 d 3.14 b 0.62 b 0.40 a 2.15 a 1.54 a 7.02 a 2.26 a

*Means followed by the same letter(s) are not significantly different from each other based on Tukey’s HSD test at 5% level of significance.

5. Conclusions
Overall, our study has shown that the different preparation of SMS as a component in growing media of potted plants resulted to varying biochemical properties affecting nutrient dynamics and availability. Based on our results, WSMS is the best preparation for the component in growing media as it increases the N and P availability, favorable C/N ratio and increased micronutrient contents. CSMS could be favorably used as a component of growing media as it also improves nutrient availability especially increasing the exchangeable basis and available micronutrient essential for plant growth. This would also follow that WSMS and CSMS will be appropriate as soil amendments in the field compared to the addition of F SMS which could be detrimental to N availability immediately after application. Application of F SMS may cause nitrogen immobilization for a prolonged period which may result in nitrogen deficiency of existing crops or newly planted crops when applied directly to the soil. Therefore, WSMS and CSMS could be used in the preparation of growing media or as soil amendments that will contribute to their disposal in an environment-friendly way and reduces the need for peat simultaneously.

6. References
[1] Raviv M, Chen Y and Inbar Y 1986 Peat and peat substitutes as growth media for container-grown plants. In The role of organic matter in modern agriculture. 257-87
[2] Page S E and Baird A J 2016 Peatlands and global change: Response and resilience. Annu. Rev. Env. Resour. 41 35-57
[3] Abad M, Noguera P and Bures S 2001 National inventory of organic wastes for use as growing media for ornamental potted plant production: case study in Spain. Bioresource Technol. 77 197–200
[4] FAO 2013 FAO STATISTICAL YEARBOOK 2013 World Food and Agriculture Food and Agriculture Organization of the United Nations Rome 2013 (http://www.fao.org/docrep/018/i3107e/i3107e.PDF)
[5] Philippoussis A N 2009 Production of mushrooms using agro-industrial residues as substrates In Biotechnology for Agro-Industrial Residues Utilisation Springer Netherlands 163-96
[6] Rinker D L 2002 Handling and using “spent” mushroom substrate around the world. Mushroom Biology and Mushroom Products, UAEA, Cuernavaca.
[7] Semple K T, Reid B J and Fermor T R 2001 Impact of composting strategies on the treatment of soils contaminated with organic pollutants. Environ. Pollut. 112(2) 269-83
[8] Sanchez J E and Royse D J 2009. Scytalidium thermophilum- colonized grain, corncobs and chopped wheat straw substrates for the production of Agaricus bisporus. Bioresource Technol. 100 1670–74
[9] Paula F S, Tatti E, Abram F, Wilson J and O’Flaherty V 2017 Stabilisation of spent mushroom substrate for application as a plant growth-promoting organic amendment J. Environ. Manage. 196 476-86
[10] Nguyen V T and Wang C H 2016 Effects of Organic Materials on Growth, Yield, and Fruit Quality of Honeydew Melon. Commun. Soil Sci. Plant Anal. 47(4) 495-504
[11] Orge, R. F., & McHenry, M. P. (2013). Biowaste conversion technology for household food and energy security in the Philippines: appropriate on–site small–scale rice husk waste carbonisation. International Journal of Inovation and Sustainable Development, 7(4), 387-399.
[12] Allison LE, Moodie CD 1965 Methods of soil analysis. In: Black CA, Evans DD, Ensminger LE, White JL, Clark FE, Dinauer RC (Eds.) Part 2. Chemical and Microbiological Properties. Agronomy No. 9. American Society of Agronomy, Madison WI 1379–96
[13] Yeomans JC, Bremmer JM 1989 A rapid and precise method for routine determination of organic carbon in soil Commun. Soil Sci. Plant Anal. 19 1467–75
[14] Olsen SR, Xole, CV, Watanabe FS and Dean LA 1954 Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. US Department of Agriculture, Circular 939
[15] Knudsen D, Peterson GA and Pratt PF 1982 In: ASA-SSSA (Ed.), Lithium, Sodium and Potassium: Methods of Soil Analysis Madison 2 225–46
[16] Lindsay E L and Norvell W A 1978 Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42 421–28
[17] Stamets P and Chilton JS 1983 The mushroom cultivator. Agarikon Press, Olympia
[18] Abad M, Naguera P and Bures S 2001 National inventory of organic wastes for use as growing media for ornamental potted plant production: case study in Spain Bioresource Technol. 77 197–200
[19] Ultra Jr VU, Nunez J P and Lee S C 2016 Influence of charcoal-based soil amendments on growth and nutrient uptake of rice (Oryza sativa) in Cadmium contaminated soil Emir. J. Food Agric. 28(12) 872
[20] Nunez JP, Ultra VJr, Park JS, Seo PD and Lee SC 2012 Soil nutrient dynamics, supplying capacity and agronomic effects of charcoal-based amendments to rice. Proc. The 50th Anniversary of the Korean Society of Crop Science: 2012 International Symposium on Current Status and Prospects of Environment-Friendly Agriculture in Asian Region. Oct.11-12, 2012. Naju-si, Jeollanam-do, Korea. Korean J.Crop Sci. 52 (2) 44
[21] Asai H, Samson BK, Stephan HM, Songyiikhangsuthor K, Homma K, Kiyono Y, Inoue Y, Shiraiwa T & Horie T 2009 Biochar amendment techniques for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. Field Crops Res. 111 81–84
[22] Masulili A, Utomo WH and Syechfani MS 2010 Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. J. Agric. Sci. 2(1) 39.

Acknowledgement
Gratitude was extended to the Environmental Science Laboratory, Catholic University of Daegu, South Korea for the chemical analysis of soil and growing media samples.