Spent mushroom substrates as component of growing media for lettuce seedlings

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Abstract. Spent mushroom substrates (SMS) instead of peat for lettuce seedlings could reduce the costs of natural capital. SMS, peat and vermiculite were combined in various ratios. The effects of different mixed seedling substrates on lettuce seedling growth and nutrient content were investigated. The results show that, with increasing SMS content in mixed substrate, height, root length index of lettuce seedling increased, number of leaves was decreased, phosphorus and potassium content of lettuce seedlings was increased gradually. The root length, leaf number, shoots fresh weight, biomass of 50% SMS in mixed substrate was better than other treatments (T3). The above results indicate that SMS mixed substrate can improve the growth of lettuce seedlings, and 50% SMS in mixed substrate was suitable for lettuce seedlings.

1. Introduction

Growing media were applied apt environment for plant growth, including organic materials such as peat, and inorganic materials such as perlite [1]. Usually, the physical and chemical properties of single substrate were not satisfactory for plant growth, so mixing substrates was popular in soilless culture, such as peat and perlite; peat and compost [2]. Growing media should have large particles with adequate pore space between the particles [3].

Throughout the world, the raw materials used vary based on their limited availability [4]. With the rapid development of soilless cultivation, growing media has become the biggest limiting factor. Peat becomes the most commonly used horticultural substrate, because it has stable physical and chemical properties [5]. However, peat prices are high; the global resource of peat is limited and cannot be updated in a short time. Therefore, many countries began to restrict the exploitation of peat. Researchers use compost, agricultural organic waste, sewer sludge and the like as substitutes for peat.

The annual output of edible mushrooms in China was about $1 \times 10^7$ tons (2006), accounting for more than 70% of the world's total output [6]. Each year, a large amount of edible mushroom waste is produced, which accumulates or burns away, which leads to waste of resources and serious environmental pollution. Using the mixed substrate of spent mushroom substrates, the results show that the bulk density and porosity of SMS are within the appropriate range of nursery substrate, and the total nitrogen (N), phosphorus (P), potassium (K) content was significantly higher than that of peat mixed substrate [7]. The use of SMS not only addresses the issue of waste of resources in the
production of mushrooms, but also effectively reduces costs. Mushroom residue matrix as the mushroom cultivation process has been fully decomposed, the composition of the structure tends to be stable, and the structure of the mushroom residue was granular analogous to soil aggregate structure. Mushroom residue is a good substrate to replace peat, but due to the conductivity (EC) of mushroom residue substrate, the pH value is too large, which is not conducive to the nursery. In this study, the use of mushroom residue and peat physical and chemical properties of the experimental analysis of the mushroom residue matrix was improved. Peat pH, EC value is too small and mushroom matrix mixed, you can learn lessons from each other. Using mushroom residue, peat and vermiculite, five treatments were established up to determine the effects of physical and chemical properties, seed germination index and morphological growth and nutrient content of lettuce seedlings, slag organic substrate. Despite this, there is little research on their use as a growing media. Therefore, the main purpose of this experimental study was to mix commercial peat and various concentrations of spent mushroom substrates bases into a series of mixtures and study the properties and effects of the mixtures, thereby linking the growth and nutrient content of the mixtures and lettuces of different concentrations.

Lettuce (Lactuca sativa L.), belonging to the family Compositae, is a one or two-year-old herb; its common name is lettuce [8], is a widely grown and popularly consumed vegetable worldwide. Lettuce is a low-sugar, low-fat vegetable that is not only rich in vitamin C, vitamin E, calcium, phosphorus, iron and other minerals and vitamins but also contains malic acid, tartaric acid, lactic acid, mannitol and the active thyroid hormone; thus, it has a high nutritional value [9]. The stem and leaf extract of lettuce can enhance gastric juice, stimulate digestion, increase appetite, and has a hypnotic analgesic effect. In addition, lettuce extract can lower cholesterol, assist in the treatment of neurasthenia, and have other effects, such as the risk of chronic diseases such as cancer, cardiovascular disease, and aging-related functional decline. As a result, lettuce has become a popular vegetable, and its productivity has increased every year [10]. Epidemiological studies have shown that there is a correlation between increasing the consumption of vegetables and reducing the risks of chronic diseases such as cancer, cardiovascular disease and age-related functional decline. Lettuce has a shallow root, a large leaf area, and does not tolerate drought. It has very high moisture content, drought conditions will significantly decrease its quality and yield, causing major economic losses. These health benefits are considered as related to macronutrients, micronutrients and bioactive compounds in vegetables. The use of spent mushroom substrates as a component of the hybrid substrate for lettuce seedlings growth instead of peat was studied.

2. Materials and methods

2.1. Experimental material

Spent mushroom substrates were mixed with commercial peat in unlike proportions. Among them, vermiculite was bought on the market and SMS was fermented from the plant medium after mushroom cultivation. T5 with peat (66.7%) and vermiculite (33.3%) was verified as a control (CK). To prepare the substrates, the residues were dried at 45 °C in an air forced oven for 48 h and then they were ground to 5 mm to obtain homogeneity. The variety of lettuce was ‘Gemini’, lettuce seedlings was planted in plug seedlings in greenhouse, Beijing University of Agriculture. The volume ratio of spent mushroom substrates was screened based on the lettuce seedlings morphological growth and nutrient content.

The seeds of lettuce were sown on different growth media in a dish and one seed was sown per cell. The treatment of this experiment (growth medium) was formed in a completely randomized design with three replicates per treatment. Germination is held in a light incubator at 27±1°C and 90-95% relative humidity. When the seedlings reached the size of the viable transplant, respectively, the plants were harvested and the aerial parts of all the plants were weighed to determine the fresh weight. The plants were then washed, dried (in a forced air oven at 60°C for 72 hours) and ground to 0.5 mm for analysis.
Six treatments were established for the experiment as Table 1. T1 was full of SMS; T2 was consisted of 75% SMS and 25% peat; T3 included SMS and peat each accounted for half; T4 was consisted of 25% SMS and 75% peat; T4 included One hundred percent of peat; 66.7% peat and 33.3% vermiculate was set up as control (CK).

Table 1. Proportion of for experimental seedling substrates (percentage by volume).

| Treatment | SMS (%) | Peat (%) | Vermiculite (%) |
|-----------|---------|----------|-----------------|
| T1        | 100     | 0        | 0               |
| T2        | 75      | 25       | 0               |
| T3        | 50      | 50       | 0               |
| T4        | 25      | 75       | 0               |
| T5        | 0       | 100      | 0               |
| CK        | 0       | 66.7     | 33.3            |

2.2. Morphological growth of lettuce seedlings

When the seedlings reached a commercial transplant size, 15 seedlings were randomly harvested from each treatment at 45 days of lettuce. In the stem, the seedling height (H) was evaluated from the root collar to the shoot tip and measured using a ruler; (LFW) and fresh weight (RFW) of the fresh weight (FW). Finally, the seedlings were placed in an air forced oven at 105 celsius degrees. Dry for 24 hours to determine the dry weight (DW), including dry aboveground weight (SDW) and root dry weight (RDW) [11].

2.3. N, P and K content of lettuce seedlings

Some chemical properties were assessed: N using the Dumas method [12], phosphorus as per Murphy and Riley [13]. Assimilable elements were assessed in 1:5 (v/v) suspension, using water to extract N and P, ammonium acetate to extract K. In the corresponding extracts, N was measured by reflectometry in RQflEx 10 colorimeter by Merck, phosphorus as per Murphy and Riley (1962). All elemental analyses were repeated three times.

2.4. Data processing and analysis

For all data, homogeneity of variance assumptions were tested utilizing a Levene’s test. If assumptions were met, an ANOVA and Tukey post-hoc test were utilized. The statistical analysis was based on the one-way analysis of variance of the mean values of each parameter for each treatment (substrate), in order to test the statistically significant differences, to compare the differences between specific treatments, the Tukey-b test at P < 0.05 were used. Analysis was performed using SPSS.

3. Results and analysis

3.1. Effects of different SMS mixed substrate on morphological indicators of lettuce seedlings.

As can be seen from Table 2, the overall trend showed that with peat content reducing, the plant height, root length index was gradually increased. With the increasing of peat content, the content of SMS gradually decrease, and the number of leaves was gradually increased. The difference of stems in each treatment was not significant.

The root length, leaf number, above ground fresh weight, whole plant dry weight and other indicators of T3are better in all treatments. The fresh weight, root fresh weight and root fresh weight of different treatment seedlings was different, but fresh weight and root dry weight decreased with the increase of peat content, root weight, roots fresh weight increasingly. With the decreasing of the content of SMS, the content of peat increasing, the fresh weight of shoot and the dry weight of shoot slightly increased, the same trend of change was shown.
Table 2. Effects of different SMS mixed substrate on the morphological indicators of lettuce seedlings.

| Treatment | H(cm) | LN | RL(cm) | D(mm) | SFW(mg) | RFW(mg) | SDW(mg) | RDW(mg) | DW(mg) |
|-----------|-------|----|--------|-------|---------|---------|---------|---------|--------|
| T1        | 12.3ab| 2.7c| 1.8b   | 0.81a | 173.65b | 6.80a   | 5.42b   | 0.27a   | 5.68b  |
| T2        | 13.6a | 3.2ab| 1.5bcd | 0.85a | 306.02ab| 11.85a  | 9.77ab  | 0.43a   | 10.20ab|
| T3        | 13.2a | 3.3ab| 3.3a   | 0.81a | 376.87ab| 11.15a  | 12.20a  | 0.58a   | 12.78a |
| T4        | 13.2a | 3.0bc| 1.3cd  | 0.85a | 368.57ab| 10.27a  | 10.43ab | 0.40a   | 10.83ab|
| T5        | 11.5b | 3.5a | 1.1d   | 0.86a | 294.72ab| 8.90a   | 10.50ab | 0.37a   | 10.87ab|
| CK        | 13.2a | 3.3ab| 1.6bc  | 0.80a | 390.23a | 9.45a   | 13.05a  | 0.43a   | 13.48a |

Note: Different letters showed significant differences (P < 0.05)

3.2. Effects of different SMS mixed substrate on nutrient contents and accumulation of lettuce seedlings

Macronutrient content in the graft is statistically affected by the type of waste and the proportion of the mixture. Nitrogen, phosphorus and potassium are critical nutrients for plant growth. The supply status of N, P and K directly affects the yield and quality of crops and is the major limiting factor in crop production. As can show in Table 3, phosphorus content and potassium content in lettuce seedlings increased with the increase of SMS. Because the accumulation of lettuce seedlings was equal to the elemental content of lettuce seedlings multiplied by the whole plant dry weight, change range of the dry weight of each treatment was less than that of the nutrient elements in lettuce seedlings. However, dry weight changes in the same tendency.

Table 3. Effects of different SMS mixed substrate on the nutrient contents and accumulation of lettuce seedlings.

| Treatment | Nitrogen Concentration (g.kg⁻¹) | Phosphorus Concentration (mg.Plant⁻¹) | Potassium Concentration (g.kg⁻¹) | Accumulation (mg.Plant⁻¹) |
|-----------|---------------------------------|--------------------------------------|---------------------------------|--------------------------|
|           | Accumulation (mg.Plant⁻¹)       |                                      | Accumulation (mg.Plant⁻¹)       |                          |
| T1        | 2.69b                           | 15.30b                               | 8.93ab                          | 50.81b                   |
| T2        | 3.08ab                          | 31.44ab                              | 9.68a                           | 98.71ab                  |
| T3        | 2.77b                           | 35.43ab                              | 8.86ab                          | 113.44a                  |
| T4        | 3.31a                           | 36.21ab                              | 8.67b                           | 93.96ab                  |
| T5        | 2.97ab                          | 32.33ab                              | 8.61b                           | 92.91ab                  |
| CK        | 3.12ab                          | 42.29a                               | 9.30ab                          | 125.14a                  |

The nutrient contents of lettuce were influenced by the proportion of SMS mixing substrate. K contents of SMS mixing substrate were greater than CK. In addition, N and P content of SMS mixing substrate was similar to CK, and no significant differences were found among the different treatments.

4. Discussion and conclusion

Peat is the most commonly used horticultural cultivation substrate, but the high price, limited resources, a lot of mining will do harm to the environment. Mushroom residue as edible fungus waste, its processing, can be a superior cultivation substrate.

Liu et al. [14] showed that the use of vinegar residue as organic substrate should be combined with not less than 25% peat and should be safe for vegetables, nurseries and cultivation. The results showed that seedling root length, shoot fresh weight, dry biomass and other indicators of 50% SMS mixed substrate were preferable to other treatments. It was not only can reduce costs and improve the quality of lettuce seedlings for 50% SMS mixed substrate instead of peat substrate for lettuce nursery. It is a good alternative to peat organic substrate mixed with SMS. From the results obtained, it can be concluded that the medium containing SMS had sufficient physical properties and significant
phytonutrient content. Regarding the most suitable substrate for plant growth, any substrate refined with waste was found to be ample for lettuce seedling production. Therefore, all of these conclusions indicate that the use of discarded mushroom matrices in professional horticulture serves to treat them in an environmentally friendly manner while reducing the need for peat.

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