Effect of Maize Straw Composite Substrate on Tomato Seedlings Growth

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Abstract. In order to make full use of the agricultural waste resource maize straw, the alternative organic matrix of peat was studied to realize agricultural recycling. In this study, with peat: vermiculite = 2:1 (v/v) as the control, the physicochemical properties of the matrix of maize straw fermentation after mixed with vermiculite in different volumes (3:1, 2:1, 3:2, 1:1) and the effect of applying the composite substrate to the tomato seedling were studied. The results showed that the effect of vermiculite contents on dry bulk density of mixing substrate was positive, however the effect of vermiculite contents on total porosity of mixing substrate was negative; The pH value of maize stalk fermented substrate treatments were among 7.01-7.21, but the pH value of peat was acidic; the treatment, fermented maize stalk substrates: vermiculite=1:1 (v/v), can nurse strong tomato plug seedling after sowed 42 d, it does not differ significantly between the treatment and peat on plant height, number of leaves, shoot dry weight and dry weight of whole tomato plant; Also it did not differ significantly among all treatments on content of chlorophyll, chl a/b, and root system vigor of tomato seedlings. Therefore, it is suggested that in the production practice, corn stalk fermentation matrix and vermiculite 1:1 mix to carry out seedling, compared with peat seedling, sowing 3-5 days in advance, so as to achieve the effect of peat seedling.

Keywords: Maize straw, fermented substrate, plug seedling, tomato.

1. Introduction
As an advanced seedling raising technology, factory plug seedlings have been popularized and applied in horticultural production in my country. At present, the commonly used seedling substrate is a composite substrate of peat and vermiculite or perlite [1,2]. Peat is recognized as the most excellent seedling substrate at home and abroad. But it is non-renewable material, and excessive exploitation of peat will cause serious ecological problems [3]. Therefore, looking for substitutes for peat has become a hot research topic at home and abroad and achieved certain results [4-6]. Many alternatives have been found as substrates, such as sugarcane bagasse [7], pine bark [8] and so on. China is rich in maize stalk resources, according to statistics in 2018, my country’s total maize output reached 257.35 million tons [9], estimated according to the ratio of maize to straw of 1:2 [10-11], until 2018, my country’s maize straws have reached 514.7 million tons. Maize straws are rich in nutrients [12] but the utilization rate is very low. In addition to direct mechanical straws returning to the field and being used as fodder for livestock, quite a few of them are piled up near the field, roadside and village, and even some of them are directly burned, causing environmental pollution and resource waste [10-13]. The use of agricultural waste maize straws to ferment to replace peat substrate as a plug seedling substrate,
can not only turn waste into treasure to increase agricultural income, but also reduce the extraction of peat, has great significance to protect the ecological environment.

The maize stalk fermentation substrate used in this study uses crushed maize straw as raw material. Drying chicken manure and urea are used as supplementary materials to compost a horticultural organic substrate synthesized by biological fermentation. This experiment studied the physical and chemical properties of maize straw fermentation substrate and vermiculite mixed with different volumes and their effects on tomato plug seedlings, which screen out the best substrate formula suitable for tomato plug seedlings.

2. Materials and Methods

2.1. Experimental Materials and Design

The tomato (Lycopersicon esculentum Mill.) variety ‘Queen of Xinfendu’ was used, provided by Henan Yuyi Seed limited company; Peat was purchased from Zhengzhou City Flower Market; The maize straw fermentation substrate is a product developed by the Maozhuang substrate factory of Henan Agricultural University. The experiment was carried out in a plastic greenhouse in the experimental base of the College of Horticulture, Henan Agricultural University.

The experimental substrate used maize straw fermentation substrate and vermiculite mixed in different proportions as seedling substrate. Then set up a total of 5 treatments, They are: T1, maize straw fermentation substrate (V): vermiculite (V)=3:1; T2, maize straw fermentation substrate (V): vermiculite (V)=2:1; T3, maize straw fermentation substrate (V): vermiculite (V)=3:2; T4, maize straw fermentation substrate (V): vermiculite (V)=1:1; Take peat (V): vermiculite (V)=2:1 as the control CK. After mixed with different proportions of the compound matrix, the tomato seedlings were cultivated, The seedling container is a 50-hole plug. The germination of tomatoes was accelerated before sowing and when the germination rate reaches 90%, the seeds with the same germination are selected for sowing, and 3 trays are sown for each treatment, arranged randomly. After each treatment, the cotyledons were flattened and the garden was poured to test the nutrient solution. From the 22nd day after tomato sowing, 15 tomato seedlings were randomly selected from each treatment to determine the morphological indicators. Including plant height, number of main stem leaves, maximum root length, root volume, dry weight of shoots, dry root weight and dry weight of whole plant. Samples were taken every 5 d for a total of 5 samples. 40 days after sowing of tomato seedlings, 5 plants were randomly selected from each treatment to determine the chlorophyll content (CC), chlorophyll a/b (chl a/b), and root vitality (RSV) of the leaves.

2.2. Experimental Items and Methods

Determination of bulk density and porosity: Use a container of known volume (V) (the quality of the container is W0), fill it with natural air-dried substrate and weigh W1; Then soak in water and weigh W2; After the water is drained naturally, weigh W3. Finally calculated according to the following formula: Bulk density = (W1-W0)/V , Total porosity (TP)=[(W2-W1)/V]×100%, Aeration porosity (AP)=[(W2-W3)/V]×100%, Water holding porosity (WHP) = total porosity-ventilation porosity, Water-air ratio = water-holding porosity/aeration porosity.

Determination of pH and EC value of substrate: Mix the air-dried substrate (mass) and deionized water (volume) in a ratio of 1:5 and filtrate was taken after 24 hours. The pH and EC values were determined with HANNA Hi8134 pH meter and HANNA Hi8733 EC meter respectively. The indicators for measuring plants include plant height, dry weight, number of main stem leaves, root length and root volume. Among them, the plant height is the length from the root base to the growth point; Dry weight means take the plants and place them in an oven at 105 °C for 15 min, and then weigh their dry weight. Root vitality adopts TTC method; The leaves of chlorophyll content is extracted by a mixed solution.
3. Results

3.1. Main Physical and Chemical Properties of the Maize Straw Fermentation Substrate Mixed with Vermiculite

After the mixture of maize straw fermentation substrate and vermiculite in different proportions, the bulk density increases with the addition of vermiculite (Table 1). The control peat has the smallest bulk density, while that of T3 and T4 treatment was the largest, and the difference between them was not significant. The total pores in all treatments decreased with the increase of bulk density; The total pores in comparison with CK were the largest, and those in T1 were second, with no significant difference; The total pores in T3 and T4 were the smallest. The ventilation pores in each treatment ranged from 13.4% to 18.8%. The ventilation pores in T4 treatment were the largest and significantly higher than those in other treatments. The water-holding pores of CK in comparison are the largest, while those of T4 treatment were the smallest. In seedling management, attention should be paid to increasing the number of irrigation. It is generally believed that the water-air ratio of the ideal matrix should be between 2 and 4 \[10\]. It can be seen from Table 1 that the water-air ratio of each treatment meets the requirements and can well coordinate the relationship between water and air. Compared with CK partial acid, each treatment of corn straw fermentation matrix was partial alkali. For most crops, they prefer neutral partial acid environment. As far as EC of each treatment was concerned, T1 and T3 treatment had the highest value, and the difference between them was not significant, nor was the difference between the other three treatments. After mixing with vermiculite, the EC value of corn stalk fermentation substrate could be significantly reduced, so that it could better adapt to the growth requirements of plants.

| Treatment | BD/g·cm\(^{-3}\) | TP/% | AP/% | WRP/% | WRP/AP | pH    | EC/mS·c\(^{-1}\) |
|-----------|-----------------|------|------|--------|---------|-------|-----------------|
| T1        | 0.29c           | 71.0a| 16.2bc| 54.8a  | 3.38b   | 7.01a | 2.93a           |
| T2        | 0.35b           | 69.5b| 15.1c| 54.4a  | 3.59a   | 7.21a | 2.51b           |
| T3        | 0.38a           | 60.7c| 13.4d| 47.3b  | 3.52ab  | 7.12a | 2.99a           |
| T4        | 0.37a           | 62.4c| 18.8a| 43.5b  | 2.32c   | 7.11a | 2.31b           |
| CK        | 0.24d           | 72.9a| 17.4b| 55.5a  | 3.23d   | 5.57b | 2.25b           |

3.2. Effect of Maize Straw Composite Substrate on Morphological Indexes of Tomato Seedlings

Figure 1 shows that, in terms of plant height, the growth trend of each treatment was relatively consistent, with slow growth in the early stage and rapid growth in the later stage. Among them, CK peat grew more rapidly than other treatments, followed by T4 treatment. With the exception of treatment T3, there was no significant difference in plant height in the last observation for other treatments. There was no significant difference in leaf number of each treatment in each growth period. The growth trend of maximum root length and root volume was consistent in all treatments. In terms of root length, CK growth increased rapidly in the early stage of seedling but tended to be flat in the late stage. Among the other treatments, T4 grows the fastest in the early growth stage, and T1 is relatively flat with T2. However, T1 grows faster than T4 in the late growth stage, and the maximum root length in the late growth stage is not significantly different from the control. In terms of root volume, in the early stage of seedling, the root volume of CK compared with other treatments increased rapidly, which was significantly different from other treatments. In the later stage, T4 grows slowly, while the root volume of other treatments all grows rapidly.
3.3. Effects of Maize Straw Composite Substrate on Dry Matter Accumulation of Tomato Seedlings

As can be seen from Figure 2, in terms of shoot dry weight, CK grew rapidly in the early stage, and at 27, 32 and 37d after sowing, it was significantly different from other treatments. However, in 42d after sowing, the growth was relatively slow. Seedlings treated with T4 grew slowly in the early stage, but grew most rapidly in the later stage. In the last observation, there was no difference with the control.

The overall trend of dry weight of root and aboveground parts was similar. CK grows rapidly in the early stage but slowly in the late stage, while T4 grows slowly in the early stage but rapidly in the late stage.

The dry matter accumulation of whole plant, shoot and root of tomato seedlings showed a relatively consistent trend. At 22 d after sowing, T4 was superior to other treatments, but not significantly different from other treatments. During the period from 22d to 37d after sowing, CK grow rapidly in the control group, while the growth in the other treatments was flat. During the period from 37d to 42d after sowing, CK growth in the control group slowed down, but increased rapidly in other treatments, among which T4 grow most rapidly, and there was no significant difference between T4 and CK in the last observation.
3.4. Comparison of Tomato Seedling Morphological Indexes of Tomato Seedlings in Maize Straw Compound Matrix 42 days after Sowing and 37 days after Sowing with Peat

It can be seen from Table 2 that the number of leaves and root volume treated with corn straw composite matrix showed no difference between 42d and 37d after sowing with peat. In terms of plant height, each treatment of maize straw composite matrix was higher than that of peat treatment, among which T4 was the largest and reached a very significant level with peat treatment. The root lengths of T2, T3 and T4 were not significantly different from those of the control group. There was no significant difference between the abovementioned dry weight and peat in T4 treatment, and other treatments were lower than control peat treatment. There was no significant difference in root dry weight between T4 treatment and control peat, while there was significant difference between T4 treatment and control peat. There was no significant difference in dry matter accumulation between the whole plant treated T4 and the control group.

Table 2. Comparison of maize straw complex substrate on morphologic characters of tomato seedling after sowing 42 days with peat after sowing 37 days.

| Treatment | Plant height/cm | Number of blades/piece | Root length/cm | Root volume/mL | Shoot dry weight/g | Root dry weight/g | Dry weight of plant/g |
|-----------|----------------|------------------------|----------------|----------------|-------------------|------------------|---------------------|
| T1        | 20.00a         | 5.3a                   | 17.52b         | 1.5a           | 0.4265c          | 0.0730b          | 0.4995b             |
| T2        | 21.22a         | 5.4a                   | 15.90a         | 1.6a           | 0.5006b          | 0.0844ab         | 0.5850b             |
| T3        | 17.80b         | 5.2a                   | 16.00a         | 1.5a           | 0.3086d          | 0.0558c          | 0.3620c             |
| T4        | 21.72a         | 5.4a                   | 16.04a         | 1.3a           | 0.6604a          | 0.0978a          | 0.7582a             |
| CK        | 17.75b         | 5.4a                   | 15.99a         | 1.4a           | 0.7016a          | 0.0976a          | 0.7992a             |

3.5. Effect of Maize Straw Compound Substrate on Physiological Indexes of Tomato Seedlings

It can be seen from Table 3 that at 40 days after sowing, the chlorophyll content of each treatment ranged from 1.25 mg·g-1 to 1.47 mg·g-1, and there was no significant difference among each treatment. In terms of chlorophyll a/ B, each treatment was between 3.2 and 3.68, and there was no significant difference in analysis of variance among treatments. In terms of root activity, CK was the highest in comparison, Followed by T3 and T4, and the lowest in T1 and T2. However, variance analysis showed
that there was no significant difference between the two treatments.

### Table 3. Effect of maize straw complex substrate on physiology properties of tomato seedling.

| Treatment | CC/mg·g⁻¹ | chl a/b   | RSV/mg·(g·h)⁻¹ |
|-----------|-----------|-----------|-----------------|
| T1        | 1.40a     | 3.20a     | 0.59a           |
| T2        | 1.42a     | 3.26a     | 0.59a           |
| T3        | 1.25a     | 3.68a     | 0.69a           |
| T4        | 1.32a     | 3.55a     | 0.68a           |
| CK        | 1.47a     | 3.42a     | 0.71a           |

### 4. Conclusion and Discussion

It can be seen from the results of this test that the tomato seedlings treated with T4, i.e., the mixed matrix with vermiculite volume ratio of 1:1, are better than those treated with other corn stalk fermentation matrix. The seedling period of maize straw fermentation matrix is longer than that of peat, so the seedling should be raised in advance.

The bulk density of the standard solid matrix should be around 0.1 ~ 0.8 g cm⁻³, the total porosity should be around 60%, the pore size ratio should be around 0.5, the chemical properties should be stable (it is not easy to decompose harmful substances), the pH should be close to neutral, and no toxic substances such as phenols exist. According to this standard, the physical shape of each treatment is within this range. However, the base pH of maize straw fermentation was metaphony, and the suitable pH of tomato growth process was 6 ~ 7. In the mixing with vermiculite, the problem of base pH was not effectively solved. It can be used in future tests to increase sulfur and other substances, reduce pH value, or by mixing with other substances. In the ratio of vermiculite to vermiculite, each treatment can effectively reduce the EC value of maize straw fermentation matrix and meet the needs of plants.

In this study, maize straw fermentation substrates with vermiculite mixed with various treatments in the early stage of the growth was slower, compared with the controlled plant, on root length, dry weight and dry weight of underground growth was very slow, speculated that the reason may be that the EC value is high, or alkaline pH, or there are inhibitory substances, such as phenolics, but in the later growth rapidly. From maize straw compound matrix of 42 days after seeding and peat 37 days after planting comparison results of tomato seedling morphological index, T4 treatment, namely maize straw fermentation matrix and the processing of vermiculite volume ratio 1:1, in observation of the indicators, plant height, leaf number, root length, root volume, dry weight, root dry weight on the ground, and all the indexes of plant dry matter accumulation, no significant difference compared with CK. Therefore, it is suggested that in production practice, if maize straw fermentation matrix is used for seedling raising, it can be mixed with vermiculite 1:1, and seeded 3 ~ 5 days in advance than peat seedling raising, so as to achieve the seedling raising effect of peat matrix.

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