Effect of Spent Mushroom Substrate on Physical and Chemical Properties and Enzymic Activity of Rice

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Abstract In order to explore the substitution substrate for rice seedling on upland fields, this paper uses spent mushroom substrate to study the physical and chemical properties of substrate, enzymic activity and number of tillers during the cultivation of rice seedling on upland fields. The results show that at the three stages of rice seedling cultivation (two-leaf stage, three-leaf stage, four-leaf stage), the content of organic matter and EC in spent mushroom substrate is higher than in the control soil, pH is within the range suitable for the growth of rice, and other nutrients (total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus) are slightly different in different periods; except phosphatase, there are significant differences in urease, catalase and sucrase between spent mushroom substrate and the control soil; the number of tillers under spent mushroom substrate is larger than under the control.

Key words Spent mushroom substrate, Rice, Physical and chemical indicators, Enzymic activity

1 Introduction

Rice is one of the main food crops in the world, and its total yield accounts for about 30% of total global crop yield[1]. In 2013, the total rice yield in Jilin Province reached nearly 727000 ha[2]. Jilin's rice seedlings are cultivated on upland fields, and there is a need to dig a lot of dry farmland topsoil each year as seedbed soil, resulting in the loss of topsoil, ecological destruction and other issues. Therefore, in agricultural production, it is extremely important to develop new seedlings in agricultural production. China is a major producer of edible fungi whose output accounts for more than 70% of total world edible fungus production. Yanbian Korean Autonomous Prefecture is the main growing area of edible fungus in Jilin Province[3-4]. According to statistics, the production capacity of black edible fungus reached 1.38 billion bags in 2014, but with the continuous expansion of the capacity, spent mushroom substrate treatment poses enormous pressure on producers and brings a great damage to environment. A number of studies show that spent mushroom substrate contains rich elements such as organic matter, nitrogen, phosphorus and potassium, and has strong ability to retain water and nutrients[5-7]. Currently, spent mushroom substrate replaces turfy soil as the soilless culture substrate to be used for the production of vegetables and flowers, and it has made great progress[8-10], but there are few studies of spent mushroom substrate as rice cultivation substrate. Therefore, we substitute spent mushroom substrate for rice seedling substrate under dryland nursery, and study the rice physical and chemical properties and soil enzymic activity changes in the process of cultivating rice seedling on upland fields, in order to provide a theoretical basis for the rice seedling production on upland fields.

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2 Materials and methods

2.1 Materials The crop material for experiment is Songjing 10, and the substrate material is spent black fungus substrate provided by Institute of Edible Fungi of Yanbian Academy of Agricultural Sciences.

2.2 Experimental method It is based on the method of reference[11].

2.3 Determination of soil physical and chemical indicators Based on 5:1 ratio of water and soil, 50 ml water is added to 10 g soil and is kept still for 30 min after being shaken for 10 min, and soil pH and EC are determined with pH meter and conductivity analyzer. Soil available nitrogen is determined using UV spectrophotometry[12]; soil available phosphorus is determined using sodium bicarbonate leaching-colorimetry[12]; soil available potassium is determined using ammonium acetate extraction-flame photometry[12]; soil total phosphorus is determined using molten sodium hydroxide-Mo-Sb colorimetry[12]; soil total potassium is determined using molten sodium hydroxide-flame photometry[12]; soil total nitrogen is determined using Kjeldahl[12]; soil organic matter content is determined using loss on ignition method.

2.4 Determination of soil enzyme activity Soil urease is determined using indophenol colorimetry[13-14]; soil alkaline phosphatase is determined using disodium phenyl phosphate colorimetry[13-14]; sucrase is determined using 3, 5-dinitrosalicylic acid colorimetry[13-14]; catalase is determined using potassium permanganate titration[13-14].

2.5 Determination of the number of tillers It is performed based on the method of reference[15].

2.6 Data analysis Spss 15.0 is used for statistical analysis.

3 Results and analysis

3.1 Physical and chemical properties of substrate at the two-leaf stage of rice seedlings The nutrients needed by rice seedlings at two-leaf stage are mostly from rice endosperm. Only a small portion of nutrients are supplied by substrate[16]. From Table 1, it can be found that total nitrogen, organic matter, available phosphorus and EC content in spent mushroom substrate is 3.63 g/kg, 52.67 g/kg and 697 μS/cm more than in the control, respectively, indicating that spent mushroom substrate can increase the effectiveness of seedbed substrate nutrient. After adjusting the acid, it can be seen that substrate pH is 5.87 and soil pH is 5.16 after the rice planting, and pH value is within the range suitable for the growth of rice.

Table 1 Physical and chemical properties of substrate at the two-leaf stage of rice seedlings

Treatment	Available nitrogen mg/kg	Total nitrogen g/kg	Organic matter g/kg	Available phosphorus mg/kg	Total phosphorus g/kg	Available potassium mg/kg	Total potassium g/kg	pH	EC μS/cm
Spent mushroom substrate	20.65	5.26	89.213	17.65	0.46	191	16.38	5.87	835.0
Soil	24.67	1.63	36.548	11.96	0.61	345	15.86	5.16	138.0

3.2 Physical and chemical properties of substrate at the three-leaf stage of rice seedlings After the three-leaf stage, the seedlings enter into the autotrophic growth phase, and the potassium is very important to rice seedling root growth. Table 2 shows that the content of total potassium in spent mushroom substrate is 11% higher than in soil, while the content of available potassium in soil is 92.4% higher than in spent mushroom substrate. The content of organic matter and EC in spent mushroom substrate is 52.63% and 73.12% higher than in soil, respectively. pH value is within the range suitable for the growth of rice.

Table 2 Physical and chemical properties of substrate at the three-leaf stage of rice seedlings

Treatment	Available nitrogen mg/kg	Total nitrogen g/kg	Organic matter g/kg	Available phosphorus mg/kg	Total phosphorus g/kg	Available potassium mg/kg	Total potassium g/kg	pH	EC μS/cm
Spent mushroom substrate	23.60	5.24	86.14	24.26	0.44	186	19.50	5.80	532.0
Soil	28.34	1.79	40.80	12.44	0.51	358	17.24	5.20	143.0

3.3 Physical and chemical properties of substrate at the four-leaf stage of rice seedlings When rice seedlings enter into the four-leaf stage, the seedlings start to grow independently, so it begins to enter into the transplanting period. The nutrients in substrate directly affect the rooting and reviving time of rice seedlings. From Table 3, it is found that the content of available nitrogen, total nitrogen, organic matter, total potassium and EC in spent mushroom substrate is 10.02%, 66.58%, 46.64%, 17.78% and 67.93% higher than in soil, respectively. Substrate pH is within the range suitable for the growth of rice.

Table 3 Physical and chemical properties of substrate at the four-leaf stage of rice seedlings

Treatment	Available nitrogen mg/kg	Total nitrogen g/kg	Organic matter g/kg	Available phosphorus mg/kg	Total phosphorus g/kg	Available potassium mg/kg	Total potassium g/kg	pH	EC μS/cm
Spent mushroom substrate	24.34	3.86	69.84	19.38	0.37	198	18.00	5.85	469.0
Soil	21.90	1.29	37.26	19.95	0.46	377	14.80	5.17	150.4

3.4 Activity of related enzymes in spent mushroom substrate

3.4.1 Activity of phosphatase. Phosphatase is an enzyme that catalyzes mineralization of soil organic phosphorus compound, and its activity directly affects the decomposition, transformation and bioavailability of organic phosphorus in soils. It is an important indicator to evaluate soil phosphorus transformation[17]. Fig. 1 shows that there is no difference in phosphatase activity between spent mushroom substrate and soil, and the phosphatase activity of soil is 0.73 mg/g·d^{-1} higher than that of spent mushroom substrate, indicating that the phosphorus conversion capacity of spent mushroom substrate is weaker than that of soil.

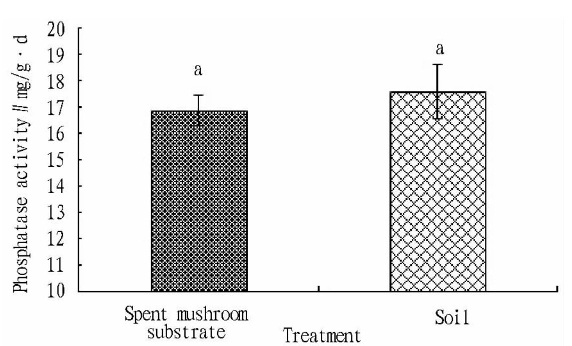

Fig. 1 Phosphatase activity of spent mushroom substrate and soil for rice seedlings

3.4.2 Activity of sucrase. Sucrase can hydrolyze sucrose to produce glucose and fructose, and promote sucrose decomposition. It is a key enzyme in the conversion and cycle of carbon[18]. As can be seen in Fig. 2, there is a significant difference in sucrase activity between spent mushroom substrate and soil, and the sucrase activity of spent mushroom substrate is 57.13% higher than that of soil, indicating that the spent mushroom substrate is more conducive to carbon conversion, which can be also confirmed by the organic matter in paddy soil at different stages.

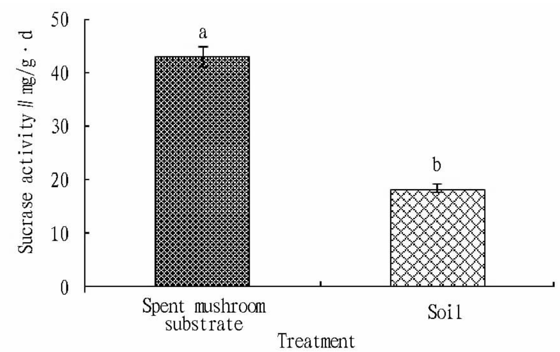

Fig. 2 Sucrase activity of spent mushroom substrate and soil for rice seedlings

3.4.3 Activity of catalase. Catalase is an important oxidoreductase in plants, and it can clear the hydrogen peroxide produced by plants through respiratory metabolism or photosynthesis, as well as excessive reactive oxygen in plants, to maintain the balance of active oxygen metabolism[19]. Fig. 3 shows that there is a significant difference in catalase activity between spent mushroom substrate and soil, and the catalase activity of spent mushroom substrate is 6.56% higher than that of soil.

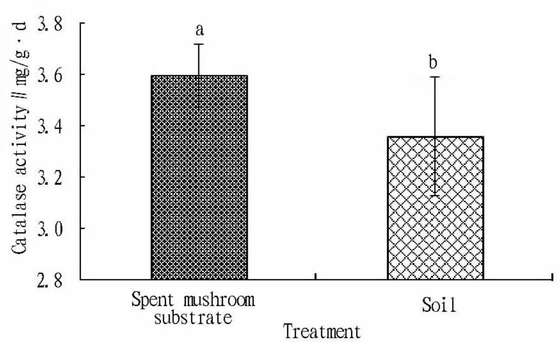

Fig. 3 Catalase activity of spent mushroom substrate and soil for rice seedlings

3.4.4 Activity of urease. Urease can hydrolyze urea into ammonia and carbon dioxide, and it is an important enzyme for nitrogen transformation[20]. As shown in Fig. 4, there is a significant difference in urease activity between spent mushroom substrate and soil, and the urease activity of spent mushroom substrate is 31.43% higher than that of soil, indicating that spent mushroom substrate is more conducive to improving the nitrogen supply for rice growth, which can be also confirmed by the physical and chemical properties of paddy soil at different seedling stages.

3.5 Effect of different substrate on the tiller number after transplanting of rice Fig. 5 shows that there is a significant difference in rice tiller number between spent mushroom substrate

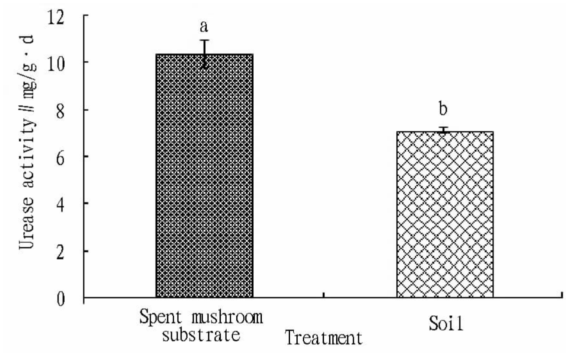

Fig. 4 Urease activity of spent mushroom substrate and soil for rice seedlings

and soil substrate, and the tiller number under spent mushroom substrate is 14.02% larger than under soil substrate, indicating that spent mushroom substrate can make rice seedlings have stronger tillering capability, and is conducive to the growth of seedlings. In the experiment, we also find that the rice seedling roots are more developed under spent mushroom substrate, reducing the recovering time after transplanting seedlings.

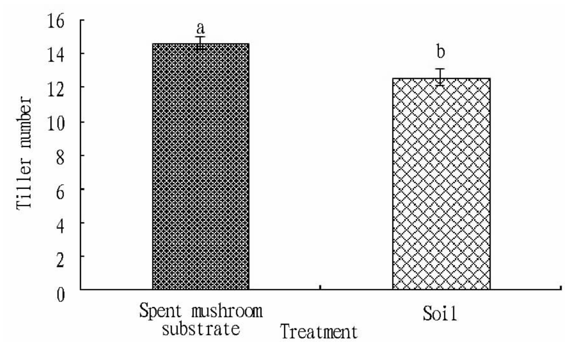

Fig. 5 Effect of spent mushroom substrate and soil on rice tiller number

4 Conclusions

This paper uses spent mushroom substrate to study the physical and chemical properties of substrate, enzymic activity and number of tillers during the cultivation of rice seedling on upland fields. The results show that at the three stages of rice seedling cultivation (two-leaf stage, three-leaf stage, four-leaf stage), the content of organic matter and EC in spent mushroom substrate is higher than in the control soil, pH is within the range suitable for the growth of rice, and other nutrients (total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus) are slightly different in different periods; except phosphatase, there are significant differences in urease, catalase and sucrase between spent mushroom substrate and the control soil; the number of tillers under spent mushroom substrate is significantly larger than under the control.

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field, dry land and garden plot is significantly higher than that of other land types. Most of non-point source pollution for seven years is produced by paddy field and dry land, accounting for 66% and 83% of non-point source TN, TP pollution, respectively. There is a large difference in spatial distribution of non-point source pollution, and Guanqiao, Longmen, Changkeng and Shangqing in Anxi County and Dapu in Yongchun County, have serious non-point source pollution, so they are the key towns to control non-point source pollution.

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