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Effect of Banana Stalk Organic Fertilizer on the Growth of Chinese Cabbage

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Abstract In order to solve the problem of waste disposal after banana harvest, we use banana stalk to produce banana stalk organic fertilizer, through a plot experiment. We compare the influence of normal organic fertilizer (Wanlubao) and banana stalk organic fertilizer as base fertilizers on Chinese cabbage growth, and evaluate the economic benefits of banana stalk organic fertilizer. The results show that organic fertilizer has little effect on water content and nutrient content of Chinese cabbage, but has significant effect on plant height and leaf width. Using organic fertilizer can increase the production of Chinese cabbage by 22.50% –43.10%. With 6750 kg/ha normal organic fertilizer, Chinese cabbage gets the highest yield, which reaches 30135 kg/ha, followed by the treatment of 6750 kg/ha stalk organic fertilizer. At farmers' conventional fertilization level (4500 kg/ha), stalk organic fertilizer can increase the yield by more than 3.50% in comparison with the normal organic fertilizer, and the economic benefit increases by 1800 yuan/ha. As a kind of banana waste cycling product, banana stalk organic fertilizer is of low cost and good effect, and can be used instead of normal organic fertilizer.

Key words Banana stalk organic fertilizer, Commercial organic fertilizer, Chinese cabbage, Benefit evaluation

1 Introduction

The banana is a world-famous tropical and subtropical edible fruit, botanically a berry, produced by several kinds of large herbaceous flowering plants in the genus Musa. Owing to unique flavor and plenty of nutrients, there is a huge demand for bananas, and it maintains the second to the third position in the world's fresh fruit trade. It has high nutritional and economic value[1-4]. Hainan's unique natural conditions promote the rapid development of banana planting, and the banana industry occupies a very important position in Hainan's agricultural economy[5-7]. However, the large-scale cultivation of bananas also brings a series of practical problems, and the problem of banana stalk treatment and resource utilization after harvesting is always the focus and difficulty in study of banana cultivation and production. It is estimated that more than 1.5 million t of wastes were generated after banana was harvested in Hainan in 2014. Meanwhile, in several main banana producing areas at home, the banana garden is damaged by the natural disasters during the typhoon season every year, and there is a large number of banana wastes produced. How to reasonably dispose of the huge underutilized banana wastes is an issue to be urgently addressed in banana production areas[8-10]. Banana stalk is bulky and wet, and the previous study reported the use of banana stalk to produce cotton cloth and textile materials[11-12], but the preparation process is complicated, and the industrialization cost is high. Banana stalk contains large amounts of cellulose and hemicellulose, and is rich in N, P, K and other nutrients[13]. With banana stalk as raw material, the finished organic fertilizer can be produced, with broad market prospects and high application value[14]. Based on this, with the thoroughly decomposed banana stalk as raw material, the finished banana stalk organic fertilizer is produced through the fertilizer preparation process of grinding, dehydration, composting, mixing, granulating, sieving and packaging, and the banana stalk is used as base fertilizer to study the impact of banana stalk fertilizer on the growth of Chinese cabbage, in order to provide a reference for the resource-based utilization of banana waste.

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2 Materials and methods

2.1 Experimental design The plot experiment method is adopted to study the effect of banana stalk organic fertilizer on Chinese cabbage growth. The experiment was carried out in the experimental base of Yongfa Town, Chengmai County, Hainan Province (19°45′14.50"N, 110°11′59.06"E). The experimental plot is located in the greenhouse of Hainan Academy of Agricultural Sciences, and the greenhouse has a steel frame shed structure, with specifications of 30 m × 20 m. It has sun-shading and rainproof effect, and the sprinkling irrigation system is used for irrigation. The experiment has five treatments (4500 kg/ha banana stalk organic fertilizer; 6750 kg/ha banana stalk organic fertilizer; 4500 kg/ha conventional organic fertilizer (Wanlubao); 6750 kg/ha conventional organic fertilizer (Wanlubao); non-fertilization), and three parallel groups (Table 1). The experimental time is from May to July 2015. The previous crop in greenhouse is leaf vegetable, and after the harvest and natural idling for 15 days, the plowing is started. The temperature in greenhouse is maintained at 25-40℃, and except the difference in application mode of base fertilizer, the remaining water and fertilizer management modes are

consistent. The soil background values of greenhouse are shown in Table 2, and "Kangre 5" Chinese cabbage is selected as the variety for experiment. It is sown 12 days after the application of base fertilizer, transplanted to definitive place 25 days after the application, and harvested 54 days after the application. The growing season of Chinese cabbage lasts for 43 days.

Table 1 Experimental design of different organic fertilizer treatments

Treatment	Experimental design (base fertilizer)	Application rate//kg/ha
1	Banana stalk organic fertilizer	4500
2	Banana stalk organic fertilizer	6750
3	Conventional organic fertilizer (Wanlubao)	4500
4	Conventional organic fertilizer (Wanlubao)	6750
5	Non-fertilization (control)	0

Table 2 Soil physicochemical properties

Testing indicator	TN %	TP %	TK %	Alkali-hydrolyzable nitrogen mg/kg	Available P//mg/kg	Available K//mg/kg	Organic matter g/kg	pH
Original soil	0.122	0.135	2.37	204	126.0	417	19.7	5.8

2.2 Sample collection and determination Under each treatment, 240 seeds are sown and 120 plants are transplanted to definitive place, respectively, with planting specifications of 0.25 cm ×0.25 cm. The budding rate is measured five days after the sowing of Chinese cabbage; the plant height and leaf width are measured after slow seedling; the nutrient content and aboveground biomass during the growth and harvest periods are measured, respectively; the yield is measured and the economic benefit is evaluated during the harvesting period. The budding rate is measured using metric method; plant height and leaf width are determined using the measurement method; SPAD value is read using portable SPAD meter (SPAD-502). The plant is carefully taken along with the roots when collecting the plant samples. After removing the soil on the roots, rinsing the plant with water, washing the plant with distilled water and using absorbent paper for drying, scissors are used to separate the aboveground part of plant from roots, and the fresh weight of the aboveground part is measured. The fresh plant is deactivated at 105℃ for 30 min, dried to constant weight at 60℃, and placed in bottle after being crushed for testing. Multi-point sampling method is used to collect soil samples, and after natural drying, they are ground through 2-mm sieve. Plant samples are digested with H_2SO_4-H_2O_2; nitrogen is measured by azotometer; potassium is measured by flame photometer; phosphorus is measured by molybdenum blue colorimetric method; soil samples are analyzed and tested based on the conventional analysis methods for soil physical and chemical properties[15-16].

2.3 Data analysis Excel 2010 is used for statistical analysis of all experimental data, and DPS 7.05 is used for significance analysis.

3 Results and analysis

3.1 Effect of different base fertilizer treatments on the budding rate of Chinese cabbage As can be seen from Fig. 1, the application rate of base fertilizer has no significant effect on the budding rate of Chinese cabbage, and the budding rate under all treatments is 65.50%-72.50%. The budding rate is highest under Treatment 2, reaching 72.50%, while the budding rate is lowest under Treatment 3, reaching 65.50%, but there is no significant difference between treatments. The budding rate under CK is 71.00%, and the highest rate is not more than 80.00%, mainly because the sowing occurs in the summer when the temperature is too high and water evaporates quickly. At the same time, the unusual droughts and hot weather lead to massive power shortage and power rationing, which to some extent affects the cooling in greenhouse and normal operation of irrigation system, thereby resulting in low budding rate.

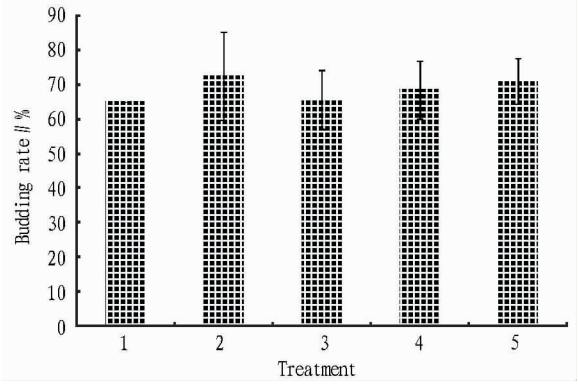

Fig. 1 The budding rate of Chinese cabbage under different base fertilizer treatments

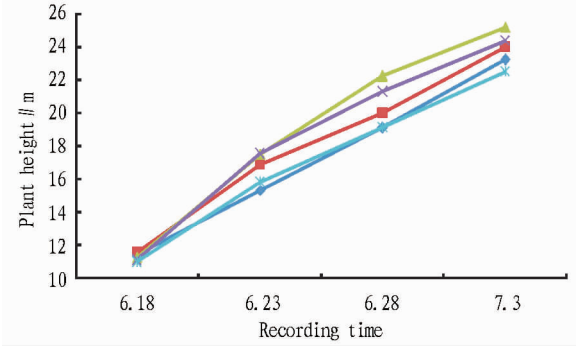

Fig. 2 Change in plant height of Chinese cabbage under different base fertilizer treatments

3.2 Plant height variation of Chinese cabbage under different base fertilizer treatments Organic fertilizer can promote plant growth, improve soil physical and chemical properties, and improve soil fertility and water retention capacity. As can be seen

from Fig. 2, with the growth of Chinese cabbage, the plant height differences are significant, and the Chinese cabbage under organic fertilizer treatments grows better than under the control, but the application rate of organic fertilizer has little impact on the plant height of Chinese cabbage. Compared with the stalk organic fertilizer, the plant height of Chinese cabbage under the normal organic fertilizer treatment is better, and within 15 days after reestablishment, the average plant height under Treatment 3 reaches 25.22 cm, an increase of 13.96 cm; the plant height under Treatment 4 reaches 24.41 cm, an average increase of 13.30 cm; the plant height under Treatment 2 and 1 increases by 12.48 cm and 11.83 cm, respectively; the plant height under the control is only 22.54 cm, an increase of 11.55 cm.

3.3 Change in Chinese cabbage leaf width under different base fertilizer treatments Leaf is the main edible part of Chinese cabbage, and functional leaf width is an important indicator for the Chinese cabbage growth. Its growth has a direct impact on the yield and quality of Chinese cabbage. The experimental results (Table 3) show that the change in functional leaf width of Chinese cabbage shares the similar regularities with the change in its plant height; the growth rate of leaf width under various organic fertilizer treatments is higher than under the control; the leaf width under the normal organic fertilizer is slightly better than under the stalk organic fertilizer. 15 days after being transplanted to definitive place, the leaf width under Treatment 4 reaches 15.98 cm, an increase of 9.59 cm; the leaf width increases by 9.47 cm under Treatment 2; the leaf width increases by 9.23 cm and 9.20 cm under Treatment 1 and 3, respectively; the leaf width under the control is only 14.76 cm, an increase of only 8.54 cm.

Table 3 Change in Chinese cabbage leaf width under different base fertilizer treatments Unit: cm

No.	Treatment	June 18	June 23	June 28	July 3
1	Stalk fertilizer 4500 kg	6.15 ±0.73	9.91 ±0.56	12.90 ±0.85	15.39 ±1.14
2	Stalk fertilizer 6750 kg	6.37 ±0.34	9.98 ±1.12	12.92 ±0.96	15.85 ±1.74
3	Wanlubao fertilizer 4500 kg	6.47 ±0.51	9.91 ±0.99	13.03 ±0.90	15.67 ±0.93
4	Wanlubao fertilizer 6750 kg	6.38 ±0.40	10.08 ±0.76	12.94 ±0.50	15.98 ±1.29
5	Non-fertilization (CK)	6.22 ±0.76	9.61 ±0.70	12.03 ±0.98	14.76 ±1.30

3.4 Change in Chinese cabbage moisture and fresh weight under different base fertilizer treatments Chinese cabbage has a short growth cycle and grows fast. The fresh weight of aboveground part of Chinese cabbage was measured in the growth period (June 26) and maturity period (July 7), respectively. The results (Table 4) show that the Chinese cabbage moisture is 91.88% – 94.13%, there is a small difference between the treatments, and the Chinese cabbage moisture in the growth period is slightly higher than in the maturity period. Within 10 days from the growth period to maturity period (Fig. 3), the average fresh weight of Chinese cabbage increases by 182.57 g per plant. The fresh weight of Chinese cabbage in the maturity period is in the descending order of Treatment 4 > Treatment 2 > Treatment 1 > Treatment 3 > Treatment 5. The fresh weight increases most obviously under Treatment 4, and the fresh weight during the harvest period reaches 235.30 g per plant, an average increase of 211.36 g per plant. For the treatments with a large amount of base fertilizer, the Chinese cabbage yield is also high. Under the conditions of applying 6750 kg/ha base fertilizer, the fresh weight of Chinese cabbage under Treatment 2 is smaller than under Treatment 4, but under the conditions of applying 4500 kg/ha base fertilizer, the fresh weight of Chinese cabbage under Treatment 1 is greater than under Treatment 3. Under the control, the fresh weight of Chinese cabbage during the harvest period is smallest among the treatments, only reaching 164.44 g per plant, with an average increase of 140.46 g per plant.

Table 4 Change in Chinese cabbage moisture under different base fertilizer treatments Unit: %

No.	Treatment	Growth period	Harvest period
1	Stalk fertilizer 4500 kg	93.15 ±6.14	93.23 ±3.34
2	Stalk fertilizer 6750 kg	94.13 ±2.29	92.83 ±3.21
3	Wanlubao fertilizer 4500 kg	92.73 ±3.12	91.88 ±1.23
4	Wanlubao fertilizer 6750 kg	92.11 ±2.31	92.81 ±3.45
5	Non-fertilization (CK)	93.61 ±3.01	93.29 ±2.45

3.5 Chinese cabbage nutrient accumulation under different base fertilizer treatments The application rate of base fertilizer is different under various treatments, but different treatments have little effect on the Chinese cabbage nutrient accumulation, and the total nitrogen amount under various treatments in the harvest period is slightly smaller than in the growth period while the total phosphorus and total potassium show no obvious regularity. During the growth and harvest periods, the plant's potassium content is high, which may be related to the high background values of total potassium and available potassium in the test soil. The experimental plot is in the greenhouse mainly for experimental research of fertilizer efficiency, and the total and available nutrient content in soil is high, resulting in the accumulation of a large amount of potassium in Chinese cabbage.

3.6 Economic benefit analysis The Chinese cabbage production inputs include seeds, labor, water and electricity, fertilizers, infrastructure, etc. According to the total cost of seeds, labor and chemical fertilizers (9000 yuan/ha), banana stalk organic fertiliz-

er cost (1.2 yuan/kg) and ordinary organic fertilizer cost (1 yuan/kg), the input cost and benefit under various treatments can be shown in Table 6. The purchase price of Chinese cabbage in Hainan is about 3 yuan/kg, the yield reaches 21060-30135 kg/ha under different treatments, and income reaches 63180-90405 yuan. Under the application rate of normal organic fertilizer at 6750 kg/ha, the economic benefit of Chinese cabbage is highest, and the net profit amounts to 74655 yuan/ha; under the application rate of stalk organic fertilizer at 4500, 6750 kg/ha, the economic benefit of Chinese cabbage also reaches 65715, 71430 yuan/ha, higher than under the treatment of 4500 kg/ha normal organic fertilizer and the control. The greater the amount of organic fertilizer input, the higher the yield. The yield under the stalk organic fertilizer treatments is slightly lower than under the treatment of 6750 kg/ha normal organic fertilizer, but higher than under the treatment of 4500 kg/ha normal organic fertilizer. Due to local farmer's fertilization habit, the application rate of organic fertilizer during field planting in Hainan Province is generally lower than 4500 kg/ha, and without realizing large-scale production, the production cost is only 0.2 yuan/kg higher than under the ordinary organic fertilizer treatment. In this study, the economic benefit under the treatments of stalk organic fertilizer is only slightly lower than the treatment of 6750 kg/ha normal organic fertilizer, but higher than the treatment of 4500 kg/ha normal organic fertilizer. From resources, environmental protection, waste utilization and actual production, it is more worthwhile than commercial organic fertilizer.

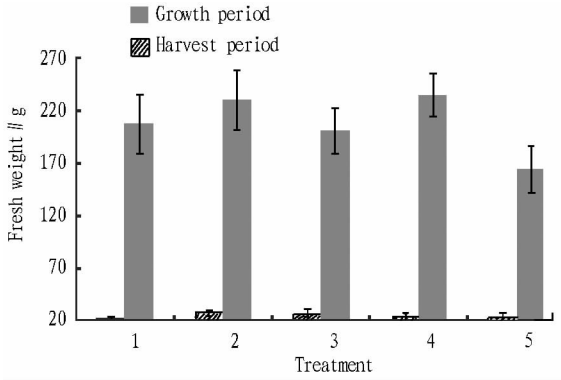

Fig. 3 Change in the fresh weight of Chinese cabbage under different base fertilizer treatments

Table 5 Chinese cabbage nutrient accumulation during the growth and harvest periods under different base fertilizer treatments Unit: %

No.	Treatment	Total nitrogen		Total phosphorus		Total potassium	
		Growth period	Harvest period	Growth period	Harvest period	Growth period	Harvest period
1	Stalk fertilizer 4500 kg	4.52	4.56	0.49	0.47	7.34	8.25
2	Stalk fertilizer 6750 kg	4.52	4.31	0.52	0.46	8.14	7.43
3	Wanlubao fertilizer 4500 kg	4.63	4.01	0.47	0.47	7.2	7.94
4	Wanlubao fertilizer 6750 kg	4.26	3.95	0.44	0.54	6.88	8.36
5	Non-fertilization (CK)	4.49	4.32	0.50	0.50	7.84	7.72

Table 6 Economic benefit analysis

No.	Treatment	Fresh weight per plant // g	Yield kg/ha	Input yuan/ha	Income yuan/ha	Net profit yuan/ha
1	Stalk fertilizer 4500 kg	209	26700	14400	80115	65715
2	Stalk fertilizer 6750 kg	230	29505	17100	88530	71430
3	Wanlubao fertilizer 4500 kg	201	25800	13500	77400	63900
4	Wanlubao fertilizer 6750 kg	235	30135	15750	90405	74655
5	Non-fertilization (CK)	164	21060	9000	63180	54180

4 Conclusions and discussions

In this study, we choose the banana waste with enormous utilization potential as material for organic fertilizer preparation, and make a comparative study on the Chinese cabbage growth under three treatments (non-fertilization; applying banana stalk organic fertilizer; applying ordinary commercial organic fertilizer). We compare the influence of normal organic fertilizer (Wanlubao) and banana stalk organic fertilizer as base fertilizers on Chinese cabbage growth, and evaluate the economic benefits of banana stalk organic fertilizer. The results show that organic fertilizer has little effect on water content and nutrient content of Chinese cabbage, but has significant effect on plant height and leaf width. As the base fertilizer, organic fertilizer can not only provide the necessary nutrients for plants, but also generate carbon dioxide, and act as the raw material for photosynthesis[22-24]. Meanwhile, organic fertilizer forms aggregates in the decomposition process, and these decomposition products have great specific heat capacity but small thermal conductivity, with strong temperature control performance, and they can reduce soil bulk density, improve aeration of the soil, and improve water and fertilizer retention capacity of the soil[25]. Using organic fertilizer can increase the production of Chinese cabbage by 22.50%-43.10%. With 6750 kg/ha normal organic fertilizer, Chinese cabbage gets the highest yield, which reaches 30135 kg/ha, followed by the treatment of 6750 kg/ha stalk organic fertilizer. At farmers' conventional fertilization level (4500 kg/ha), stalk organic fertilizer can increase the yield by

more than 3.50% in comparison with the normal organic fertilizer, and the economic benefit increases by 1800 yuan/ha. There are many previous studies on banana waste resource-based utilization pathway and stacking conditions for the preparation of organic fertilizer, but few studies focus on the comparison of application effect of finished banana stalk fertilizer and ordinary commercial fertilizer[17-21]. The banana stalk fertilizer with small application scale has higher production cost and process requirements than ordinary commercial organic fertilizer, but in view of its application value and environment-friendliness, the banana stalk organic fertilizer has great market prospects and promotional value.

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