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Effect of Different Mechanical Processing Methods on Nitrogen Fixation Efficiency of Soybean Nodulation

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Abstract: In recent years, China's soybean planting area has been expanding continuously. However, soybean farming faces various challenges, one of which is how to improve nitrogen fixation efficiency. It is important to study the effect of different mechanical treatments on nitrogen fixation efficiency of soybean root nodules. The nitrogen fixation efficiency of soybean seed after milling and ultrasonic treatment was observed. The experimental results showed that the nitrogen fixation efficiency of soybean root nodules was significantly improved after mechanical treatment. Further analysis showed that mechanical treatment changed the shape and internal structure of soybean root nodules, increased the contact area between root nodules and air, and promoted the growth of nitrogen-fixing bacteria. It is concluded that mechanical treatment has an important effect on nitrogen fixation efficiency of soybean root nodules. The research results have important theoretical and practical significance for improving the nitrogen fixation efficiency of soybean, and provide scientific basis for the sustainable development of soybean industry.

Keywords: Soybean; Nodulation; Nitrogen Fixation; Mechanical Processing; Efficiency

1. Introduction

1.1 Overview of soybean nodulation

Soybean (Glycine max) is a major crop worldwide, and its planting area has been expanding in recent years [1][2][3]. Nitrogen fixation is an important process for soybean plants to obtain nitrogen, which is an essential nutrient for soybean growth and development [4]. This process is facilitated by a symbiotic relationship between soybean plants and nitrogen-fixing bacteria rhizobia, which form special structures called nodules on the roots of plants [5].

The formation of nodules is a complex process involving a series of molecular and physiological interactions between plants and rhizobia [6]. After recognizing specific signals produced by the rhizobia, the soybean plant begins to form infection lines that guide the rhizobia toward the root hairs. Once inside the root hairs, the rhizobia are internalized and transported to the developing root nodule primordium, where they differentiate into bacterioids and fix atmospheric nitrogen into ammonia, which the soybean plant can use to meet its nitrogen requirements [7].

The nodulation efficiency of soybean is a key factor affecting the overall nitrogen fixation efficiency of the plant [8]. Improving the nodulation process has been the focus of numerous studies aimed at improving the nitrogen fixation capacity of soybean crops and ultimately increasing yields.

1.2 Influence of mechanical processing on nitrogen fixation efficiency

Mechanical processing has been widely studied as a means to improve the nitrogen fixation efficiency of soybean plants. These methods include applying physical forces to soybean seeds, such as grinding or ultrasonic treatment, which can change the structure and characteristics of the seeds [9].

Grinding, or milling, is a commonly used machining method by which the seed coat is broken by grinding, exposing the internal contents, including nodular bacteria and seed nutrients, to the surrounding environment. The increased surface area generated by grinding can promote the contact between nodule bacteria and the air, and promote the growth and colonization of nodule bacteria [10].

Ultrasonic treatment is another machining method to study the nodulation effect of soybean. Ultrasonic waves produce high-frequency vibrations that can damage the cell wall of soybean seeds and promote the release of nodular bacteria. The increase of bacterial release can promote the colonization of rhizobia in root nodules and improve nitrogen fixation efficiency [11].

2. Test materials

Materials used in this study include soybean seeds, mechanical equipment for processing, and laboratory equipment for measurement and analysis.

The soybean seed was selected Zhoudou 12 cultivated by Zhoukou Academy of Agricultural Sciences. Zhoudou 12 is purple flower, gray hair, oval leaves, limited podding habit. The average growth period was 112 days, the plant height was 74.42 cm, the effective branches were 1.71, the effective pod number per plant was 32.08 and the kernel number per plant was 58.98. A hundred grains weigh 23.72 grams. Lodging resistance was better and the lodging resistance to Mosaic virus disease was moderate. The average crude protein content was 40.25% and crude fat content was 19.95%. The grain is nearly round, yellow, umbilical kidney shape, umbilical color light brown.

The mechanical treatment methods used in this study included grinding and ultrasonic treatment. The high speed grinding machine was used for grinding, and the grinding time and grinding intensity were determined. The ultrasonic treatment is carried out using an ultrasonic bath that exposes the soybean seeds to high-frequency sound waves of a specific duration.

3. Results and analysis

In this section, we will detail the data collection process for this study. The data collection process is designed to be comprehensive and accurate, ensuring the reliability of the results.

Firstly, 200 soybean seeds were randomly selected for experiment. The seeds were divided into four groups: control group, treatment group 1, treatment group 2, and treatment group 3. The 50 seeds in the control group were not subjected to any mechanical treatment, the 50 seeds in the treatment group 1 were ground, the 50 seeds in the treatment group 2 were ultrasonic, and the 50 seeds in the treatment group 3 were subjected to various mechanical treatments such as grinding and ultrasonic.

After mechanical treatment, soybean seeds are planted in different POTS filled with a standard soil mixture. The POTS were placed in a greenhouse under controlled environmental conditions, including temperature, light intensity and humidity. These plants are regularly watered and fertilized to ensure optimal growing conditions.

The data collection time was the whole growth cycle of soybean, during which all parameters were measured. These parameters include the number and size of nodule on the root system and the nodule's nitrogen fixation efficiency. Data collection was standardized to minimize experimental error.

Table 1 Measurement results of plants during the peak flowering period of Zhoudou 12

breed	Handling situation	Lateral root length(cm)	Number of lateral roots	Number of nodules per plant
Zhou Dou12	not have	12.3	18.1	24.5
	Processing group 1	14.5	19.5	33.9
	Processing group 2	14.1	19.2	33.4
	Processing group 3	15.5	20.4	35.6

As can be seen from Table 1, compared with untreated control, after mechanical treatment, the number and length of lateral roots of Zhoudou 12 increased significantly, and the number of nodule per plant increased significantly. The number and length of lateral roots and the number of rhizobia per plant were better in the combination of grinding and ultrasonic treatment than in the single treatment of grinding or ultrasound.

Table 2 Results of yield traits of Zhoudou 12

breed	Handling situation	Height (cm)	Number of main stem nodes (number)	Effective branching (number)	Effective number of pods per plant (number)	Number of grains per plant (number)	Single plant grain weight (g)	hundred grain weigh (g)
Zhou Dou12	not have	74.56	16.93	1.79	33.31	60.21	13.89	23.07
	Processing group 1	75.85	17.42	2.21	38.95	65.17	16.42	25.20
	Processing group 2	76.43	17.59	2.36	37.45	63.26	15.29	24.17
	Processing group 3	78.67	17.73	2.57	39.43	68.94	18.30	26.54

As can be seen from Table 2, compared with untreated control, Zhoudou 12 after mechanical treatment, its plant height, main stem node number, effective branching, effective pod number per plant, kernel number per plant, kernel weight per plant and 100 kernel weight were significantly increased. The plant height, number of main stem segments, effective branching, number of effective pods per plant, number of seeds per plant, weight of seeds per plant and weight of 100 seeds in the combination of grinding and ultrasonic treatment were better than those in the single treatment group.

4. Conclusions

The aim of this study was to investigate the effect of different mechanical treatment methods on nitrogen fixation efficiency of soybean root nodules. The nitrogen fixation efficiency of soybean root nodules was observed by grinding and ultrasonic treatment of soybean seeds. The experimental results showed that the nitrogen fixation efficiency of soybean root nodules was significantly improved after mechanical treatment.

Further analysis showed that the superposition of multiple mechanical treatments was more conducive to changing the shape and internal structure of soybean root nodules and increasing the contact area between root nodules and air. This change promoted the growth of nitrogen-fixing bacteria in the nodules and enhanced the nitrogen-fixing activity. In summary, the superposition of multiple mechanical treatments plays a crucial role in improving the nitrogen fixation efficiency of soybean root nodules.

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