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Effects of Rice Bran on Seed Germination and Seedling Growth of Rice

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Abstract
Aiming at the problem of rice bran promoting seed germination and seedling growth, rice bran was used as a substrate to explore its effects on rice seed germination and seedling growth, in order to provide a scientific basis for the promotion and application of rice bran recycling. Using rice bran and rice bran extract as substrates, and "Quanyou Xiang 88, Quanyou 1606, Quanyou 851" as experimental materials, three types of fertilization treatments were set up: Rice bran as basal fertilizer and rice bran extract soaking seeds are divided into three treatments: rice bran treatment (RT), rice bran solution treatment (RS), and conventional treatment (CT)., as well as three concentration gradients of basal fertilizer treatment with different concentrations of rice bran. Comparative analysis was conducted on the changes in germination indicators of rice seeds, agronomic traits of rice seedlings, root morphology indicators, and physiological indicators under different treatments to evaluate the fertilization effect and screen for appropriate fertilization concentrations and methods. The results indicate that rice bran treatment significantly shortens the seed germination process and improves sprouting efficiency in rice. Rice bran promotes seedling growth and optimizes physiological indicators. Rice bran extract and mixtures exhibit synergistic effects, enhancing resource utilization efficiency.

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Keywords: rice bran; rice seed germination; physiological parameters; seedling growth; growth-promoting effects

1. Introduction

As one of China's primary staple crops, rice holds a pivotal position in the country's agricultural production. According to statistical reports released by the National Food and Strategic Reserves Administration, China's total grain output in 2023 reached an impressive 697.46 million tons, with rice production accounting for 206.6 million tons approximately one-quarter of the total grain yield [1]. Notably, China's annual rice bran production exceeds 12 million tons, making it the most valuable by-product of rice processing. Rice bran consists of a mixture of rice germ, seed coat, aleurone layer, and a portion of the endosperm. Although it constitutes only 7%-11% of the total weight of brown rice [2], its nutritional value is remarkably high, containing up to two-thirds of the nutrients found in brown rice.

In rice cultivation, seed germination is a critical initial stage in the growth cycle, influenced by multiple factors [5]. Rice bran is rich in natural bioactive compounds, including proteins, polysaccharides, unsaturated fatty acids, dietary fiber, vitamins, antioxidants (such as γ-oryzanol, tocopherols, tocotrienols, and ferulic acid), and minerals (including K, Ca, Mg, and Fe) [6–8]. It also possesses a unique ratio of saturated, monounsaturated, and polyunsaturated fatty acids, along with functional components such as phenolic compounds and oryzanol [9]. These constituents have a certain growth-promoting effect on rice seed germination and hold potential applications in plant growth enhancement. However, the precise mechanisms by which rice bran influences seed germination remain incompletely understood [10–13].

Rice bran contains approximately 10% phytic acid, making it a significant source of this compound. Based on a series of studies by Li and Chen, it has been established that phytic acid plays a role in seed germination [14-17]. In this experiment, we selected rice seed varieties Quanyouxiang 88, Quanyou 1606, and Quanyou 851 as research subjects and applied multiple rice bran treatments. By examining germination rate, coleoptile emergence, root length, seed weight, phytic acid content, and other key indicators, we conducted an in-depth investigation into the effects of rice bran on rice seed germination and seedling growth. The findings aim to provide scientific support and a theoretical foundation for rice seed treatment technologies.

2. Materials and methods

2.1 Tested rice

In this experiment, rice bran collected from the previous autumn harvest was used as the test substrate. To ensure experimental accuracy, the rice bran was first air-dried indoors for 5-7 days, then crushed and sieved through a 100-mesh sieve to obtain the desired sample.

The tested rice varieties included Quanyouxiang 88, Quanyou 1606, and Quanyou 851, all of which are indica-type three-line hybrid rice cultivars. Specifically: Quanyouxiang 88: A late-season rice variety, Quanyou 1606: A medium-season rice variety, Quanyou 851: An early-season rice variety. All three cultivars are particularly well-suited for cultivation in the high-temperature and high-humidity environments of south of China.

2.2. Preparation of rice bran-based culture medium

Precisely weigh 200 grams of rice bran and place it in an autoclave for sterilization at 121°C for 30 minutes. Once cooled, divide the rice bran into pre-prepared storage bags, with each bag containing 10 grams, totaling 20 bags for subsequent use. Under sterile conditions, take 10 grams of rice bran and thoroughly mix it with 30 mL of sterile water to ensure homogeneity. The goal is to achieve proper moistening of the rice bran while maintaining a loose consistency and avoiding clumping, resulting in a 3:1 (water:rice bran) mixture. After preparing the initial mixture, adjust the ratios to 4:1 and 5:1, respectively. Then, transfer these mixtures with different ratios into pre-prepared culture media for subsequent experimental procedures.

2.3. Preparation of rice bran extract

Materials Required: Rice bran; Solvent: Water; Equipment: Blender, microwave oven, filter paper

Pretreatment (Enzyme Inactivation): Dry rice bran at high temperature (>80°C) to inactivate enzymes. Fractionation of Aleurone Layer: Mix pretreated rice bran with water at a different ratio (w/v) and stir thoroughly. Allow the mixture to settle for layer separation. The aleurone layer forms a distinct middle layer due to density differences. Isolate the aleurone layer using a filtration mesh. Extract Preparation (Microwave-Assisted Extraction): Mix the isolated aleurone layer with water at a 1:25 ratio (w/v). Heat in a microwave oven at high power (385W) for 20 minutes to rapidly disrupt cell walls. Filter the solution to obtain crude rice bran extract [18-19].

2.4. Treatment of rice seeds

For each different rice variety, we prepared 150 seeds, which were divided into 5 groups with 30 seeds per group. To ensure synchronized germination, a series of pretreatment steps were implemented. Seeds were placed in warm water (32°C) for 8 hours under constant temperature. After soaking, seeds were treated with a 0.1% potassium permanganate ($KMnO_4$) solution for 15–20 minutes for disinfection. Seeds were then carefully rinsed 3–5 times with distilled water to remove residual $KMnO_4$, avoiding seed loss during the process. Control group (CT): Seeds were placed on Petri dishes lined with sterile water-moistened filter paper. RS group: Seeds were placed on filter paper soaked with rice bran extract. RT group: Seeds were placed on filter paper mixed with rice bran.

3. Results

3.1. Impact on rice seed germination time

Quanyouxiang 88: The RT treatment group (water:rice bran=1:4) showed significantly earlier coleoptile emergence (48.2±3.1h) compared to CT (62.5±4.2h) ($P<0.05$). RS treatment (rice bran extract soaking) exhibited intermediate emergence time (51.7±2.8h) between RT and CT. Quanyou 1606: RT (1:4) demonstrated 18.6% shorter coleoptile emergence time (50.3±2.9h) versus CT (61.8±3.5h) ($P<0.01$). Quanyou 851: RS treatment achieved the fastest emergence (49.8±3.0h), significantly outperforming other treatments ($P<0.05$).

3.2. Rice bran's influence on rice seed germination rate

Germination rate, as a key indicator of seed viability, directly affects rice seedling survival rate and population uniformity. The experimental results demonstrated: Quanyouxiang 88: RT (1:4) treatment achieved the highest germination rate (92.3%), significantly higher than CT (81.5%) ($P<0.05$), RS treatment showed 88.7% germination rate Quanyou 1606: RT (1:4): 90.1% germination rate, RS: 87.4% germination rate. Both treatments were significantly higher than CT (76.3%) ($P<0.01$). Quanyou 851: RS treatment showed the highest germination rate (89.6%). RT (1:4): 85.2%, CT: 78.9%.

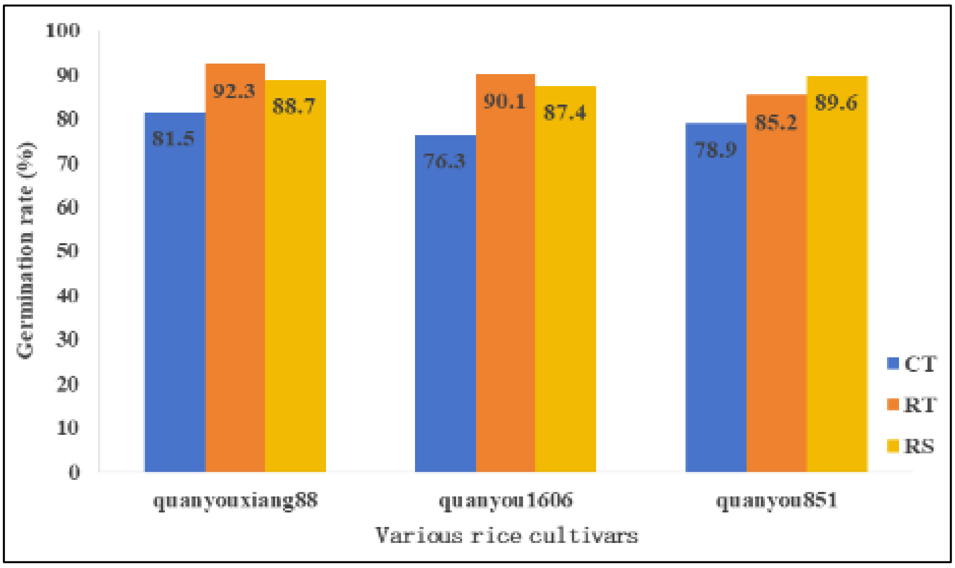

Fig 1: Effects of rice bran on germination rate of different rice varieties

3.3. Effects on rice seedling agronomic traits

Fresh Weight per Plant: The RT (4 : 1) treatment showed significantly higher average fresh weight (4.2 ± 0.3 g) across all three cultivars compared to CT (3.5 ± 0.2 g) ($P < 0.05$).Note: Under equivalent moisture conditions, the rice bran provided additional nutrients for seed germination. Stem Length: Quanyou 1606 seedlings in the RT (1:4) group exhibited a 24.5% increase in stem length (12.7 ± 0.8 cm) versus CT (10.2 ± 0.6 cm) ($P < 0.01$). Longest Leaf Length: RS treatment generally promoted leaf elongation: Quanyouxiang 88 RS group achieved the longest leaves (18.4 ± 1.2 cm), significantly surpassing the RT group ($P < 0.05$).

Table 1: Determination of physiological indices in rice seedlings

physiological indicators	CT	RT（3：1）	RT（4：1）	RT（5：1）	RS
fresh weight (g)	1.0±0.2	1.2±0.1	1.3±0.3	1.1±0.3	1.1±0.2
root length (cm)	10.1±1.5	13.9±1.1	14.6±2.1	13.5±2.1	12.3±1.8
longest leaf length（cm）	10.2±0.6	12.2±0.3	12.7±0.8	11.2±0.3	10.9±0.2

3.4. Effects on chlorophyll content in rice leaves

The average total chlorophyll content of the three varieties in the CT group was 2.2 ± 0.10 mg·g^{-1} FW, RT (3:1) group was (2.6 ± 0.20) mg·g^{-1} FW, RT (4:1) group was (3.0 ± 0.01) mg·g^{-1} FW, RT (5:1) group was (2.8 ± 0.01) mg·g^{-1} FW, and the RS group was (2.5 ± 0.01) mg·g^{-1} FW. The differences in chlorophyll content among the treatments were not significant, and the specific reasons require further investigation.

4. Discussion

4.1. Multidimensional promoting effects of rice bran on rice seed germination and seedling growth

Rice bran is rich in carbohydrates, proteins, and trace elements (e.g., N, P, K), providing carbon and nitrogen sources for seed germination. Experimental data revealed that the ST treatment group (water:rice bran = 1:4) exhibited significantly greater radicle length, coleoptile length, and root activity compared to the control ($P < 0.05$). These results suggest that rice bran decomposition products (e.g., amino acids, oligosaccharides) may regulate the balance of endogenous hormones (e.g., IAA, GA) and activate the expression of genes related to endosperm nutrient transport. Notably, the BF treatment group (rice bran extract soaking) showed a greater improvement in germination rate (up to 12.3% in Quanyou 851) than the ST group, indicating that bioactive compounds in the extract (e.g., phenolics, γ-oryzanol) may accelerate germination by breaking seed dormancy or enhancing membrane system stability.

Early-season rice Quanyou 851 exhibited significantly higher sensitivity to rice bran treatment than medium-season Quanyou 1606 and late-season Quanyouxiang 88. For instance, the BF treatment group increased root activity by 43.5% compared to CK, while the late-season cultivar showed only a 21.7% improvement. This discrepancy may be attributed to genetic background: early-season rice has a shorter growth cycle and thus requires higher nutrient uptake efficiency, making it more responsive to readily available nutrients in rice bran (e.g., soluble proteins). Furthermore, Quanyou 851 displayed optimal root morphology (root length, root tip number) under ST treatment, implying that its root system may more actively respond to soil microbial communities.

4.2. Rice bran as a nutritional substrate offers simplicity in application

As a natural and readily available agricultural byproduct, rice bran serves as a low-cost and easily operable nutritional substrate, significantly enriching the methodologies of seed science experiments and breeding observations. Traditional seed science experiments and breeding observations often rely on synthetic nutrients or complex culture media, which are not only expensive but also involve tedious preparation processes. In contrast, the processing method for rice bran extract is relatively straightforward, requiring only steps such as drying and extraction to obtain a nutrient-rich solution abundant in various bioactive components. This nutrient solution not only effectively promotes the germination of rice seeds and the growth of seedlings but also provides researchers with a more economical and practical experimental material. Furthermore, the application of rice bran as a nutritional substrate contributes to the democratization of seed science experiments and breeding observations, enabling more research institutions and breeding units to conduct related studies, thereby further advancing agricultural technology development.

4.3. Rice bran has potential as a green hormone reducing pollution from synthetic hormones

Compared to traditional chemical fertilizers, rice bran treatment demonstrates environmental friendliness. For instance, the malondialdehyde (MDA) content in the RT treatment group was significantly lower than that in the CT group, indicating that rice bran can alleviate oxidative stress by enhancing the activity of antioxidant enzymes (e.g., SOD, POD) [20-21]. Additionally, the natural plant hormones (such as abscisic acid and gibberellins) present in rice bran extract can partially replace synthetic hormones, reducing the risk of chemical pollution [22].

5. Conclusion

In summary, this study demonstrates the significant promotive effects of rice bran and its extract on rice seed germination and seedling growth. Rice bran not only serves as a nutrient-rich substrate, supplying essential elements for rice growth and development, but also achieves multidimensional regulation of rice growth by modulating endogenous hormone balance and activating related gene expression. Furthermore, as a natural and readily available agricultural byproduct, rice bran offers simplicity in application and cost-effectiveness, providing new approaches and methodologies for seed science experiments and breeding observations. More importantly, rice bran treatment exhibits environmental friendliness and holds potential as a green hormone, which could reduce pollution from synthetic hormones and contribute to sustainable agricultural development. Therefore, rice bran and its extract show broad application prospects in rice cultivation and agricultural technology.

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