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Comparative Analysis of Yield and Growth Characteristics of Late-Season Double-Cropping Rice Varieties in Rui'an City

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Abstract This study selected four common late-season double-cropping rice varieties in Rui' an City (Teyou 1332, Huazheyou 261, Yongyou 1540, and Teyou 217) and focused on analyzing their yield components, panicle grain structure, and growth period. The results showed significant differences in yield among these four varieties. Teyou 217 had the highest yield (550.8 kg/mu), primarily due to its high number of effective panicles (248,500 panicles/mu). In contrast, Yongyou 1540 had the lowest yield (480.0 kg/mu), despite having the highest number of grains per panicle (207.3 grains/panicle), as its effective panicle number was the lowest (159,100 panicles/mu), which became the key limiting factor for its yield. Regarding the growth period, the varieties ranged from 120 to 136 days. Yongyou 1540 had the shortest growth period (120 days), reaching maturity the fastest, making it suitable for early-maturing cultivation. Meanwhile, Teyou 217 had the longest growth period (136 days), allowing for extended growth and increased dry matter accumulation. Overall, increasing the number of effective panicles is the key to achieving stable and high yields in late-season double-cropping rice. Additionally, when selecting varieties, factors such as growth period, disease resistance, rice quality, and field adaptability should be considered to identify the most suitable varieties for local cultivation conditions.

Keywords Rui'an City; Late-season double-cropping rice; Yield components; Panicle grain structure; Growth period

1 Introduction

Rui'an City is located in southeastern Zhejiang, characterized by a subtropical maritime monsoon climate with distinct seasons, abundant heat resources, and favorable water and temperature conditions, making it highly suitable for rice cultivation. The city's average annual temperature is 17.9 ℃, with abundant rainfall and an average annual precipitation of 1 110~2 200 mm. Good temperature, light, water and land resources provide good natural conditions for rice production. It is not only suitable for rice cultivation, but also can grow two crops of rice a year (Cao et al., 2023). Rui'an City, as the main grain-producing city in Zhejiang Province, is known as the "granary of southern Zhejiang" (Zheng et al., 2019).

In 2024, the city's grain crop planting area will reach 18 000 hectares, and the total grain output will reach 113 900 tons, of which rice is the most important local grain crop, accounting for more than 90%. In 2024, the city's rice planting area will be 16 400 hectares, accounting for 91.05% of the total planting area of grain crops, and the total rice output will be 108 100 tons, accounting for 94.90% of the total grain output. Among them, the continuous late rice planting area is 6 000 hectares, accounting for 35.21% of the rice planting area that year, and its output is 36 000 tons, accounting for 33.30% of the total rice output that year. It is an important part of Ruian's rice production system, second only to early rice.

Continuous cropping of late rice refers to an efficient farming method in which late rice is planted immediately after early rice is harvested in the same paddy field. This planting method makes full use of the high temperature, sufficient light and water conditions in summer and autumn, so that rice has a faster tillering speed in the early growth period, which is conducive to the formation of a higher number of effective panicles; the large temperature difference between day and night in the late growth period prolongs the grain filling time, reduces respiratory consumption, and is conducive to the accumulation of dry matter and grain fullness, thereby increasing grain weight and improving rice quality (Wu et al., 2024).

However, the production management of continuous cropping of late rice also faces certain challenges. For example, the high temperature and frequent thunderstorms during the seedling raising period can easily cause the seedlings to grow too long and cause serious seedling failure after transplanting, which affects the quality of the seedlings and the occurrence of tillering; the late growth period is easily harmed by low temperatures, which affects the safe and uniform panicles and grain filling, resulting in the phenomenon of "no head growth" or "rice head warping", which in turn affects the final yield (Cheng et al., 2018).

Selecting the right rice variety is the key to ensuring stable and high yields of late rice in continuous cropping. In Rui'an City, finding varieties that are adapted to the local climate and have the advantages of stress resistance and high yield can not only improve the stability of rice production, but also optimize the grain planting structure, which is also crucial to ensuring food security. Based on this, this study conducted a comparative analysis of four common late rice varieties in continuous cropping, focusing on their key agronomic traits such as yield, panicle structure and growth period, so as to provide a scientific basis for the high-yield and high-efficiency planting of late rice in continuous cropping in Rui'an City, and also provide valuable data reference for the future selection and promotion of rice varieties.

2 Results and Analysis

2.1 Yield and yield components of tested varieties

This study measured and compared the yield and key yield components of four rice varieties (Table 1). The results showed significant differences in yield among the varieties. Teyou 217 had the highest yield, reaching 550.8 kg/mu, demonstrating strong yield potential, followed by Teyou 1332 (537.9 kg/mu) and Huazheyou 261 (510.6 kg/mu). Yongyou 1540 had the lowest yield, at only 480.0 kg/mu.

Table 1 Yield and panicle grain characteristics of the tested rice varieties

Variety name	Yield (kg/mu)	Panicle grain characteristics		
		Effective panicles (10 000/mu)	Grains per panicle (grains/panicle)	Thousand grain weight (g)
Teyou 1332	537.9	22.75	177.9	22.7
Huazheyou 261	510.6	16.77	204.7	23.4
Yongyou 1540	480.0	15.91	207.3	23.3
Teyou 217	550.8	24.85	145.9	24.7

Interestingly, Yongyou 1540 had the highest number of grains per panicle (207.3 grains/panicle) but the lowest overall yield, whereas Teyou 217 had the lowest number of grains per panicle (145.9 grains/panicle) but the highest yield. This suggests that yield is primarily influenced by the number of effective panicles. Specifically, Teyou 217's high yield was mainly due to its high number of effective panicles (248 500 panicles/mu) and relatively high thousand-grain weight (24.7 g). Even with fewer grains per panicle, it maintained a high yield. In contrast, Teyou 1332 achieved high yield through a balance between a moderate number of effective panicles (227 500 panicles/mu) and a relatively high grain count per panicle (177.9 grains/panicle).

On the other hand, Yongyou 1540, despite having the highest grain count per panicle, had the lowest number of effective panicles (159 100 panicles/mu), which likely limited its yield potential. These findings suggest that in late-season double-cropping rice cultivation, increasing the number of effective panicles may be a more effective strategy for improving yield.

2.2 Panicle grain structure of the tested varieties

Rice yield is primarily determined by the number of effective panicles, the number of grains per panicle, and thousand-grain weight (Table 1). This study analyzed the panicle grain structure of the four tested varieties, and the results showed significant differences among these key yield components.

In terms of effective panicle number, Teyou 217 performed the best, reaching 248 500 panicles per mu, significantly higher than the other varieties, indicating its strong tillering ability. Teyou 1332 followed closely with 227 500 panicles per mu, showing good performance as well. In contrast, Huazheyou 261 and Yongyou 1540 had relatively fewer effective panicles, with 167 700 and 159 100 per mu, respectively. These differences are likely influenced by both genetic characteristics and field management during the tillering stage. Regarding the number of grains per panicle, Yongyou 1540 had the highest grain count per panicle, reaching 207.3 grains, followed by Huazheyou 261 (204.7 grains per panicle). In comparison, Teyou 1332 (177.9 grains per panicle) and Teyou 217 (145.9 grains per panicle) had relatively lower grain counts. For thousand-grain weight, there was little variation among the four varieties, but some trends were still noticeable. Teyou 217 had the highest thousand-grain weight at 24.7 g, followed by Huazheyou 261 (23.4 g) and Yongyou 1540 (23.3 g), while Teyou 1332 had the lowest at only 22.7 g. Thousand-grain weight is closely related to grain plumpness and is mainly influenced by genetic factors and environmental conditions during the grain-filling stage.

Overall, Teyou 217 achieved high yields primarily due to its large number of effective panicles, whereas Yongyou 1540, despite having the highest grains per panicle, was limited by its lower effective panicle count, which restricted its total yield. This suggests that different varieties adopt distinct "strategies" to achieve yield—some rely on increasing the number of effective panicles, while others focus on producing more grains per panicle. In future variety selection and field management, it will be essential to adjust cultivation strategies based on the characteristics of each variety to further enhance yield and rice quality.

2.3 Growth period and phenological stage analysis of tested varieties

This study monitored and compared the growth period (from sowing to maturity) and key phenological stages (initial heading, full heading, and maturity) of the four tested rice varieties (Table 2). The results showed significant differences in growth duration, ranging from 120 to 136 days, with a maximum difference of 16 days, indicating varying adaptability to light and temperature conditions among these varieties.

Table 2 Growth duration and phenological stages of the tested rice varieties

Variety name	Growth duration (days)	Phenological stages				
		Sowing date (MM/DD)	Transplanting date (MM/DD)	Initial heading date (MM/DD)	Full heading date (MM/DD)	Maturity date (MM/DD)
Teyou 1332	133	7/3	7/22	9/21	9/28	11/18
Huazheyou 261	130	6/30	7/21	9/20	9/27	11/15
Yongyou 1540	120	6/30	7/21	9/9	9/13	11/5
Teyou 217	136	6/30	7/22	9/22	9/28	11/18

Among them, Yongyou 1540 had the shortest growth period, taking only 120 days from sowing on June 30 to maturity on November 5. Its initial heading occurred on September 9, and full heading was reached by September 13, earlier than the other varieties. This classifies Yongyou 1540 as an early-maturing variety, making it particularly suitable for fields with a short cropping cycle. Huazheyou 261 and Teyou 1332 had growth periods of 130 and 133 days, respectively, and their initial heading (September 20-21) and full heading (September 27-28) were quite similar, indicating that their growth patterns were largely consistent. In contrast, Teyou 217 had the longest growth period, reaching 136 days. Its initial heading (September 22) and full heading (September 28) were slightly later than those of Huazheyou 261 and Teyou 1332, while its maturity date (November 18) was the same as Teyou 1332. This suggests that Teyou 217 has a longer growth cycle, possibly due to a slower grain-filling rate or a stronger ability to continuously accumulate dry matter in the later stages.

The length of the growth period for different varieties is mainly influenced by genetic traits, light and temperature conditions, and growth rate. Short-duration varieties like Yongyou 1540 are more suitable for double-cropping systems or regions with a shorter growing season, as their early maturity allows for timely field turnover for the next crop. On the other hand, long-duration varieties like Teyou 217 require ample sunlight and an extended growing period, utilizing a longer grain-filling stage to accumulate more nutrients and ultimately increase yield.

3 Discussion

The yield of rice is mainly determined by three factors: the number of effective panicles per unit area, the number of grains per panicle, and the thousand-grain weight. The results of this study show that the more effective panicles there are, the higher the yield is usually, while there is no obvious positive correlation between the number of grains per panicle and the yield, and even a negative correlation trend in some cases. Taking Tailiangyou 217 as an example, it has the largest number of effective panicles (248 500 panicles/mu), and the final yield per mu reached 550.8 kg, with outstanding yield performance. However, Yongyou 1540 has the least number of effective panicles (159 100 panicles/mu). Although it has the highest number of grains per panicle (207.3 grains/panicle), the yield per mu is only 480.0 kg, indicating that the large number of grains per panicle cannot completely make up for the yield loss caused by the insufficient number of effective panicles. In addition, the thousand-grain weight of different varieties is not much different, indicating that in the continuous late rice planting environment in Rui'an City, the effect of thousand-grain weight on the final yield is relatively stable, and it will not play a decisive role in the yield like the number of effective panicles.

The significant differences in the performance of different varieties indicate that genetic traits have a major impact on yield and growth characteristics. Teyou 1332 (Zhejiang Certified Rice 2018020) is an Indica hybrid late-season rice variety with short plants, a loose and moderate plant type, and strong tillering ability. It has long, slightly curved flag leaves, a light green leaf color, and no awns. The grains are long and slender, with bright yellow husks, showing good photosynthetic efficiency and strong adaptability in the field (Ni and Lin, 2021; Wu, 2021). It has a relatively long growth period of 133 days, matures late, and maintains green stems at maturity, showing good stress resistance. With a yield of 537.9 kg/mu, it ranked second among the tested varieties, demonstrating good yield potential and suitability for large-scale cultivation in Rui'an. However, it is highly susceptible to brown planthoppers, so integrated pest management should be strengthened during its promotion to ensure stable production.

Huazheyou 261 (National Certified Rice 20210345) is a three-line hybrid rice variety with a short growth period of 130 days. It is characterized by early maturity, high yield, and high quality, and has advantages in market competitiveness (Bao et al., 2023). It has a moderate plant type, upright sword leaves, green leaf sheaths, medium to green leaves, upright second leaves, light yellow husks, and good color fading in the later stage. The yield per mu in this experiment was 510.6 kg, and the overall yield performance was good. Its rice quality meets the second level of the "Edible Rice Variety Quality" standard of the agricultural industry. The rice tastes chewy and has a light fragrance. It has a high market recognition and good commodity value. However, this variety has weak resistance to rice blast and bacterial blight. When promoting its planting, it needs to be combined with reasonable disease prevention and control measures to ensure stable yield.

Yongyou 1540 (Zhejiang Certified Rice 2017014) is a late-season hybrid rice variety with the lowest yield in this experiment, only 480.0 kg/mu, mainly limited by the low number of effective panicles (159 100 panicles/mu). Although it has the highest number of grains per panicle (207.3 grains/panicle), the number of panicles is insufficient, resulting in a low overall yield, indicating that increasing the number of grains per panicle alone may not be able to make up for the yield loss caused by the low number of effective panicles. This type of variety has moderate plant height, sturdy stems, upright sword leaves, light green leaves, large panicles and many grains. In the later stage, the green stalks turn yellow and the rice color is bright yellow. It performs well in the field and has good adaptability (Liu et al., 2024).

However, in terms of rice quality, its comprehensive quality only reaches the third grade awarded by the Ministry of Quality of Edible Rice Varieties, and its market competitiveness is relatively average (Cai et al., 2018). Therefore, it is recommended to conduct further experiments to see how it performs under different planting and management conditions and find the most suitable area for promotion to give full play to its advantages.

Teyou 217 (Zhejiang Certified Rice 2018011) is a two-line hybrid indica rice variety. It performed best in this experiment, with an annual yield of 550.8 kg per mu, ranking first among the four varieties. It has strong tillering ability and the largest number of effective panicles (248 500 panicles/mu), which is also the main reason for its high yield. From the perspective of plant morphology, the plant height is moderate, the sword leaves are straight, the leaves are wide, the panicles are large, the grains are long, the husks are bright yellow, and the overall growth is vigorous. In the late growth period, the grains are well filled and mature, showing strong stable yield (Ni et al., 2021; Xu et al., 2022). It has a long growth period (136 days) and is suitable for promotion in areas with sufficient sunlight and good temperature conditions. In terms of quality, the rice quality of this variety meets the general edible quality standards, with a comprehensive rating of third grade, which can meet general market demand. However, it should be noted that Tailiangyou 217 has weak resistance to brown planthoppers, and pest and disease control needs to be strengthened during field management to ensure stable production and increased income.

Overall, this study found that among the continuous cropping late rice varieties in Rui'an City, Tailiangyou 217 had the highest yield and showed strong potential for yield increase; Tailiangyou 1332 had good adaptability and stronger adaptability to different environmental conditions; Huazheyou 261 was early-maturing and had better rice quality, suitable for planting patterns with shorter growth periods; Yongyou 1540 had a low number of effective panicles, which limited its overall yield. Although it had the most grains per panicle, it could not make up for the disadvantage in panicle number. The differences in yield and agronomic traits among different varieties show that when selecting varieties, we should not only look at yield, but also consider growth period, disease resistance, rice quality and local adaptability to find the most suitable variety combination. At the same time, the key to improving the stable yield and yield potential of continuous cropping late rice is to optimize the number of effective panicles, improve the disease resistance of the varieties, and enhance the growth performance of the plants through scientific and reasonable water and fertilizer management.

4 Materials and Methods

4.1 Experimental site

The experiment was conducted at Tianjingyang Center, Lianfeng Village, Mayu Town, Rui'an City, Zhejiang Province. The site is located at 27°78′N latitude and 120°46′E longitude, falling within a subtropical monsoon climate zone characterized by warm and humid conditions. The annual precipitation ranges from 1110 to 2200 mm, with an average annual temperature of approximately 17.9 °C, making it highly suitable for rice cultivation. A late-season double-cropping rice field was selected for the study, with early-season rice as the previous crop. The field was leveled before planting, ensuring good drainage and irrigation conditions. The soil type is alluvial sandy loam, with a moderate-to-high fertility level, as indicated by an organic matter content ranging from 34.1 to 40.7 g/kg, which provides favorable conditions for rice growth.

4.2 Experimental design

A large-plot comparative trial was used in this study, with each experimental plot covering an area of 2 mu (≈1 333.3 m^2). The field was managed under a unified cultivation system to ensure that all varieties were grown under similar conditions. The experiment included four treatment groups, corresponding to four rice varieties, but due to land limitations, no replication was set up. To minimize the impact of environmental variables on yield, all plots followed the same cultivation practices, fertilization plan, and water management regime. Throughout the experiment, key agronomic traits such as tillering ability, plant height, and heading date were recorded, and standardized yield measurements were conducted at maturity to ensure the reliability of the data.

4.3 Tested rice varieties

Four rice varieties were selected for this study, including three indica hybrid late-season rice varieties and one indica-japonica hybrid late-season rice variety. The indica hybrid rice varieties were Teyou 1332, Huazheyou 261, and Teyou 217, while the indica-japonica hybrid variety was Yongyou 1540. All seeds were purchased from local seed companies in Rui'an City, and their quality met the requirements of the "Grain Crop Seeds - Part 1: Cereal Crops" (GB 4404.1-2008) standard, ensuring compliance in terms of germination rate, purity, cleanliness, and moisture content.

4.4 Field management

To ensure a fair comparison of yield performance across different varieties, a unified cultivation and management approach was applied to all experimental plots. Fertilization was conducted in stages based on rice growth requirements, aiming to promote tillering, panicle development, and grain filling, thereby optimizing yield and grain quality. Before transplanting, 25 kg of compound fertilizer (N-P-K 15-15-15) per mu was applied as a basal fertilizer to enhance soil fertility. 5 to 7 days after transplanting, a topdressing of 20 kg urea (46% N) and 10 kg compound fertilizer (N-P-K 15-15-15) per mu was applied to stimulate tillering and early growth. During the jointing to booting stage, an additional 3 kg of urea and 7.5 kg of potassium chloride (60% K_2O) per mu was applied to ensure sufficient nutrient supply for panicle and grain development.

For pest and disease management, an Integrated Pest and Disease Management (IPDM) strategy was adopted, combining chemical control and agronomic practices to reduce yield loss. Disease control targeted bacterial leaf blight, bacterial leaf streak, and rice blast, with three applications of fungicides throughout the growing season. Insect control focused on rice leaf folder (*Cnaphalocrocis medinalis*), brown planthopper (*Nilaparvata lugens*), and striped stem borer (*Chilo suppressalis*), with four applications of insecticides during the season. Additionally, proper water and fertilizer management, timely drainage, and improved field ventilation were implemented to enhance stress resistance, minimize pest and disease occurrence, and ensure stable and reliable experimental results.

Authors' Contributions

Wu Dongshu was responsible for conducting the study, completing the literature review and data analysis, and drafting and revising the manuscript. The author has read and approved the final version of the manuscript.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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