Rice Genomics and Genetics 2025, Vol.16, No.4, 180-198
http://cropscipublisher.com/index.php/rgg

Case Study Open Access

Comprehensive Evaluation of Growth Traits, Physiological Resistance, and Ecological Cultivation of New Rice Varieties: A Case Study from the Demonstration Base in Damao Village, Jiashan

Zhigang Fu
Jiashan County Fengchan Grain & Oil Professional Cooperative, Jiashan, 314110, Zhejiang, China
Corresponding email: 414192496@qq.com
Rice Genomics and Genetics, 2025, Vol.16, No.4 doi: 10.5376/rgg.2025.16.0016
Received: 08 May, 2025
Accepted: 18 Jun., 2025
Published: 06 Jul., 2025

Preferred citation for this article:
Fu Z.G., 2025, Comprehensive evaluation of growth traits, physiological resistance, and ecological cultivation of new rice varieties: a case study from the demonstration base in Damao village, Jiashan, Rice Genomics and Genetics, 16(4): 180-198 (doi: 10.5376/rgg.2025.16.0016)

Abstract In order to promote the development of green agriculture and improve rice yield and stress resistance, this study was based on the demonstration base of Dahao Village in Jiashan. The comprehensive performance of the new late rice varieties displayed locally in terms of growth traits, physiological resistance and ecological cultivation mode was systematically evaluated. The differences between *indica-japonica* hybrid rice and conventional late *japonica* rice in terms of plant height, tillering ability, fruiting rate, and 1 000-grain weight were analyzed. At the same time, their adaptability to adverse stresses such as pests and diseases, lodging, and premature aging was investigated. Combined with green agricultural practices, such as substrate seedling cultivation, controlled-release fertilizer application, and green prevention and control technologies, their effects on rice growth and yield were evaluated. This study also selected typical varieties "Yongyou 33", "Jiangliangyou 7901", "Xiushui 1717" and "Jiahe 567" for case analysis to explore the synergistic relationship between variety traits, management mode and yield. The results show that the integration of high yield, high resistance and ecological cultivation is the key direction for achieving sustainable rice production. This study provides a practical basis and theoretical support for the green transformation of rice cultivation and variety promotion in East China.
Keywords Rice; Growth traits; Physiological resistance; Ecological cultivation; Green agriculture

1 Introduction

Damao Village, Jiashan County, is located in the hinterland of the Hangjiahu Plain in the Yangtze River Delta, at the junction of Jiashan, Zhejiang and Jinshan, Shanghai, with obvious location advantages. The base has a flat terrain, medium to high soil fertility, a complete ditch road network, and convenient transportation, which is conducive to the demonstration and radiation promotion of agricultural scientific and technological achievements. In recent years, relying on its location and scientific research strength, the local area has actively carried out demonstrations of new rice varieties, accelerated the promotion of excellent varieties, and injected new impetus into the high-quality development of the rice industry. The development and growth of the rice industry cannot be separated from the strong support of new and excellent varieties. As the core area of the grain production functional area of Jiashan County, Dahao Village has a good foundation and conditions for demonstrating new varieties.

The promotion of new varieties is of great significance to ensuring food security and promoting the transformation of green agriculture. On the one hand, with the growth of population and the advancement of urbanization, the demand for rice continues to increase, and increasing yield is a key means to ensure food supply (Chen et al., 2024). The selection and application of new varieties have been proven to be one of the most effective ways to increase rice production. The coverage rate of improved varieties of major crops in my country has exceeded 96%, and the planting area of independently bred varieties accounts for more than 95%. The rice yield has increased from 457.4 kg/mu in 2016 to 469.6 kg/mu in 2020, and the promotion of new varieties has contributed greatly. On the other hand, new varieties often have better resistance and quality characteristics, which can reduce the input of pesticides and fertilizers, and meet the requirements of green and sustainable development (Blaise, 2021; Hang et al., 2024). For example, the water-saving and drought-resistant rice series such as "Hanyou 73" have been promoted in more than 10 million mu of land nationwide and won the National Science and Technology Progress Award, reflecting the advantages of new varieties in efficient resource utilization and stress resistance.

This study sorted out the types and distribution of new *indica*-*japonica* hybrid rice and conventional late *japonica* rice varieties displayed in the demonstration base in Dahao Village, Jiashan, and classified and introduced the characteristics of the main participating varieties; starting from plant morphology and growth and development indicators, the growth traits and yield performance of the new varieties were analyzed, including plant height, tillering and ear formation, panicle-grain structure, fruit set rate, 1 000-grain weight and other indicators; the physiological resistance and adversity adaptability of the new varieties were evaluated, such as disease and insect pest resistance, lodging resistance, fertilizer tolerance, and aging status at maturity; the ecological cultivation techniques used in the demonstration base were summarized, including the matrix seedling raising machine transplanting mode, controlled-release fertilizer "one base and one topdressing" fertilization and green prevention and control measures, and their effects on the production benefits of new varieties; on this basis, typical representative varieties were selected for case analysis, the comprehensive performance of different types of varieties was compared, and the relationship between variety traits and cultivation management and yield was explored. This study aims to clarify the unique growth and stress resistance advantages of the new variety and its interactive effects with supporting cultivation measures, provide a scientific basis for the selection and large-scale promotion of excellent rice varieties in the region in the future, summarize the successful experience of the demonstration base in Dahao Village, Jiashan, in order to promote the establishment of a regional agricultural green yield-increasing technology system.

2 Classification and Distribution of New Rice Varieties

2.1 Types of varieties: *indica-japonica* hybrids and conventional late *japonica* rice

The Dahao Village Demonstration Base in Jiashan concentrated on displaying two types of new late rice varieties, *indica*-*japonica* hybrid rice and conventional late *japonica* rice. Among them, *indica*-*japonica* hybrid rice is a hybrid advantage variety selected through hybridization between *indica* and *japonica* subspecies, with the characteristics of high yield potential and wide adaptability (Zhou et al., 2020). For example, the "Yongyou" series of *indica*-*japonica* hybrid rice is composed of *indica* sterile lines and *japonica* restorer lines, which fully exerts the hybrid advantages between subspecies and shows high and stable yield in the Yangtze River Delta region. "Yongyou 33" is one of the representative varieties. Conventional late *japonica* rice refers to late rice varieties among *japonica* rice varieties that have not been hybridized and bred by conventional breeding methods. They usually have shorter rice plants, a late maturity period, better rice quality and resistance, and occupy an important position in the late rice production in the lower reaches of the Yangtze River. For example, the "Xiushui" and "Jiahe" series are representative varieties of conventional late *japonica* rice in Jiangsu and Zhejiang. Among the 19 new varieties displayed in this demonstration base, there are 9 *indica*-*japonica* hybrid rice and 10 conventional late *japonica* rice. By classifying and displaying hybrid rice and conventional rice varieties, it is helpful to intuitively compare the differences in growth performance and adaptability between the two types of varieties, and provide a basis for the promotion of different types of varieties.

2.2 Demonstration area and spatial arrangement

The demonstration base adopts a layout mode combining "centralized display, small area trial + large-scale demonstration". In the display stage, each new variety is planted in a small area of about 1 mu, and the total display area of 19 new varieties is about 20 mu. Each display area is arranged in the same field, and the cultivation management is unified to fairly compare the trait differences and yield performance between varieties. Based on the display and screening, the base carried out large-scale demonstrations of 5 new varieties with excellent performance, including 2 *indica*-*japonica* hybrid rice (91.78 mu of "Yongyou 33" and 10 mu of "Jiangliangyou 7901"), and 3 conventional *japonica* rice (7.51 mu of "Xiushui 1717", 14.83 mu of "Jiahe 567", and 8.65 mu of "Xiushui 1813"), with a total demonstration area of about 133 mu. These demonstration plots are located in the core area of the base, which is convenient for mechanized operation and field observation (Figure 1).

By combining the display and screening of the small area with the demonstration and promotion of the large area, it is ensured that the characteristics of many new varieties can be compared, and the selected varieties can be verified on a large scale, so as to play the demonstration and driving role of new varieties.

Figure 1 Planting base

2.3 Brief description of selected variety characteristics

The main new rice varieties displayed in the demonstration base have their own characteristics (Figure 2). "Yongyou 33" (*indica*-*japonica* hybrid rice) is a late *japonica* hybrid rice bred by Ningbo Seed Industry. It has a plant height of about 130 cm, medium to high, moderate plant shape, and medium to strong tillering ability. The sword leaves are straight, the leaf color is medium green, the panicle is large, the grains are dense, and the fruiting rate is high. The grains are round and the rice has excellent appearance quality. It matures in a medium to early period, and has outstanding high temperature resistance. It can still maintain high yield and high-quality rice quality under continuous high temperature conditions. The lodging resistance is stronger than other varieties in the same series, and no lodging is seen in the field. However, it is susceptible to rice planthoppers and borers, and pest control needs to be strengthened. "Yongyou 33" is a high-yield and stable variety with great potential for yield increase. It has been widely demonstrated and applied in Zhejiang and other places.

Figure 2 Rice grown at the planting base

"Jiangliangyou 7901" (*indica*-*japonica* hybrid rice) is the first international two-line *indica japonica* hybrid rice variety, jointly developed by Zhejiang University, Zhejiang Jiaxing Agricultural Science Research Institute and

Zhejiang Zhijiang Seed Industry. The plant height is about 125 cm and the growth period is early. This variety has large ears and many grains, full grains, good fruit set rate, and has the characteristics of early maturity, high yield, and excellent rice quality. The field is beautiful in maturity, the color is good, and the rice looks bright yellow. The regional demonstration yield per mu can reach more than 750 kilograms. However, due to the high plant type and slightly poor stem elasticity, local tilting or lodging is prone to occur in the later stage when nitrogen fertilizer is sufficient. Therefore, it is necessary to pay attention to controlling the amount of nitrogen fertilizer in the later stage in cultivation to avoid greed for green lodging. "Jiang Liangyou 7901" is suitable for promotion as an early-maturing and high-yield hybrid rice, and can achieve high quality and high yield under the premise of ensuring water and fertilizer management.

"Xiushui 1717" (conventional late *japonica* rice) is a new late *japonica* rice variety bred by Jiaxing Academy of Agricultural Sciences, which was approved by Zhejiang Province in 2021. The variety has a plant height of about 100 cm, a compact plant type, medium tillering ability, short and upright sword leaves, upright panicles, medium to large panicle type, and high fruit set rate. The whole growth period is about 2 days earlier than the control "Xiushui 134", and the color is good when mature. The field performance is resistant to lodging, the medium stalk is strong, the number of panicles is large, and the yield potential is significant. The average yield per mu is 5.8% higher than the control. The rice appearance quality is medium and the rice quality is good. The disadvantage is that the leaves are slightly thin and the leaf tips are slightly dry during maturity, indicating that the resistance to late season decline is slightly poor. "Xiushui 1717" has a moderate maturity period and good stable yield. It is suitable for single-season late rice planting in Zhejiang Province and has been rated as a high-quality *japonica* rice variety with promotion potential.

"Jiahe 567" (conventional late *japonica* rice) is a new early-maturing late *japonica* rice variety bred by Jiaxing Academy of Agricultural Sciences. It passed the Zhejiang Provincial Approval in 2022 (Zheshen Rice No. 2022006). "Jiahe 567" is a semi-dwarf early-maturing variety with a plant height of about 96.5 cm, a compact plant shape, thick stems, and good lodging resistance. The tillering ability is strong, the effective panicles are many, the panicles are large, the total number of grains per panicle is about 160, the fruiting rate is close to 90%, and the thousand-grain weight is about 27 grams. The growth period is about 4 days shorter than that of the control "Xiushui 134". The average yield per mu in the two-year regional trial reached more than 615 kg, an increase of about 10% over the control; the yield per mu in the production trial was 621 kg, an increase of 3.2% over the control. In terms of resistance, it is moderately resistant to rice blast and has strong heat resistance; it is moderately susceptible to bacterial leaf blight and highly susceptible to brown planthoppers. The monitoring and prevention of rice planthoppers need to be strengthened in the field. This variety has no lodging and remains upright even in continuous rainy and typhoon weather. The rice quality meets the national standard for grade 3 high-quality rice, with a high rate of whole polished rice and good transparency of rice grains. "Jiahe 567" has excellent yield and adaptability. In the demonstration, the yield per mu ranked first, with an increase of 15.0% over the control "Xiushui 134". Therefore, it is considered to be a new and superior conventional rice variety with high and stable yield prospects (Ding et al., 2023).

In addition to the above varieties, other varieties displayed in the demonstration base have their own highlights, such as "Yongyou 1516", "Jiafengyou 27", "Zhejingyou 4", "Xiuyou 6", "Xiushui 1813", "Xiushui 1926", etc. In the classification comparison, it can be found that the overall plant type of *indica*-*japonica* hybrid rice varieties is taller, the number of panicles is larger, and the yield increase potential is outstanding; conventional *japonica* rice varieties have moderate plant height, good uniformity, and relatively better rice quality and stress resistance.

3 Analysis of Growth Characteristics and Yield Performance

3.1 Plant height, tillering capacity, and effective panicle rate

Different types of new rice varieties show obvious differences in plant height and tillering characteristics. *Indica*-*japonica* hybrid rice varieties usually have taller plant heights and larger canopies (Xu et al., 2020). For example, the plant height of "Yongyou 33" is about 130 cm, while the plant height of conventional *japonica* rice

"Jiahe 567" is about 96 cm. Higher plant height is conducive to the formation of a larger population leaf area and photosynthetic potential of hybrid rice, but it may also increase the risk of lodging. Conventional late *japonica* rice varieties such as "Xiushui 1717" have a plant height of about 102 cm, which is medium to short, and is relatively resistant to lodging. In terms of tillering, all varieties are planted by machine transplanting, with similar basic seedling density, but there are differences in the number of effective tillers. Hybrid rice varieties have vigorous individual growth and more tillers per plant, but some ineffective tillers are difficult to form ears in the later stage; conventional rice varieties have medium tillering ability, good population uniformity, and often higher ear formation rate. Field surveys show that the highest number of seedlings per mu of "Yongyou 33" reached 1.73 million, 210 000 ears/mu, and an ear formation rate of about 68.4%; the highest number of seedlings of "Xiushui 1717" was about 3.07 million, 150 400 ears, and an ear formation rate of 68.4%. The highest number of seedlings of "Jiahe 567" was 3.02 million, 202 000 ears, and an ear formation rate of 66.9%. It can be seen that the ear formation rate of different varieties ranges from about 65% to 70%. High-yield varieties often maintain a higher ear formation rate, which is related to the reasonable distribution of their tillers and the quality of the population. Zhou et al. (2020) pointed out that the panicle formation rate of high-yield, high-nitrogen and high-efficiency *indica*-*japonica* hybrid rice can be stabilized at 68%~70%, and the leaf area index is high during the heading period and decays slowly in the later period, which helps to increase the number of panicles in the group. Among the new varieties demonstrated this time, "Yongyou 33" and "Xiushui 1717" all showed a high panicle formation rate and a large number of spikelets in the group, which laid the foundation for high yield. However, for hybrid rice varieties with high plant height and lush growth, it is necessary to be vigilant about the risk of lodging in the later period, and to reasonably plant densely and control the nitrogen fertilizer level to balance the growth of the group and the resistance to lodging.

3.2 Panicle traits and grain filling success

Panicle traits directly determine the yield composition of rice, and new varieties have their own characteristics in panicle-grain structure and fruiting rate. New varieties of *indica*-*japonica* hybrid rice often have the advantage of "large panicle and many grains", and the total number of grains per panicle is significantly higher than that of conventional *japonica* rice varieties (Liu et al., 2023). For example, the average total number of grains per panicle of "Yongyou 33" is about 307, and that of "Jiangliangyou 7901" is about 280; in comparison, the total number of grains per panicle of "Xiushui 1717" is about 150, and that of "Jiahe 567" is about 143. Hybrid rice increases the number of grains per panicle through large panicles, thereby increasing the yield potential per plant. At the same time, most new varieties show a high fruiting rate. Demonstration survey data show that the fruiting rate of "Yongyou 33" is about 85.2%, and the fruiting rate of "Jiangliangyou 7901" is about 85%; the fruiting rate of conventional rice "Xiushui 1717" is 94.8%, and the fruiting rate of "Jiahe 567" is 94.3%. The fruiting rate of most new varieties is between 85% and 95%. The fruiting rate of conventional japonica rice is generally slightly higher than that of hybrid rice, which may be due to the moderate number of grains per panicle of conventional varieties and more complete filling, while some hybrid rice panicles have large grains and are prone to empty grains in unfavorable environments. However, the overall fruit setting rate of the demonstration varieties was ideal, and no serious empty and barren phenomenon occurred. Some varieties with poor performance, such as "Zhehangyou 220", had a fruit setting rate of only about 89%, fine grains in the ears, and limited yield increase potential. The "Yongyou" series of varieties have the advantages of large ears and high fruit setting rate, and the filling is uniform and consistent. The ears and grains in the "Yongyou 33" demonstration field are full, and although the fruit setting rate is slightly lower than that of some conventional rice, it still remains above 85% in high temperature years, showing good filling ability and adaptability to the environment. The high or low fruit setting rate reflects the reproductive growth intensity and tolerance to stress of the variety. High-yield varieties maintain a high fruit setting rate while having large ears and many grains, indicating that they have both sufficient assimilates and good resistance to stress filling. The new varieties demonstrated this time have obvious advantages in ear traits: *indica*-*japonica* hybrid rice increases yield by significantly increasing the number of grains per ear, while conventional *japonica* rice ensures a higher number of fruited grains with a higher fruit setting rate. The different panicle characteristics of the two types of varieties provide different ways to achieve high yields.

3.3 1000-grain weight and yield comparison

The thousand-grain weight reflects the fullness and size of rice grains and is one of the important factors affecting yield. The thousand-grain weight of the new varieties demonstrated this time is generally between 25 and 29 grams, and there is little difference between varieties. The thousand-grain weight of "Yongyou 33" is about 26.6 grams, and that of "Jiangliangyou 7901" is about 26.3 grams; the conventional rice "Xiushui 1717" is 25.7 grams, and that of "Jiahe 567" is 27.3 grams; the control "Xiushui 134" has a thousand-grain weight of 27.7 grams. It can be seen that the grain size of the new varieties is generally comparable to that of the traditional varieties, some are slightly higher than the control, and some are slightly lower, but the difference does not exceed ±10%. This shows that the new varieties mainly increase yield by increasing the number of panicles and the fruiting rate, rather than simply increasing the grain size. In fact, too large grains may reduce the fruiting rate, while too small grains affect the thousand-grain weight. The relationship between grain weight and grain number needs to be weighed in breeding. In terms of actual yield, the new varieties have increased yields to varying degrees compared with the control varieties. In the plot display test, "Xiushui 134" was used as the conventional rice control and "Yongyou 1540" was used as the hybrid rice control. It can be found that the yields of most new varieties exceeded the control. For example, "Xiushui 1717" increased its yield by 5.8% compared with the control, and "Jiahe 567" increased its yield by 15.0%; the hybrid rice "Yongyou 33" increased its yield by 3.7% compared with the control, showing high and stable yields. New varieties such as "Chunjiang 204" increased their yield by 6.9%, following closely behind. Only a few varieties such as "Zhejing 100" and "Zhehujing 58" had slightly lower yields than the control (a reduction of about 10%), indicating that they are not adapted to the climatic conditions in this region. In large-scale demonstrations, the average yield of new *indica-japonica* hybrid rice varieties was about 780 kilograms per mu, and the yield of conventional late *japonica* rice was about 600-650 kilograms per mu. Hybrid rice varieties have significantly improved their yield levels with their greater biological yield and hybrid vigor, and their yield per mu is about 15%-20% higher than that of conventional rice. This result is basically consistent with the increase in hybrid rice yield across the country. It is generally believed that the increase in hybrid rice yield over conventional rice can reach 10%-20%. For example, in the double-season rice high-yield research field in Hunan, the double-season hybrid rice yield per mu reached more than 1 530 kilograms, setting a new record. The yield of hybrid rice such as "Yongyou 33" exceeded 550 kilograms per mu, while the conventional rice control was 627.4 kilograms per mu. If the difference in growth period is taken into account, the high-yield potential of late hybrid rice can be seen. Of course, conventional late *japonica* rice varieties have also been improved, and their yield levels have also been greatly improved. For example, "Jiahe 567" performed outstandingly among conventional rice varieties, with an acreage yield of 721.5 kg, which is significantly better than traditional varieties. While maintaining the high-quality rice standard in thousand-grain weight, the new variety significantly increased the actual yield by increasing the number of panicles and the fruiting rate. This shows that breeders have successfully achieved a combination of high yield and high quality while maintaining the quality of rice (Huang et al., 2024). Academician Yuan Longping also pointed out that high yield and quality are not irreconcilable contradictions, and hybrid rice can achieve improvements in both yield and quality at the same time.

4 Evaluation of Physiological Resistance and Stress Adaptability

4.1 Resistance to pests and diseases

Pest and disease resistance is a key factor in whether new varieties can stably exert their yield-increasing potential. The new rice varieties demonstrated this time have relatively good disease and pest resistance overall, but there are certain differences between different varieties. For the main disease rice blast, many new varieties show a medium resistance level. For example, "Jiahe 567" was identified as having a maximum loss rate of 3 levels for panicle neck blast and a comprehensive resistance index of 3.0 for rice blast, which is a medium resistance to rice blast; "Xiushui 1926" also showed medium resistance to rice blast, and no obvious lesions were found in the field. In contrast, most new varieties have average resistance to the bacterial disease rice bacterial leaf blight, such as Jiahe 567, which has a maximum resistance of 5 levels to bacterial leaf blight, which is a medium level of sensitivity. This suggests that attention should be paid to the prevention of bacterial leaf blight in rainy and hot seasons. For insect pests, some new varieties have good tolerance to rice planthoppers and the like. For example, the conventional rice "Xiushui 1926" showed high resistance to brown planthoppers in the field, and "Xiushui 1717" also did not suffer from rice planthopper damage, which shows that its insect-resistant gene background is good.

However, some varieties are more sensitive to certain pests. For example, "Yongyou 33" and hybrid rice of the same series are susceptible to rice planthoppers and borers during the tillering period. The base observed that there were traces of rice leaf rollers on the leaf sheaths of this variety, and it is necessary to apply pesticides in advance during the peak tillering period to prevent it. "Jiahe 567" was determined to be highly susceptible to white-backed planthoppers. Once planthoppers migrate into the field, if prevention and control are not timely, it will pose a threat to yield. This is related to the nutrient accumulation caused by the pursuit of high yields in hybrid rice and some conventional rice, and the plants are relatively tender, which often attracts migratory pests to parasitize. Boring pests such as the striped stem borer and the stem borer also occur to varying degrees in the base, but because the demonstration fields use moth-attracting lamps and sex attractants, combined with biological pesticides for prevention and control, no large-scale damage has been caused. The disease and insect pest resistance of new varieties meets production requirements, but it is necessary to implement policies based on the varieties: for varieties with relatively weak resistance, monitoring and green control should be strengthened during the critical period. For example, for varieties with high susceptibility to planthoppers, traps can be arranged in advance during the peak of planthopper migration in July and August, and biological pesticides can be sprayed in time; for varieties with moderate susceptibility to rice blast, attention should be paid to reasonable density planting and nitrogen fertilizer control to reduce the incidence of rice blast, and pesticides should be applied before and after the break to prevent spikelet blast (Li, 2024; Lyu, 2024). It is worth mentioning that ecological regulation plays an important role in the prevention and control of diseases and insect pests of new varieties. Flowering plants such as cosmos and sulphur chrysanthemum were planted on the ridges of rice fields in the demonstration base, providing habitats and nectar sources for predatory natural enemies, and significantly increasing the number of natural enemy insects such as spiders and parasitic wasps in rice fields. Studies have shown that planting nectar plants such as sunflowers, marigolds, and cosmos on the ridges of rice fields can enhance the pest control effect of natural enemies, reduce the population density of major pests, and maintain rice yields (Figure 3) (Ali et al., 2019). Therefore, the development of new variety resistance needs to be combined with scientific plant protection strategies.

Figure 3 Flowering plants around rice paddies

4.2 Lodging resistance and nitrogen-use tolerance

Lodging resistance is an important indicator for measuring the safety of rice production, especially for high-yield varieties. Once rice lodges on a large scale, not only will the yield be severely lost, but the quality of rice will also decline significantly. Therefore, while pursuing high yields, breeders have improved the stem strength and lodging resistance of new varieties through semi-dwarf breeding and other means. Most new varieties remain upright during maturity and show good lodging resistance. For example, "Xiushui 1717" is a medium-dwarf variety with thick stems. It did not lodge under the continuous rainy conditions of the typhoon in northern Zhejiang in 2021. "Jiahe 567" is less than 1 meter tall, with short and tough internodes at the base. It did not lodge during the typhoon season in northern Zhejiang in 2021, indicating that it has strong lodging resistance. Although the hybrid rice "Yongyou 33" is relatively tall, its stems are elastic and its root system is well-developed. It did not lodge in this demonstration field, effectively supporting large panicles and heavy loads. Some new varieties such as "Jiafengyou 121" also show good lodging resistance. Relatively speaking, some varieties have insufficient lodging resistance. For example, the stems of "Zhejingyou 4" softened and lodged in the later stage of maturity, and it was judged to be unsuitable for local promotion; "Zhehangyou 220" had poor lodging resistance in the later stage due to its too compact plant type and high height. In general, conventional late *japonica* rice varieties generally have good lodging resistance due to their short plants; the lodging resistance of *indica*-*japonica* hybrid rice varieties varies from variety to variety and requires specific analysis. The application of semi-dwarf genes in breeding has enabled many new varieties to have a higher lodging resistance foundation (Teng et al., 2021).

However, cultivation measures are also important. For example, mechanized cultivation methods have a significant impact on the lodging resistance of rice plants. A study compared the stem characteristics of varieties under different cultivation methods and found that pot seedling machine transplanting can shorten the internodes at the base of rice, thicken the stem wall, and increase the dry weight, thereby significantly improving the stem's bending resistance and bending moment resistance and reducing the lodging index. The matrix seedling machine transplanting method used in this demonstration belongs to this category, which helps new varieties to fully exert their lodging resistance potential. On the other hand, the fertilizer tolerance of new varieties (i.e., the response to high nitrogen fertilizer input) varies significantly among different varieties. Varieties with good fertilizer tolerance will not grow vigorously even if they are fertilized too much, and are not prone to lodging in the later stage; while varieties with poor fertilizer tolerance will easily lead to excessive vegetative growth and loose stem tissue once excessive nitrogen fertilizer is applied, resulting in lodging or late maturity. "Yongyou 33" requires control of late fertilization in management because if there is too much nitrogen fertilizer in the late tillering stage, it will increase the risk of rice planthopper damage and reduce lodging resistance. "Xiuyou No. 6" has dark leaves and is less tolerant to fertilizer. If fertilizer is applied too heavily, the stems will grow too long and easily fall over. Therefore, measures such as "reducing weight, early sowing, and sparse planting" should be taken to enhance lodging resistance for this type of variety (Xing et al., 2017). In contrast, "Jiafengyou 121" has better lodging resistance, does not react excessively to fertilizer, and can still maintain upright under fertilization conditions, showing good fertilizer tolerance. "Jiahe 567" has medium to weak fertilizer tolerance. When nitrogen fertilizer is too heavy, the field maturity phase is poor in the later stage, and it is also easily damaged by borers and leaf rollers. Therefore, it is required to sow and control fertilizer appropriately early in cultivation to prevent lodging due to greed. New varieties are generally better than old varieties in lodging resistance and fertilizer tolerance, but high-yield varieties require more meticulous management to avoid the hidden danger of lodging caused by their high biological yield. By selecting and breeding semi-dwarf and thick-stem varieties combined with scientific fertilization, high yield and lodging resistance can be achieved in synergy (Wang et al., 2022). The practice of this demonstration base has proved that under the conditions of reasonable control of fertilization level and supporting mechanized cultivation, none of the new varieties suffered serious lodging, which provides confidence for subsequent large-scale promotion.

4.3 Senescence and consistency of grain filling

The aging rate of functional leaves in the late growth period of rice and the consistency of grain filling will directly affect the yield and quality. Varieties with strong tolerance to late premature senescence have a longer photosynthetic time during the grain filling period, which is conducive to full grain filling. If the variety has "premature senescence", that is, the leaves turn yellow too early, it may lead to insufficient filling stamina, unfull grains or even an increase in barren grains. This demonstration comparison found that different new varieties have obvious differences in leaf color change speed and filling synchronization during maturity. The overall performance of hybrid rice varieties is slow color change in the late stage, the leaves remain green for a long time, and sufficient source energy is provided during the filling period. "Yongyou 33" maintains beautiful leaf color before maturity, a long functional period of sword leaves, and consistent and full grain filling. The color change of the whole plant is relatively uniform, indicating that the transport of nutrients to the grains is synchronous, and no obvious premature aging occurs in the later stage. Other varieties in the "Yongyou" series also generally have green leaves under the panicle, and the mature characteristics of live stalks are obvious. Studies have shown that the leaf area index of high-yield *indica-japonica* hybrid rice types decays slowly after heading, and the LAI at maturity remains above 3.8, which is exactly the performance of no premature aging and continuous filling in the later stage. The experiment of Zhou et al. (2020) proved that the dry matter accumulation of high-yield hybrid rice can reach 7.9 tons/hectare in the later stage, and more than 21 tons of dry matter in the whole growth period, which is due to its delayed aging in the late growth period and maintaining strong photosynthetic production capacity.

Most of the conventional rice varieties can also mature normally, but some varieties show slight signs of premature aging. For example, the tip of the leaves of "Xiushui 1717" is slightly yellowed at the maturity stage, indicating that its sword leaves are slightly aged at the end of filling. However, the overall impact on yield is not significant, because its maturity is only slightly earlier than the control by 2 days, and the grains have been fully filled. "Zhejing You 4" is an obvious early aging type, with insufficient filling stamina. Most of the leaves in the field turn yellow when mature, and the fullness of the grains is poor. Therefore, the base recommends not to promote this variety in this area. Some other hybrid rice varieties have the problem of inconsistent filling. For example, "Xiuyou 6" has been observed to have a "double filling" phenomenon, that is, some grains are filled and mature first, while the grains on the secondary branches are delayed, and the maturity is not synchronized. This may result in some grains on the same ear being ripe and some still green at harvest, which affects both yield and quality. The cause of the formation may be related to the variety's ear type and flowering habits. For this type of variety, it should be appropriately "early sowing, early planting, and sparse planting" in cultivation to extend the filling time and improve synchronization. For varieties such as "Jiafengyou 27" and "Jiafengyou 121", the base evaluated that their "color change in the mature stage is not as good as the Yongyou series", indicating that the proportion of green stems in the later stage is slightly lower than that of the "Yongyou" series. However, both of them are still within the normal maturity range, and there is no serious premature aging phenomenon, but they are slightly inferior to "Yongyou". In contrast, "Xiushui 1926" still maintains green stalks and yellow ripeness during the maturity period, and the mature phase is green and beautiful, indicating that the late assimilation products are fully transported. Most new varieties can mature with live stalks, and premature aging is not common in this demonstration, only a few varieties have a slight performance. This is related to the emphasis on late vitality in breeding in recent years. At the same time, scientific cultivation measures (such as appropriate topdressing in the later stage and foliar spraying to prevent premature aging) can also slow down leaf aging. Some high-yield varieties may have a slight lag in filling of the lower grains due to large panicles and many grains, which needs to be solved by improving variety structure or cultivation regulation. This new demonstration variety showed good synchronization and aging resistance during the filling period, and fully realized the yield potential. This is also an important physiological basis for new rice varieties to achieve stable and high yields.

5 Ecological Cultivation Techniques and Green Agricultural Practices

5.1 Substrate-based seedling raising and mechanized transplanting

The demonstration base in Dahao Village, Jiashan, highlights mechanization and standardization in cultivation technology, and realizes the matching of good varieties and good methods. First, in the seedling cultivation stage, the matrix seedling stacking tray dark seedling emergence technology is adopted, that is, the seeds after soaking and germination are sown in the nutrient matrix seedling tray, stacked and shaded for 3 days to promote uniform seedlings, and then moved into the seedling field for normal management. The seedlings cultivated by this method have a well-developed root system and uniform quality, laying the foundation for machine transplanting. The seedling age is controlled at about 21 days (3 leaves and 1 heart) to ensure that the seedlings are young and vigorous when transplanted. In the planting stage, the base uniformly uses high-speed transplanters for mechanized transplanting to achieve standardized transplanting of seedlings. The machine transplanting specifications vary according to the variety type: the row spacing of *indica* and *japonica* hybrid rice is 30 cm×22 cm, and there are 2-3 seedlings per cluster; the row spacing of conventional late japonica rice is 30 cm×16 cm, and there are 4-5 seedlings per cluster. This fixed-width narrow row spacing mode takes into account the needs of different types of varieties for population density. Mechanical transplanting ensures uniform spacing and seedling numbers, reduces manual errors, and is conducive to group ventilation and light transmission and resource utilization. At the same time, machine transplanting improves transplanting efficiency, and 1 hectare can be transplanted in 5 hours, greatly reducing labor intensity (Vijay et al., 2024).

More importantly, mechanized cultivation methods can also improve rice plant type and lodging resistance. Studies have shown that compared with manual blanket seedling transplanting or direct seeding, rice transplanted by pot seedling machine has shortened 1-3 internodes at the base, thickened stems, improved internode fullness, significantly increased stem bending moment, and reduced lodging index. The practice of this demonstration also verified this point: the machine-transplanted seedlings have deep roots and neat tillers, and the new varieties generally have thick stems, and basically no lodging occurs during maturity. Mechanized transplanting also promotes early group formation. The machine-transplanted fields of "Yongyou 33" and other varieties reached a maximum of 170 000 seedlings per mu 10 days after transplanting, and tillering started quickly. This creates conditions for making full use of the growth period and increasing the number of ears per mu. Of course, mechanized cultivation also requires that seedling cultivation be adapted to field engineering, such as leveling the land and managing the water layer reasonably, to ensure the quality and survival rate of transplanting. The combination of substrate seedling cultivation and machine transplanting mode has achieved mechanization and standardization of the entire rice production process. It not only improves cultivation efficiency and reduces costs, but also optimizes group structure and enhances the plant's resistance to lodging. For the large-scale promotion of new varieties, this supporting model can ensure that the yield-increasing advantages of new varieties are fully utilized. Based on this demonstration, Yuhang District and other places have promoted the rice machine-transplanted stacked tray seedling technology, providing strong support for improving the quality and efficiency of regional grain production.

5.2 Effectiveness of the “one basal, one top” controlled-release fertilizer strategy

The demonstration base adopted the efficient fertilization mode of "one base and one topdressing" of controlled-release fertilizer in fertilization management, that is, a one-time basal application of controlled-release fertilizer before transplanting, and a small amount of topdressing of ear fertilizer according to the seedling conditions during the tillering period. The specific method is: when tilling and preparing the land before transplanting, 40 kg of controlled-release compound fertilizer (N-P-K ratio 25-12-15) per mu is applied as basal fertilizer, and 7.5 kg/mu of slow-release fertilizer containing 30% nitrogen is applied as tillering fertilizer about 10 days after transplanting, and 12.5 kg of compound fertilizer is applied as ear fertilizer before heading. This scheme realizes the centralized slow-release supply of nitrogen fertilizer, which greatly reduces the number of fertilization and labor input compared with traditional split-time fertilization. More importantly, the one-time basal application of controlled-release fertilizer can simultaneously meet the nutrient requirements of rice at all growth stages, reduce nutrient leaching and volatilization, and improve the utilization efficiency of nitrogen fertilizer (Chen et al., 2020). Studies have shown that compared with conventional urea application in batches, one-time application of polymer-coated urea can significantly increase rice yield under equal nitrogen conditions, such as an increase of about 10%-16% in early rice and about 5%-14% in late rice.

The demonstration results also show that the fields using the "one base and one topdressing" technology of controlled-release fertilizer have neat and effective tillering, moderate and light leaf color, no excessive greed for green, normal color change in the later stage, and obvious yield increase effect. The analysis shows that controlled-release fertilizer slowly releases nitrogen, meets the nutrient needs of rice in key periods such as jointing and heading, and avoids excess nitrogen in the seedling stage and late stage, which is conducive to the formation of higher heading rate and fruiting rate. Improving the efficiency of nitrogen fertilizer utilization not only increases production and efficiency, but also has important environmental significance. Excessive nitrogen application often leads to nitrogen leaching, volatilization and runoff loss, causing environmental pollution and greenhouse gas emissions (Chivenge et al., 2021). The use of controlled-release fertilizers to reduce nitrogen excess can help reduce ammonia volatilization and nitrogen leaching in rice fields, and reduce the adverse effects of nitrogen fertilizer input on the environment. At the same time, controlling the total nitrogen dosage can also inhibit excessive plant growth and enhance lodging resistance, which is particularly critical for varieties with general fertilizer tolerance as mentioned above. It is worth mentioning that the total nitrogen fertilizer application rate of the demonstration base (15.4 kg/mu of pure nitrogen) is slightly lower than the conventional level, but the yield level has increased instead of decreased. This is consistent with many research results: by optimizing the fertilization method, even if the nitrogen application rate is appropriately reduced, the yield can still be maintained stable and the nitrogen fertilizer utilization rate can be improved (Hu et al., 2023). The promotion and application of side deep fertilization equipment has further improved the accuracy and efficiency of controlled-release fertilizer application. The "one base and one topdressing" technology of controlled-release fertilizer has achieved significant fertilizer-saving and efficiency-enhancing effects in this demonstration. In the future, the promotion of this technology in rice production is expected to reduce the application of chemical fertilizers and reduce production costs while achieving stable, high yields and environmental friendliness. Improving the level of nitrogen fertilizer management is of great significance to achieving sustainable development of rice production.

5.3 Integrated green pest control practices

The demonstration base has implemented the concept of "green plant protection" in the prevention and control of pests and diseases, and has comprehensively applied a variety of eco-friendly technologies to achieve good results. First, in terms of rice field ecological regulation, the base makes full use of the ridges and gaps between fields to plant flowering plants and insect-proof grasses. For example, nectar-producing flowers such as Cosmos and Sulfur Flower, as well as attractant plants such as Vetiver, are planted on both sides of the mechanized farming road. These companion plants provide habitats and food sources for natural enemies of rice fields (such as spiders, parasitic wasps, insectivorous flies, etc.), forming a "nectar source belt between flower fields", thereby increasing the number and diversity of natural enemies. Ali et al. (2019) pointed out that planting flowering plants on the ridges of rice fields can significantly increase the number of predatory ladybugs and parasitic wasps, and the parasitism rate is significantly improved. The number and damage symptoms of major pests in the ecological engineering fields are significantly lower than those in the control fields without flowers and plants, and the rice yield is not affected. The fields planted with flowers and plants are significantly less damaged by borers and planthoppers, indicating that ecological pest control has played a role. Secondly, the base promoted physical lure and control technology. After transplanting rice seedlings in each field, insect monitoring lamps or frequency-vibration insecticidal lamps were uniformly installed to lure and kill the nocturnal adult *Chilo suppressalis* and *Sesamia inferi*; and sex pheromone lures were hung to trap the adult rice leaf roller in a targeted manner to interfere with its reproductive cycle. These physical measures reduced the base number of pest populations and gained the initiative for subsequent prevention and control. Thirdly, in chemical control, the principles of precise use of drugs and green pesticides were adhered to. The demonstration field only used high-efficiency and low-toxic pesticides three times during the entire growth period: once in early July during the tillering period, three times from late August to early September during the heading period to prevent and control rice smut, and one more time before maturity depending on the insect situation. The agents used include Jinggangmycin, biological pesticide avermectin, etc., which are compounded with a small amount of high-efficiency chemical pesticides, and the dosage is strictly controlled. For example, the combination of "benzaproconazole + Jinggangmycin" is used to prevent and control rice smut, which improves the prevention effect while reducing the dosage of a single agent. To control planthoppers and borers, biological pesticides such as avermectin are used in rotation with chemical agents to reduce resistance. This precise and small-scale application strategy greatly reduces the total amount of pesticides used. It is estimated that the amount of active ingredients of pesticides per mu in the demonstration field is more than 20% less than the conventional amount, and the incidence of pests and diseases has not increased.

The adoption of green control technology not only ensures the ecological safety of rice production, but also improves the quality and safety level of agricultural products. The traditional reliance on chemical pesticides has brought environmental pollution and food safety risks. For example, the abuse of broad-spectrum pesticides has caused ecological imbalance in rice fields and outbreaks of brown planthoppers. Green control has reduced the input of chemical pesticides through multiple measures and achieved effective control of major pests and diseases. For example, rice blast and rice false smut did not cause substantial losses to new varieties throughout the demonstration season, borers and planthoppers only occurred sporadically, and there was no concern about excessive pesticide residues in rice. Studies have shown that integrating ecological control, biological control and scientific use of pesticides in rice production can maintain a low level of rice field pests while ensuring rice yields and farmers' income (Hajjar et al., 2023). In rice fields that adopt green control technology, the rice yield per mu is significantly higher than that of those that do not adopt it, and the loss rate of pests and diseases is significantly reduced. The practice of this demonstration is consistent with this. It can be said that green control provides a strong guarantee for the high and stable yield of new varieties, and it is also the only way for modern rice production. Yuhang District and other places have promoted the experience of Dahao Village, promoted green control technology for rice pests and diseases throughout the district, and increased farmers' adoption rate through government subsidies and technical training, achieving a win-win situation of reducing chemical pesticides and increasing rice production efficiency.

6 Case Study: Comprehensive Evaluation of Representative Varieties

6.1 Comparative analysis of hybrid rice “Yongyou 33” and “Jiangliangyou 7901”

As the two major *indica*-*japonica* hybrid rice varieties that performed outstandingly in this demonstration, "Yongyou 33" and "Jiang Liangyou 7901" have both commonalities and characteristics in growth traits and comprehensive performance. In terms of yield performance, both varieties are high-yield types: in the large-scale demonstration, the average per-acre yield of "Yongyou 33" in 100 acres of continuous plots reached about 780 kilograms, and the per-acre yield of "Jiang Liangyou 7901" in small-scale demonstrations was also stable at more than 750 kilograms. This is significantly higher than the average yield of conventional *japonica* rice in the same period, reflecting the yield-increasing advantage of hybrid rice. "Yongyou 33" is one of the important varieties for high-yield research in the county because of its larger demonstration area and more outstanding stability in yield increase. In terms of plant type and lodging resistance, "Yongyou 33" has a moderate to high plant height but strong stems, large ears with many grains and evenly spaced ears, showing strong lodging resistance. In the high temperature, drought and local windy weather in 2024, "Yongyou 33" basically did not lodging. This is related to its genetic characteristics of both semi-dwarf and thick stalks. At the same time, its root system is well-developed and solid, and has strong grip on the soil. In contrast, "Jiangliangyou 7901" has a slightly shorter plant height (about 125 cm), but because the ears are larger and heavier, lodging and tilting may occur locally in the later stage when nitrogen fertilizer management is improper. Base technicians observed that the support of the lower stems of 7901 was slightly insufficient after excessive topdressing, indicating that its lodging resistance was slightly inferior to that of "Yongyou 33", and it was necessary to prevent lodging by controlling nitrogen fertilizer in the later stage during production. In terms of stress resistance, the high temperature resistance of "Yongyou 33" is particularly prominent. In the summer of 2024, the south of the Yangtze River region experienced continuous high temperatures, but the heading and flowering of "Yongyou 33" were basically normal, and the fruit set rate remained above 85%, without high-temperature forced emptying. "Jiang Liangyou 7901" has an earlier growth period and has entered the grain filling stage at the hottest time, so it is relatively well protected from high temperatures, but its overall heat resistance is also acceptable and has not been affected by high temperatures on a large scale. However, both varieties are weak in insect resistance and both need to strengthen pest and disease control. "Yongyou 33" is susceptible to rice planthoppers and leaf rollers; "Jiang Liangyou 7901" is susceptible to oviposition by the *Chilo suppressalis* during the heading stage due to its early maturity. Fortunately, the base has basically controlled the damage of borers by using sex attractants to kill them. In terms of maturity and color fading and quality, "Yongyou 33" has uniform color change in the later stage, mature live stalks, bright yellow rice, low broken rice rate, and good rice appearance, which is favored by the market and processing companies;

"Jiangliangyou 7901" has golden husk color, good transparency, and good rice appearance quality and taste, reaching the second-level quality level in Zhejiang Province's quality inspection. According to feedback from the grain department, 7901 has high polished rice rate and whole polished rice rate, which is a combination of high yield and high quality. The rice quality of both varieties is better than that of conventional *japonica* rice main varieties, which has a positive effect on improving grain quality (Ding et al., 2023).

In terms of cultivation points, "Yongyou 33" requires attention to planting enough basic seedlings in the early stage, reasonable density planting, and control of nitrogen in the middle and late stages to prevent greed, and pay attention to timely prevention and control of borers and planthoppers; "Jiangliangyou 7901" emphasizes timely early sowing, appropriate seedling age, and not too much tillering fertilizer. In principle, no nitrogen is applied after jointing to prevent lodging in the later stage. Based on the demonstration experience, the "one control and two promotions" management strategy for "Yongyou 33" has a better effect, that is, controlling nitrogen and density, promoting tillering and strong stalks, and promoting flowering and grain fertilizer; for Jiangliangyou 7901, the "front promotion, middle control, and back protection" strategy is adopted, that is, promoting tillering in the early stage, controlling fertilizer and water in the middle stage, and protecting filling and leaf functions in the late stage. In general, "Yongyou 33" and "Jiangliangyou 7901", as excellent representative varieties of *indica-japonica* hybrid rice, have demonstrated the characteristics of high yield, high quality, and wide adaptability. However, "Yongyou 33" is more inclined to stable yield and stress resistance, which is suitable for the pursuit of stable yield and complex climatic conditions. Jiangliangyou 7901 has higher yield potential and better rice quality, but has relatively strict requirements for cultivation and management. In actual promotion, the corresponding varieties can be selected according to regional production conditions and management level. For example, in areas prone to high temperatures and with high planting levels, "Yongyou 33" performs more reliably; in areas with early-maturing planting systems and the pursuit of the highest yield and rice quality, "Jiangliangyou 7901" can play a greater role, but it needs to be well managed in the later stage of the field. The successful application of the two reflects the different breeding ideas and adaptability of modern hybrid rice varieties, and has positive significance for enriching rice varieties and ensuring food production security.

6.2 Demonstration results of conventional rice "Xiushui 1717" and "Jiahe 567"

Among conventional late *japonica* rice varieties, "Xiushui 1717" and "Jiahe 567" are the two highlight varieties of this demonstration. They represent different types of new conventional rice varieties in Jiangsu and Zhejiang: the former has moderate maturity, stable yield and resistance to lodging, and the latter has early maturity, high yield and excellent comprehensive traits. In terms of yield, "Xiushui 1717" yielded about 664.1 kg per mu in the demonstration, an increase of 5.8% over the control "Xiushui 134", and the yield level was in the upper middle among conventional rice. "Jiahe 567" performed particularly well, with an output of 721.5 kg per mu, an increase of 15.0% over the control, and the increase in yield ranked first among conventional rice. The yield of Jiahe 567 is even close to the level of general hybrid rice, showing that conventional rice also has high production potential after genetic improvement (Ding et al. 2023). In terms of growth period, "Xiushui 1717" is a medium-early variety with a full growth period of about 152 days, which is 3-4 days shorter than the control; "Jiahe 567" is even earlier, with a full growth period of about 148 days, which is 4 days shorter than the control. "Jiahe 567" is usually sown in late May, with full ears at the end of August and mature at the end of October. The early maturing characteristics are conducive to avoiding low temperatures in late autumn and reducing the risk of maturity. In terms of lodging resistance, both varieties have inherited the fine tradition of lodging resistance of Xiushui and Jiahe series. "Xiushui 1717" has a moderate plant height (102 cm), thick and elastic stems, and shows good lodging resistance in windy and rainy environments. Although "Jiahe 567" has many tillers and large panicles, it rarely lodges due to its short stalks (96 cm) and high stalk strength. During the typhoon and heavy rain in Zhejiang in September 2021, there were almost no lodged plants in the "Jiahe 567" field. It can be seen that both varieties meet the requirements of large-scale mechanical harvesting. In terms of disease and insect resistance, the approved data of "Xiushui 1717" is moderately resistant to rice blast, mild sheath blight, and good heat resistance during the heading stage; no obvious disease epidemic was observed in the field, and only mild premature aging of the leaf tips occurred. "Jiahe 567" has good overall resistance, moderate resistance to rice blast at the neck, and no rice false smut has occurred. The main drawback of both is that their resistance to rice planthoppers is average: "Xiushui 1717" needs to pay attention to preventing planthoppers, and "Jiahe 567" is highly susceptible to brown planthoppers, and their large-scale occurrence should be strictly prevented. This also reminds that when promoting these two varieties, green integrated prevention and control of planthoppers should be kept up. In terms of rice quality, "Xiushui 1717" rice quality reaches high-quality grade 3, with short and round rice grains, good transparency, and moderate soft and glutinous taste, which is a typical southern *japonica* rice flavor. It is reported that "Xiushui 1717" has won awards in the national *japonica* rice taste quality evaluation. "Jiahe 567" rice quality also reaches the national standard high-quality grade 3, with medium-long grain shape, low chalkiness, and good taste quality. In the 2022 Zhejiang Province late *japonica* rice regional trial, "Jiahe 567" taste score reached 74 points, ranking at the top. Therefore, the two varieties have both high yield and better quality, and are competitive in the market. In terms of promotion adaptability, "Xiushui 1717", as a continuous late *japonica* rice, is suitable for one-season late rice planting in Zhejiang and adjacent areas. Its growth period is moderate, suitable for connection with medium rice or wheat stubble. "Jiahe 567" is early maturing, resistant to high temperature and certain drought during the panicle neck filling period, suitable for single-season late rice in the plains of Zhejiang, and can also be used in double-season late rice seed production. It is worth mentioning that "Jiahe 567" has integrated the bloodline of multiple excellent strains of Jiaxing Academy of Agricultural Sciences during the breeding process, and has good adaptability.

In the 2020-2021 regional trial in Zhejiang Province, 8 out of 10 pilot sites increased production, with an increase rate of 80%, and stable performance. In the 2021 production trial, all pilot sites increased production. These data show that Jiahe 567 has excellent performance under different ecological conditions and is considered to be a high-yield and stable variety that can be promoted throughout the province (Ding et al. 2023). Although "Xiushui 1717" does not have the outstanding yield increase rate of "Jiahe 567", it is stable and has outstanding stress resistance. It is also a variety that has performed well in multiple demonstration sites in the Yangtze River Delta. At the Shanghai Yangtze River Delta *Japonica* Rice New Variety Exhibition, "Xiushui 1717" was also rated as a "potential variety", further proving its comprehensive strength. By comparison, "Xiushui 1717" and "Jiahe 567" represent two directions of conventional late rice breeding: the former emphasizes plant robustness, good resistance, and strong stable yield; the latter pursues the limit of yield and excellent quality. The two complement each other and can serve regional grain production together. In terms of promotion, it is recommended to match them according to the planting system: "Jiahe 567" can be given priority in fields that need to be sown early and have extremely high yield requirements; "Xiushui 1717" can be selected in fields with general production conditions and hope for stable and reliable yield. The successful application of the two varieties has broken the stereotype that "conventional rice yield is not as good as hybrid rice" and reflects the great potential of modern conventional rice breeding. With the selection and breeding of more new lines, conventional rice is expected to further approach or even surpass the yield level of hybrid rice while maintaining high quality, which is of positive significance to ensuring food security and meeting consumers' demand for high-quality rice.

6.3 Correlation between varietal traits, management strategies, and yield outcomes

Through the above analysis of typical varieties, it can be seen that the high yield of new rice varieties is the result of the interaction between the variety's own genetic characteristics and cultivation management. From the perspective of varieties, the key traits that determine yield include panicle-grain structure, plant height and stalk strength, fruit set rate and thousand-grain weight. Among them, the number of panicles and the fruit set rate jointly determine the number of grains per panicle, which is directly related to the yield; plant height and stalk strength affect lodging resistance, which in turn determines whether the effective panicles can be fully utilized; thousand-grain weight is related to the fullness of the grains, but there is little difference between the varieties in this study. Each new variety achieves the high-yield goal through different combinations of traits: hybrid rice relies on large panicles and many grains (such as "Yongyou 33" with 300+ grains per panicle) and a high fruit set rate, while conventional rice relies on a large number of panicles (such as "Jiahe 567" with 200 000 effective panicles/mu) and a high fruit set rate to achieve high yield.

This shows that different genetic types can achieve similar yield levels through different pathways. Secondly, in terms of cultivation management, reasonable density levels, fertilization strategies and plant protection measures enable the potential of different varieties to be fully utilized. For example, if the fertilizer and water in the later stage of "Yongyou 33" are not controlled, it is easy to lodging and reduce yield. However, in the demonstration, its lodging resistance was guaranteed by controlling fertilizer and water, thus giving full play to its potential for large panicles and increased yields; "Jiahe 567" achieved high ear formation rate and high fruiting rate under the protection of timely early sowing and insect control measures, making up for its general lack of fertilizer tolerance and maximizing its advantage of early maturing and large panicles. This shows that optimizing management based on variety characteristics is a necessary condition for increasing yield.

Only when each variety is matched with a suitable cultivation mode can the best population structure and yield components be formed. For example, sparse planting of hybrid rice with strong tillering ability is conducive to ventilation and light transmission, reducing ineffective tillering; for conventional rice with average tillering ability, appropriate dense planting is used to ensure sufficient panicles. For another example, varieties with slightly weaker lodging resistance use nitrogen control technology to enhance stem strength, while fertilizer-tolerant varieties can appropriately increase fertilizer to exert their potential for increasing yield (Chen et al., 2019).

In the dynamic process of yield formation, there are differences in population growth and dry matter distribution among different varieties, but high-yield varieties can often coordinate the relationship between vegetative growth and reproductive growth, and achieve a balance between early accumulation and late distribution. Comprehensive correlation analysis shows that large population spikelets, high ear formation rate and full filling are common characteristics of all high-yield varieties. The realization of these characteristics depends on the varieties' strong photosynthetic production capacity (for example, the varieties in the Dahong Village base have a high leaf area index) and a slow leaf senescence rate (Zhou et al., 2020).

For example, "Yongyou 33" maintains a high green leaf area after heading, and the dry matter accumulation reaches more than 21 tons/hectare, which is the basis for its large ears and good fruiting. At the same time, management measures such as appropriate topdressing in the later stage can also delay premature leaf senescence and provide a continuous source of assimilates for high-yield varieties (Hou et al., 2021). In addition, the relationship between quality and yield is also a comprehensive consideration. The traditional view is that high yield often sacrifices quality, but new variety breeding is committed to taking both into account. Demonstration varieties such as "Jiahe 567" and "Xiushui 1717" have increased yields while maintaining good rice quality, which is closely related to their genetic background and reasonable cultivation. For example, timely harvesting and scientific drying can avoid the quality decline caused by delayed harvesting due to excessive pursuit of yield. Modern molecular breeding is also solving the contradiction between high yield and high quality, and has discovered some genes that can take into account both grain shape and yield.

Studies have shown that changing the rice grain shape gene can improve rice quality but will lose 14% of yield. If this relationship can be balanced through molecular design, it will greatly improve the breeding efficiency of high-yield and high-quality varieties. Through demonstration tests and comparisons with typical varieties, this study revealed that the yield performance of new rice varieties depends on the combined effects of genetic characteristics and cultivation management. The growth traits of the variety (such as plant type, panicle type, and resistance) determine its yield increase path and adaptation to the environment, while the supporting cultivation technology converts these potentials into realistic high yields.

Different types of new varieties can complement each other in terms of yield composition and learn from each other. Future breeding and cultivation should place more emphasis on the combination of the two, that is, the coordinated optimization of "variety × environment × management". For example, disease-resistant genes can be introduced into high-yield, non-disease-resistant varieties, or cultivation methods can be improved for varieties with weaker lodging resistance to compensate (Figure 4) (Fiaz et al., 2021).

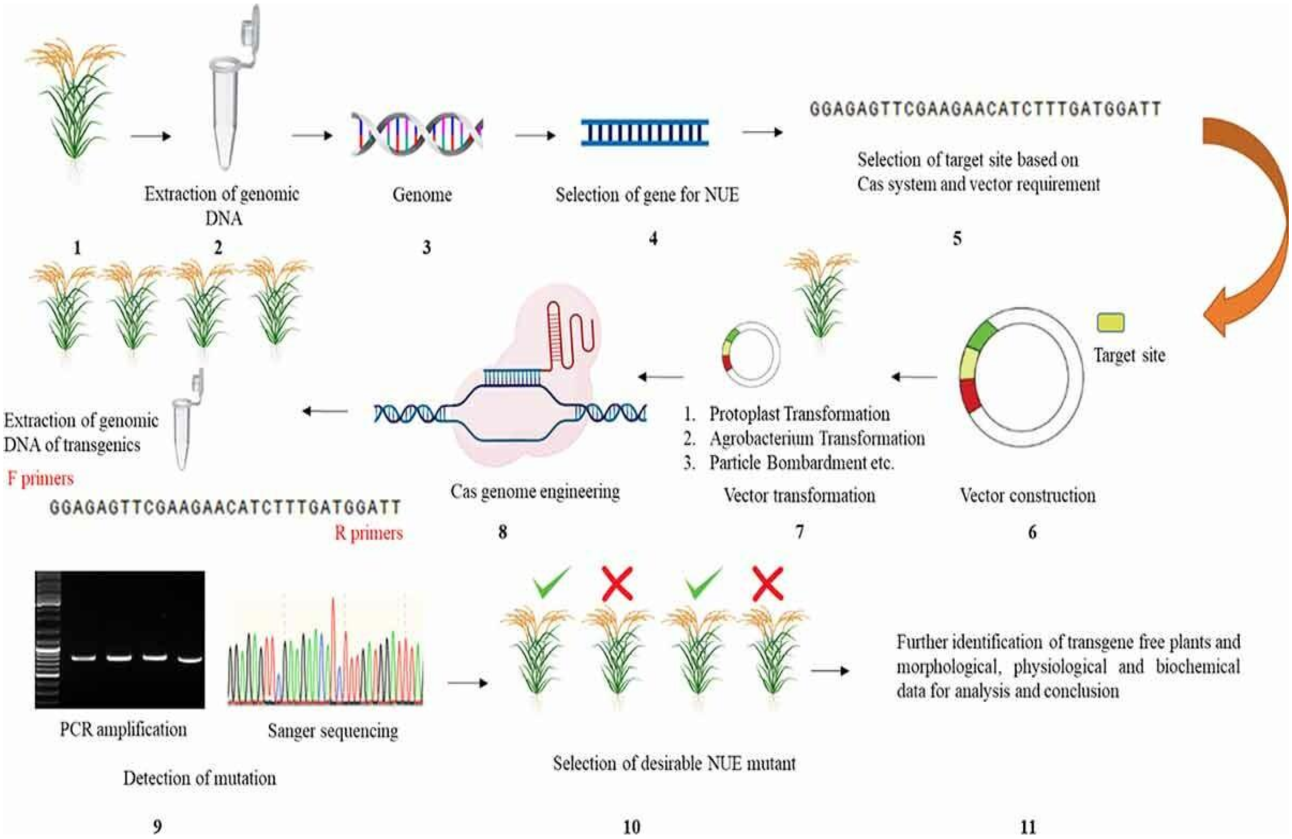

Figure 4 The basic flow chart of genome editing scheme for rice NUE improvement (Adopted from Fiaz et al., 2021)

7 Concluding Remarks

The successful experience of the demonstration of new rice varieties in Dahao Village, Jiashan, shows that the promotion and application of excellent varieties is an important means to promote the green and efficient transformation of regional agriculture. First, the new varieties have greatly increased the yield per unit area, achieved the goal of increasing grain production on limited arable land, and provided a guarantee for food security. The yield of many new varieties in this demonstration exceeded 600 kilograms per mu, which strongly supported the increase in grain yield per unit area in Jiashan County. According to statistics, in recent years, with the application of a batch of high-yield new varieties, the rice yield per unit area in Zhejiang Province has steadily increased, with an increase of more than ten kilograms per mu compared with five years ago. Secondly, new varieties generally have better stress resistance and adaptability, reducing the excessive dependence of production on pesticides and fertilizers. For example, the promotion of varieties resistant to rice blast and lodging has reduced the application of pesticides and crop losses. The high-temperature resistant hybrid rice Yongyou 33 still maintains stable yields under extreme weather conditions, which is of practical significance for ensuring grain production in the context of future climate change. Thirdly, the combination of new varieties and green cultivation technology has promoted the reduction and efficiency of agricultural inputs. For example, the Jiashan base has reduced the use of nitrogen fertilizer by 15%-20% by promoting new varieties of controlled-release fertilizers, while significantly improving the utilization rate of nitrogen fertilizer; implementing green pest control, the field pest loss rate of new varieties has been significantly reduced, the pesticide residues in rice are lower, and the quality is safer. It can be seen that good varieties largely determine the implementation effect of good laws, and the two complement each other and jointly lead the green transformation of agriculture. At present, the area of self-bred varieties of crops in my country has exceeded 95%, and the contribution rate of good varieties in agricultural production has continued to increase. The promotion of new rice varieties not only increases farmers' production and income, but also reduces environmental costs, reflecting the connotation of green production. This is also in line with the country's strategic requirements of "storing grain in technology" and the concept of green development. The case of Dahao Village in Jiashan proves that as long as the scientific research results are transformed into excellent varieties that are suitable for the local area and matched with a scientific planting system, a new path of improving the quality and efficiency of grain production and being friendly to resources and the environment can be found.

While promoting new varieties, the Dahao Village Demonstration Base actively explores ecological planting models, providing a typical example for the sustainable development of regional agriculture. Its significance is reflected in the following aspects: First, it promotes the integrated innovation of agronomic measures and realizes the mechanization, intelligence and standardization of the whole process of rice planting. From seedling raising, transplanting to fertilization and prevention and control, the base adopts advanced agricultural machinery and technology, such as stacked tray seedling raising machine, side deep fertilizer machine, digital insect monitoring and reporting, etc. This greatly improves labor productivity, attracts more new business entities to participate in grain production, and also provides the possibility for large-scale planting. Second, it reduces agricultural non-point source pollution and production costs, and realizes efficient resource utilization. Through controlled-release fertilizer nitrogen reduction, efficient water management and green prevention and control, nitrogen leaching and pesticide residues in the base rice fields are significantly reduced, and the input of chemical fertilizers and pesticides per kilogram of grain is more than 15% lower than that of conventional planting. These measures reduce environmental load and maintain the ecological balance of farmland. At the same time, due to the reduction of chemical input, the total production cost has decreased, and the increase in yield has brought higher returns, forming a win-win situation for economy and ecology. Third, it improves the quality and market competitiveness of agricultural products. Rice produced under the ecological cultivation model is safer and higher quality due to the small amount of chemical pesticides and fertilizers, which meets the demand of modern consumers for green food. The "Jiashan Fragrant Rice" rice produced by the demonstration base has a significant premium in the market, and its brand value is prominent. This shows that ecological planting is not only an environmental need, but also driven by significant economic benefits. Fourth, it has accumulated experience that can be promoted and replicated for the green development of agriculture. The Dahao Village model has a good demonstration and radiation effect, and surrounding areas have learned from it. Through on-site observation and technical training, many high-yield demonstration plots in Jiaxing City and even the Yangtze River Delta region have promoted similar planting models. This is of guiding significance for achieving green rice production in a larger range. In addition, the successful implementation of the ecological planting model also relies on multi-party collaboration: scientific research, promotion, cooperatives and large planting households form a joint force to jointly promote the implementation of technology. This provides inspiration for building a long-term mechanism for green development of agriculture. The practice of new varieties + ecological cultivation in Dahao Village, Jiashan, fully proves the feasibility and comprehensive benefits of developing green agriculture. Its experience shows us that in future agriculture, only by taking the path of "high yield, high quality, high efficiency, ecology and safety" can we achieve true agricultural modernization. The exploration of this base provides a realistic template for achieving this goal.

Although the demonstration of this study has achieved remarkable results, there are still some issues that deserve in-depth research and practical improvement in order to further promote the green and efficient development of regional grain production. First, in terms of new variety selection and breeding, we should continue to strengthen the cultivation of high-yield and high-quality varieties with multiple resistance. In particular, in view of the shortcomings of some new varieties that are not resistant to insects and have limited room for quality improvement, future breeding should make comprehensive use of molecular marker-assisted breeding, new gene discovery and gene editing technologies to cultivate rice varieties that are high-yield, widely adaptable, high-quality and multi-resistant. For example, it is possible to consider introducing anti-planthopper genes and high-temperature stable fruiting genes to cope with the increasingly severe biological and climatic adversity challenges. Secondly, in terms of cultivation technology, it is necessary to further improve the precise cultivation mode of different types of varieties. Although this demonstration summarizes some experience, the optimal planting density, fertilizer and water management schemes of different varieties can still be refined through field trials. It is recommended to establish a cultivation mode optimization test for the main promoted varieties, including nitrogen fertilizer gradient tests, population dynamic monitoring, etc., to clarify the optimal management parameters for each variety. On this basis, an intelligent variety cultivation decision support system is developed to provide farmers with personalized guidance through big data and sensor technology. Third, in terms of regional collaborative promotion mechanism, the cooperation and linkage of scientific research, promotion, enterprises and farmers should be strengthened. The success of this demonstration is inseparable from the technical support provided by scientific research units such as Jiaxing Academy of Agricultural Sciences and Ningbo Academy of Agricultural Sciences. It is recommended to continue to deepen this cooperation mechanism in the future, establish a new variety trial demonstration alliance, unify the planning of new variety display and demonstration layout in the region, share resources and exchange information. At the same time, the enthusiasm of seed companies and new agricultural operators should be brought into play to promote the diffusion of new varieties and new technologies through market-oriented mechanisms. For example, rice companies, grain cooperatives and breeding units should be guided to cooperate in building demonstration bases to achieve a close integration of production, learning, research and application. Fourth, in terms of policy support, local governments should introduce more incentive policies to encourage the application of new varieties and green planting. For example, subsidies should be given to entities that adopt green prevention and control, weight loss and drug reduction measures and have significant results, and rewards should be given to new variety promotion projects with great demonstration and driving effects. At the same time, efforts should be made to increase the acquisition and brand building of green and high-quality grains, increase the benefits of green production, and use economic levers to encourage farmers to actively adopt new varieties and new technologies. Finally, it is also necessary to strengthen farmer training and popular science propaganda. New varieties and supporting technologies can only be truly implemented if they are understood and mastered by farmers. We should make full use of agricultural technology promotion departments and rural demonstration households to carry out various forms of training, such as field classes, observation and exchange, and online guidance, to improve the scientific and technological farming level and green planting awareness of the majority of farmers. The experience of Dahao Village in Jiashan has painted a beautiful picture of green agriculture in the future for us, but it still needs to be explored and improved on a wider range and at a deeper level.

Acknowledgments

I would like to express my gratitude to the reviewers for their valuable feedback, which helped improve 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.

References

Ali M.P., Bari M.N., Haque S.S., Kabir M.M.M., Afrin S., Nowrin F., Islam M.S., and Landis D.A., 2019, Establishing next-generation pest control services in rice fields: eco-agriculture, Scientific Reports, 9: 10180.
https://doi.org/10.1038/s41598-019-46688-6

Blaise D., 2021, Nitrogen use efficiency in crops with new and available technologies, Annals of Plant and Soil Research, 23(4): 416-423.
https://doi.org/10.47815/apsr.2021.10068

Chen F., Qiu H., Zhao Y., Wei X., and Wan X., 2024, Impact of new maize variety adoption on yield and fertilizer input in China: implications for sustainable food and agriculture, Agricultural Systems, 218: 104004.
https://doi.org/10.1016/j.agsy.2024.104004

Chen J., Arafat Y., Din U., Yang B., Zhou L., Wang J., Letuma P., Wu H., Qin X., Wu L., Lin S., Zhang Z., and Lin W., 2019, Nitrogen fertilizer amendment alters the bacterial community structure in the rhizosphere of rice and improve crop yield, Frontiers in Microbiology, 10: 2623.
https://doi.org/10.3389/fmicb.2019.02623

Chen Z., Wang Q., Ma J., Zou P., and Jiang L., 2020, Impact of controlled-release urea on rice yield, nitrogen use efficiency and soil fertility in a single rice cropping system, Scientific Reports, 10: 10432.
https://doi.org/10.1038/s41598-020-67110-6

Chivenge P., Sharma S., Bunquin M., and Hellin J., 2021, Improving nitrogen use efficiency—a key for sustainable rice production systems, Frontiers in Sustainable Food Systems, 5: 737412.
https://doi.org/10.3389/fsufs.2021.737412

Ding Z.Q., Huang H.X., Lai L.C., Wang S.L., Pan Y.Y., and Shi Y., 2023, Jiahe567, a new late *japonica* rice variety, China Seed Industry, 1: 130-131.

Fiaz S., Wang X., Khan S., Ahmar S., Noor M., Riaz A., Ali K., Abbas F., Mora-Poblete F., Figueroa C., and Alharthi B., 2021, Novel plant breeding techniques to advance nitrogen use efficiency in rice: a review, GM Crops & Food, 12(1): 627-646.
https://doi.org/10.1080/21645698.2021.1921545

Hajjar M.J., Ahmed N., Alhudaib K., and Ullah H., 2023, Integrated insect pest management techniques for rice, Sustainability, 15(5): 4499.
https://doi.org/10.3390/su15054499

Hang S., Wang Q., Wang Y., and Xiang H., 2024, Evolution of rice cultivar performance across China: a multi-dimensional study on yield and agronomic characteristics over three decades, Agronomy, 14(12): 2780.
https://doi.org/10.3390/agronomy14122780

Hou M., Yu M., Li Z., Ai Z., and Chen J., 2021, Molecular regulatory networks for improving nitrogen use efficiency in rice, International Journal of Molecular Sciences, 22(16): 9040.
https://doi.org/10.3390/ijms22169040

Hu Y., Cai Q., Xu Y., Xue J., Yu E., Wei H.Y., Xu K., Huo Z.Y., and Zhang H.C., 2023, One-time fertilization of controlled-release urea with compound fertilizer and rapeseed cake maintains rice grain yield and improves nitrogen use efficiency under reduced nitrogen conditions, Frontiers in Plant Science, 14: 1281309.
https://doi.org/10.3389/fpls.2023.1281309

Huang M., Zhang R., Chen G., Liu L., Li Z., Chen J., and Cao F., 2024, Achieving higher grain yield in hybrid rice through the promotion of individual growth and development, Agronomy Journal, 116(5): 2427-2434.
https://doi.org/10.1002/agj2.21632

Li J.Q., 2024, Harnessing entomopathogenic fungi for pest control in rice: case studies and efficacy, Molecular Microbiology Research, 14(1): 92-98.
https://doi.org/10.5376/mmr.2024.14.0010

Liu X., Deng X., Kong W., Sun T., and Li Y., 2023, The pyramiding of elite allelic genes related to grain number increases grain number per panicle using the recombinant lines derived from *indica–japonica* cross in rice, International Journal of Molecular Sciences, 24(2): 1653.
https://doi.org/10.3390/ijms24021653

Lyu J., 2024, Meta-analysis of genetic resistance to major rice pests and pathogens, Molecular Pathogens, 15(6): 273-281.
https://doi.org/10.5376/mp.2024.15.0027

Teng X.Y., Wang J.M., Li P.Z., Lin X.Y., and Sun Q., 2021, Advances on studies relating to lodging resistance of rice plant, Fujian Journal of Agricultural Sciences, 10: 1245-1254.
https://doi.org/10.19303/j.issn.1008-0384.2021.10.018

Vijay J., Mahesh L., Rao N.V., Reddy D., and Venugopal G., 2024, Comparative study on cost analysis of mechanical and manual transplanting of rice, Journal of Scientific Research and Reports, 30(10): 39-43.
https://doi.org/10.9734/jsrr/2024/v30i102428

Wang X.F., Lu Z.H., Liu W., Lu D.B., Wang S.G., Wu H.X., Fang Z.Q., and He X.Y., 2022, Advances in lodging resistance of rice since the “Green Revolution”, Guangdong Agricultural Sciences, 3: 1-13.
https://doi.org/10.16768/j.issn.1004-874X.2022.03.001

Xing Z.P., Wu P., Zhu M., Qian H.J., Cao W.W., Hu Y.J., Guo B.W., Wei H.Y., Xu K., Dai Q.G., Huo Z.Y., and Zhang H.C., 2017, Effect of mechanized planting methods on plant type and lodging resistance of different rice varieties, Transactions of the Chinese Society of Agricultural Engineering, 1: 52-62
https://doi.org/10.11975/j.issn.1002-6819.2017.01.007

Xu D., Zhu Y., Chen Z., Han C., Hu L., Qiu S., Wu P., Liu G., Wei H., and Zhang H., 2020, Yield characteristics of *japonica*/*indica* hybrids rice in the middle and lower reaches of the Yangtze River in China, Journal of Integrative Agriculture, 19: 2394-2406.
https://doi.org/10.1016/S2095-3119(19)62872-8

Zhou L., Liu Q.Y., Tian J.Y., Zhu M.H., Cheng S., Che Y., Wang Z.J., Xing Z.P., Hu Y.J., Liu G.D., Wei H.Y., and Zhang H.C., 2020, Differences in yield and nitrogen absorption and utilization of *indica-japonica* hybrid rice varieties of Yongyou series, Acta Agronomica Sinica, 5: 772-786
https://doi.org/10.3724/SP.J.1006.2020.92051