

Breeding of a New Medium *Indica* Variety Liangyou 7968 with Good Quality and Disease Resistance

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Abstract With global warming and frequent occurrence of severe weather, rice diseases are also on the rise. Therefore, the breeding of new rice varieties with disease resistance is still the breeding direction for rice breeding experts. "Liangyou 7968" is a new hybrid rice combination with double resistance to bacterial blight and rice blast. This paper introduced the breeding process, characteristics, high-yielding cultivation techniques and high-yielding seed production technical regulations for Liangyou 7968.

Key words Disease resistance; Liangyou 7968; Breeding research

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Rice serves as one of the important food crops in the world, and its yield and quality are crucial for ensuring food security^[1-4]. However, rice is threatened by many diseases during its growth, such as rice blast, sheath blight and bacterial blight^[5], which lead to rice yield reduction and quality decline. With the rapid development of molecular biology and genetics, people's understanding of the mechanism of rice disease resistance is deepening. Exploring rice disease-resistant genes, disease-resistant signal pathways and their interaction with pathogenic bacteria from the genetic level provides a theoretical basis for cultivating rice varieties with high disease resistance^[6]. Meanwhile, global climate, agricultural ecosystems and rice planting patterns have also made the occurrence and prevalence of rice diseases more complicated and changeable.

The purpose of breeding disease-resistant rice varieties is to improve rice yield, ensure national food security, reduce production costs, protect ecological environment and promote the sustainable development of agriculture. Planting disease-resistant rice varieties can effectively resist pests and diseases, reduce rice yield loss and ensure national food security. For example, Huiliangyou 985 bred by Anhui Academy of Agricultural Sciences^[7] has the characteristics of high quality, good disease resistance, high yield and good stress resistance, which solves the breeding problems of high quality with low yield and high yield without disease resistance. Since the national examination in 2021, the annual promotion area has exceeded 70 000 hm². Planting disease-resistant rice varieties not only lowers the amount of pesticides and fertilizers and the costs of agricultural production, but also reduces

environmental pollution. For example, the application of urea was reduced by 97.5 kg/hm² by reducing the application of pesticides for 1–2 times, which was beneficial to the protection of the ecological environment^[8]. The breeding and application of disease-resistant rice varieties are helpful to improving agricultural production efficiency and promoting agricultural sustainable development. The popularization and application of disease-resistant rice varieties can improve the quality and yield of rice, increase farmers' income, and simultaneously improve the market competitiveness of rice, which is conducive to rural revitalization and accurate poverty alleviation.

Liangyou 7968 was bred with N779S as the female parent and 14Z268 as the male parent. Both parents carry bacterial blight and rice blast. In 2020, it was sampled and identified by the Institute of Plant Protection and Agro-products Safety, Anhui Academy of Agricultural Sciences to be moderately resistant to rice blast (comprehensive index of 4.0) and resistant to bacterial blight, so it is a double-resistance variety. This variety was bred by Rice Research Institute, Anhui Academy of Agricultural Sciences, and passed the variety approval of Anhui Variety Committee on October 20, 2022, with an approval number of Wanshendao 20220010.

Breeding Process

The female parent "N779S" of Liangyou 7968 is a thermo-sensitive two-line sterile line bred by Rice Research Institute, Anhui Academy of Agricultural Sciences by crossing 1892S with line 7J278 with double resistance (resistance to bacterial blight and rice blast) and continuous backcrossing. It was approved by Anhui Variety Approval Committee in August 2012. The male parent "14Z268" was bred by Rice Research Institute of Anhui Academy of Agricultural Sciences. In specific, Rice Research Institute of Anhui Academy of Agricultural Sciences conducted sexual hybridization between D205 material carrying the resistance gene to bacterial blight and Teyou 559 as the male parent in the regular

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Dewen ZHANG (1972–), male, P. R. China, researcher, master, devoted to research about breeding of new rice varieties with stress resistance and identification techniques of rice heat tolerance.

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season of 2004 in Hefei, and then sexually crossed F1 as the female parent with Enhui 58 resistant to rice blast as the male parent in Lingshui, Hainan in the winter of 2004, and a three-way hybrid D205/559/Enhui 58 was harvested in the regular season. Next, through 17 generations of systematic breeding in 9 years, a restorer line showing compact plant type, stout stem and slightly longer growth period and tending to be stable, was screened out in the regular season of 2014, and designated 14Z268.

In 2013, N779S was combined with 14Z268. Outstanding performance was observed in 2014. The combination participated in plot experiments in Anhui Province from 2016 to 2017, and isolated seed production was conducted. In 2018, it entered the variety comparison test in Anhui Province.

The breeding process is as follows:

The regular season of 2004	D205 (bacterial blight resistance gene)/559 (Teyou 559, male parent)
Winter of 2004	D205/559//Enhui 58 (rice blast resistance gene)
The regular season of 2005	Rice lines were planted separately, and compact individual plants were selected from 18 lines.
Winter of 2005	Individual plants with good luxuriance and compact plant type were selected from 21 lines.
The regular season of 2006	Rice lines were planted separately, and the ideal line numbered 6HF515-3 was harvested, subjected to test cross and used for forming combinations.
Winter of 2006	Multiple lines were widely tested, and their combining ability was determined.
The regular season of 2007	In the regular season, the heterosis of the tested combinations was identified, and it was determined that 7C2116-2 had stronger heterosis.
Winter of 2007	Ideal lines were selected for extensive test cross.
The regular season of 2013	N779S was combined with ideal lines.
Winter of 2013	Manual seed production was carried out in a small scale.
The regular season of 2014	Isolated seed production was carried out. The restorer line was named 14Z268.

Table 1 Regional test results of Liangyou 7968 in 2019 and 2020

Variety	Average plant height//cm	Effective panicles per hectare//10 ⁴	Total number of grains per panicle//grains	Number of filled grains per panicle//grains	Seed setting rate//%	1 000-grain weight//g	Whole growth period//d
Liangyou 7968	123.2	255.0	179.7	153.8	85.6%	27.4	137.7
II You 838 (CK)	127.3	217.5	188.1	164.3	87.2	28.3	138.8

Planting density

Generally, the planting density is 225 000 – 300 000 holes/hm², with 2 – 3 seedlings per hole.

Fertilization management

The fields with medium fertility are applied with N 210 – 240 kg/hm², P₂O₅ 105 – 120 kg/hm², K₂O₂ 10 – 225 kg/hm² in total.

Main Characters

Morphological characters

It is a medium *indica* two-line hybrid rice variety. The results of regional trials in 2019 and 2020 were as follows: average plant height 123.2 cm, effective panicles per hectare 2.55 million, total number of grains per panicle 179.7 grains, number of filled grains per panicle 153.8 grains, seed setting rate 85.6%, and 1 000-grain weight 27.4 g. The whole growth period was 137.7 d, and the maturation period was equivalent to the maturation period of the control (II You 838) (Table 1).

Yield performance

In 2019, the average yield in regional trials was 9 830.70 kg/hm², which was 3.88% higher than that of control variety (not significant). In 2020, the average yield in regional trials was 9 453.45 kg/hm², which was 5.56% higher than that of control variety (extremely significant). In 2021, the average yield in production tests was 9 551.25 kg/hm², which was 9.55% higher than that of control variety (Table 2).

Rice quality and resistance

It was tested by Anhui Rice and Products Testing Center in 2020. The results showed a brown rice rate of 79.9, a head milled rice rate of 39.7, a chalkiness degree of 3.8, transparency of 3, an alkali spreading value of 4.2, gel consistency of 69, an amylose content of 12.6, a grain length of 6.7, a milled rice rate of 72.4, a length-width ratio of 3.1, and a chalky grain rate of 22. It is comprehensively judged as ordinary.

According to the disease resistance identification of Institute of Plant Protection and Agro-products Safety, Anhui Academy of Agricultural Sciences in 2019, it was moderately susceptible to rice blast (comprehensive index 5.8), susceptible to false smut (diseased panicle rate 13.0%), and resistant to bacterial blight. In 2020, it was moderately resistant to rice blast (comprehensive index 4.0), susceptible to false smut (diseased ear rate 15.0%), and resistant to bacterial blight.

Key Points of Cultivation Techniques

Sowing time

Sowing is conducted in the middle rice area of Anhui from the end of April to the first ten-day period of May.

In nitrogen fertilizers, the base fertilizer accounts for 50% – 60%, the tillering fertilizer accounts for 20%, and the panicle fertilizer accounts for 20% – 30%. All phosphate fertilizers are used as the base fertilizer. For potassium fertilizers, the ratio of base fertilizer to panicle fertilizer is 6 : 4^[9]. Urea is applied as the tillering fertilizer 4 – 5 d after transplanting at a rate of 75 – 112.5 kg/hm².

At the jointing stage, 60–75 kg/hm² of urea should be applied according to seedling conditions and the weather. At the booting stage (when young panicles are 1–2 cm), 75–90 kg/hm² of urea and 75 kg/hm² of potassium chloride are applied. In the later stage, foliar fertilizers or growth regulators can be sprayed according to seedling conditions.

Table 2 Yields of Liangyou 7968 in regional trials in 2019, 2020 and 2021

Year	Average yield per unit area // kg/hm ²	Increase compared with control // %
2019	9 830.70	3.88
2020	9 453.45	5.56
2021	9 551.25	9.55

Water management

Seedlings are transplanted with shallow water, which is naturally dried 4–5 d after planting, and after re-watering, topdressing for turning green and cultivating, the field is dried for 2–3 d^[10]. After irrigation, a shallow water layer of 2–3 cm is kept in the field to promote tillering. When the total number of tillers in the whole field reaches 90% of the expected number of panicles, water will be drained to dry the field. After re-watering, re-drying can be performed in case of vigorous growth, and the operation is repeatedly until jointing. A shallow water layer with a depth of 3 cm is kept 15–5 d before heading and 5–15 d after heading, and a moist condition and intermittent irrigation are kept before and after this period. That is to say, the field is kept dry and wet alternatively until yellow maturation. Water is drained 7 d before maturation^[11].

Prevention and control of diseases, pests and weeds

The principle of prevention and control is prevention first, and comprehensive prevention and control. At the seedling stage, attention is paid to the control of *Rhizoctonia solani* and rice thrips. It is necessary to strengthen the prevention and control of pests and diseases during the seedling stage, and adhere to the principle of "bringing pesticides to the field"^[12]. Over fertilization or overgrowth of seedlings should be avoided to prevent lodging or remaining green when it is due to become yellow and ripe. Series irrigation and long-term deep irrigation are strictly prohibited. Attention should be paid to the protection from natural enemies and the elimination of weeds in the field. The forecasting of diseases and pests should be strengthened, so as to implement timely drug application and overall prevention and control.

The main diseases of mid-season rice are rice blast, sheath blight and false smut^[13]. Rice blast is timely prevented and treated with 75% tricyclazole 900 g/hm² at the initial stage of the disease, and sheath blight is sprayed with 20% Jinggamyacin 750 g/hm² at the jointing-booting stage, and once at the peak of the disease, with an interval of 5–7 d. False smut of rice is prevented with triadimefon emulsifiable concentrates 750 ml + 20% Jinggamyacin 600 g/hm² 7 d before and at the beginning of heading by spraying. Spraying is conducted again at the full heading stage in case of rainy and wet weather.

Pests in mid-season rice mainly include rice thrips, leaf

rollers, *Chilo suppressalis* and *Naranga aenescens* Moore^[14]. Insecticides such as Bt, Regent, bisultap and abamectin are selected to control the pests in the middle and late stage. If there are rice planthoppers at the booting and heading stages of rice, 48% Lesbon EC 1 500 ml/hm² or 10% imidacloprid powder 230–450 g/hm² should be sprayed for control.

A 5 cm water layer is kept in the field 4–5 d after transplanting, and 750 ml of mefenacet · bensulfuron-menthyl compound is sprayed per hectare, or 1 500 ml of "Yelao" is mixed with soil, which is then evenly spread to control weeds in the paddy field.

Key Points of Seed Production Techniques

The male parent of Liangyou 7968, 14R268, has compact plant type, strong stem, slightly longer growth period, big panicle, large amount of pollen and late flowering. The female parent (N779S) shows rolled-inwardly flag leaves, and has high stigma exertion rate and good outcrossing rate. The duration from seeding to heading is short, and this combination is suitable for seed production with a high seed yield.

Determination of the difference between the sowing dates of male and female parents

For seed production in Anhui Province along the Huaihe River, the cultivation of the male parent is divided into two stages, with a difference of 10 d between the first and second stages. In the first stage, the male parent is sown around April 30 and starts heading around August 7. The duration from sowing to heading is about 98–102 d, and the leaf number of main stem is 16.0–17.0. The female parent is sown around May 20, and starts heading around August 8. The duration from sowing to heading is about 78–83 d, and the leaf number of main stem is 14.5–15.0. The time difference between male and female parents is (19 ± 1) d, and the leaf difference is 1.5–2.5 leaves.

Sparsely and evenly sowing male and female parents to cultivate strong seedlings

The sowing quantity of the male parent is 3.75 kg/hm², and the seedlings are raised in wet conditions. The age of the male parent is about 35 d for the first stage and 25–28 d for the second stage. The sowing quantity of the female parent is 30.0 kg/hm², and the method of soaking in the day time and exposing in the night to accelerate germination^[15]. The seedlings are raised in wet conditions, and the age of the female parent is about 18–20 d. The seedlings of the male and female parents are required to be short, strong, tillered and neat when transplanting.

Transplanting sufficient basic seedlings

The row ratio of male parent to female parent is 2 : 12, and the width of the compartment is 210.0 cm. The male parent is transplanted in two rows, one row for each of the first and second stages, with a row spacing of 16.7 cm × 20.0 cm, 2–3 plants per hole. About 66 000 holes are planted for the male parent per hectare. The plant spacing for the female parent is 13.3 cm × 13.3 cm, and the distance from the male parent is 20.0 cm at the sunny side and 26.7 cm at the dark side of the sun^[16]. The female parent is transplanted with two plants per hole, about 563 000 holes per hectare, ensuring more than 2.7 million basic seedlings per

hectare.

Rationally managing fertilizers and water and strengthening pest control

On the basis of applying more farm manure, 750.0 kg/hm² of ammonium bicarbonate, 600.0 kg/hm² of ordinary calcium superphosphate and 150.0 kg/hm² of potassium chloride were applied as the basic fertilizer. Five days after the male parent is planted, 60.0 kg/hm² of urea is applied only to the male parent. Five days after the female parent is planted, the male and female parents are fertilized with urea at a rate of 187.5 kg/hm² at the same time.

Timely forecasting the flowering period and taking good control measures

Artificial pollination is carried out when heading rates of the male and female parents are about 20%. On the day, artificial pollination is started at about 10 min after flowering of the male parent (about 11:00 a. m. at noon), for three times in successive, with an interval of 20 min each time.

Applying "920" skillfully to improve outcrossing rate

When the main stems of male and female parents split to show an opening (the eighth stage), no more than 2/3 of the flag leaves are cut off for the male parent, and no more than 1/2 of the flag leaves are cut off for the female parent, so as to facilitate flowering and pollination and improve the outcrossing rate of the female parent^[17]. On the second day, 30.0 g of "920" is sprayed per hectare (both parents are sprayed with it) for initiation. On the fourth day, when the heading rate of the female parent is about 15% (2 d after initiation), both parents should be sprayed with "920" at the same time at a rate of 60.0 g/hm², and then, the male parent is sprayed again at the same concentration. On the sixth day, both parents are sprayed with "920" at the same time at a rate of 60.0 g/hm², and then, the male parent is sprayed again at the same concentration.

Strictly removing other plants to ensure seed quality

Before using the "920" hormone, the seed production field is inspected line by line, and early-maturing miscellaneous plants and other suspicious miscellaneous plants are removed^[18]. During the artificial pollination period, before flowering every day, a special person is selected to check line by line and remove missing miscellaneous plants. Before harvesting, miscellaneous plants are carefully removed for 1–2 times.

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