Breeding and High-Yield Cultivation Technology of the Nationally Approved Novel Wheat Variety, Wanximai 8

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Abstract Wanximai 8 is a novel wheat variety developed by the Lu'an Academy of Agricultural Sciences. It was created through inter-species hybridization and genealogical selection, utilizing Wanximai 0638 as the female parent and Nannong 04Y29 as the male parent. This variety received national approval in 2023. This variety exhibits several advantages, including high yield, robust overall resistance, resistance to lodging, and moderate growth period. In this paper, we present an overview of the parental origin and breeding process, as well as the characteristics and cultivation techniques associated with Wanximai 8.

Key words Wheat; Wanximai 8; Breeding; Characteristics; Cultivation technique

1 Introduction

Wheat is a significant staple crop in China, with over 40% of the population relying on it as a primary food source. The level of wheat production has a direct impact on food security and agricultural sustainability within the country[1]. Given the limited availability of arable land in China, enhancing wheat yields is the most effective approach for ensuring the overall production of wheat. The development of novel varieties, along with the research and dissemination of advanced cultivation techniques, serves as the foundation for improving wheat yield[2]. The newly developed wheat variety, Wanximai 8, is characterized as an early maturing spring variety. Its primary attributes include balanced three key factors for yield, high productivity, compact plant structure, robust resistance to lodging, uniformity, well-formed spikes, and effective maturity performance. In 2023, the National Crop Variety Validation Committee approved the validation (validation No.: GSM 20230028) of this variety, confirming its suitability for cultivation in the winter wheat regions of the middle and lower reaches of the Yangtze River, specifically in the provinces of Zhejiang, Jiangxi, Hubei, Hunan, and Shanghai. Additionally, it is appropriate for planting in the southern areas of Xinyang and Nanyang in Henan Province, as well as in the southern regions of the Huaihe River in Jiangsu and Anhui provinces.

2 Parental origin and breeding process

2.1 Parental origin The female parent, Wanximai 0638, is a self-breeding variety developed by the Lu'an Institute of Agricultural Sciences. This variety is characterized by high yield, stable production, and superior quality. At the China Quality Annual Meeting and Appraisal Information Conference held in December 2019, organized by the Ministry of Agriculture and Rural Affairs, Wanximai 0638 was awarded the champion title in the cake group. The female parent Nannong 04Y29 is a wheat variety selected by the Institute of Cytogenetics at Nanjing Agricultural University from the cross between 92R137 and Yangmai 158, with Yangmai 158 being used as a recurrent parent.

2.2 Breeding process In the spring of 2010, the hybridization of Wanximai 0638 and Nannong 04Y29 was initiated. From 2011 to 2015, single-plant selections (F_1-F_5) were conducted to identify superior strains. Subsequently, from 2015 to 2016, comparative evaluations of the selected strains were performed. During the period from 2016 to 2017, a multi-replicate tasting was carried out at the Lu'an Academy of Agricultural Sciences. In 2017 - 2018, a comparative variety test utilizing a 10-point scoring system was executed. The hybrid also participated in the variety comparison test organized by the Middle and Lower Yangtze River Science and Enterprise Consortium from 2018 to 2019. Furthermore, from 2019 to 2021, it was involved in the regional testing conducted by the same consortium, culminating in a production test from 2021 to 2022. The selection and breeding process of Wanximai 8 is illustrated in Fig. 1.

2010	Wanximai 0638 × Nannong 04Y29
	↓
2011-2016	Single-plant selections for consecutive 6 generations to identify superior strains characterized by high yield, reduced susceptibility to disease, and enhanced resistance to lodging
	↓
2017-2018	Comparative variety test
	↓
2018-2019	Variety comparison test organized by the Middle and Lower Yangtze River Science and Enterprise Consortium
	↓
2019-2021	Regional test conducted by the Middle and Lower Yangtze River Science and Enterprise Consortium
	↓
2021-2022	Production test conducted by the Middle and Lower Yangtze River Science and Enterprise Consortium

Fig. 1 Selection and breeding process of Wanximai 8

3 Characteristics of varieties

3.1 Botanical characteristics Wanximai 8 is a spring wheat variety characterized by a whole growth period of 195.7 d, exhibiting a slightly delayed ripening stage in comparison to the control variety, Yangmai 20. The seedlings exhibit an erect growth habit,

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possess broad and short leaf blades, display a dark green leaf color, and demonstrate a robust tillering capacity. The variety exhibits a plant height of 86.7 cm, characterized by compact growth structure and notable resistance to lodging. It demonstrates good overall neatness, with well-organized spike layers and moderate growth period. The spikes are fusiform in shape, possess long awns, and feature red grains that are semi-hard and exhibit fullness. The yield three factors for the regional tests conducted in 2019 – 2020 and 2020 – 2021 were as follows: 323 000 and 307 000 spikes per 667 m^2; 40.1 and 38.0 kernels per spike; and 40.6 and 41.3 g for 1 000-grain weight, respectively.

3.2 Resistance identification The resistance assessment conducted by the Institute of Plant Protection at the Chinese Academy of Agricultural Sciences during 2019 and 2020 indicated that the variety exhibited moderate resistance to mildew and slow stripe rust, while demonstrating high susceptibility to leaf rust, powdery mildew, and sheath blight. Additionally, the resistance assessment conducted by the same institution during 2020 and 2021 revealed that the variety displayed moderate resistance to mildew and moderate susceptibility to stripe rust, leaf rust, powdery mildew, and sheath blight. During 2019 and 2020, lodging resistance was assessed, revealing that 95.2% of the evaluated pilots exhibited three or fewer levels of lodging resistance and 90.5% of the pilots had less than 40% of the lodging area. In the subsequent period of 2020 to 2021, it was found that 95% of the pilots also demonstrated three or fewer levels of lodging resistance, with 95% of the pilots experiencing less than 40% of the lodging area.

3.3 Quality analysis In 2020, a quality analysis conducted by the Quality Supervision, Inspection and Testing Centre for Cereals and Products of the Ministry of Agriculture and Rural Affairs in Harbin identified several characteristics of Wanximai 8. The analysis reported a kernel weight of 828 g/L, a crude protein content of 14.00%, a wet gluten content of 31.9%, a water absorption rate of 61.8%, and a dough stabilization time of 4.0 min. These findings indicate that Wanximai 8 is classified as a medium gluten wheat. The analysis conducted by the same institution in 2021 indicated a kernel weight of 822 g/L, a crude protein content of 15.63%, a wet gluten content of 35.2%, a water absorption rate of 58.2%, and a dough stabilization time of 3.5 min, characterizing it as a medium-gluten wheat variety.

4 Yield performance

In 2020, Wanximai 8 participated in a regional trial organized by the Middle and Lower Yangtze River Science and Enterprise Consortium. The average yield recorded was 442.18 kg/667 m^2, which represented a 2.93% increase compared to the control variety, Yangmai 20. This difference was statistically significant, positioning the variety 10th in the trial rankings. Out of the 21 points summarized, there were 16 instances of yield increases, with 13 pilots achieving yield enhancements of 2% or greater. The proportion of points meeting the established standard was 61.9%. In the subsequent test conducted in 2021, the average yield was recorded at 425.10 kg/667 m^2, representing a 3.22% increase compared to the control variety Yangmai 20, with a highly significant difference observed. This yield ranked 10th in the overall test. The summary indicated a total of 18 instances of yield increases across 20 points, which included 15 trials that achieved yield increases of 2% or greater, resulting in a standard attainment rate of 75%. The two-year test yielded an average production of 433.64 kg/667 m^2, representing a 3.08% increase compared to the control variety, Yangmai 20. The yield enhancement over the two-year period was statistically significant. Additionally, 28 out of the 41 points summarized exhibited a yield increase of 2% or greater, leading to a standard attainment rate of 68.3%. In the production trial conducted in 2022, the average yield was 472.88 kg/667 m^2, reflecting a 2.20% increase compared to the control group. Notably, 9 out of the 10 points in the summary demonstrated an increase in yield, resulting in a standard attainment rate of 90%.

5 Cultivation technique points

5.1 Pre-sowing preparation

5.1.1 Seed preparation. Wheat seeds must undergo a process of sun-drying and dressing prior to sowing. The sun-drying of seeds facilitates maturation and enhances resistance to insects and mold[3]. It is recommended that seeds should be coated with a seed coating agent comprising difenoconazole, fludioxonil, and thiamethoxam. In the case of uncoated seeds, insecticides, fungicides, and yield-enhancing fungi are typically employed to manage subterranean pests as well as other diseases and pests affecting wheat.

5.1.2 Land preparation and base fertilizer application. The selection of an appropriate land preparation pattern is contingent upon various factors, including soil conditions and field size. Typically, basal fertilizer is applied to an area of 667 m^2, utilizing either 40 – 50 kg of a 45% high-concentration compound fertilizer with a nutrient ratio of 20∶10∶15 or 40 – 50 kg of a 45% compound fertilizer with a nutrient ratio of 15∶15∶15, supplemented by 8 kg of urea. The base fertilizer is typically broadcasted first and subsequently incorporated into the soil through plowing. Alternatively, it may be applied simultaneously with sowing using a seed-fertilizer drill seeder.

5.1.3 Three-ditch supporting. Due to the inadequate drainage characteristics of paddy field plots utilized for rice stubble wheat cultivation, it is essential to implement a system of three ditches, namely the furrow ditch, waist ditch, and field side ditch, to enhance drainage support. The depths of the three ditches within the field should be 0.2, 0.25, and 0.35 m, respectively. Additionally, the depth of the larger ditch located outside the field should range from 0.6 to 0.8 m. The spacing between the furrow ditches should be maintained at 3 – 4 m to ensure connectivity among the ditches. Furthermore, the horizontal ditch must be linked to the external ditch to facilitate drainage, ensuring that the ditches remain dry once precipitation ceases.

5.2 Sowing

5.2.1 Sowing period. The optimal sowing period for Wanximai 8 occurs between October 25 and November 10.

5.2.2 Seeding rate. In the optimal sowing period, the recommended seeding rate for drill sowing is between 12.5 and 14.5 kg/667 m^2.

If the sowing date is postponed, it is advisable to increase the seeding rate accordingly, with an increment of 0.5 kg/667 m^2 for every three-day delay. If the sowing date is advanced, the seeding rate should be decreased by 0.5 kg/667 m^2 for every three-day advancement[4]. The recommended seeding rate for broadcasting is between 15 and 20 kg/667 m^2. Conversely, when the sowing date is delayed, it is advisable to increase the seeding rate by 1.0 kg/667 m^2 for every three-day postponement.

5.3 Applying balance fertilizer, jointing fertilizer and foliar fertilizer In wheat fields characterized by yellow wheat seedlings, reduced number of tillers, and loss of fertilizer, it is recommended that urea should be applied at a rate of 4 – 5 kg/667 m^2 during early to mid-February, coinciding with periods of rain and snow, to facilitate balanced growth of the wheat seedlings. In fields exhibiting optimal seedling conditions, it is recommended to apply jointing fertilizer extensively. A top-dressing of 7.5 – 10.0 kg of urea per 667 m^2 should be administered once the first internode of the wheat reaches a predetermined length following the jointing stage. This practice aims to promote the development of larger spikes and increased number of grains. Foliar applications of 2% – 3% urea in conjunction with 0.5% – 1.0% potassium dihydrogen phosphate were administered at a rate of 50 – 60 kg/667 m^2 from the flowering stage to the grouting stage.

5.4 Timely control of pests, diseases and weeds Weed control should be implemented promptly during periods when grass resistance is minimal. In wheat fields infested with grass weeds, the application of 15% clodinafop-propargyl at a rate of 16 – 24 g/667 m^2, 6.9% fenoxaprop-p-ethyl EW at a rate of 40 – 60 mL/667 m^2, or 5% pinoxaden EC at a rate of 100 – 120 mL/667 m^2 is recommended. These herbicides should be diluted in 40 kg of water and applied during the 3 – 5-leaf stage of the weeds. In wheat fields characterized by a predominance of broad-leaved weeds, it is recommended to dilute 50 – 60 mL of a 20% fluroxypyr-meptyl emulsion or 10 – 15 g of a 10% tribenuron WP with 40 – 50 kg of water per 667 m^2. This mixture should be applied from the 3 – 4-leaf stage of the wheat until just prior to jointing. Optimal application of the herbicides occurs during the 2 – 4-leaf stage of the broad-leaved weeds, ensuring that the herbicides are uniformly distributed on the stems and leaves. In wheat fields characterized by the presence of mixed grass and broad-leaved weeds, a combination of 5% pinoxaden EC at a rate of 120 mL/667 m^2, 3% mesosulfuron-methyl OD at a rate of 10 mL/667 m^2, 28% ethyl ethane sulphonate at a rate of 30 mL/667 m^2, and 20% fluroxypyr-methyl EC at a rate of 50 – 60 mL/667 m^2 may be applied for effective weed control.

Aphids can be effectively managed through the application of a 5% imidacloprid EC, which should be diluted with water and applied at a rate of 60 – 100 mL/667 m^2.

Sheath blight is a disease that significantly affects the wheat variety Wanximai 8, necessitating effective control measures during the wheat revival and jointing periods[5]. When the average disease incidence reaches 10% – 15%, it is recommended to apply 40 – 60 g of 10% difenoconazole WDG, or 40 – 60 g of 10% hexaconazole SC, or 35 – 40 mL of 25% propiconazole EC, diluted in 45 – 50 kg of water, per 667 m^2. The application of these agents should occur in the morning when dew is present, facilitating the movement of the solution to the base of the wheat plants. Following the initial application, a second treatment should be administered approximately 10 d later in areas where the disease is severe.

When the incidence of wheat powdery mildew in the spring reaches 15%, or when the proportion of diseased leaves reaches 5%, it is recommended to apply 30 – 35 mL of 25% propiconazole EC, 48 – 60 mL of 12.5% epoxiconazole SC, 30 – 50 mL of a mixture of 23% kresoxim-methyl and epoxiconazole, or 30 – 40 mL of 25% pyraclostrobin SC. These agents should be diluted in 45 – 50 kg of water and applied in regular doses. In fields with severe disease, the treatment should be repeated after 5 – 7 d.

Wheat scab should be proactively managed, and fungicidal agents should be applied from the full heading stage to the early flowering stage to mitigate the risk of disease occurrence. It is advisable to conduct the initial application during the flowering period, followed by a second application 5 – 7 d later. For the first time, 40 – 60 mL of 20% pydiflumetofen and 25% propiconazole, or 40 – 45 mL of 30% prothioconazole, or 20 – 25 mL of 45% tebuconazole (15%) and prochloraz (30%) EW, or 25 – 30 mL of 42% pyraclostrobin (10%) and tebuconazole (32%) may be utilized. These agents exhibit favorable permeability and resistance to rain wash. It is recommended that they should be diluted with 30 – 45 kg of water prior to application. For the second application, 100 – 200 mL of 25% phenamacril, which possesses a longer duration and has the capability to inhibit toxin production, may be diluted with 30 kg of water for spraying. Alternatively, mixed formulations, such as 40 – 60 mL of 48% phenamacril · tebuconazole, can be diluted with 30 – 45 kg of water for spraying. It is imperative that these agents are utilized in strict accordance with the specified guidelines, and that the dosage is not reduced arbitrarily.

5.5 Timely harvest The optimal harvesting period for manual harvesting occurs during the wax ripeness stage, while the appropriate timeframe for harvesting with large-scale combine harvesters extends from the end of wax ripeness to the early stage of complete ripeness. Following the harvesting process, it is essential to dry, package, and store the products promptly to ensure a high yield and successful harvest.

6 Application prospects

With the enhancement of wheat production levels, lodging has emerged as a significant challenge in wheat cultivation. The current extreme weather conditions associated with global warming have heightened the likelihood of wheat lodging. Additionally, wheat mildew is expected to experience an outbreak approximately once every 1 – 2 years. The selection of wheat varieties exhibiting robust resistance to lodging and downy mildew is crucial for wheat production in breeding programs. The newly developed wheat variety, Wanximai 8, possesses several advantageous traits, including balanced three key factors for yield, high productivity, compact plant structure, robust resistance to lodging, uniformity, well-formed

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ucts. Furthermore, by refining the market mechanism, the competitiveness and added value of these products can be significantly improved.

6.3 Promoting sustainable development In the future, Shatian Town must maintain its emphasis on the sustainable development of selenium-rich agriculture. This involves enhancing efforts in ecological environmental protection, minimizing the application of chemical fertilizers and pesticides, and mitigating agricultural surface source pollution. Additionally, it is essential to strengthen initiatives aimed at soil improvement and fertility enhancement to ensure the sustainable utilization of selenium-rich soil. By promoting sustainable practices, the long-term stability of selenium-rich agriculture can be achieved, thereby maximizing social benefits.

6.4 Strengthening talent development In the future, Shatian Town must enhance its efforts in the training and recruitment of talents. This includes fostering collaboration with colleges, universities, and research institutions to attract and develop a greater number of agricultural professionals. Additionally, it is essential to improve the mechanisms for farmers' training and vocational education to elevate the overall quality and professional skills of the agricultural workforce. By bolstering the training and recruitment of talents, Shatian Town will ensure robust support in terms of human resources and intellectual capital for the advancement of selenium-rich agriculture.

6.5 Strengthening policy support and funding In the future, Shatian Town must persist in actively pursuing support from governmental policies and funding. It should collaborate closely with local government entities to formulate improved policy measures and financial support programs. By leveraging policy and financial assistance, the development of selenium-rich agriculture will yield greater benefits and assurances, thereby further enhancing farmers' enthusiasm for engaging in selenium-rich agricultural practices.

7 Conclusions

Selenium-rich agriculture is an emerging field within contemporary agricultural development, characterized by significant prospects for growth and substantial market potential. In the future, it is imperative to further advance research and dissemination efforts related to selenium-rich agriculture, and continuously enhance the technical framework and market mechanisms, thereby elevating the development of selenium-rich agriculture to a more advanced level and expanding its application across broader sectors.

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spikes, and effective maturity performance. This variety is well-suited for promotion across diverse regions and holds significant potential for market development.

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