













# Water-Saving Evaluation of Jingmai Series Hybrid Wheat Varieties in China

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**Abstract.** Hybrid wheat is generally recognized for its outstanding stress resistance and yield stability. Under water stress conditions, it often achieves higher yield compared to conventional wheat varieties. In this study, two winter wheat hybrids from the Jingmai series were used as research objects. With conventional wheat varieties as controls, three different spring limited irrigation methods were adopted under various ecological environments to compare the population structure, leaf quality, and yield components of hybrid wheat. The results showed that: under the condition of no spring irrigation, hybrid wheat exhibited prominent drought resistance and high yield potential, with a significantly higher yield level than conventional wheat; the average water-saving index (WSI) of hybrid wheat was 1.514, and its water-saving performance was rated as extremely strong; there was no significant difference in yield between the irrigation mode of only one irrigation at the jointing stage in spring and the normal irrigation mode of irrigation at both jointing stage and flowering stage in spring; under water-limited conditions, the total stem number of hybrid wheat at the raising stage and jointing stage was 13.9% and 15.8% higher than that of conventional wheat, respectively; under the three irrigation methods of W2, W1, and W0, the tiller ear-bearing rate of hybrid wheat was 14.8%, 22.6%, and 4.8% respectively, which was also significantly higher than that of conventional wheat. The research results confirmed that hybrid wheat has prominent advantages in water-saving and drought resistance. A relatively high tiller ear-bearing rate is the basis for hybrid wheat to achieve water-saving and high yield, and panicle number is the main contributing factor for realizing stable and high yield of hybrid wheat. Improving the tiller ear-bearing capacity through moderate irrigation can create a suitable population, thereby realizing the unity of water-saving and high yield of hybrid wheat

aluminum alloys are widely used in the production of agricultural machinery parts. This article discusses the technology of increasing the tensile strength of aluminum alloys under the influence of various modifying elements. Samples were cast and tested. The studies were conducted on aluminum-copper and aluminum-magnesium alloys from aluminum alloys. As a result of the tests, the tensile strength of aluminum alloys was increased by 5%-7%. Based on the results obtained, a graph was constructed showing the dependence of the number of modifying elements on the tensile strength. At the end of the article, the authors present their conclusions based on the results of the studies.

**Keywords:** hybrid wheat, water saving, tiller ear-bearing rate, high yield

## 1 Introduction

As one of the most crucial food crops worldwide, the stable yield and secure supply of wheat are directly tied to the global food security landscape and the development of agricultural economies across all countries. Nevertheless, against the backdrop of worsening global climate change, uneven distribution of water resources, and the continuous expansion of arable land in arid and semi-arid regions, water scarcity has emerged as a core bottleneck restricting the increase in wheat yield. This issue is particularly pronounced in major wheat-producing areas in northern China, where the shortage of irrigation water in spring is even more acute. How to achieve high and stable wheat yield under the condition of limited water resources has thus become a key research topic in the field of agricultural science that urgently requires breakthroughs [1].

In recent years, crop scientists have carried out systematic exploration of water-saving theories and research and development of related technologies centered on improving wheat water use efficiency [1-4]. They have proposed a technical path to achieve water-saving and high yield by optimizing population structure, regulating cultivation measures, and giving full play to the population advantages of wheat. Moreover, a series of supporting cultivation technologies such as late sowing with dense planting and precise water-fertilizer coupling have been successfully developed [3,4], providing effective solutions for the water-saving production of conventional wheat. At the same time, practical studies have shown [5] that, relying on the outstanding stress resistance and broad adaptability brought by its genetic characteristics, hybrid wheat performs excellently in coping with abiotic stresses like drought and salinity. Especially in the field of water-saving and stress resistance, it demonstrates advantages that conventional wheat can hardly match [6,7]. Its high-yield and stable-yield performance has been verified in pilot plantings in multiple regions, offering a new variety option to alleviate the pressure of wheat production in water-scarce areas.

Notably, compared with conventional wheat, hybrid wheat has a significant tillering advantage in terms of individual growth and development—there are more lateral branches (tillers) germinating from the base of the main stem, and their growth vigor is stronger. Theoretically, this trait can contribute to yield improvement by increasing the number of effective panicles in the population. However, current research on the tillering advantage of hybrid wheat mostly focuses on its growth performance under normal

water and fertilizer conditions. In-depth studies on how to regulate the tiller ear-bearing process and convert the tillering advantage into water-saving and high-yield capacity in water-limited environments are still insufficient, and there is also a gap in reports on relevant technical mechanisms and practical applications.

Based on this, this study takes the Jingmai series hybrid wheat independently developed by the Beijing Academy of Agricultural and Forestry Sciences as the research object. Comparative experiments are conducted in different ecological regions, with locally dominant conventional wheat varieties as controls. Three limited irrigation treatments are designed. The differences between hybrid wheat and conventional wheat in aspects such as dynamic changes of population stems and tillers, leaf quality (specific leaf weight), and yield components (panicle number, grains per panicle, 1000-kernel weight) are systematically monitored and compared. The purpose is to clarify the response mechanism of hybrid wheat to water stress, explore the key technical points of its water-saving cultivation, and provide a scientific basis and technical support for accelerating the popularization and application of hybrid wheat in arid and semi-arid regions and constructing a water-saving and efficient wheat production system.

## 2 Materials and methods

The tested varieties were Jingmai 6 and Jingmai 7, hybrid wheat varieties independently developed by the Beijing Academy of Agricultural and Forestry Sciences. The control varieties were conventional wheat varieties Jingdong 17, Jingdong 12, and Lunxuan 987.

The experiment was carried out at the Shunyi Comprehensive Experimental Station of the Hybrid Wheat Research Institute of Beijing Academy of Agricultural and Forestry Sciences, the Experimental Field of Moyu County Seed Management Station in Hotan, Xinjiang, and the Experimental Field of the Agricultural Science Institute of the 4th Division of Yili, Xinjiang. All the tested fields were long-term wheat variety comparison test fields, implementing a double-cropping system of winter wheat and summer corn per year.

Taking two-line hybrid wheat varieties Jingmai 6 and Jingmai 7 as test materials, and referring to the conventional wheat water-saving cultivation mode [1], three water-saving irrigation treatments were set up in spring: no irrigation (W0), one irrigation (jointing water, W1), and two irrigations (jointing water + flowering water, W2). Each treatment had four replicates, and the area of each plot was 7.2 m<sup>2</sup> (9 rows, row width of 16 cm, row length of 5 m). The sowing date was from October 5 to 10. Based on the requirements of conventional wheat water-saving cultivation technology [2], the sowing density of the tested materials in this experiment was designed to be 300×10<sup>4</sup> plants/hm<sup>2</sup>, which was consistent with the planting density required by the national unified wheat variety test in China.

The sowing date of the control varieties was from October 5 to 10, and the designed sowing density was the same as that of the tested hybrid wheat materials, which was 300×10<sup>4</sup> plants/hm<sup>2</sup>. Each plot had an area of 7.2 m<sup>2</sup> (9 rows, row width of 16 cm, row length of 5 m) with four replicates.

At the flowering stage, 30 flag leaves, the second leaves from the top, and the third leaves from the top were selected from plants with uniform growth, mixed together. A hole punch was used to punch holes in the middle of the leaves, avoiding the main veins. Then, the leaf samples were placed in an oven at 105°C for 30 minutes for deactivation of enzymes, and then dried to a constant weight in an oven at 80°C for weighing to calculate the specific leaf weight. The calculation formula is as follows:

Specific leaf weight (mg/cm<sup>2</sup>) = Leaf weight / Leaf area

After wheat emergence, 4 uniform sample segments of 2×100 cm were selected and fixed in each treatment. During the key growth periods of wheat, such as regreening stage, raising stage, jointing stage, and maturity stage, the dynamic changes of population stems and tillers were investigated, and the tiller ear-bearing rate was calculated. The calculation formula is as follows:

Tiller ear-bearing rate (%) = (Panicle number at maturity stage - Basic seedlings) / (Total stem number at raising stage - Basic seedlings) × 100

Before wheat maturity, theoretical yield estimation was carried out for each combination, and the panicle number per unit area, grains per panicle, and 1000-kernel weight were investigated. All plots were harvested separately, followed by separate threshing, drying, and weighing to calculate the yield and the percentage of yield increase or decrease. The water-saving index (WSI) was calculated based on the grain yield of the plot. The calculation formula is as follows:

$$WSI = (Y_a^4 / Y_m) / (Y_A^4 / Y_M) \quad (1)$$

In the formula:

WSI — Water-saving index of the tested variety (line);

Y<sub>a</sub> — Yield of the tested variety (line) under water-saving treatment;

Y<sub>m</sub> — Yield of the tested variety (line) under normal irrigation;

Y<sub>M</sub> — Yield of the control variety (line) under normal irrigation;

Y<sub>A</sub> — Yield of the control variety (line) under water-saving treatment.

Among them, Jingdong 17 was selected as the control variety. The experimental data were statistically analyzed using SPSS 11.5 and Excel 2003.

### 3 Results

The investigation of population structure (Table 1) showed that there was no significant difference in the total population stem number between hybrid wheat and conventional wheat at the regreening stage. However, at the raising stage and jointing stage, the total stem number of hybrid wheat was 13.9% and 15.8% higher than that of conventional wheat, respectively. Under the three irrigation methods of W2, W1, and W0, the ear number of hybrid wheat reached 783×10<sup>4</sup>/hm<sup>2</sup>, 674×10<sup>4</sup>/hm<sup>2</sup>, and 584×10<sup>4</sup>/hm<sup>2</sup>, respectively, which was 21.3%, 10.8%, and 7.9% higher than that of conventional wheat. Further comparison showed that the tiller ear-bearing rate of hybrid wheat was 14.8%, 22.6%, and 4.8% respectively, which was also significantly higher than that of conventional wheat. These results indicated that the prominent tillering advantage and relatively high tiller ear-bearing rate are important foundations for hybrid wheat to achieve water-saving and high yield under low-density planting conditions.

**Table 1.** Dynamics of plant population quantity in three irrigation treatments ( $\times 10^4/\text{hm}^2$ )

Varieties	Treatments	basic seedling	Growth Stages				
			re-greening	raising	Jointing	Maturity	
JingMai6	W0	356	651	1106	1076	561	
	W1	330	521	1106	1065	671	
	W2	305	630	1271	1140	765	
JingMai7	W0	206	450	981	900	606	
	W1	221	576	1080	866	675	
	W2	225	761	1236	1050	801	
JingDong12	W0	356	366	1076	885	600	
	W1	266	606	1140	1005	666	
	W2	300	846	990	926	701	
JingDong17	W0	251	591	1056	810	510	
	W1	285	645	1140	900	645	
	W2	356	681	1155	996	666	
LunXuan987	W0	351	600	861	716	591	
	W1	366	566	840	761	621	
	W2	356	795	930	896	675	
Average	Hybrid	W0	281	551	1044	989	584
		W1	276	549	1094	966	674
	Wheat	W2	266	696	1254	1095	783
		W0	320	519	998	804	567
	Conventional	W1	306	606	1040	888	644
		W2	338	774	1025	939	681

The investigation of the specific leaf weight of the top three leaves under different irrigation treatments (Table 2) showed that with the decrease of irrigation amount, the specific leaf weight of the top three leaves showed an increasing trend, and the leaf quality of hybrid wheat was relatively higher. Under different irrigation treatments, the specific leaf weight of hybrid wheat was higher than that of conventional wheat. These results indicated that the leaf quality of hybrid wheat is superior to that of conventional wheat, and spring water-controlled irrigation measures are more conducive to improving the leaf quality of hybrid wheat and increasing the specific leaf weight.

**Table 2.** Specific leaf weight of top leaf in different irrigation treatments ( $\text{mg}/\text{cm}^2$ )

Varieties		Treatments			Average
		W2	W1	W0	
JingMai6		3.60	3.75	4.00	3.80
JingMai7		3.60	3.85	4.20	3.90
JingDong12		2.90	3.30	3.55	3.25
JingDong17		3.35	3.60	4.25	3.75
LunXuan987		3.50	3.15	3.85	3.50
Average	Hybrid Wheat	3.60	3.80	4.10	3.83
	Conventional Wheat	3.25	3.35	3.88	3.49

Under the three irrigation methods of W0, W1, and W2 (Table 3), the yield levels of hybrid wheat were 5469 kg/hm<sup>2</sup>, 6918 kg/hm<sup>2</sup>, and 7212 kg/hm<sup>2</sup>, respectively, and there was no significant difference in yield between W1 and W2. The average yield of hybrid wheat under the three irrigation methods was 6533 kg/hm<sup>2</sup>, which was 8.3% higher than that of conventional wheat. However, with the decrease of irrigation amount, the yield increase range of hybrid wheat showed an increasing trend, increasing by 0.3%, 4.1%, and 28.1% compared with conventional wheat, respectively. Especially under the condition of no spring irrigation, the yield increase range of hybrid wheat was significant, and consistent experimental results were obtained in multi-ecological area planting. In conclusion, under spring-controlled irrigation conditions, the high-yield performance of hybrid wheat is better than that of conventional wheat, and the impact of irrigation on the yield of hybrid wheat is smaller than that on conventional wheat. These further reveals that hybrid wheat has good water-saving and high-yield performance and strong "risk resistance" ability to changes in environmental conditions, indicating that hybrid wheat is more suitable for popularization and application in arid and semi-arid areas. The water-saving index (WSI) is an important indicator to measure the water-saving performance of varieties. According to research, a WSI $\geq$ 1.400 is considered to indicate extremely strong water-saving performance. The experimental results showed that the average water-saving index of the two hybrid wheat varieties, Jingmai 6 and Jingmai 7, was 1.514, showing extremely strong water-saving performance.

**Table-3.** Comparison of yield and WSI in different irrigation treatments

Sites	Varieties	WSI	Grain Yield (kg/hm <sup>2</sup> )			
			W0	W1	W2	Average
HeTian, Xinjiang	JingMai6	1.260	2287.5	5931.0	7075.5	5098.0
	JingMai7	1.434	4783.5	5997.0	6496.5	5759.0
	JingDong12	-	1786.5	5214.0	5428.5	4143.0
	JingDong17	-	2998.5	5355.0	5926.5	4760.0
	LunXuan987	-	3355.5	4284.0	5782.5	4474.0
YiLi, Xinjiang	JingMai6	1.840	7575.0	8290.5	8862.0	8242.5
	JingMai7	1.791	6861.0	8133.0	8433.0	7809.0
	JingDong12	-	6432.0	9579.0	10062.0	8691.0
	JingDong17	-	5574.0	7146.0	9004.5	7241.5
	LunXuan987	-	5289.0	9375.0	9609.0	8091.0
ShunYi, Beijing	JingMai6	1.596	5385.0	6798.0	6057.0	6080.0
	JingMai7	1.164	5920.5	6355.5	6348.0	6208.0
	JingDong12	-	5473.5	6478.5	6567.0	6173.0
	JingDong17	-	4567.5	6061.5	6112.5	5580.5
	LunXuan987	-	4689.0	6645.0	6682.5	6005.5
Average	Hybrid Wheat	1.514	5469.0	6918.0	7212.0	6533.0
	Conventional Wheat	-	4270.5	6643.5	7189.5	6034.5

Correlation analysis (Table 4) showed that under spring water-limited irrigation conditions, the yield of hybrid wheat had an extremely significant positive correlation with panicle number ( $r_1=0.883^{**}$ ), while the correlation with grains per panicle and 1000-kernel weight did not reach a significant level ( $r_2=0.190$ ,  $r_3=0.105$ ). Path analysis showed that the direct effects on the yield of hybrid wheat were in the order of panicle

number (0.891) > grains per panicle (0.214) > 1000-kernel weight (0.010). Statistical analysis indicated that under spring water-limited irrigation conditions, panicle number is the most important contributing factor for realizing stable and high yield of hybrid wheat, and the increase of grains per panicle and kernel weight will help to further improve the yield level of hybrid wheat under spring-controlled irrigation conditions.

**Table 4.** The correlation analysis of yield components and yield of hybrid wheat under water-saving condition

	grain yield	panicle number	kernel no. Panicle <sup>-1</sup>	1000-kernel weight
grain yield				
panicle number	0.883**			
kernel no. Panicle <sup>-1</sup>	0.190	-0.031		
1000-kernel weight	0.105	-0.272	0.167	

There have been a large number of studies on water-saving cultivation of conventional wheat [1-4]. Generally, high-density and large-population planting methods are adopted to achieve water-saving and high yield, with sowing density often exceeding  $500 \times 10^4$  plants/hm<sup>2</sup> [2], or even reaching  $750 \times 10^4$  plants/hm<sup>2</sup>. Water-saving cultivation of conventional wheat emphasizes control-oriented management in spring. If the measures are improperly applied or the timing is not properly grasped, high-density planting often leads to an excessively large population, resulting in problems such as poor population quality and lodging in the later stage, and it is difficult to achieve a coordinated balance among the yield components. The results of this experiment showed that when the planting density of hybrid wheat was reduced by nearly half compared with conventional wheat, by giving full play to the advantage of individual tiller ear-bearing, it could still meet the appropriate population indicators for water-saving cultivation, and the individual quality was further optimized, with a more reasonable population structure, which could greatly reduce the risk of lodging. Studying the mechanism of forming the water-saving and drought-resistant advantages of hybrid wheat will help to further understand and tap the heterosis of wheat and accelerate the production and application of hybrid wheat.

The results of this experiment showed that under the three water-saving irrigation methods of W2, W1, and W0, hybrid wheat showed prominent water-saving and drought-resistant advantages compared with conventional wheat. The average water-saving index reached 1.514, the water-saving performance was rated as extremely strong, and the average yield increase range in multi-site experiments reached 8.3%. The overall stable and high yield performance was superior to that of conventional wheat, which was consistent with the previous research results [8,9]. From the perspective of population structure establishment, hybrid wheat varieties such as Jingmai 6 and Jingmai 7 have the typical characteristics of high tillering ability and high tiller ear-bearing rate, which enable them to obtain an ideal population structure even under low planting density conditions, thereby realizing water-saving and high yield. In terms of yield components, the main contributing factor to the yield of hybrid wheat varieties such as Jingmai 6 and Jingmai 7 is panicle number, which is also the core and foundation for them

to achieve water-saving and high yield. Therefore, to give full play to the water-saving and drought-resistant advantages of hybrid wheat, the sowing density can be appropriately reduced [9].

## 4 Conclusion

The results of this experiment showed that under spring water-limited irrigation conditions, panicle number contributes the most significantly to the yield formation of hybrid wheat, while the contributions of grains per panicle and 1000-kernel weight are relatively small. Panicle number is the main contributing factor for realizing stable and high yield of hybrid wheat. Due to the reduced sowing density, the population structure of hybrid wheat tends to be optimized, the conditions for panicle differentiation are improved, and it is easy to form large panicles with more grains. Based on the prominent advantage of high tillering ability of hybrid wheat, research on key technologies for improving seed setting rate and kernel weight will help to further improve the yield level of hybrid wheat under water-saving cultivation conditions.

**Disclosure of Interests.** The authors have no competing interests to declare that are relevant to the content of this article.

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