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Emergency remedial measures to salvage losses from Chinese wheat post-harvest sprouting

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Abnormal weather at harvest time results in wheat lodging and post-harvest sprouting in China's main wheat-producing areas. Measures such as promoting resistant varieties, using mechanical equipment for harvesting, spraying agents to prevent sprouting, timely storage and drying, screening of already sprouted seeds, timely drainage for farmlands, and full utilization of drying sites can salvage wheat losses. In addition, we have publicly released a spray formula consisting of potassium chloride, abscisic acid, organosilicone, and sodium selenite. This formula is effective and economical for inhibiting wheat germination in high-humidity environments.

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CHINA'S MAJOR WHEAT-PRODUCING AREAS SUFFERED FROM CLIMATE DISASTERS

Current crop yields are insufficient to feed the world's population by 2050[1]. In addition, abnormal weather conditions around the world have frequently occurred in recent years, seriously threatening food security[2]. Post-harvest sprouting (PHS) is a global disaster that refers to the phenomenon of crops sprouting on parent plants due to high air humidity before harvest. Cultivated crops generally have a lower dormancy level than their wild ancestors, which improves the seeding performance of cereals such as wheat, barley, rice, and maize. However, extra-high germination rates lead to the frequent occurrence of PHS in areas with high rainfall, resulting in an annual economic loss of $1 billion[3].

Optimizing crop-growing areas is an important means of adapting agriculture to climate change[4]. Therefore, rice in China is mainly grown in the south, which has high air humidity, high temperatures, and low wind speeds. In contrast, wheat is the main crop in the north because the sunnier and less humid climate ensures the maturing of the grain and drying after harvest. However, in May and June 2023, abnormal weather patterns occurred in wheat-growing areas in northern China, with widespread and prolonged rainfall and strong convective weather such as heavy downpours, strong winds, and hail (China Meteorological Administration, https://weather.cma.cn/). Henan is the largest wheat-growing province, accounting for approximately a quarter of China's annual wheat output (Fig. 1). The most extensive and longest-lasting rainstorm hit Henan during the same period since 1961 (average rainfall exceeding 30 mm and some areas up to 100–200 mm), leading to flooded fields and sprouting wheat at the ripening stage. Unwelcome rainfall hinders the harvesting and processing of wheat, greatly reducing grain yields and nutrient value. The safe storage moisture content of wheat should be between 8% and 14%[5]. However, the moisture content of harvested wheat exceeds 30% (Xinhua News, http://www.xinhuanet.com/). The Chinese government attaches great importance to undoing the damage of this natural calamity and sets up 200 million CNY to facilitate the harvesting and drying of wheat and compensate farmers.

MEASURES TO ADDRESS WHEAT SPROUTING CAUSED BY CONTINUOUS RAINFALL

Scientists and the government have developed various methods to reduce losses caused by PHS (Fig. 2). These include promoting resistant varieties[6], providing accurate weather forecasts and warnings, draining the field in a timely manner, deploying mechanized equipment for emergency harvesting, making full use of sites for drying, ensuring proper storage, and screening germinated seeds. However, as wheat in northern China was already at the ripening stage during the May 2023 rains, there was little that breeding techniques could do. In addition, continuous rainy weather has increased soil moisture content and prevented further harvesting. The lack of dry weather, coupled with insufficient drying machines, has also made the drying process difficult.

At this point, it is particularly important to use biochemical methods to recover losses (Fig. 3A). Hormones, especially abscisic acid (ABA) and gibberellin (GA), play a key role in seed germination[7]. In dormant seeds, ABA synthesis increases and GA synthesis decreases, thereby inhibiting amylase activity, reducing the energy supply for sprouting, and preventing seed germination. Seed dormancy is broken only when the balance shifts from ABA to GA[8]. Additionally, high water content is a prerequisite for seed germination and pre-harvest sprouting. Hypertonic saline solution can cause seeds to lose water, lower seed water content, and induce ABA synthesis to maintain dormancy[9]. In addition, silicon can form a barrier on seed coats to separate seeds from the external environment, inhibit pathogen colonization, and reduce the effects of high humidity on seeds from outside[10]. Furthermore, elements such as potassium and silicon can help wheat increase stem hardness and prevent lodging[11].

USING AGRICULTURAL SPRAY TO SALVAGE LOSSES OF CHINESE WHEAT

Based on the above theory, in order to benefit more people, we have publicly released a spray formula (Table 1) for emergency treatment of sprouting in wheat and verified its effectiveness in the laboratory. The reagents we use are all permitted for agricultural applications in China and are safe in concentrations.

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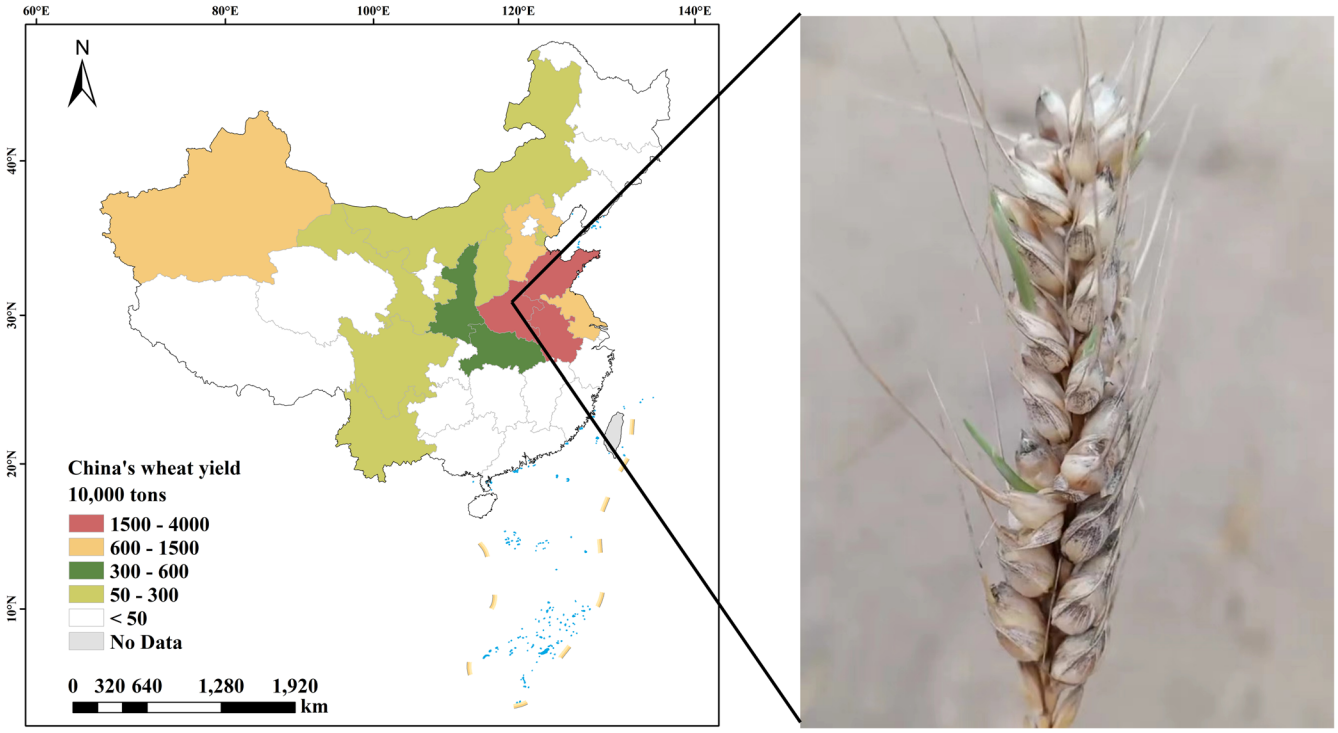

Fig. 1 Distribution of wheat producing areas in China and post-harvest sprouting of wheat in Henan Province. Henan, as the province with the highest wheat production in China, accounted for 28% of China's wheat production in 2021, according to data from the National Bureau of Statistics of China (http://www.stats.gov.cn). In May and June 2023, heavy rainfall in Henan caused some wheat spikes to sprout. The photo was taken on June 1, 2023 in Anyang City, Henan Province.

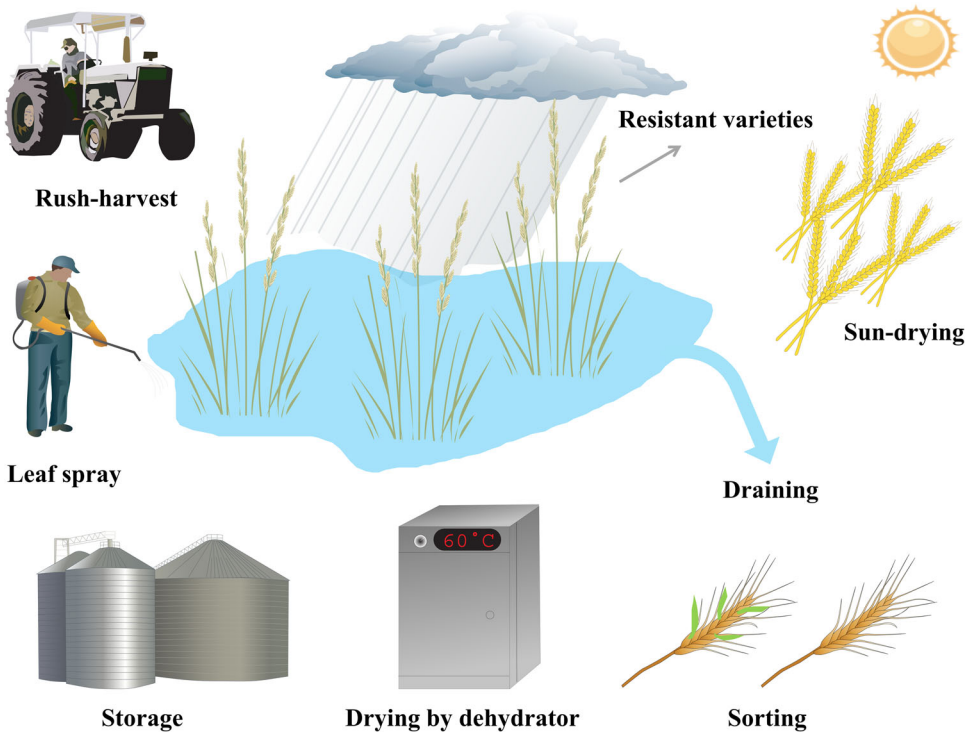

Fig. 2 Measures to salvage wheat losses. High humidity and heavy rainfall caused lodging and sprouting in wheat. The figure introduces measures such as promoting resistant varieties, using mechanical equipment for harvesting, spraying agents to prevent sprouting, timely storage, drying, screening of already sprouted seeds, timely drainage of farmland, and full utilization of drying sites to salvage wheat losses. Image materials are from the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/).

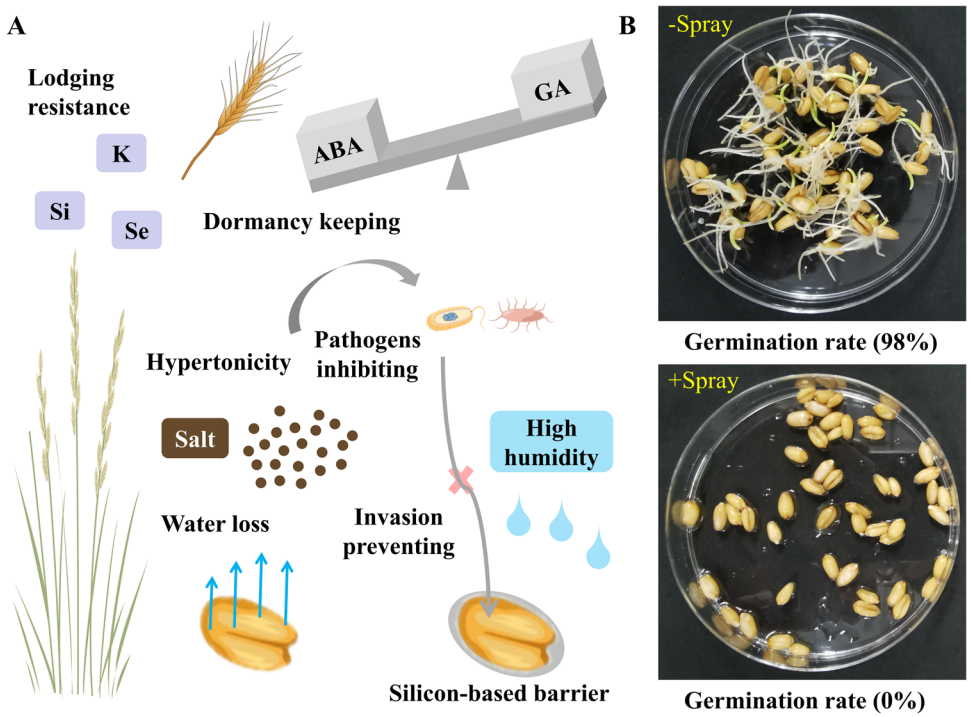

Fig. 3 The principle and efficacy of sprays for inhibiting the germination of wheat seed. A shows that ABA maintains seed dormancy, while K, Si, and Se help wheat resist lodging. High concentrations of salt promote water loss in seeds and kill pathogens, while silicon forms a barrier on the seed surface to block water molecules and inhibit pathogen colonization. **B** indicates that after using this spray, the wheat (cv. Yangmai 29) did not germinate on the third day.

Table 1. Formula for the spray that suppresses wheat seed germination.

Reagent	Concentration	Input (calculated at 300 L per hectare)	Function
Potassium chloride	1 g/L	0.15 USD	Form a high osmotic pressure environment, promote seed water loss, inhibit pathogen activity, and resist lodging[11,14]
Abscisic acid	5 μl/L	21.15 USD	Keep seeds dormant[8]
Organosilicon	1 ml/L	1.65 USD	Increase adhesion, form a silicon layer to block moisture, inhibit pathogen infection, resist lodging, and improve nutritive value[10]
Sodium selenite	0.1 g/L	0.9 USD	Improve the nutritive value and limit the aerobic respiration of seeds[15]

The application rate is 300 L per hectare. Prices are obtained from Taobao (https://www.taobao.com/).

In this formula, high concentration potassium chloride (1 g/L) and trace amounts of sodium selenite (0.1 g/L) are used to create an external hypertonic environment, promote water loss in wheat seeds, and provide potassium to enhance lodging resistance; abscisic acid (5 μl/L) is used to maintain seed dormancy; organosilicone (1 ml/L) serves as an auxiliary agent to prevent spray loss due to rainfall while forming a silicon layer to block moisture; in addition, adding silicon and selenium as beneficial elements helps wheat resist lodging and improve grain quality, supplementing the human body with selenium[12]. As shown in Fig. 3B, in an environment of 90% humidity, the germination rate of the control group was 98% on the third day, while the spray treatment group (spray dosage is about 0.5 ml/dish) had a germination rate of 0%. In addition, the treatment group also remained ungerminated until day 7. This spray can greatly prolong seed dormancy and create opportunities for wheat harvesting. Besides, the material cost of this spray is only 23.85 USD/hectare, making it economical and practical.

This article summarizes the damage caused by rainy weather to crops and remedial measures, and also provides a feasible and economical method. Further optimization of reagent development, field verification, and promotion are needed. Adverse weather conditions and abnormal weather patterns caused by climate change will become more frequent not only in China but also in Europe and beyond[13]. Therefore, in the future, countries around the world should make a concerted effort to improve meteorological forecasting, issue early warning, assist farmers to start spraying and harvesting, facilitate the transportation of harvesting equipment, and provide drying and storage sites when dealing with similar weather disasters.

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AUTHOR CONTRIBUTIONS

Z.P. wrote the main manuscript text. Y.L. reviewed the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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