Effect of low temperature levels on the developmental characteristics of wheat spikelets

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Abstract

Low temperature may damage wheat (Triticum aestivum L.) spikes and severely reduce their setting percentage. Different levels of low temperature have different effects on spikelet developmental characteristics and produce different physiological mechanisms. In this study, we selected wheat varieties with different levels of cold resistance (low temperature tolerant varieity Yannong 19 and low temperature sensitive variety Xinmai 26), and low temperature stress was simulated in an artificial climate chamber at 2, or -2°C for 6 h (01:00-06:00) in morphological assays, exploring the effect on the cell structure characteristics and sugar content in young wheat ears at booting stage (all of the flag leaf leaves of 50% of the tillers in the population were extracted from the leaf sheaths, and the young spikelets wrapped by the flag leaf sheaths were obviously enlarged). The results of the cell structure observation as well as the setting percentage showed that the cells had more irregular malformations and less inclusions in young panicle, which ultimately led to the lower seed setting rate of wheat. In addition, the accumulation of sucrose in the wheat spike and the hindrance of the material transport process ultimately. In addition, sucrose content in young panicles of wheat increased, while glucose and fructose content decreased, indicating that low temperature seriously affected the decomposition of sucrose. Overall, these findings suggest that low temperature at booting induces sucrose accumulation in the young ears, thereby having a negative effect on wheat production.

Keywords

Booting stage, Cold stress, Triticum aestivum, Spikelet, Damage characteriscs

Introduction

Wheat (Triticum aestivum L.) is one of the most important crops in the world and serves as a staple food for approximately 60% of the world's population (Zhao et al., 2019). Winter wheat in Huang-Huai-Hai Plain accounts for around 75% national wheat grain production (NBSC, 2019). In recent decades, climate disasters, including spring cold spells, have disrupted crop production and caused yield losses, and yield reduction is generally around 10-30% (Zheng et al., 2015). It should be noted that the intensity, frequency and duration of cold stress events are increasing with climate change (Zohner et al., 2020). Low temperatures induce abnormal pollen and ovule development, and reduce anther size and fertile pollen grains, thereby decreasing the rate of seed setting (Thakuret et al, 2010). It has been shown that the reduction in spike number was 8–15% and the yield loss was 5-14% with a 5-day spring low-temperature episode (with daily minimum temperature in the range of 0-4 ^{o}C) in winter wheat (Li et al., 2015).

Depending on the stress intensity and on the wheat growth period when the low temperature occurs, different physiological processes are involved in the wheat response. Low temperature stress also has a significant effect on sugar metabolism, wheat accumulates large amounts of carbohydrates at low temperatures to enhance membrane stability, which results into stomatal closure, blocked photosynthetic electron transfer and inhibition of carbon assimilation (Li et al., 2014), this ultimately leads to a reduction in the amount of material transported to the seeds. This study investigates the differences in the developmental injury characteristics of wheat spikelets exposed to two different levels of low temperature. It also gives insigihts into the physiological mechanisms underpinning cold stress tolerance during spikelet development.

Materials and Methods

This study was conducted at the Anhui Agricultural University, Anhui, Hefei, China, from 20th October 2018 to 20th May 2019 (31.5 2°N, 117.17°E). Two wheat cultivars, Yannong 19 (cold-tolerant) and Xinmai 26 (cold-sensitive), were planted in plastic pots, with sow 16 seeds per bucket and leave 8 seedlings at the three-leaf stage. Each pot was filled with sieved yellow brown soil with available nitrogen, phosphorus, potassium and organic matter of 81.5 mg·kg^{-1}, 33.1 mg·kg^{-1}, 76.2 mg·kg^{-1}, and 10.6 g·kg^{-1}, respectively. Before sowing, 0.8 g N, 0.84 g (NH4)2HPO4 and 1.2 g K2O per pot were applied as base fertilizer, and an extra 0.6 g N per pot, was top-dressed at jointing stage (1.5-2.0cm between nodes exposed to the ground). when the young ears reached the booting stage, each variety was subjected to three temperature treatments:(1) CK, the wheat plants were placed in the artificial climate chamber, the day and night temperatures were 15°C; (2) T1, the wheat plants were transferred into a light- and temperature-controlled artificial climate chamber, and the temperature was set to 2 ± 0.1°C for 6 hr; (3) T2, the temperature was set to -2 ± 0.1°C for 6 hr, and 10 pots for each treatment The temperature settings were based on locally recorded low temperatures that caused low-temperature stress at the booting stage and had seriously adverse effects on wheat production. After T1 and T2 treatments, some plants were sampled immediately, and other treated pots were moved back to the big field for normal growth.

Statistical analysis

All data presented represent the mean value ± SE of three independent duplications. The SPSS 22.0 statistical software package was used to conduct ANOVAs. and statistical divergence among treatments was determined using Duncan's multiple range test ($P < 0.05$).

Results

Effect of low temperature on cell structure and morphology of wheat spikelets

Figure1 shows Low temperature affects the cellular structure of the spikelets, mainly by lowering the spikelet inclusions, increasing the number of abortedta. Compared to CK, T1 treatment had no significant effect on the organ integrity of the spikelets (Fig B, E), while T2 treatment significantly disrupted the integrity of the spikelet cells, resulting in a significant reduction in pollen number (Fig C, F), and xinmai26 is more severely damaged than yannong19.

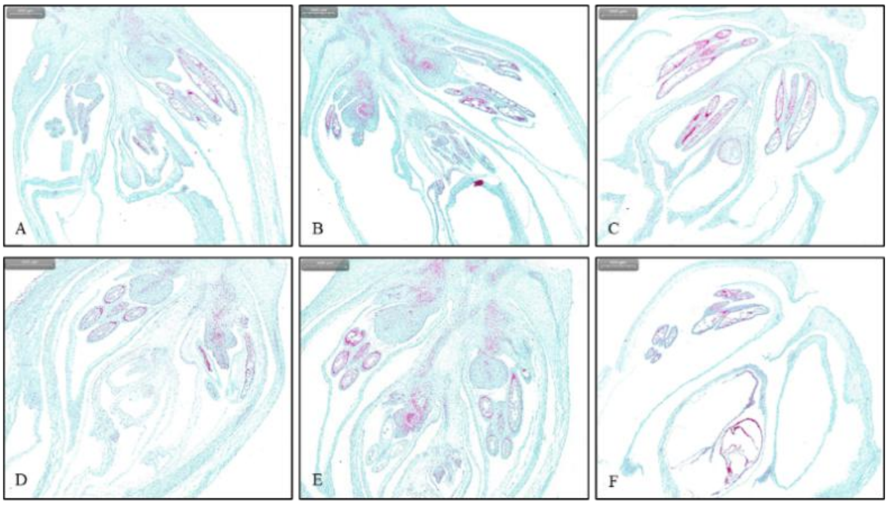

Figure 1. Effect of low temperature on cell structure and morphology of wheat spikelets at booting stage

A: Yannong 19 in the natural environment (CK); B: Yannong 19 under low temperature at 2 °C (T1); C: Yannong 19 under low temperature at -2 °C (T2); D: Xinmai 26 in the natural environment (CK); E: Xinmai 26 under low temperature at 2 °C (T1); F: Xinmai 26 under low temperature at -2 °C (T2).

Effect of low temperature on the sugar content of wheat spike

Low temperature significantly increased soluble sugar and sucrose contents in young wheat panicles, while the glucose content is decreased. The soluble sugar and sucrose contents in the two wheat varieties decreased in the order CK< T1< T2 ($p < 0.05$). In spikelets of cold sensitive Xinmai 26, a significant increase in glucose content was observed at T1 or T2 compared with the control, and there was a significant difference between T1 and T2. While the in cold-tolerant variety Yannong 19 a significant difference only between treatments and controls ($P < 0.05$). Under T1 and T2 treatments, the glucose content was reduced by 7.8% (T1) and 10.1% (T2) in Yannong 19, 9.3% (T1) and 29.9% (T2) in Xinmai 26. This result could indicate that in low temperature freezing reduced sucrose catabolism in young spikes, resulting in impaired energy transport.

Table 1. Effect of low temperature on the sugar content of wheat ears at booting stage

Varieties	Treatments	Soluble sugar content (mg/g·FW)	Sucrose content (mg/g·FW)	Glucose content (mg/g·FW)
	CK	642.57c	155.23c	24.32a
Yannong19	T1	774.76b	232.28b	22.45b
	T2	884.26a	388.05a	21.86b
	CK	807.71c	156.44c	30.53a
Xinmai26	T1	945.67b	213.04b	27.69b
	T2	1099.84a	261.50a	21.40c

Effect of low temperature on setting rate

The setting rate in both varieties exhibited a significant decline as low temperature continued to drop (Figure 3). Compared with CK, the setting rate was reduced by 30.6% (Yannong19) and 32.3% (Xinmai26) at the T1 treatment. The setting rate under T2 treatment was reduced by 53.2% in Yannong 19 and 51.1% in Xinmai 26, respectively.

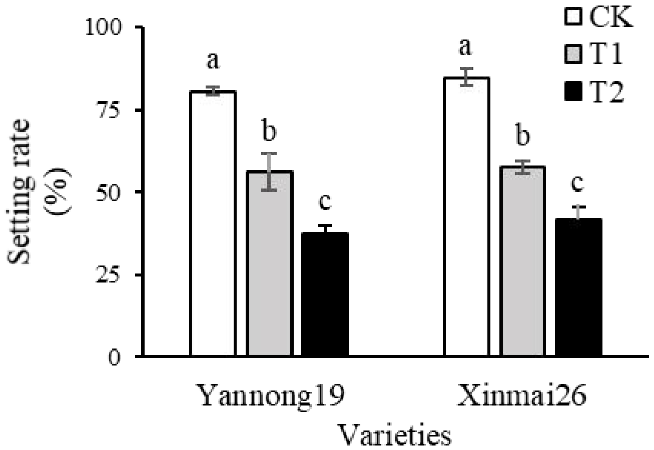

Figure 3. Setting rate of two wheat genotypes under low temperature stress at booting stage

Conclusion

Low temperature at booting stage increased the damage rate of wheat spikelet and decreased the seed-setting rate of wheat spikelet. In addition, low temperature at booting stage increased the contents of soluble sugar and sucrose and decreased the content of fructose in spikelets. In conclusion, low temperature at booting stage affects sucrose transport and metabolism, destroying the integrity of spikelets, thereby reducing the seed setting rate of wheat.

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