A wheat-Aegilops umbellulata addition line improves wheat agronomic traits and processing quality

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Wheat processing quality is mainly correlated with high-molecular-weight glutenin subunits (HMW-GS) of grain endosperm. In bread wheat, the number of HMW-GS alleles are limited. However, wheat relative species possess numerous HMW-GS genes. In our previous study, a pair of novel HMW-GS 1Ux3.5+1Uy1.9 was characterized in Aegilops umbellulata. In this work, a novel wheat-Ae. umbellulata addition line, GN05, carrying a pair of 1U chromosome was developed and identified via cytogenetic analysis. Protein composition analysis indicated that GN05 carried HMW-GS of Ae. umbellulata. Accumulation of glutenin macropolymer (GMP) showed that GN05 had a much higher GMP content than the recurrent parent Chinese Spring. Rheological characteristics were analyzed by mixing test and the dough quality of GN05 was significantly improved compared to Chinese Spring. The results presented here may provide a valuable resource for the improvement of bread wheat quality.

Key Words: Aegilops umbellulata, wheat, addition line, agronomy traits, processing quality.

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Extraction and analysis of glutenin macropolymer (GMP)
To analyze the dynamic accumulation trend of GMP, seeds in the middle spikelets were collected at 3, 5, 10, 15, 20, 25, and 28 days after anthesis. GMP concentration was measured according to Zhang et al. (2013).

Results and Discussion

Chromosome constitution and HMW-GS composition
SDS-PAGE analysis indicated that HMW-GS 1Ux3.5+1Uy1.9 and LMW-GS of Y361 are present in GN05 (Fig. 1), and a pair of exogenous chromosomes was detected in GN05 (Fig. 2A, 2B). In Aegilops umbellulata, HMW-GS and LMW-GS genes are located on the long arm and short arm of chromosome 1U, respectively (Rawat et al. 2011, Wang et al. 2018). In this work, HMW-GS pair 1Ux3.5+1Uy1.9 used as a molecular marker, finally, the additional chromosome was identified as 1U and GN05 is a wheat-Ae. umbellulata 1U disomic addition line.

Hybridization between wheat and wheat relative species for the development of introgression lines is an important strategy frequently used in wheat improvement programs.
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Several aneuploidy and translocation lines derived from wheat and its closely related species have been developed (Garg et al. 2009, Wang et al. 2016, Wen et al. 2017, Zhao et al. 2010). Molecular markers and fluorescent tags were traditionally used for the identification of exogenous chromosome fragments (Zhao et al. 2010). In this work, the HMW-GS pair 1Ux3.5+1Uy1.9 was used as a key marker to identify the additional chromosome because this pair was only expressed in chromosome 1U (Hou et al. 2017).

**Agronomic traits of GN05**

Phenotype and agronomic comparisons between Chinese Spring and GN05 have been shown in **Fig. 3** and **Table 1**. GN05 showed shorter plant height and more spikes per plant than Chinese Spring, contributing to lodging resistance and yields increasing. However, the average duration of anthesis of GN05 is 198.7 days, much longer than Chinese Spring (172.2 days), limiting the rotation of wheat and other crops. The analysis of protein content revealed that total protein concentration of GN05 is 13.2%, significantly higher compared with Chinese Spring (10.7%). There were no significant differences among the number of seeds per spike and thousand seed weight (**Table 1**).

Spikes per acre, numbers of seeds per spike, and thousand seed weight are three factors affecting wheat yield (Yang et al. 2016). Possession of multiple tillers is an important trait that could increase wheat yield. *Ae. umbellulata* possesses the trait of multiple tillers and this characteristic has been transferred to the addition line (**Fig. 3**, **Table 1**). The reduced plant height of modern wheat cultivars is an important breeding objective because shorter plants have an improved rate of floret survival, increased grain number per spike, and reduction of lodging when plants are grown under high fertilizer regimes (Mo et al. 2018). The height of GN05 was 50.6 cm, shorter than Chinese Spring, suggesting that GN05 possesses a high yield potential. Previous studies indicated that a high protein content of wheat is required for bread making, in addition, flour protein content had a significant impact on Chinese steamed bread quality (Würschum et al. 2016, Zhu et al. 2001). As indicated in **Table 1**, protein content of GN05 significantly higher than Chinese Spring that suggesting GN05 possessed a better dough strength.

**Dough quality analysis**

As indicated in **Fig. 4**, the rate of GMP accumulation in GN05 is much higher than that of Chinese Spring, and GN05 showed a higher amount of GMP. Rheological properties showed that the parameters of middle peak time, middle peak height, right of peak slope, width at peak, and width at 8 min of GN05 were all considerably higher than those of Chinese Spring (**Fig. 5**). These results revealed that GN05 possessed much higher dough strength than its recurrent parent Chinese Spring.

Although there is a complex mixture of wheat storage proteins, HMW-GS was identified to have a key role in wheat processing quality (Payne 1987). The composition of HMW-GS affected GMP content and further significantly correlated with the quality parameters (Don et al. 2003). Our present work has revealed that HMW-GS 1Ux3.5 of

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**Table 1.** Agronomic traits of GN05 and Chinese Spring

| Agronomic traits | Chinese Spring | GN05 |
|------------------|----------------|------|
| Flowering time (day) | 172.2 ± 2.12a | 198.7 ± 1.03b |
| Plant height (cm) | 152.3 ± 0.22b | 101.7 ± 1.37a |
| Number of spike per plant | 9.2 ± 3.44a | 16.5 ± 2.23b |
| Number of seeds per spike | 31.5 ± 0.12a | 36.7 ± 0.53a |
| Thousand seed weight (g) | 31.1 ± 1.17a | 32.5 ± 2.52a |
| Grain protein content (%) | 10.7 ± 0.32a | 13.2 ± 1.17b |

Each trait was investigated five individual plants. Means followed by different letters within the same column were significantly different from each other ($p < 0.05$).
Ae. umbellulata possesses a unique structure that contributed to excellent dough quality (Hou et al. 2017). The rheological properties of dough indicated that the addition line showed better quality than the recurrent parent Chinese Spring (Fig. 5).

Overall, GN05 is a wheat-Ae. umbellulata 1U addition line that possesses much better agronomic traits and dough quality than Chinses Spring. However, its long period of anthesis limited the rotation of wheat and other crops. The flowering time of wheat should be restricted between 170–180 days that is suitable for cultivation mode in Guizhou Province of China. In a future study, an introgression line containing HMW-GS of Ae. umbellulata and possessing a short period of anthesis will be developed and applied as a germplasm resource for the further improvement of wheat.

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