A method for quantification of heat resistance of quality in different wheat cultivars

Qiang Li¹, Xianghai Meng¹, Ding Li¹, Minghui Zhao¹, Shuluan Sun¹, Yuan Li²*, Guanli Lu¹*, Wenchen Qiao¹*

¹ Dryland Farming Institute, Hebei Academy of Agricultural and Forestry Sciences, Key Lab of Crop Drought Tolerance Research of Hebei Province, Hengshui Hebei 053000, P.R.China
² Seed Management Department of Hebei province, Shijiazhuang Hebei 050000, P.R.China
liqiang417@sdau.edu.cn

Abstract. Heat stress seriously affects wheat production in many regions of the world. At present, due to the lack of effective methods to quantify heat stress and heat tolerance of different wheat varieties, heat tolerance research is still the weakest field in wheat genetics and breeding. A new index heat resistance index of quality (HRIQ) as an indicator of both quality potential and quality stability was calculated for heat resistance quantification. HRIQ of Zeleny was highly significantly positively correlated with Zeleny under normal treatment ($R^2=0.8605$, $P<0.01$), and negatively correlated with the change rate of Zeleny under heat stress ($R^2=0.7707$, $P<0.01$). HRIQ of protein content was highly significantly positively correlated with protein content under normal treatment ($R^2=0.7169$, $P<0.01$), and negatively correlated with the change rate of protein content under heat stress ($R^2=0.7432$, $P<0.01$). In this study, 14 varieties with better quality and heat stability, such as Xiaoyan 60 and Kenong 1006 were identified, which can be applied to improve the heat stability of Wheat quality.

1. Introduction
In recent years, the extreme weather events, especially high temperature, have become frequent due to global warming, which cause severe damage to crop yields [1-3]. Wheat (Triticum aestivum L.) is one of the most important cereal crops in the world. As climate warming, the heat stress, especially during the post anthesis period (terminal heat), has seriously affected the production of wheat. So, the aim of this study was to investigate and evaluate a new method for quantification of heat resistance of quality in different wheat cultivars.

2. Materials and methods
2.1. Cultivars
The 160 winter wheat (Triticum aestivum L.) cultivars in North China Plain were evaluated for heat resistance of quality. These cultivars were sown at the research station in Hebei hengshui (37°44′N, 115°42′E and elevation 20m above mean sea level). Shiluan02-1 was selected as the control cultivar in this study.

The experiment was conducted on sandy loam soil under field conditions and a split block design with three replicates and two treatments was followed during 2018-2019 crop seasons. Each cultivar
was grown in 4 rows of 4 m length with 15.5 cm space between rows. After making an adjustment for seed size, the seed rate was maintained at a uniform population of 300 plants per m² (3 million plants per hectare), according to 1000 grain weight and germination percentage. Standard agronomic practices recommended for normal fertility (340 kg/ha N: 172.5 kg/ha P₂O₅: 40 kg/ha K₂O) were followed. Full rates of K₂O and P₂O₅ were applied at the time of sowing. Nitrogen was supplied in split applications, 170 kg/ha N at sowing, and 170kg/ha N at the first irrigation. Care was taken to avoid moisture and biotic stress by ensuring timely irrigation and pesticide control.

2.2. Heat treatments
Fifteen days after the anthesis for 80% of these wheat cultivars, the temperature-controlled phytotron greenhouse was transferred to cover the 160 cultivars and remained for twenty days, increasing the maximum temperature from 27.7°C to 42.2°C during 2018-2019. According the meteorological data for 30 years in this area, the temperature inside the movable greenhouse was controlled as 5°C (±0.5°C) higher than that of outside to more realistically simulate the heat stress of this region.

2.3. Heat resistance assessment
We used a new parameter ‘heat resistance index of quality’ (HRI_Q) which was determined using a modified formula given for susceptibility index (S) to evaluate the heat resistance of quality[2]. In order to indicate the quality potential under heat stress, the absolute quality under heat stress(Q) was joined into the formula. In order to remove the effect of variation in quality potential under non-stress, relative quality (HRC=Q/Q_P) were calculated. In addition, corresponding data of control cultivar were used in the formula to remove other unconcerned variable disturbance like heat intensity.

Thus heat-resistance index is given by the following simple formula:

$$HRI_Q = Q_S / Q_{CK} \cdot HRC_S / HRC_{CK}$$

After modified:

$$HRI_Q = Q_S \cdot Q_{SP}\cdot Q_{CKP} (Q_{CK})^{-1}$$

In this study, we used protein content and Zeleny to evaluate the quality. The cultivars were then classified by HRI_Q as resistant (≥1.20), moderately resistant (1.00 to ≤ 1.19), moderately susceptible (0.80 to ≤ 0.99), and susceptible (≤ 0.79).
Table 1 HRIQ scale for stability to heat stress for different wheat cultivars.

| Scale | HRIQ | Opinion          |
|-------|------|------------------|
| 1     | ≥1.20| tolerant         |
| 2     | 1.00-1.19| moderately tolerant |
| 3     | 0.80-0.99| moderately susceptible |
| 4     | ≤0.79| susceptible      |

2.4. Quality tests

Grain hardness, moisture, and grain and flour protein content were determined by near-infrared spectroscopy (NIRS) (DA7200 Analyzer) calibrated based on AACC methods for protein content and Zeleny\(^5\). Lower hardness index (%) values correspond to harder cultivars. Grain protein and flour protein were adjusted to a 12.5% and 14% moisture basis, respectively.

3. Result

3.1. Evaluation of HRIQ

In this study, 160 materials were evaluated under heat stress and normal treatment. It was found that the newly established heat resistance index of quality of Zeleny was highly significantly positively correlated with Zeleny under normal treatment ($R^2 = 0.8605$, $P<0.01$), and negatively correlated with the change rate of Zeleny under heat stress ($R^2 = 0.7707$, $P<0.01$); The heat resistance index of protein content was significantly positively correlated with the protein content under normal treatment ($R^2 = 0.7169$, $P<0.01$), and negatively correlated with the change rate of protein content under heat stress ($R^2 = 0.7432$, $P<0.01$).

The maximum HRIQ of Zeleny was 1.40 in Xiaoyan 54 (Zeleny =42.71ml, Zeleny change rate=-12.01%) while the minimum HRIQ of Zeleny was 0.72 in Fanmai5 (Zeleny=28.6ml, Zeleny change rate=14.65%) and Tainong7508 (Zeleny=32.16ml, Zeleny change rate=29.35%). The maximum HRIQ of protein content was 1.13 in Xiaoyan 60 (protein content=16.67%, protein change rate=-10.68%) while the minimum HRIQ of protein content was 0.64 in Tainong7508 (protein content=14.38%, protein change rate=35.74%). Under heat stress, the Zeleny and protein content of Tainong7508 decreased most which indicated that the quality of this cultivar is sensitive to heat stress.

![Graph of HRIQ vs Zeleny](image1)

![Graph of HRIQ vs Change rate of Zeleny](image2)
3.2. Wheat cultivars evaluation

Taking the heat stable wheat variety Shiluan 02-1 as the control and referring to the newly established grading standard for heat stability of wheat (Table 1), 14 varieties (Table 2) with better quality and heat stability, such as Xiaoyan 60 and Kenong 1006, were identified, which can be applied to improve the heat stability of Wheat quality.

| NO. | Cultivar  | NO. | Cultivar  | NO. | Cultivar  | NO. | Cultivar  |
|-----|-----------|-----|-----------|-----|-----------|-----|-----------|
| 1   | Xiaoyan60 | 5   | Zhoumai18 | 9   | Yannong15 | 13  | Jiyanmai7 |
| 2   | Xiaoyan54 | 6   | Kenong1006| 10  | Xingmai1  | 14  | Zhili57   |
| 3   | Xinmai18 | 7   | LIA3937   | 11  | Shanmai159|     |           |
| 4   | Xinmai23 | 8   | Xinong889 | 12  | Yunfengyou1371| | |

References

[1] Gooding MJ, Ellis RH, Shewry PR, Schofield JD. Effects of restricted water availability and increased temperature on the grain filling, drying and quality of winter wheat. Journal of Cereal Science. 2003, 37: 295–309.

[2] Hoffmann S, Debreczeni K, Hoffmann B and Nagy E. Grain yield and baking quality of wheat as affected by crop year and plant nutrition. Cereal research communications. 2006, 34 (1): 473-476.

[3] Figueiredo ICRD, Pinto CABP, Ribeiro GHMR. Efficiency of selection in early generations of potato families with a view toward heat tolerance. Crop breeding and applied biotechnology. 2015, 15(4): 210-217.

[4] Fischer RA and Maurer R. Drought resistance in spring wheat cultivars. 1: grain yield response. Aust J. Agric. Res. 1978, 29: 897-912.

[5] AACC International. 2000. Approved Methods of the American Association of Cereal Chemists. 10th ed. The Association, St. Paul, MN