# Mitigating the effects of high temperature on leaf net photosynthetic rate and grain yield by spraying two reagents

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## Abstract

High temperature in the grain-filling stage of winter wheat is one of the important meteorological disasters that has a great influence on growth characteristics and grain yield. The purpose of this study was to mitigate the effects of high temperature on wheat production by selecting useful chemical reagents and suitable spraying time. In 2017-18, wheat varieties i.e. Huaimai 33 and Annong 0711 were used to study the alleviating effects of spraying two reagents in different time periods (prior to, during and post high temperature treatment, HTT) in grain-filling stage. The Pn, SPAD, 1000-grain weight and yield of wheat under high temperature could be improved by spraying Epibrassinolide (BR) and $KH_2PO_4$, and spraying $KH_2PO_4$ had the better effect compared to BR in alleviating the harm caused by high temperature. The time to spray prior to HTT, or post has better effects compared to spray during HTT.

## Key Words

Winter wheat, high temperature, BR, $KH_2PO_4$, grain yield

## Introduction

Wheat is one of the most important grain crops in China, where the optimum temperature of wheat grain-filling stage is supposed to be 20-24°C, but the stage is in the transition period from spring to summer, thus it is easy to encounter high temperature incidents (Hays et al. 2007). According to data analysis from 1979 to 2000, up to 10% yield potential of wheat is lost (You et al. 2009) and grain quality is compromised (Dixon et al. 2009; Caffe-Treml et al. 2011), which can be attributed to 1°C temperature enhancement during wheat season in China. As predicted, global wheat production will be reduced by 6% for each degree increase in temperature in future (Lipiec et al. 2013). Therefore, it is of great significance to study the cultivation techniques and chemical techniques to alleviate the harm of terminal high temperature. Epibrassinolide (BR) is regarded as the sixth largest hormone. Spraying BR is beneficial to the improvement of photosynthetic performance and dry matter accumulation of wheat (Li et al, 2015). $KH_2PO_4$ is a commonly used and effective spraying reagent in wheat to enhance abiotic stress tolerance (Yang et al. 2018). However, when to spray is rarely reported in coping with terminal heat stress in wheat.

## Methods

The experiment was carried out in 2017-2018 at Anhui Agricultural University in Hefei, China (31°58′N, 117°240′E). Wheat cultivars are Huaimai 33 and Annong 0711, which was widely grown locally. The seeds are sowing on November 5 in 2017. Field trials were conducted in plots (2m×3m) and 25 cm between rows in randomized complete blocks with three replications. Field management followed local agricultural practice. In the experiment, natural temperature +5°C temperature was set as high temperature treat(HTT) by covering the plastic film (the thickness of plastic film is 0.08 mm, the transmittance of plastic film is up to 95%, about 2.5 m high) at 11:00-16:00 of 12-18 d after flowering (DAF). Fig. 1 showed the temperature changes during DAF12-18, no 'burning leaves' and obvious 'ripening' phenomenon observed during high-temperature treatment. BR ('B') and $KH_2PO_4$ ('C') reagents was sprayed and water was used as CK ('A'). The spraying concentration of BR and $KH_2PO_4$ were 0.1mg/L and 0.2%. All reagent were sprayed using the 673.8L/$hm^2$ amount at three periods: prior to treatment (1), during the treatment (2) and post treatment (3) at 17:30 every day.

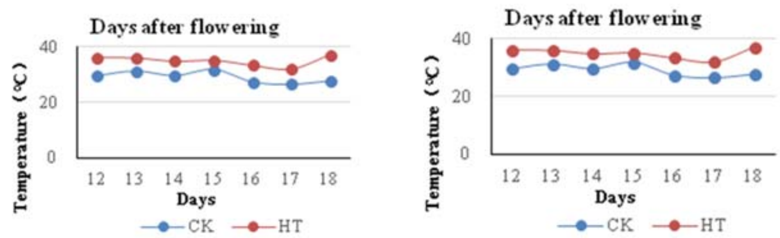


**Fig. 1 The maximum temperature time course after flowering (a) and (b) imposing time in a day in heat stress treatment (HT) and control (CK).**

## Results

*2.1 Effects of spraying $KH_2PO_4$ and BR on Pn and SPAD in flag leaves of wheat under high temperature*

The changes of Pn and SPAD in wheat flag leaves under different treatment were shown in Table 1 and Table 2. The Pn and SPAD of flag leaves decreased during grain filling in all three treatments. Huaimai 33 and Annong 0711 had a similar effect. Compared to the CK, spraying BR and $KH_2PO_4$ was beneficial to the improvement of flag leaf Pn and SPAD, and the effect showed that $KH_2PO_4$ > BR > CK. In terms of spraying time, spraying BR and $KH_2PO_4$ prior to and post high temperature treatment maintained higher levels of Pn and SPAD.

**Table 1. Effects of spraying $KH_2PO_4$ and BR on Pn (μmol $CO_2$ $m^{-2}$ $s^{-1}$) in flag leaves of wheat under high temperature**

| Cultivar | Treatment | 10 DAF | 20 DAF | 30 DAF |
|---|---|---|---|---|
| Huaimai 33 | A1 | 26. 33±2. 24a | 18. 80±1. 00d | 11. 10±0. 22c |
| | A2 | 26. 00±1. 21a | 18. 20±0. 90d | 10. 98±0. 06c |
| | A3 | 25. 83±0. 84a | 18. 47±0. 06d | 11. 22±0. 16c |
| | B1 | 26. 07±0. 87a | 21. 87±1. 25c | 13. 03±0. 13b |
| | B2 | 25. 87±1. 94a | 21. 50±1. 30c | 12. 91±0. 06b |
| | B3 | 25. 57±2. 05a | 22. 47±1. 25bc | 13. 87±0. 35a |
| | C1 | 26. 13±3. 23a | 24. 27±0. 75a | 13. 98±0. 15a |
| | C2 | 26. 10±1. 22a | 23. 87±1. 05ab | 13. 19±0. 34b |
| | C3 | 25. 83±1. 10a | 24. 90±0. 60a | 14. 15±0. 08a |
| Annong 0711 | A1 | 25. 23±0. 81a | 17. 90±0. 60de | 8. 96±0. 20e |
| | A2 | 24. 43±0. 67a | 17. 57±0. 75e | 7. 73±0. 46f |
| | A3 | 25. 47±1. 11a | 18. 20±0. 40adc | 9. 16±0. 06e |
| | B1 | 24. 83±0. 55a | 19. 60±0. 40abc | 11. 37±0. 37c |

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|---|---|---|---|---|
| | B2 | 25. 50±0. 92a | 19. 20±0. 50bcd | 10. 75±0. 28d |
| | B3 | 24. 90±0. 61a | 20. 90±1. 20a | 12. 32±0. 51ab |
| | C1 | 25. 63±1. 00a | 21. 00±0. 70a | 12. 53±0. 45a |
| | C2 | 25. 00±0. 72a | 20. 50±1. 50ab | 11. 72±0. 28bc |
| | C3 | 25. 43±0. 61a | 21. 10±0. 60a | 12. 72±0. 16a |

10DAF: 10 d after flowering (prior to high temperature treatment); 20DAF: 20d after flowering (in high temperature treat); 30 DAF: 30 d after flowering (post high temperature treatment); Different lowercase letters in the same column indicate significant difference at 5% level.

**Table 2. Effects of spraying $KH_2PO_4$ and BR on SPAD of wheat flag leaf under high temperature**

| Cultivar | Treatment | 10 DAF | 20 DAF | 30 DAF |
|---|---|---|---|---|
| Huaimai 33 | A1 | 53. 97±2. 15a | 52. 31±2. 66bc | 34. 17±0. 55c |
| | A2 | 52. 90±2. 00a | 50. 25±2. 49c | 31. 70±0. 81d |
| | A3 | 54. 80±2. 12a | 53. 21±0. 05bc | 34. 80±1. 65c |
| | B1 | 55. 57±2. 27a | 55. 62±1. 27ab | 42. 70±1. 34ab |
| | B2 | 55. 80±1. 2a | 54. 11±0. 53ab | 41. 87±1. 31b |
| | B3 | 56. 80±2. 08a | 55. 94±0. 60ab | 43. 73±0. 67ab |
| | C1 | 56. 00±1. 31a | 55. 83±1. 17ab | 43. 87±1. 00ab |
| | C2 | 56. 07±1. 00a | 54. 9±2. 05ab | 42. 47±1. 45b |
| | C3 | 54. 80±2. 16a | 56. 16±0. 67a | 44. 60±0. 79a |
| Annong 0711 | A1 | 50. 57±1. 34a | 48. 56±0. 20c | 32. 60±1. 4b |
| | A2 | 49. 23±2. 80a | 48. 22±1. 15c | 30. 50±1. 66b |
| | A3 | 50. 97±0. 47a | 48. 14±0. 98c | 33. 30±1. 04b |
| | B1 | 49. 77±2. 12a | 50. 64±0. 20ab | 42. 07±1. 12a |
| | B2 | 48. 33±1. 84a | 49. 20±2. 19b | 41. 10±1. 80a |
| | B3 | 49. 80±1. 48a | 51. 53±0. 23ab | 43. 87±0. 35a |
| | C1 | 50. 37±1. 50a | 50. 71±0. 46ab | 43. 07±0. 51a |
| | C2 | 49. 83±1. 24a | 49. 60±1. 76b | 42. 93±0. 67a |
| | C3 | 50. 03±1. 70a | 52. 23±2. 43a | 44. 20±0. 30a |

10DAF: 10 d after flowering (prior to high temperature treatment); 20DAF: 20d after flowering (in high temperature treat); 30 DAF: 30 d after flowering (post high temperature treatment); Different lowercase letters in the same column indicate significant difference at 5% level.

### *2.2 Effect of spraying $KH_2PO_4$ and BR on wheat yield under high temperature*

The effect of spraying $KH_2PO_4$ and BR on wheat 1000-grain weight and theoretical yield under high temperature was similar with the effect on Pn and SPAD (Table 3) with $KH_2PO_4 > BR > CK$, but there was no significant difference between $KH_2PO_4$ and BR in the increase of grain number per ear. Huaimai 33 and Annong 0711 had a similar effect. The results indicated that high temperature at DAF12-18 could significantly reduce wheat yield through reduce 1000-grain weight, and spraying $KH_2PO_4$ had the better effect of alleviating high temperature harm. Compared with CK, spraying $KH_2PO_4$ and BR at different stages could increase 1000-grain weight and yield, and pre-high temperature prevention and post-high-temperature remediation could better alleviate grain-filling high temperature harm and maintain high 1000-grain weight and stable yield.

**Table 3. Effects of spraying $KH_2PO_4$ and BR on yield and its components under high temperature**

| Cultivar | Treatment | Spike number ( ten thousand·$hm^{-2}$) | Grain number per spike | 1000-grain weight (g) | Theoretical yield (kg· $hm^{-2}$) |
|---|---|---|---|---|---|
| Huaimai 33 | A1 | 630.36±6.41a | 35. 45±1. 05d | 33. 74±0. 62e | 7,537.19±133.40f |

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|---|---|---|---|---|---|
| | A2 | 629.71±11.00a | 35. 23±1. 47d | 33. 96±0. 26e | 7,529.05±158.01f |
| | A3 | 631.05±9.57a | 36. 07±0. 82cd | 34. 64±0. 58d | 7,881.09±114.14e |
| | B1 | 632.37±4.51a | 37. 18±0. 37abc | 36. 57±0. 05b | 8,597.10±71.59bcd |
| | B2 | 631.71±4.98a | 36. 57±1. 54cd | 35. 97±0. 01c | 8,308.92±269.15d |
| | B3 | 632.03±5.23a | 38. 31±1. 06ab | 36. 78±0. 10b | 8,906.92±352.33ab |
| | C1 | 634.71±10.18a | 37. 40±70. 27abc | 36. 68±0. 20b | 8,705.92±122.23bc |
| | C2 | 632.71±9.68a | 36. 69±0. 65bcd | 36. 31±0. 09bc | 8,428.85±184.19cd |
| | C3 | 634.37±2.78a | 38. 49±0. 30a | 37. 81±0. 20a | 9,232.42±143.41a |
| Annong 0711 | A1 | 623.00±14.26a | 30. 20±1. 43cd | 32. 48±0. 08cd | 6,108.12±195.08e |
| | A2 | 621.66±8.37a | 29. 94±1. 77d | 32. 22±0. 18d | 5,994.29±266.52e |
| | A3 | 623.33±8.10a | 30. 85±1. 97bcd | 32. 94±0. 52c | 6,331.71±346.21de |
| | B1 | 623.33±11.90a | 32. 63±0. 57ab | 34. 32±0. 26b | 6,938.54±173.03b |
| | B2 | 623.02±5.24a | 30. 93±0. 58bcd | 33. 88±0. 80b | 6,529.45±144.90cd |
| | B3 | 624.33±4.30a | 32. 49±0. 22ab | 33. 95±0. 34b | 6,886.95±105.16bc |
| | C1 | 625.33±8.02a | 33. 45±1. 05a | 34. 42±0. 22b | 7,199.60±209.27ab |
| | C2 | 624.66±13.15a | 32. 11±0. 43abc | 34. 34±0. 09b | 6,889.04±200.04bc |
| | C3 | 625.99±12.62a | 33. 76±1. 66a | 35. 63±0. 05a | 7,524.00±213.32a |

Different lowercase letters in the same column indicate significant difference at 5% level.

## Conclusion

Spraying $KH_2PO_4$ and BR can help alleviate high temperature impacts on grain-filling in wheat by increasing the flag leaf Pn and SPAD, as well as 1000-grain weight and thus grain yield of wheat. It is shown that spraying $KH_2PO_4$ had the better effect than did BR in dealing with high temperature. The time to spray prior to onset of heat stress, or post has similar effects, both better than spraying during heat stress. These findings will be valuable in cultivation coping with terminal heat stress.

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