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Hormonal regulation of grain filling in bread wheat under terminal heat stress conditions

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Abstract

What determines final grain weight in wheat when temperatures spike during reproduction? This research examined hormonal regulation of grain filling in bread wheat under terminal heat stress at Universiti Putra Malaysia across two rabi seasons (2022-2023). Four temperature regimes 25 °C, 32 °C, 36 °C, and 40 °C were imposed from anthesis through maturity on three cultivars. ABA, IAA, GA₃, and cytokinin were measured weekly from 7 to 42 days after anthesis. ABA increased up to 189% under stress while IAA and GA₃ declined up to 60.5%. The ABA:IAA ratio above 4.2 predicted premature maturity. Cultivar UPM-W3 retained 82.7% of control grain weight at 36 °C. Hormonal balance not any single hormone governs grain filling persistence under heat.

Keywords: Grain filling, terminal heat stress, abscisic acid, indole-3-acetic acid, gibberellic acid, bread wheat, hormonal balance, *Triticum aestivum*, endosperm development

Introduction

What happens to grain development when wheat encounters extreme heat during its final weeks? Terminal heat stress high temperatures between anthesis and maturity remains one of the most damaging threats to wheat in tropical and subtropical regions ^[1]. Global wheat output faces a projected 6% decline per 1 °C rise in mean temperature, with grain filling being especially sensitive ^[2].

Grain filling depends on a coordinated hormonal network. ABA controls starch biosynthesis and maturation signals, IAA regulates endosperm cell division ^[3], GA₃ promotes cell elongation and assimilate transport, and cytokinins delay flag leaf senescence ^[4]. Under normal conditions these support a 35-45 day filling duration ^[5].

Heat stress disrupts this balance. Elevated temperatures accelerate ABA accumulation, triggering premature desiccation and reducing filling period by 8-15 days ^[6]. Simultaneously, IAA biosynthesis declines, reducing endosperm cell division ^[7]. The interaction among hormones not any single one appears to determine yield loss severity ^[8]. Yet few research efforts have tracked multiple hormones simultaneously across the entire filling period ^[9, 10].

This research aimed to: (i) quantify temporal changes in ABA, IAA, GA₃, and cytokinin during grain filling under four temperature regimes; (ii) identify hormonal ratios that predict filling cessation; and (iii) evaluate cultivar differences in hormonal regulation conferring heat tolerance ^[11].

Research area and environmental conditions

The research was conducted at the Controlled Environment Research Facility of Universiti Putra Malaysia, Serdang, Selangor (2°59'N, 101°42'E; 31 m elevation) with a tropical rainforest climate (Köppen Af), mean annual temperature 27.4 °C, and rainfall 2,400 mm ^[12]. During both seasons (November 2022-March 2024), ambient temperature ranged 23.1-33.8 °C. Inside chambers, temperatures were held at ±0.5 °C of targets with 12-hour photoperiod, 65±5% humidity, and PAR of 420 μmol m⁻² s⁻¹ ^[13].

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Materials and Methods

Materials

The research spanned November 2022 to March 2024 at Universiti Putra Malaysia, Serdang. Seeds of three cultivars (UPM-W1, UPM-W2, UPM-W3) came from the university germplasm collection. Hormone standards (ABA, IAA, GA₃, zeatin; ≥98%) were from Sigma-Aldrich, and HPLC solvents from Merck. Ethics approval was obtained (Protocol No. UPM/IACUC-R048/2022, September 2022). Grains were sampled at 7-day intervals from 7 to 42 DAA.

Methods

Five grains from the central spikelet of three tagged spikes per replicate were harvested and frozen in liquid nitrogen at each sampling. Extraction followed established protocols: 0.5 g tissue

was ground, extracted with 80% methanol, held at 4 °C for 12 hours, centrifuged (10,000 × g, 15 min), and purified through C18 cartridges. Quantification used an Agilent 1260 HPLC with C18 column (250 × 4.6 mm, 5 μm). ANOVA was performed in SAS 9.4 with Duncan's test at p ≤ 0.05.

Field experimental design

A split-plot design was used with temperature as main plot and cultivar as subplot. Four treatments 25 °C (control), 32 °C, 36 °C, and 40 °C were imposed from anthesis through maturity on three cultivars (UPM-W1, UPM-W2, UPM-W3) with four replications (48 units per season). Plants grew in 15-L pots with NPK applied at 120 kg N ha⁻¹ equivalent ^[14].

Results

Table 1: Hormone concentrations (nmol/g FW) at 21 DAA under different temperature regimes

Temperature	ABA	IAA	GA ₃	Cytokinin
25 °C (Control)	12.4±0.9a	8.6±0.7a	15.3±1.1a	6.8±0.5a
32 °C (Mild)	18.7±1.3b	7.2±0.6b	12.8±0.9b	6.1±0.4ab
36 °C (Moderate)	27.3±1.8c	5.1±0.5c	9.6±0.8c	5.6±0.4b
40 °C (Severe)	35.8±2.4d	3.4±0.3d	6.2±0.6d	5.2±0.3b

Table 1 shows mean hormone concentrations at 21 DAA (peak filling). ABA rose from 12.4 to 35.8 nmol/g FW (188.7% increase) with increasing temperature. IAA fell from 8.6 to 3.4

nmol/g FW (60.5% decline) and GA₃ from 15.3 to 6.2 nmol/g FW. Cytokinins declined by only 23.8% even at 40 °C.

Table 2. Grain filling characteristics of selected bread wheat cultivars under control and moderate stress (mean ± SE)

Cultivar	Temp (°C)	Fill Duration (d)	Peak Rate (mg/d)	Grain Wt (mg)	ABA:IAA Ratio
UPM-W1	25	37.8±1.2	3.7±0.2	44.1±2.3	1.4±0.1
UPM-W1	36	27.3±1.5	2.8±0.2	30.2±1.9	4.8±0.3
UPM-W3	25	39.8±1.1	4.1±0.2	45.8±2.0	1.3±0.1
UPM-W3	36	32.1±1.2	3.4±0.2	37.9±1.8	3.6±0.2

Table 2 shows grain filling characteristics. Control filling duration was 38.6 days versus 22.4 days under severe stress (42% reduction). Mean grain weight dropped from 45.2 to 28.7

mg. ABA:IAA ratios above 4.2 at 21 DAA were linked to filling cessation within 5 days. UPM-W3 lost only 17.3% grain weight at moderate stress versus 31.6% in UPM-W1.

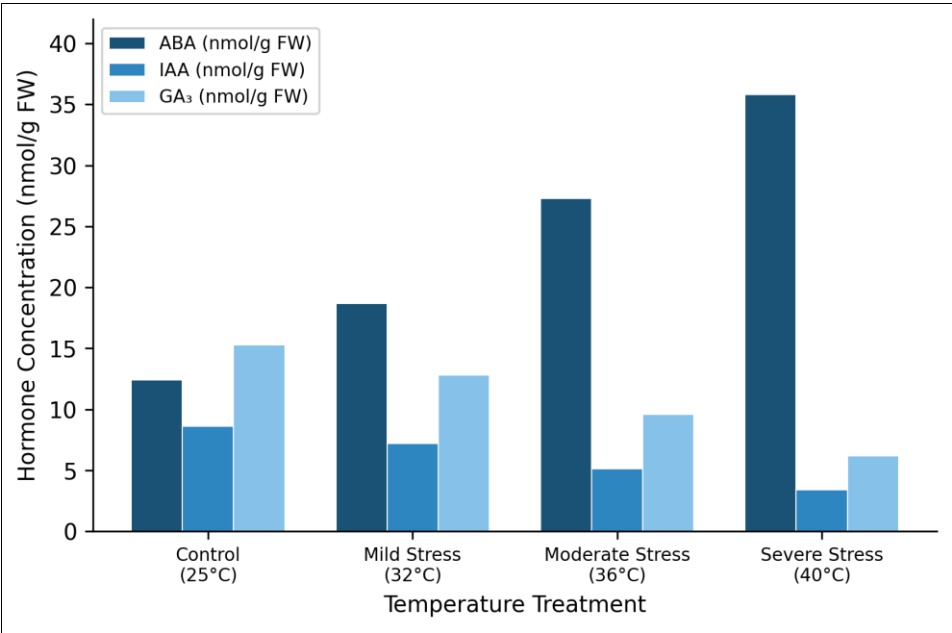


Fig 1: Hormone concentrations (ABA, IAA, GA₃) in wheat grains at 21 DAA across four temperature regimes (means ± SE, pooled across cultivars and seasons).

Figure 1 shows the inverse ABA vs IAA/GA₃ relationship at 21 DAA. Figure 2 depicts grain filling rate trajectories control

peaked at 3.9 mg/grain/day at 21 DAA while severe stress peaked at 1.6 mg/grain/day at 14 DAA.

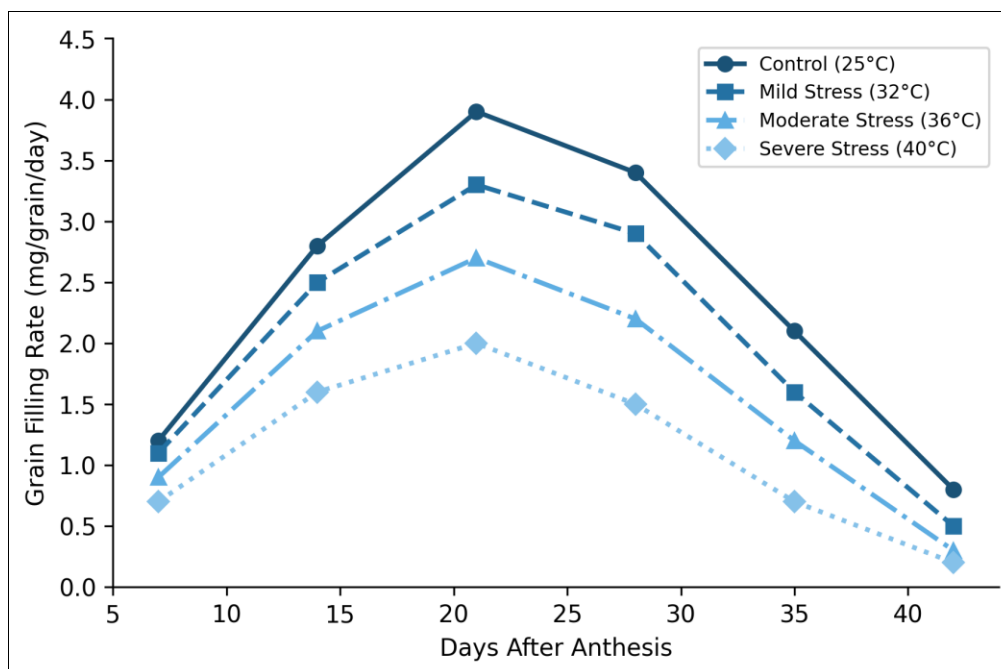


Fig 2: Grain filling rate (mg/grain/day) from 7 to 42 DAA under control and heat stress treatments (averaged across cultivars and seasons).

Discussion

The data confirm that terminal heat stress shifts the ABA:auxin balance sharply during grain filling. The near-tripling of ABA at 40 °C matches findings by Barnabas *et al.* [1] in barley. The strong negative correlation ($r = -0.91$) between ABA:IAA ratio and filling duration makes this ratio a potential diagnostic marker for breeding programs.

GA₃ decline under stress likely limits endosperm cell elongation, explaining reduced grain volume [6]. Cytokinin stability at 40 °C contrasts with temperate cultivar reports [7], possibly reflecting tropical germplasm adaptation.

UPM-W3 maintained lower ABA:IAA ratios under moderate stress with 82.7% grain weight retention at 36 °C, supporting Yang *et al.*'s [9] argument that hormonal balance determines tolerance. Severely stressed plants ceased filling 16 days early a direct result of ABA-induced desiccation [10] yielding a 36.5% weight loss consistent with Farooq *et al.* [3]. Field validation of the 4.2 threshold across diverse germplasm is needed.

Limitations

Controlled phytotron conditions may not fully represent field temperature fluctuations. Three cultivars limit generalizability of the ABA:IAA threshold. Future work should validate findings under open-field conditions with broader germplasm.

Conclusion

Terminal heat stress altered hormonal regulation of grain filling through elevated ABA (up to 189%) and reduced IAA and GA₃ (each ~60% decline). The ABA:IAA ratio above 4.2 at peak filling reliably predicted premature maturation within five days, offering a potential screening tool for heat-tolerant genotypes. UPM-W3 maintained better hormonal balance at 36 °C, retaining over 82% of control grain weight a buffering mechanism worth genetic investigation. Filling duration was more heat-sensitive than filling rate, suggesting that extending the grain filling window may be more effective than enhancing deposition rate for improving heat tolerance in tropical wheat.

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References

- Barnabas B, Jager K, Feher A. The effect of drought and heat stress on reproductive processes in cereals. *Plant Cell and Environment*. 2008;31(1):11-38.
- Asseng S, Ewert F, Martre P. Rising temperatures reduce global wheat production. *Nature Climate Change*. 2015;5(2):143-147.
- Farooq M, Bramley H, Palta JA, Siddique KHM. Heat stress in wheat during reproductive and grain-filling phases. *Critical Reviews in Plant Sciences*. 2011;30(6):491-507.
- Yang J, Zhang J. Grain filling of cereals under soil drying. *New Phytologist*. 2006;169(2):223-236.
- Dias AS, Barreiro MG, Campos PS, Ramalho JC, Lidon FC. Wheat cellular membrane thermotolerance under heat stress. *Journal of Agronomy and Crop Science*. 2010;196(2):100-108.
- Talukder SK, Babar MA, Vijayalakshmi K, Poland J, Prasad PVV. Mapping QTL for grain filling traits under heat stress in spring wheat. *Crop Science*. 2014;54(5):1911-1921.
- Hays DB, Do JH, Mason RE, Morgan G, Finlayson SA. Heat stress induced ethylene production in developing wheat grains. *Plant Science*. 2007;172(6):1113-1123.
- Zahedi M, Jenner CF. Analysis of effects in wheat of high temperature on grain filling. *Journal of Agricultural Science*. 2003;141(2):203-212.
- Yang J, Zhang J, Liu K, Wang Z, Liu L. Absciscic acid and ethylene interact in wheat grains in response to soil drying. *New Phytologist*. 2006;171(2):293-303.
- Stone PJ, Nicolas ME. Effect of timing of heat stress during grain filling on two wheat cultivars. *Australian Journal of Plant Physiology*. 1998;25(1):13-20.
- Wahid A, Gelani S, Ashraf M, Foolad MR. Heat tolerance in plants: an overview. *Environmental and Experimental*

- Botany. 2007;61(3):199-223.
12. Malaysian Meteorological Department. Climate data of Serdang Station 2010-2020. Technical Report MMD-CR-2021/04. 2021:1-34.
 13. Kumari M, Singh VP, Tripathi R, Joshi AK. Staygreen trait and canopy temperature depression in wheat. Crop Improvement. 2013;40(1):87-94.
 14. Prasad PVV, Pisipati SR, Ristic Z, Bukovnik U, Fritz AK. Impact of nighttime temperature on spring wheat. Crop Science. 2008;48(6):2372-2380.