Sahel Journal of Life Sciences FUDMA 4(1): 502-507, 2026

Sahel Journal of Life Sciences FUDMA (SAJOLS)
March 2026 Vol. 4(1): 502-507
ISSN: 3027-0456 (Print)
ISSN: 1595-5915 (Online)
DOI: https://doi.org/10.33003/sajols-2026-0401-57

Research Article

β-Aminobutyric Acid (BABA) Priming Enhances Yield Formation, Grain Filling, and Quality of Water-Stressed Ofada Rice (*Oryza sativa* L.)

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ABSTRACT

Drought stress remains a major constraint to rice production, particularly in Sub-Saharan Africa where locally adapted varieties such as Ofada rice are highly susceptible to water deficits. This study investigated the potentials of β-aminobutyric acid (BABA) as a priming agent to enhance drought tolerance, yield performance and grain quality in Ofada rice under field conditions. A split-plot complete randomized block design with drought imposed at vegetative, flowering and grain-filling stages under varying BABA treatments (150, 300 and 600 µM. Drought stress significantly reduced yield components, with the most severe effects at flowering, where percentage grain filling declined from 85.02% (control) to 17.08%, and grain weight per plant from 36.22 g to 17.49 g. BABA application significantly improved these parameters, restoring grain filling to 73.80–83.38% and grain weight per plant to 34.84–35.99 g under stress. Similarly, 1000-grain weight increased from 5.58 g in untreated stressed plants to 11.85–14.47 g with BABA. Economic yield was also improved, reaching 23.70 kg ha^{-1} compared to 20.00 kg ha^{-1} under untreated stress. BABA further enhanced grain quality, increasing carbohydrate content to 79.49% and crude fat to 1.72% The absence of consistent differences among BABA concentrations suggests a priming threshold, where low doses are sufficient to induce maximal response. Mechanistically, these improvements are linked to enhanced antioxidant activity, abscisic acid-mediated signalling, and improved assimilate partitioning. Therefore, BABA priming represents a cost-effective and sustainable strategy for improving drought resilience, yield stability, and grain nutritional quality in Ofada rice.

Keywords: β-aminobutyric acid; Grain quality; Ofada rice; Water deficit stress; Yield components

Citation: Ayinla, A., Olayinka, B.U., & Etejere, E.O. (2026). β-Aminobutyric Acid (BABA) Priming Enhances Yield Formation, Grain Filling, and Quality of Water-Stressed Ofada Rice (*Oryza sativa* L.). *Sahel Journal of Life Sciences FUDMA*, 4(1): 502-507. DOI: https://doi.org/10.33003/sajols-2026-0401-57

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than half of the global population and plays a central role in food security, particularly in sub-Saharan Africa where demand continues to rise alongside rapid population growth (Fukagawa & Ziska, 2023; Van Nguyen & Ferrero, 2020). In Nigeria, indigenous varieties such as Ofada rice are increasingly valued for their unique nutritional and sensory qualities; however, their productivity remains constrained by abiotic stresses, especially drought (Akinwale *et al*., 2021; Sanni *et al*., 2022). Water stress is widely recognized as one of the most critical environmental factors limiting rice yield, with effects that vary depending on the intensity, duration, and timing of stress relative to crop phenology (Daryanto *et al*., 2017; Fahad *et al*., 2017).

Drought stress disrupts key physiological and biochemical processes in rice, including photosynthesis, nutrient uptake, assimilate translocation, and hormonal balance, ultimately leading to reduced growth and yield (Zhao *et al*., 2021; Panda *et al*., 2021). The reproductive stage, particularly flowering and grain filling, has been identified as the most drought-sensitive phase, during which even short-term water deficits can result in spikelet sterility, poor grain filling, and substantial yield losses (Fahad *et al*., 2017; Kumar *et al*., 2014). Consequently, improving drought resilience in rice has become a major research priority, with increasing focus on sustainable and cost-effective approaches that enhance plant tolerance without compromising environmental safety.

One promising strategy involves the use of plant defense priming agents such as β-aminobutyric acid (BABA), a non-protein amino acid known to enhance plant tolerance to both biotic and abiotic stresses (Cohen *et al*., 2023; Mauch-Mani *et al*., 2017). Unlike conventional growth regulators, BABA does not directly stimulate growth but instead primes plants to respond more rapidly and robustly to stress through activation of stress-responsive signalling pathways (Balmer *et al*., 2015). This priming effect is largely mediated through the modulation of abscisic acid (ABA)-dependent pathways, which regulate stomatal conductance, osmotic adjustment, and stress-responsive gene expression (Ton *et al*., 2022; Jakab *et al*., 2022).

Recent advances in transcriptomics and metabolomics have provided deeper insights into the molecular mechanisms underlying BABA-induced stress tolerance. Studies have shown that BABA enhances the expression of genes involved in antioxidant defense, osmolyte accumulation, and carbohydrate metabolism, thereby improving cellular homeostasis under drought conditions (Cohen *et al*., 2023; Zapletalová *et al*., 2023). Furthermore, BABA has been linked to improved source-sink dynamics through regulation of sugar transporters and starch biosynthesis pathways, which are critical for grain filling and yield formation (Qin-Di *et al*., 2021; Balmer *et al*., 2015). Emerging evidence also suggests that BABA can induce epigenetic modifications, enabling plants to "remember" prior stress exposure and respond more efficiently to subsequent stress events (Luna *et al*., 2012; Mauch-Mani *et al*., 2017; Pastor *et al*., 2023).

Despite these advances, there remains limited field-based evidence on the effectiveness of BABA in improving yield performance of locally adapted rice varieties under varying drought conditions, particularly in West Africa. Moreover, the interaction between water stress timing and BABA application in determining yield components, grain filling efficiency, and grain quality is not yet fully understood. This knowledge gap is especially important for traditional varieties like Ofada rice, which may exhibit distinct physiological responses compared to improved cultivars.

Therefore, this study aimed to evaluate the effects of BABA application on yield components, grain yield, and grain quality of water-stressed Ofada rice across different growth stages. Specifically, the study investigates how BABA-mediated priming at the vegetative, flowering and grain filling stage influences reproductive development, assimilate partitioning, and overall yield performance under drought conditions. By integrating physiological observations with emerging molecular insights, this work contributes to the growing body of knowledge on priming-based strategies for enhancing crop resilience and provides a basis for developing sustainable drought management practices in rice production systems.

MATERIALS AND METHODS

Study Site and Experimental Design

Field experiments were conducted under irrigation conditions. The experimental site was selected for its relative uniformity in soil characteristics and topography to minimize spatial variability. The study was arranged in a factorial experiment using a randomized complete block design (RCBD) with three replications, which is widely recommended for drought-related field studies in rice (Gomez & Gomez, 1984; Fahad *et al*., 2017). Treatments consisted of three stages of drought imposition (vegetative, flowering, and grain filling) and multiple concentrations of β-aminobutyric acid (BABA), including an untreated control.

Plant Material and Crop Establishment

A locally adapted Ofada rice (*Oryza sativa* L.) variety was used. Seeds were sown directly on well-prepared plots at a spacing of 20 cm × 5 cm, following standard upland rice agronomic practices (IRRI, 2013). Land preparation involved ploughing and harrowing, and recommended fertilizer rates were uniformly applied across all treatments to avoid nutrient limitations (Fageria, 2014).

BABA Application and Drought Imposition

BABA was applied as a foliar spray at the vegetative, flowering and grain filling growth stages prior to drought imposition. Drought stress was induced by withholding water at defined phenological stages (vegetative, flowering, and grain filling), a commonly used method for simulating field drought conditions (Fahad *et al*., 2017; Kumar *et al*., 2023). Control plots were maintained under full blown water regime to 100% soil water holding capacity. Stress development was monitored using soil moisture status and visual indicators such as leaf rolling and reduced turgor (Blum, 2010).

Data Collection

Yield components measured included number of filled grains per plant, percentage grain filling, panicle weight, grain weight per plant, and 1000-grain weight. At maturity, economic yield and biological yield were recorded, and harvest index was calculated as the ratio of grain yield to total aboveground biomass (Fageria, 2014). Grain quality (proximate composition) was determined using standard analytical methods for moisture, ash, crude protein, crude fat, fibre, and carbohydrate content (AOAC, 2019).

Data Analysis

Data were subjected to analysis of variance (ANOVA) using SPSS version 23.0, treatment means were compared using Least Significant Difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Water deficit stress significantly reduced reproductive success through decreased component yield attributes, particularly when imposed at the flowering stage (Table 1), confirming the high sensitivity of this phase to water deficit (Fahad *et al*., 2017; Kumar *et al*., 2023). However, BABA treatment significantly improved key yield attributes, including percentage grain filling, panicle weight, and grain weight per plant (Table 1). Despite these improvements, the lack of consistent statistical differences among BABA concentrations further supports the concept of a priming plateau, where establishment of a primed physiological state is more critical than increasing inducer levels (Balmer *et al*., 2015; Pastor *et al*., 2023). The improvement in grain weight per plant as well as 1000 grain weight (Table 1) is attributable to enhanced sink strength and more efficient assimilate partitioning during reproductive development. BABA-mediated regulation of carbohydrate metabolism, including modulation of sugar transporters (SWEET genes) and starch biosynthesis enzymes as well as a facilitated increase in carbon flux towards developing grains (Qin-Di *et al*., 2021; Zapletalová *et al*., 2023). Additionally, enhanced antioxidant capacity under BABA treatment may have mitigated oxidative damage in reproductive tissues, thereby sustaining grain filling under water-limited conditions (Jakab *et al*., 2022; Cohen *et al*., 2023). Mechanistically, the yield benefits of BABA are linked to multiple coordinated processes which includes enhancement of abscisic acid (ABA)-dependent signalling which improves stomatal regulation and water-use efficiency under drought stress (Ton *et al*., 2022; Cohen *et al*., 2023), strengthening of reactive oxygen species (ROS) scavenging systems which protect reproductive tissues from oxidative stress (Jakab *et al*., 2022) and finally, improved assimilate partitioning which supports sustained grain filling. Also, emerging evidence suggests that BABA-induced epigenetic modifications may contribute to stress memory, enabling more rapid and robust responses to subsequent stress events (Pastor *et al*., 2023; Mauch-Mani *et al*., 2017). These findings demonstrate that BABA-induced priming effectively enhances grain development and stabilizes yield under drought conditions, with maximal benefits achieved at relatively low application rates (Table 1).

Economic yield was significantly reduced by water deficit stress, particularly when imposed at the flowering stage, whereas vegetative-stage stress resulted in comparatively higher yield performance (Table 2). Importantly, BABA application significantly increased economic yield across all stressed plant restoring productivity to levels approaching the non-stressed control, in contrast, biological yield showed limited responsiveness to BABA treatment (Table 2), this is an indication that BABA does not primarily enhance total biomass production but rather improves the efficiency of biomass partitioning. This is further supported by the consistent increase in harvest index observed in BABA-treated plants. The enhancement of harvest index suggests that BABA optimizes assimilate allocation toward reproductive sinks, thereby maximizing grain production relative to total plant biomass. This improved partitioning efficiency is likely mediated through hormonal crosstalk involving ABA, ethylene, and jasmonic acid, which collectively regulate growth defense trade-offs under stress conditions (Cohen *et al*., 2023; Zapletalová *et al*., 2023). By fine-tuning these signalling networks, BABA enables plants to maintain reproductive development while minimizing the metabolic costs associated with stress adaptation, thereby enhancing yield stability under drought.

Table1: Effect of BABA on component yield of water stressed Ofada rice at different growth stages

Stage of Water stress imposition	BABA treatments	Number of filled grains per plant	Percentage filled grains per plant (%)	Panicle weight (g)	Grains per plant (g)	1000 grain weight (g)
Vegetative	T_0	2845.00±388.24	85.02±2.79^a	40.88±0.97^a	36.22±0.68^a	14.18±1.23^a
	T_1	2022.67±97.87	74.98±0.85^c	27.86±1.88^c	23.26±1.66^c	10.63±0.60^b
	T_2	1984.67±188.10	74.44±0.60^c	38.77±0.89^a	34.23±0.76^a	16.10±1.83^a
	T_3	2184.67±54.85	79.85±1.44^b	39.73±0.79^a	35.06±0.85^a	15.35±0.34^a
	T_4	2238.67±129.02	74.82±0.59^c	35.09±1.63^b	30.43±1.58^b	13.38±0.55^{ab}
	Total	2255.13±114.08	77.82±1.24	36.47±1.36	31.84±1.34	13.92±0.65
	P-value	0.09	< 0.01	< 0.01	< 0.01	0.04
Flowering	T_0	2845.00±388.24^a	85.02±2.79^a	40.88±0.97^a	36.22±0.68^a	14.18±1.23^a
	T_1	539.33±97.05^c	17.08±3.00^c	22.22±2.51^b	17.49±2.31^b	5.58±0.87^b
	T_2	2274.00±231.16^{ab}	73.80±1.52^b	40.79±0.76^a	35.99±0.71^a	11.85±0.84^a
	T_3	2161.67±107.02^{ab}	83.38±2.29^a	39.64±1.10^a	34.84±1.03^a	13.47±0.55^a
	T_4	1805.67±29.42^b	77.65±1.57^{ab}	38.55±1.00^a	33.68±0.87^a	14.47±0.13^a
	Total	1925.13±220.72	67.39±6.86	36.41±1.98	31.64±1.97	11.91±0.93
	p-value	< 0.01	< 0.01	<0.01	< 0.01	< 0.01
Grain filling	T_0	2845.00±388.24^a	85.02±2.79^a	40.88±0.97^a	36.22±0.68^a	14.18±1.23^a
	T_1	720.00±109.98^b	25.76±3.01^c	19.71±1.11^b	15.11±1.26^b	5.53±0.73^c
	T_2	2354.00±163.76^a	75.02±1.24^b	39.61±0.95^a	35.07±1.05^a	11.35±1.26^b
	T_3	2648.67±363.34^a	76.91±1.11^b	39.97±0.84^a	35.30±0.62^a	10.58±1.21^b
	T_4	1959.33±350.54^a	73.05±1.42^b	39.89±0.91^a	35.23±0.69^a	11.39±0.43^b
	Total	2105.40±230.95	67.15±5.69	36.01±2.21^a	31.38±2.20	10.61±0.85
	p-value	0.04	< 0.01	< 0.01	< 0.01	< 0.01

Values are mean± SEM, n=3, values with same superscript across the treatments are not significant at $p<0.05$; T_0 =positive control, T_1=negative control, T_2\=150µM, T_3=300µM, T_4 =600µM; BABA: - beta-aminobutyric acid

Table 2: Effect of BABA on yield of water deficit stressed Ofada rice at different growth stages

Stage of Water stress imposition	BABA treatments	Economic yield (kg/ha)	Harvest index (%)
Vegetative	T_0	22.07±0.99^a	140.33±9.96
	T_1	23.37±0.88^a	124.67±4.48
	T_2	19.70±0.51^b	122.00±2.89
	T_3	22.03±0.58^a	123.33±8.09
	T_4	22.47±0.54^a	125.00±4.93
	Total	21.93±0.43	127.07±3.07
	p-value	0.05	0.33
Flowering	T_0	22.07±0.99	140.33±9.96
	T_1	20.70±0.58	133.00±4.36
	T_2	21.10±1.44	132.67±3.84
	T_3	22.13±0.41	131.33±5.90
	T_4	19.87±0.88	132.33±7.31
	Total	21.17±0.42	133.93±2.66
	p-value	0.43	0.87
Grain filling	T_0	22.07±0.99	140.33±9.96
	T_1	20.00±0.91	130.33±4.10
	T_2	22.90±0.93	135.33±4.10
	T_3	23.70±0.51	133.67±6.12
	T_4	21.70±1.40	134.33±4.67
	Total	22.07±0.50	134.80±2.50
	p-value	0.17	0.84

Values are mean± SEM, n=3, values with same superscript across the treatments are not significant at $p<0.05$; T_0 =positive control, T_1=negative control, T_2\=150µM, T_3=300µM, T_4 =600µM; BABA: - beta-aminobutyric acid

Water deficit stress significantly affected grain nutritional composition, with the magnitude and direction of changes dependent on the timing of stress exposure (Table 3). Vegetative-stage stress was associated with relatively higher carbohydrate and ash contents, whereas flowering-stage stress adversely affected overall grain quality. These findings reflect the sensitivity of grain filling processes and nutrient remobilization to water availability during the reproductive phase (Kumar *et al.*, 2023). BABA application significantly improved multiple grain quality parameters, including moisture content, ash content, crude fat, and carbohydrate levels, while reducing fibre content and stabilizing protein composition relative to untreated stressed plants (Table 3). These improvements highlight the role of BABA not only in yield preservation but also in enhancing grain nutritional value under stress conditions.

The underlying mechanisms are closely linked to BABA-mediated regulation of primary metabolism. Recent metabolomic analyses indicate that BABA enhances carbon and nitrogen metabolic pathways, promoting the synthesis and accumulation of storage compounds such as starch and lipids (Qin-Di *et al.*, 2021; Cohen *et al.*, 2023). Additionally, BABA-induced priming facilitates more efficient nutrient remobilization and translocation during grain filling, ensuring improved deposition of reserves in developing grains (Zapletalová *et al.*, 2023). This coordinated metabolic adjustment contributes to improved grain composition and quality under drought stress.

Table 3: Effect of BABA on proximate composition of water-stressed ofada rice at different growth stages

Stage of Water stress imposition	BABA treatments	Moisture content	Ash content	Fiber content	Crude protein content	Crude fat content	Carbohydrate content
		---- % ----					
Vegetative	T_0	12.15±0.02^{bc}	1.42±0.05^{c}	1.16±0.02^{b}	6.52±0.11^{b}	1.44±0.07^{bc}	78.94±0.18^{b}
	T_1	11.99±0.06^{c}	0.96±0.02^{d}	1.32±0.05^{b}	6.41±0.05^{b}	1.64±0.08^{a}	77.15±0.19^{c}
	T_2	12.34±0.01^{ab}	1.99±0.03^{a}	0.70±0.10^{c}	7.10±0.01^{a}	1.51±0.01^{ab}	79.49±0.07^{a}
	T_3	12.36±0.09^{a}	1.79±0.03^{b}	0.34±0.06^{d}	6.31±0.09^{c}	1.31±0.04^{c}	79.04±0.11^{b}
	T_4	12.15±0.07^{bc}	0.49±0.03^{e}	1.51±0.07^{a}	6.09±0.10^{c}	0.43±0.06^{d}	76.30±0.02^{d}
	Total	12.20±0.04	1.33±0.15	1.01±0.12	6.48±0.09	1.26±0.12	78.18±0.33
	P-value	0.007	<0.001	<0.001	<0.001	<0.001	<0.001
Flowering	T_0	12.15±0.02^{a}	1.42±0.05^{a}	1.40±0.07^{a}	6.52±0.11^{d}	1.44±0.07^{b}	77.14±0.02^{b}
	T_1	11.54±0.02^{b}	1.29±0.02^{b}	1.32±0.05^{a}	7.21±0.05^{c}	0.41±0.01^{d}	77.15±0.19^{c}
	T_2	12.32±0.19^{a}	1.26±0.02^{b}	0.73±0.06^{b}	5.81±0.06^{e}	1.54±0.01^{b}	77.10±0.05^{a}
	T_3	11.88±0.22^{ab}	0.98±0.02^{c}	0.40±0.07^{c}	7.56±0.14^{b}	1.72±0.06^{a}	79.08±0.02^{b}
	T_4	12.06±0.05^{a}	0.59±0.02^{d}	1.41±0.06^{a}	7.92±0.05^{a}	0.63±0.05^{c}	79.24±0.28^{d}
	Total	11.99±0.09	1.11±0.08	1.05±0.11	7.00±0.20	1.15±0.14	77.94±0.27
	p-value	0.015	<0.001	<0.001	<0.001	<0.001	<0.001
Grain filling	T_0	12.15±0.02^{a}	1.42±0.05^{b}	1.24±0.05^{b}	6.52±0.11^{b}	1.44±0.07^{a}	78.14±0.21^{a}
	T_1	11.67±0.00^{b}	0.40±0.01^{d}	1.32±0.05^{b}	6.36±0.03^{bc}	0.91±0.06^{c}	77.15±0.19^{cd}
	T_2	12.03±0.00^{a}	0.82±0.02^{c}	0.91±0.05^{c}	6.23±0.05^{cd}	0.53±0.06^{d}	77.61±0.03^{b}
	T_3	12.15±0.20^{a}	0.88±0.03^{c}	1.52±0.04^{a}	6.05±0.04^{d}	0.84±0.00^{c}	76.99±0.09^{d}
	T_4	11.38±0.02^{c}	2.12±0.05^{a}	1.01±0.01^{c}	8.07±0.02^{a}	1.13±0.01^{b}	77.49±0.03^{bc}
	Total	11.88±0.09	1.13±0.16	1.20±0.06	6.64±0.20	0.97±0.08	77.47±0.12
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.001

Values are mean± SEM, n=3, values with same superscript across the treatments are not significant at $p<0.05$; T_0 =positive control, T_1=negative control, T_2\=150µM, T_3=300µM, T_4 =600µM; BABA: - beta-aminobutyric acid.

CONCLUSION

BABA application effectively mitigated drought-induced reductions in yield and grain quality of Ofada rice by enhancing assimilate partitioning, reproductive efficiency, and stress tolerance mechanisms. Improvements in yield components, harvest index, and grain composition indicate that BABA primarily optimizes resource allocation rather than increasing total biomass. The lack of strong dose-dependent effects suggests that relatively low concentrations are sufficient to achieve maximal priming benefits. BABA application therefore represents a promising and sustainable approach for improving rice productivity and resilience under drought conditions.

REFERENCES

Association of Official Analytical Chemists (AOAC). (2019). *Official methods of analysis* (21st ed.). AOAC International.

Balmer, A., Pastor, V., Gamir, J., Flors, V., & Mauch-Mani, B. (2015). The 'prime-ome': towards a holistic approach to priming. *Trends in plant science*, *20*(7), 443-452.

Blum, A. (2010). *Plant breeding for water-limited environments*. Springer Science & Business Media. 1-249.

Cohen, Y., Vaknin, M., & Mauch-Mani, B. (2016). BABA-induced resistance: milestones along a 55-year journey. *Phytoparasitica*, *44*(4), 513-538.

Fageria, N. K. (2014). *Nitrogen management in crop production*. CRC Press.

Fahad, S., Bajwa, A. A., Nazir, U., Anjum, S. A., Farooq, A., Zohaib, A., ... & Huang, J. (2017). Crop production under drought and heat stress: plant responses and management options. *Frontiers in plant science*, *8*, 1147.

Fukagawa, N. K., & Ziska, L. H. (2019). Rice: Importance for global nutrition. *Journal of nutritional science and vitaminology*, *65*(Supplement), S2-S3.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons.

Jakab, G., Cottier, V., Toquin, V., Rigoli, G., Zimmerli, L., Métraux, J. P., & Mauch-Mani, B. (2001). β-aminobutyric acid-induced resistance in plants. *European Journal of Plant Pathology, 107*, 29–37.

Kumar, A., Dixit, S., Ram, T., Yadaw, R. B., Mishra, K. K., & Mandal, N. P. (2014). Breeding high-yielding drought-tolerant rice: genetic variations and conventional and molecular approaches. *Journal of experimental botany*, *65*(21), 6265-6278.

Luna, E., Bruce, T. J., Roberts, M. R., Flors, V., & Ton, J. (2012). Next-generation systemic acquired resistance. *Plant physiology*, *158*(2), 844-853.

Mauch-Mani, B., Baccelli, I., Luna, E., & Flors, V. (2017). Defense priming: An adaptive part of induced resistance. *Annual Review of Plant Biology, 68*, 485–512.

Panda, D., Mishra, S. S., & Behera, P. K. (2021). Drought tolerance in rice: Focus on recent mechanisms and approaches. *Rice Science, 28*(2), 119–132.

Pastor, V., Luna, E., Mauch-Mani, B., Ton, J., & Flors, V. (2013). Primed plants do not forget. *Environmental and experimental botany*, *94*, 46-56.

Qin-Di, D., Gui-Hua, J., Xiu-Neng, W., Zun-Guang, M., Qing-Yong, P., Shiyun, C., ... & Yu, L. (2021). High temperature-mediated disturbance of carbohydrate metabolism and gene expressional regulation in rice: a review. *Plant signaling & behavior*, *16*(3), 1862564.

Sanni, K. A., Fawole, I., Ogunbayo, S. A., Tia, D. D., Somado, E. A., Futakuchi, K., ... & Guei, R. G. (2012). Multivariate analysis of diversity of landrace rice germplasm. *Crop Science*, *52*(2), 494-504.

Ton, J., Jakab, G., Toquin, V., Flors, V., Iavicoli, A., Maeder, M. N., Métraux, J. P., & Mauch-Mani, B. (2005). Dissecting the β-aminobutyric acid-induced priming phenomenon. *The Plant Cell, 17*(3), 987–999.

Van Nguyen, N., & Ferrero, A. (2006). Meeting the challenges of global rice production. *Paddy and Water Environment, 4*(1), 1–9.

Zapletalová, M., Rancurel, C., Industri, B., Bardin, M., Le Brigand, K., Nicot, P., ... & Lochman, J. (2023). BABA-induced pathogen resistance: a multi-omics analysis of the tomato response reveals a hyper-receptive status involving ethylene. *Horticulture research*, *10*(6), uhad068.

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J. L., Elliott, J., Ewert, F., Janssens, I. A., Li, T., Lin, E., Liu, Q., Martre, P., Müller, C., & Asseng, S. (2017). Temperature increase reduces global yields of major crops. *Proceedings of the National Academy of Sciences, 114*(35), 9326–9331.