Review Article

A Review on: Elevated Nighttime Temperature Impacts on Rice

ABSTRACT

High nighttime temperatures adversely affect rice grain yield and quality by causing early panicle emergence, decreased pollen germination, increased spikelet sterility, and chalkiness. The severity of these effects depends on genotype, growth stage, stress period, and temperature. High nighttime temperatures leads to structural abnormalities in starch granules, modify the amounts of amylo~~o~~se and amylopectin, and disturb the expression pattern of genes involved in starch biosynthesis and accumulation, ultimately affecting the cooking properties of rice grains. To ensure sustainable rice production in the context of global warming, rice breeding efforts must consider yield attributes focusing on the interactions between heat stress, genetic variables, and grain quality. This article provides an overview of current research on the significant impacts of high nighttime temperatures on rice grain production, starch granularity, physiochemical characteristics, and cooking properties.

Keywords: *Chalkiness, ~~S~~starch g~~G~~ranules, h~~H~~igh n~~N~~ighttime t~~T~~emperature, ~~R~~ice g~~G~~rain*

INTRODUCTION

Rice is a staple food for most people almost half of the world's population (Banjade et al., 2023 and Umilsingh et al., 2023), and with improving living standards and food culture, more attention is on quality rice, which is more concerned with appearance (grain shape, chalkiness, and translucency) and taste: a significant goal of rice research today (Fan et al., 2022). The decline in rice production in recent years is due to climate alternation, and understanding its mechanism helps to adapt climate change impacts on rice farming (Stuecker et al., 2018). The effect of heat stress on the vegetative stage of the rice plants is non-significant; however, the reproductive stage is susceptible to higher temperatures, and it has a higher impact on rice grain yield than plant biomass (Rehmani et al., 2014). Compared to low night temperature, high nighttime temperature (HNT) shortens the crop duration period and results in taller plants, but it does not impact leaf area and above-ground biomass (Laza et al., 2015). HNT also causes a slight increase in leaf-dark respiration, significantly negatively correlating with spikelet number per panicle and showing negative trends with biomass and harvest index (Xu et al., 2021). Increasing night temperature (33 °C) combined with higher day temperature~~s~~ reduces average grain weight and can cause a 100 percent ~~%~~ infertile spikelets(Ziskaab, 1996). Several research projects have recorded that HNT reduces rice grain yield, distorts grain dimensions, and deteriorates grain quality and appearance are ~~(~~explained below ~~in~~ Table 1~~)~~.

Table 1. The major research and its findings on impacts of elevated nighttime temperatures in rice plants.

Experiment	**Temperature Treatment**	**Stage of Imposed High Nighttime Temperature**	**Measurement**	**Findings**
"Rice yields decline with higher night temperature from global warming" by Peng et al.~~,~~ (2004).	The average annual temperature climbed by 1.13°C and 0.35°C, respectively, for both the maximum and minimum.	Seedling stage to the Harvesting stage.	Panicle number per tiller, plant biomass, harvest index, yield attributes, straw dry weight, filled/unfilled spikelet, dry weight of rachis.	The impact of maximum temperature is insignificant, whereas each degree increases the minimum temperature in the dry season decreases

Formatted: Font: 14 pt, No underline

Formatted: Font: 14 pt, No underline

Formatted: Indent: First line: 0.5"

Comment [UN1]: Wether nighttime or night time, please verify

Comment [UN2]: Arrange in alphabetical orders

Formatted: Font: Bold

Formatted: Indent: First line: 0.5"

Formatted: Font: Bold

Formatted Table

				grain yield by 10%.
"Rice milling quality, grain dimensions, and starch branching as affected by high night temperature" by Counce et al.~~,~~(2005).	The ambient temperature treatment is 18°C while the HNT (midnight to 5 am)is 24°C.	Panicle heading out at the booting stage to the harvesting stage.	Head rice yield, amylose/amylopectin content, Grain width, length, weight, dimension, and thickness.	Reduced head rice, grain width, and increased amylopectin chain length under HNT.
"Grain g~~G~~rowth and e~~E~~ndosperm c~~C~~ell s~~S~~ize u~~U~~nder h~~H~~igh n~~N~~ight t~~T~~emperatures in Rice (*Oryza sativa* L.)" by Morita et al.~~,~~(2005).	Controlled glasshouse experiment with 34°C HNT treatment and 22°C for ambient night temperature.	Heading stage to the harvesting stage.	Grain dry weight, Grain dimension, Endosperms cell number, and cell size.	Disturbed grain growth rate, cell size, and final grain weight.
"Effects of n~~N~~ighttime t~~T~~emperature during k~~K~~ernel d~~D~~evelopment on Rice p~~P~~hysicochemical p~~P~~roperties" by Cooper et al.~~,~~(2008).	The imposed HNT is 30°C.	Throughout the kernel development stage.	Head rice yield, Kernel mass, Grain dimensions, Chalky kernels, Amylose content, Protein and Lipid content.	Head rice grain yield, grain dimensions, and amylose content decreased, chalky grain increased, but kernel mass, total lipid, and protein content remained unaffected.
"Impact of h~~H~~igh n~~N~~ighttime t~~T~~emperature on r~~R~~espiration, m~~M~~embrane s~~S~~tability, a~~A~~ntioxidant c~~C~~apacity and y~~Y~~ield of Rice p~~P~~lants" by Mohammed et al.~~,~~(2009).	The ambient nighttime temperature is 27°C while the HNT is 32°C.	Twenty days after emergence to the harvesting stage.	Membrane thermal stability, total antioxidant capacity, and respirations.	Elevated nighttime temperature decreased the membrane thermal stability and yield by 90%, increasing the leaf respiration rate and electrolyte leakage but not impacting antioxidant capacity.
"Grain yield and quality responses of tropical hybrid rice to high nighttime temperature" by Shi et al.~~,~~(2016).	Crops were treated with 29°C (HNT) and 23°C (control).	Panicle initiation stage to maturity: whole reproductive stage.	Spikelets per meter square, Seed set percentage, Head rice yield, Chalkiness, Grain width.	HNT significantly reduced grain yield of Gharib with a 13.4% reduction in the dry season

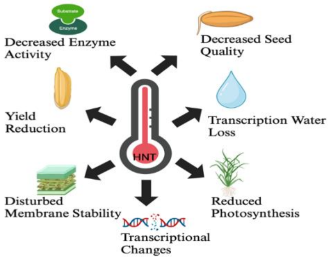
Formatted: Font: Italic

Formatted Table

				than in the wet season (18.6%).
“Differential reaction of rice plants to high night temperatures applied at different stages of growth” by Laza et al.~~,~~(2015).	Plants were exposed to 21 °C (control) and 25 °C (high) night temperatures.	For the vegetative stage, transplanting to the panicle initiation stage, and for the reproductive stage, panicle initiation to the heading stage.	Photosynthesis, night respiration rates, number of spikelets per panicle.	HNT does not significantly impact the vegetative phase, and during the reproductive phase, HNT is more harmful at early phase than other times.

The reduction in rice grain yield under HNT is not due to reduced photosynthesis but rather early panicle emergence by two days, reduced crop growth duration, and decreased pollen germination by 20%. These effects may be due to weak anther dehiscence, pollen receptivity, reduced pollen swelling, and decreased anther pore size, leading to decreased spikelet fertility by 72% (Mohammed and ~~&~~ Tarpley, 2009). Rice plants grown under nighttime heat stress experience significant impacts on rice grain yield and harvest index for both wet and dry seasons, possibly due to increased temperature sensitivity, dark respiration, and reduced carbohydrate supply to the panicle (Schaarschmidt et al., 2020). High day and night temperatures reduce the total weight of the panicle due to the decreased number of filled spikelets in each panicle and decreased dimensions of the rice kernel (Lin et al., 2010). The significant differences between daily day and night temperatures can cause adverse impacts such as chalkiness, poor rice grain quality, and decreased final grain weight (Yoshida et al., 1977). HNT decreases grain growth duration, and the reduced grain weight is not due to decreased photosynthesis but due to decreased grain growth duration (Morita et al., 2005). Higher imperfect rice rates for rice grown under HNT may be due to decreased duration of dry matter accumulation in elevated night temperatures (Song et al., 2013). Not only grain yield but HNT is also associated with several other harmful impacts on the rice plants, as mentioned in Figure 1.

Formatted: Indent: First line: 0.5"



Formatted: Centered

Figure 1. Effects of HNT on Ricep~~P~~lants

IMPACT OF HNT ON RICE GRAIN YIELD

HNT is a significant factor affecting rice production, causing early panicle emergence, reduced pollen germination, enhanced spikelet sterility, leaf respiration rate, and decreased grain length and width, resulting in up to a 90% loss in rice grain yield (Mohammed and ~~&~~ Tarpley, 2011). It is responsible for reduced head rice yield, smaller grain width, and overall rice grain dimension (Counce et al., 2005). The grain weight of rice grown under HNT is 9~~%~~-10% less than that under ambient conditions (Morita et al., 2005). Rice grown under elevated night temperatures does not experience changes in panicle number, tiller number, stem length, and plant height; however, there is a 90% reduction in grain yield under HNT (Mohammed and~~&~~ Tarpley, 2009). HNT does not impact the total number of productive tillers per plant, but spikelet sterility increases by 61% under these conditions (Mohammed and~~&~~ Tarpley, 2010). HNT reduces the number of filled grains per panicle (25.70%), seed setting rate (22.09%), thousand ~~hundred~~-grain weight (5.17%), and grain yield (31.24%). However, there are no differences in the number of effective panicles per meter square between elevated and normal air temperature conditions (Liu et al., 2013). Additionally, HNT increases the total number of spikelet sterility due to the decreased rate of pollen germination and enhances the rate of carbon loss due to increased respiration, but it does not affect the total leaf photosynthetic rate of rice plants (Mohammed and~~&~~ Tarpley, 2010). HNT significantly impacts grain yield, seed setting percentage, and 1000-grain weight in rice. For instance, total dry weight, 1000 grain weight, and grain yield decreased by 13.5%, 7.9%, and 21.8%, respectively, in the sensitive rice cultivar Gharib. However, the tolerant cultivar N-22 is not affected; the seed setting rate increased by 7.6% in the N-22 cultivar under HNT stress (Shi et al., 2013). HNT has different growth stage-specific impacts on rice plants, ultimately reducing rice grain yield, as mentioned in Figure 2.

Formatted: Indent: First line: 0.5"

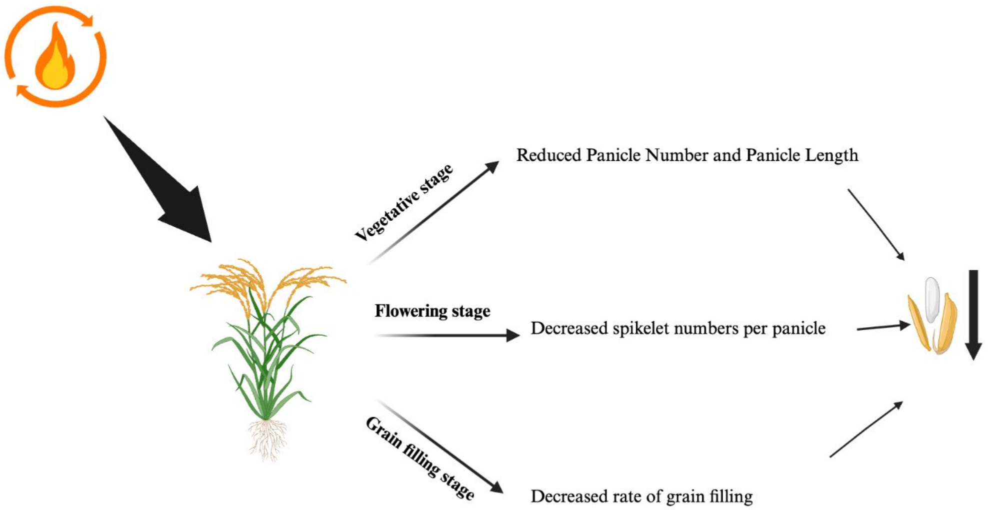


Figure 2. Significant effects of HNT on the different growth stage of Rice Plants

Formatted: Centered

Formatted: Indent: First line: 0.5"

HNT at the post-anthesis stage of rice decreases the 1000-grain weight, seed setting rate, and above-ground biomass accumulation, ultimately reducing grain yield (Dong et al., 2014). Although the number of panicles and tillers increased, the number of fertile spikelets decreased, and rice grain yield under HNT, even under CO_2 fertilization, was reduced significantly by 8.5%; however, there was no impact on 1000-grain weight (Roy et al., 2015). Temperature shifts from 24°C (ambient) to 35°C decrease

Formatted: Subscript

rice grain yield by one-third, but grain weight per panicle varies according to the cultivar (Coast et al., 2015). Among different stages, the spikelet differentiation stage shows the lowest number of spikelets, with 35.9% degenerated spikelets under heat stress (Laza et al., 2015). The impact of heat stress at nighttime on spikelet fertility and rice grain yield is cultivar-dependent and varies with the period of heat stress, plant growth stage, and temperature intensity (Wu et al., 2016). There is a significant reduction in grain yield, biomass accumulation, and harvest index for rice plants under HNT due to adverse impacts on spikelet fertility, panicle number, and spikelet number per panicle. However, there is no significant interaction between genotype and HNT for panicle number, spikelet number per panicle, and 100-grain weight (Xu et al., 2021). How increased heat stress at nighttime alters the photosynthesis and respiration rate? and its impact on the photo-assimilate pool for the sink tissue of rice plants is mentioned below in Figure 3.

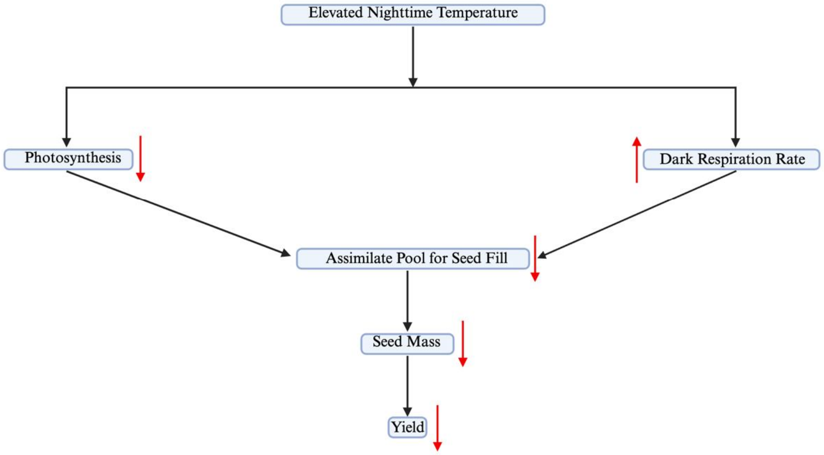


Figure 3. Impact of HNT on Rice Grain Yield

Formatted: Centered

HNT INDUCED RICE CHALKINESS

Formatted: Indent: First line: 0.5"

Post-anthesis elevated night temperature decreases rice milling quality by reducing the amount of milled rice grain and head rice grain due to increased chalkiness (Dong et al., 2014). Rice grain grown under HNT consists of at least 80% grain chalkiness, while grains from control conditions have a perfect appearance (Ishimaru et al., 2009). The chalky part of the rice grain is composed of many air spaces and spherical-shaped starch granules with round corners, while the translucent part of rice grain has fewer air spaces and tightly packed starch granules with smooth surfaces (Chun et al., 2009). Highly susceptible rice cultivars grown under HNT show a large opaque area in the endosperm, and more than 82% of grains show higher than 20% chalkiness of grain size, but tolerant rice cultivars only show 2-4% chalkiness of whole grain size by greater than 84% grains (Gann et al., 2021). The amylose content of the chalky grains is higher than the translucent grains (Lisle et al., 2000). HNT decreases the head rice yields in long-grain hybrid cultivars, probably due to higher chalkiness in grain that makes grain prone to breakage during milling (Cooper et al., 2008). At the very starting phase of grain filling, there is no significant relationship between grain chalkiness and head rice yield to the HNT; however, when at least one of the caryopses turns yellow and brown color in the panicle, there is a direct correlation of chalk with head rice yield while inverse correlation of head rice yield to the nighttime temperature, which concludes that the impact of increased nighttime air temperature on chalkiness is growth stage-specific (Ambardekar et al., 2011). Up to 50% chalk content, the HNT does not have a noticeable impact; however, for the greater than 75% chalk category, the chalk content increased by 36.4% in the susceptible cultivar Gharib (Shi et al., 2013).

IMPACT OF HNT ON STARCH GRANULAR AND PHYSIOCHEMICAL PROPERTIES

Formatted: Indent: First line: 0.5"

HNT does not significantly impact the starch granule's morphology, but the starch deposition rate is reduced due to HNT (Patindol et al., 2014). The starch endosperm cell numbers are higher in grain grown in HNT than in control, but the average cell area is smaller in HNT over control conditions (Morita et al., 2005). The organization of amyloplasts is without gaps for grains grown under control conditions; however, amyloplasts are loosely packed in grains grown under HNT, creating free spaces (Ishimaru et al., 2009). As compared to the control condition, in HNT, the packaging of starch granules into amyloplast occurs quite in advance; the amyloplasts are compounded and tightly packed with well-developed polygonal shapes in developing caryopsis for tolerant cultivars. However, for susceptible cultivars, there are round, heterogeneous-sized, poorly developed starch granules under HNT, producing white belly chalky grains (31.8% to 67.0%) (Shi et al., 2017). In translucent rice grains, amyloplasts are regular, compound type, larger (12 µm), and tightly packed with starch granules, but in the chalky part of rice grains consist of smaller size, non-systematically organized, and less tightly packed amyloplasts (Lisle et al., 2000). The starch granule structure is compact polygonal type with well-defined edges at the early stage of grain filling for HNT due to the accelerated grain filling rate (Song et al., 2013). However, amylose content decreases under elevated nighttime temperatures (Patindol et al., 2014). The reduced enzymatic activity of GBSS is the reason for lower amylose content with increasing night temperature (Cooper et al., 2008). Compared to translucent rice grain, the chalky rice grain has lower amylose content and higher short-chain amylopectin but less long-chain amylopectin (Chun et al., 2009).

ALTERED COOKING PROPERTIES DUE TO HNT

Formatted: Indent: First line: 0.5"

With increasing night temperature through different grain filling stages in rice, the amylose content, crude protein content, and setback viscosity decreased. In contrast, the total lipid content, peak viscosity, and gelatinization temperature increase, which significantly impacts the cooking quality of rice grain (Lanning et al., 2012). Changed proportions of amylose and amylopectin in rice grain grown under elevated nighttime temperatures are responsible for increased breakdown, peak, final, and total setback viscosity, impacting starch pasting properties (Patindol et al., 2014). Long-chain amylopectin content interacts positively with gelatinization temperature and relative crystallinity of rice endosperm, due to which grain grown under HNT needs more time to cook well (Song et al., 2015). Higher gelatinization temperature for grain grown under HNT impacts cooking quality and the food industry (Song et al., 2013). The pasting temperature and viscosities are higher for grains grown under higher temperatures, where grains at the superior position of the panicle have higher peak viscosity while grains at the inferior position show higherchalkiness and are a little softer (Lisle et al., 2000). Chalky rice grain consists of more air spaces and a disorganized cellular structure that allows more water diffusion during cooking and causes more water absorption and more significant grain expansion than translucent rice (Chun et al., 2009). Higher iodine index, less adhesiveness texture of cooked rice, more chewing time for cooked rice, and higher peak and final viscosity of chalky rice grains deteriorate the eating quality of rice grain (Chun et al., 2009).

HNT IMPACT ON GENE EXPRESSION

Small pit-like structures in rice grain grown under HNT are due to the loosely packed round-shaped starch granules instead of tightly packed polyhedral starch granules, which is associated with the downregulation of genes involved in starch biosynthesis at the early reproductive stage (Dhatt et al., 2019). At the early stage of grain development, there is a two to three-fold increase in transcript levels of alpha-amylase for grain grown under high temperature; however, mRNAs for alpha-amylase are not detectable in the central chalky part of the endosperm, suggesting that rather than starch degradation by alpha-amylase, the inefficient starch synthesis is the reason for grain chalkiness in elevated temperature conditions (Ishimaru et al., 2009). Among different genes involved in starch biosynthesis, the starch branching enzyme-IIb (BEIIb) is highly sensitive to the elevated nighttime temperature, and suppression of BEIIb during the grain filling stage under HNT decreases branching (Patindol et al., 2014). The expression of GBSSI and SSIIA is enhanced only six days after anthesis, and lower expression starts twenty days after anthesis under HNT. In contrast, under control conditions, the expression of SSIIA and GBSSI increases gradually between six to twenty days after anthesis (Lin et al., 2010). In susceptible lines, AGPase genes are expressed at a higher rate in the early reproductive stage; however, gradually low expression in subsequent stages occurs, at which upregulation of GBSSI and SSIIA shows consistent expression. However, in tolerant cultivars, AGPase produces sufficient ADP glucose, which GBSS and SS quickly utilize to produce amylose and amylopectin (Gann et al., 2021). The expression of cell wall invertase, vacuolar invertase, and starch synthase genes were significantly reduced in developing rice grain under HNT fifteen days after flowering (Shi et al., 2017).

Formatted: Indent: First line: 0.5"

CONCLUSION

In conclusion, HNT's effects on rice growth, development, and grain quality underscore its profound impact on multiple physiological and biochemical processes. HNT induces detrimental alterations such as early panicle emergence, reduced pollen germination, increased spikelet sterility, and chalkiness in rice grains. These changes contribute to a substantial decline in grain yield, depending on factors like genotype and growth stage. The intricate interplay between HNT and rice physiology involves disruptions in starch granule structure, changes in amylose and amylopectin content, and variations in gene expression related to starch biosynthesis. Furthermore, the negative consequences extend to cooking properties, affecting pasting characteristics and overall eating quality. As climate patterns continue to shift, understanding these various impacts becomes increasingly critical for developing strategies to mitigate the adverse effects of HNT on rice production. Effective adaptation must consider the intricate relationships between heat stress, genetic factors, and grain quality to ensure sustainable rice cultivation in changing environmental conditions.

Formatted: Indent: First line: 0.5"

REFERENCES

Ambardekar, A. A., Siebenmorgen, T. J., Counce, P. A., Lanning, S. B., &Mauromoustakos, A. (2011). Impact of field-scale nighttime air temperatures during kernel development on rice milling quality. Field Crops Research, 122(3), 179–185. https://doi.org/10.1016/j.fcr.2011.03.012

Banjade, D., Khanal, D., Shrestha, A., & Shrestha, K. (2023). Effects of Seedling and Plant Spacing on the System of Rice Intensification (SRI) for Spring Rice (Oryza sativa L. Chaite 2). *AgroEnvironmental Sustainability*, *1*(3), 229–235. https://doi.org/10.59983/s2023010304

Chun, A., Song, J., Kim, K.-J., & Lee, H.-J. (2009). Quality of head and chalky rice and deterioration of eating quality by chalky rice. Journal of Crop Science and Biotechnology, 12(4), 239–244. https://doi.org/10.1007/s12892-009-0142-4

Coast, O., Ellis, R. H., Murdoch, A. J., Quiñones, C., & Jagadish, K. S. V. (2015). High night temperature induces contrasting responses for spikelet fertility, spikelet tissue temperature, flowering characteristics and grain quality in rice. Functional Plant Biology, 42(2), 149–161. https://doi.org/10.1071/FP14104

Cooper, N. T. W., Siebenmorgen, T. J., & Counce, P. A. (2008). Effects of nighttime temperature during kernel development on rice physicochemical properties. Cereal Chemistry, 85(3), 276–282. https://doi.org/10.1094/CCHEM-85-3-0276

Counce, P. A., Bryant, R. J., Bergman, C. J., Bautista, R. C., Wang, Y. J., Siebenmorgen, T. J., Moldenhauer, K. A. K., & Meullenet, J. F. C. (2005). Rice milling quality, grain dimensions, and starch branching as affected by high night temperatures. Cereal Chemistry, 82(6), 645–648. https://doi.org/10.1094/CC-82-0645

Dhatt, B. K., Abshire, N., Paul, P., Hasanthika, K., Sandhu, J., Zhang, Q., Obata, T., & Walia, H. (2019). Metabolic Dynamics of Developing Rice Seeds Under High Night-Time Temperature Stress. Frontiers in Plant Science, 10. https://doi.org/10.3389/fpls.2019.01443

Dong, W., Chen, J., Wang, L., Tian, Y., Zhang, B., Lai, Y., Meng, Y., Qian, C., & Guo, J. (2014). Impacts of nighttime post-anthesis warming on rice productivity and grain quality in East China. Crop Journal, 2(1), 63–69. https://doi.org/10.1016/j.cj.2013.11.002

Fan, P., Xu, J., Wei, H., Liu, G., Zhang, Z., Tian, J., & Zhang, H. (2022). Recent Research Advances in the Development of Chalkiness and Transparency in Rice. In Agriculture (Switzerland) (Vol. 12, Issue 8). MDPI. https://doi.org/10.3390/agriculture12081123

Gann, P. J., Esguerra, M., Counce, P. A., & Srivastava, V. (2021). Genotype-dependent and heat-induced grain chalkiness in rice correlates with the expression patterns of starch biosynthesis genes. Plant-Environment Interactions, 2(4), 165–176. https://doi.org/10.1002/pei3.10054

Ishimaru, T., Horigane, A. K., Ida, M., Iwasawa, N., San-oh, Y. A., Nakazono, M., Nishizawa, N. K., Masumura, T., Kondo, M., & Yoshida, M. (2009). Formation of grain chalkiness and changes in water distribution in developing rice caryopses grown under high-temperature stress. Journal of Cereal Science, 50(2), 166–174. https://doi.org/10.1016/j.jcs.2009.04.011

Lanning, S. B., Siebenmorgen, T. J., Ambardekar, A. A., Counce, P. A., & Bryant, R. J. (2012). Effects of nighttime air temperature during kernel development of field-grown rice on physicochemical and functional properties. Cereal Chemistry, 89(3), 168–175. https://doi.org/10.1094/CCHEM-12-11-0146

Laza, M. R. C., Sakai, H., Cheng, W., Tokida, T., Peng, S., & Hasegawa, T. (2015). Differential response of rice plants to high night temperatures imposed at varying developmental phases. Agricultural and Forest Meteorology, 209–210, 69–77. https://doi.org/10.1016/j.agrformet.2015.04.029

Lin, C. J., Li, C. Y., Lin, S. K., Yang, F. H., Huang, J. J., Liu, Y. H., & Lur, H. S. (2010). Influence of high temperature during grain filling on the accumulation of storage proteins and grain quality in rice (Oryza sativa L.). Journal of Agricultural and Food Chemistry, 58(19), 10545–10552. https://doi.org/10.1021/jf101575j

Lisle, A. J., Martin, M., & Fitzgerald, M. A. (2000). Chalky and Translucent Rice Grains Differ in Starch Composition and Structure and Cooking Properties (Vol. 77, Issue 5).

Liu, Q. H., Wu, X., Li, T., Ma, J. Q., & Zhou, X. B. (2013). Effects of elevated air temperature on physiological characteristics of flag leaves and grain yield in rice. Chilean Journal of Agricultural Research, 73(2), 85–90. https://doi.org/10.4067/S0718-58392013000200001

Mohammed, A. R., & Tarpley, L. (2009). Instrumentation enabling study of plant physiological response to elevated night temperature. Plant Methods, 5(1). https://doi.org/10.1186/1746-4811-5-7

Mohammed, A. R., & Tarpley, L. (2010). Effects of high night temperature and spikelet position on yield-related parameters of rice (Oryza sativa L.) plants. European Journal of Agronomy, 33(2), 117–123. https://doi.org/10.1016/j.eja.2009.11.006

Mohammed, A. R., & Tarpley, L. (2011). High night temperature and plant growth regulator effects on spikelet sterility, grain characteristics and yield of rice (Oryza sativa L.) plants. Canadian Journal of Plant Science, 91(2), 283–291. https://doi.org/10.4141/CJPS10038

Morita, S., Yonemaru, J. I., & Takanashi, J. I. (2005). Grain growth and endosperm cell size under high night temperatures in rice (Oryza sativa L.). Annals of Botany, 95(4), 695–701. https://doi.org/10.1093/aob/mci071

Patindol, J. A., Siebenmorgen, T. J., Wang, Y. J., Lanning, S. B., & Counce, P. A. (2014). Impact of elevated nighttime air temperatures during kernel development on starch properties of field-grown rice. Cereal Chemistry, 91(4), 350–357. https://doi.org/10.1094/CCHEM-10-13-0211-R

Rehmani, M. I. A., Wei, G., Hussain, N., Ding, C., Li, G., Liu, Z., Wang, S., & Ding, Y. (2014). Yield and quality responses of two indica rice hybrids to post-anthesis asymmetric day and night open-field warming in lower reaches of Yangtze River delta. Field Crops Research, 156, 231–241. https://doi.org/10.1016/j.fcr.2013.09.019

Roy, K. S., Bhattacharyya, P., Nayak, A. K., Sharma, S. G., & Uprety, D. C. (2015). Growth and nitrogen allocation of dry season tropical rice as a result of carbon dioxide fertilization and elevated night time temperature. Nutrient Cycling in Agroecosystems, 103(3), 293–309. https://doi.org/10.1007/s10705-015-9741-2

Schaarschmidt, S., Lawas, L. M. F., Glaubitz, U., Li, X., Erban, A., Kopka, J., Krishna Jagadish, S. V., Hincha, D. K., & Zuther, E. (2020). Season affects yield and metabolic profiles of rice (Oryza sativa) under high night temperature stress in the field. International Journal of Molecular Sciences, 21(9). https://doi.org/10.3390/ijms21093187

Shi, W., Raveendran, M., Rahman, H., Selvam, J., Peng, S., Zou, Y., & Jagadish, K. S. V. (2013). Source-sink dynamics and proteomic reprogramming under elevated night temperature and their impact on rice yield and grain quality. New Phytologist, 197(3), 825–837. https://doi.org/10.1111/nph.12088

Shi, W., Yin, X., Struik, P. C., Solis, C., Xie, F., Schmidt, R. C., Huang, M., Zou, Y., Ye, C., & Jagadish, S. V. K. (2017). High day- and night-time temperatures affect grain growth dynamics in contrasting rice genotypes. Journal of Experimental Botany, 68(18), 5233–5245. https://doi.org/10.1093/jxb/erx344

Song, X., Du, Y., Song, X., & Zhao, Q. (2013). Effect of high night temperature during grain filling on amyloplast development and grain quality in japonica rice. Cereal Chemistry, 90(2), 114–119. https://doi.org/10.1094/CCHEM-01-12-0010-R

Song, X., Du, Y., Zhao, Q., & Cui, Y. (2015). Effects of high night temperature during grain filling on formation of physicochemical properties for japonica rice. Journal of Cereal Science, 66, 74–80. https://doi.org/10.1016/j.jcs.2015.10.006

Stuecker, M. F., Tigchelaar, M., & Kantar, M. B. (2018). Climate variability impacts on rice production in the Philippines. PLoS ONE, 13(8). https://doi.org/10.1371/JOURNAL.PONE.0201426

Umilsingh, N., Vaiyapuri, K., Thavaprakaash, N., Selvakumar, S. and Vanitha, K., 2023. Impact of irrigation and fertigation levels on growth, yield components and yield of aerobic rice (Oryza sativa L.) under drip system. *Indian Journal of Agricultural Research*, *57*(6), pp.774-779.

Wu, C., Cui, K., Wang, W., Li, Q., Fahad, S., Hu, Q., Huang, J., Nie, L., & Peng, S. (2016). Heat-induced phytohormone changes are associated with disrupted early reproductive development and reduced yield in rice. Scientific Reports, 6. https://doi.org/10.1038/srep34978

Xu, J., Misra, G., Sreenivasulu, N., & Henry, A. (2021). What happens at night? Physiological mechanisms related to maintaining grain yield under high night temperature in rice. Plant Cell and Environment, 44(7), 2245–2261. https://doi.org/10.1111/pce.14046

Yoshida, S., Hara, T., & Hara, T. (1977). Effects of air temperature and light on grain filling of an indica and a japonica rice (oryza sativa l) under controlled environmental conditions. Soil Science and Plant Nutrition, 23(1), 93–107. https://doi.org/10.1080/00380768.1977.10433026

Ziskaab, L. H. (1996). Increasing Night Temperature Can Reduce Seed Set and Potential Yield of Tropical Rice. In Aust. J. Plant Physiol (Vol. 23).

Formatted: Dutch (Netherlands)