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研究課題名（和文）Studies on regulations of DNA methylation on transgenerational memory induced by heat stress during grain filling in rice

研究課題名（英文）Studies on regulations of DNA methylation on transgenerational memory induced by heat stress during grain filling in rice

研究代表者
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交付決定額（研究期間全体）：（直接経費）　　2,400,000円

研究成果の概要（和文）：本研究では、登熟期間における高温処理時期の違いが収量および玄米の外観品質に影響を及ぼすかについて調査した。結果として、登熟後半の高温と比べて、登熟初期の高温は玄米品質に最も影響を与えることがわかった。次の課題としては異なる登熟期の高温によるエピジェネティック制御や次世代への影響を調べる予定。

研究成果の学術的意義や社会的意義
We have shown that heat stress during early phase of grain filling had more negative effects on grain yield and quality compared to that of the later phase. Elucidation of this mechanism could help to increase rice yield and quality under heat stress condition.

研究成果の概要（英文）：We have elucidated the effects of heat stress exposed at different grain developmental stages in rice on yield and quality. It was shown that heat stress during the early phase of grain filling plays important role to reduce grain yield and quality compared to the later phase, which showed almost no reduction. In all, we proposed that exposure to heat stress at different stages during grain filling resulted in different traits at harvest, which is expected to be regulated differently via epigenetic regulation. In our next study, we aim to elucidate the roles of epigenetic regulations of each grain filling stage under heat and the effects on the next generation.

研究分野：Crop science

キーワード：Rice　Heat stress　Yield　Quality　Gene expression　Grain filling

１．研究開始当初の背景

Global warming is an unavoidable environmental factor, which causes decrease in global agricultural production due to rising temperature and other climate changes. Rice (*Oryza sativa* L.), one of the most important crops, is highly affected by heat stress during grain filling stage, which results in yield and quality reduction. Our previous studies proposed that heat stress during grain filling increases chalkiness occurrence (Suriyasak et al. 2017) and delays seed germination through alterations of DNA methylation in dry seeds (Suriyasak et al. 2020). Involvement of DNA methylation changes induced by heat stress during grain filling leads to a novel interest of how plants grown from heat stressed seeds would show any phenotypic differences and how epigenetic regulations are involved in this phenomenon.

Pre-experiment showed that plants from heat stressed seeds developed higher tiller numbers during vegetative growth, smaller but thicker flag leaves, early heading phenotype and higher yield at harvest, when compared to non-stressed plants. This “Transgenerational memory” is expected to be epigenetically induced during grain filling of the mother plants, causing changes in phenotype of the progeny. Thus, it is crucial to elucidate “how and when” these epigenetic marks occur, and how heat stress exposure during different stages of affect the phenotype during grain filling together with subsequent development of the next generation plants.

２．研究の目的

In our previous reports, it has been known that heat stress during grain filling profoundly affects yield and quality within the mother’s generation, together with affecting seed germination of the next generation via epigenetic regulations. This led to the interest of how and when this phenomenon happens and what is the mechanism behind it. Therefore, in this study, we focused on how heat stress at different grain filling stages affects grain yield, quality, and seed germination performance of the next generation. It was expected that plants would respond to the heat stress exposure at each stage differently, with the unique regulation of each stage, which might be epigenetically regulated.

３．研究の方法

Material: Rice (*Oryza sativa* L.) cv. Nipponbare

Methods: Ten seedlings are transplanted to 1/5000a Wagner’s pot and grown at natural condition until booting stage. After anthesis, plants are transferred to growth chamber with temperature of control and heat stress. Plants were exposed to heat stress at four different stages, early developing, milky stage, grain ripening, and grain maturation. After harvest at 42 days after flowering, grains of each treatment were subjected to yield and quality analyses.

４．研究成果

At harvest, analyses of grain yield and quality were taken place. The results showed that heat stress throughout the grain filling period highly affected grain yield, which has been elucidated in many studies. However, here, we showed that heat stress at early and milky stages significantly reduced grain weight compared to heat stress at later stages of grain filling (Figure 1). Especially milky stage, grain filling rate was significantly dropped due to heat stress compared to other stages. These led to decrease in total grain yield in early phase of grain filling, which milky stage was highest affected. Interestingly, heat stress during ripening and maturation stage did not affect grain yield.

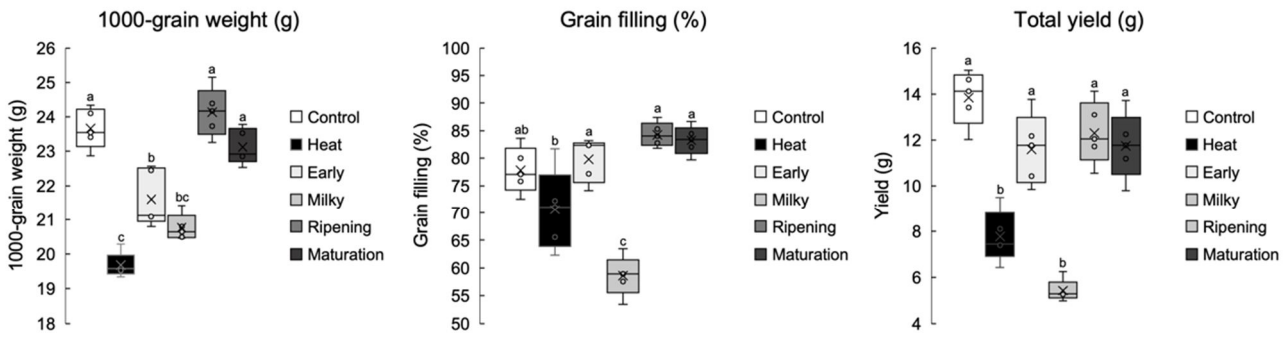

Figure 1. 1000-grain weight, grain filling percentage and total yield of plants exposed to heat stress at different grain filling stages.

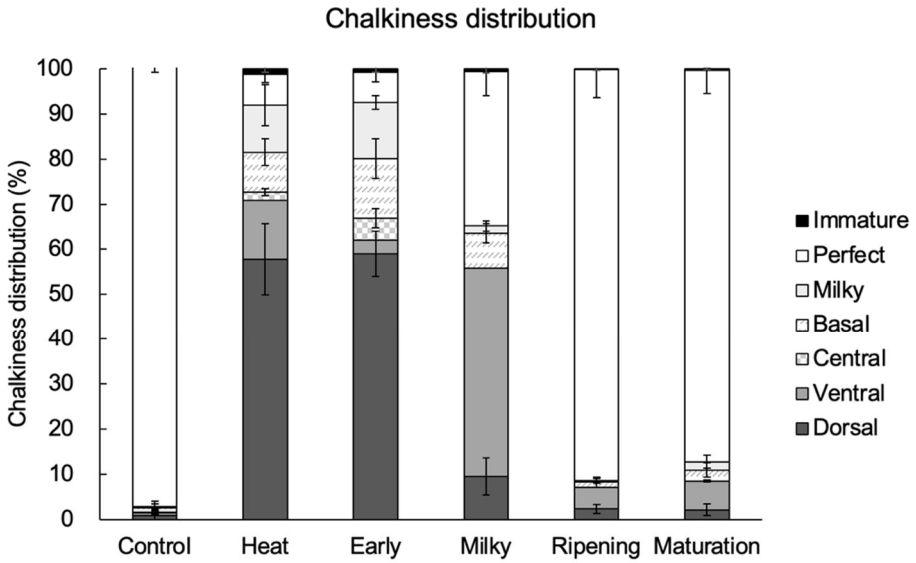

Figure 2. Chalkiness percentage and chalkiness type distribution of plants exposed to heat stress at different grain filling stages.

For grain quality, heat stress for the whole period of grain filling highly caused development of grain chalkiness (Figure 2). Heat stress during the early phase of development also led to chalkiness occurrence to the same level of whole heat period. We observed about 60% of chalkiness occurrence at milky stage, and about 10% of chalkiness in ripening and maturation stages. These results suggested that heat stress during early of grain filling highly affects grain quality, where from the milky stage affects grain yield. Heat stress from ripening stage onward rarely affects both grain yield and quality. Therefore, we expected that different transcriptional regulations might occur at each stage, which we plan to elucidate how heat stress at different stages of grain filling affects epigenetic regulations in our next study. We have previously proposed that heat stress during grain filling delays seed germination via epigenetic regulation (Suriyasak et al. 2020). Thus, we hypothesize that exposure to heat stress at each stage during grain filling might result in different subsequent development of the next generation, which we plan to further elucidate together with epigenetic mechanism underlying it.

References

Suriyasak, C. *et al.* Reactive oxygen species induced by heat stress during grain filling of rice (*Oryza sativa* L.) are involved in occurrence of grain chalkiness. *J. Plant Physiol.* **216**, 52–57 (2017).

Suriyasak, C. *et al.* Mechanism of delayed seed germination caused by high temperature during grain filling in rice (*Oryza sativa* L.). *Sci Rep* **10**, 17378 (2020). https://doi.org/10.1038/s41598-020-74281-9

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　0件）

１．著者名 Sakai Y., Suriyasak C., Inoue M., Hamaoka N., Ishibashi Y.	４．巻 110
２．論文標題 Heat stress during grain filling regulates seed germination through alterations of DNA methylation in barley (Hordeum vulgare L.)	５．発行年 2022年
３．雑誌名 Plant Molecular Biology	６．最初と最後の頁 325-332
掲載論文のDOI（デジタルオブジェクト識別子） 10.1007/s11103-022-01278-5	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕　計4件（うち招待講演　0件／うち国際学会　0件）

１．発表者名 井上 未希, 大樹 佳乃子, Chetphilin Suriyasak, 濱岡 範光, 石橋 勇志
２．発表標題 オオムギにおける青色光を介した種子発芽制御に関する研究
３．学会等名 第253回日本作物学会講演会
４．発表年 2022年

１．発表者名 坂井 優光, Chetphilin Suriyasak, 井上 未希, 濱岡 範光, 石橋 勇志
２．発表標題 オオムギの高温登熟による子実内のDNAメチル化を介した種子発芽制御機構
３．学会等名 第253回日本作物学会講演会
４．発表年 2022年

１．発表者名 澤田 悠太, 坂井 優光, 山口 訓史, 楊 欣悦, 佐々野 志帆, Suriyasak Chetphilin, 濱岡 範光, 石橋 勇志
２．発表標題 イネにおける登熟期の低温ストレスによる次世代の低温登熟耐性
３．学会等名 第255回日本作物学会講演会
４．発表年 2023年

１．発表者名 坂井 優光，澤田 悠太，Suriyasak Chetphilin，濱岡 範光，石橋 勇志
２．発表標題 登熟期間における高温ストレスがイネの玄米品質に及ぼす影響
３．学会等名 第255回日本作物学会講演会
４．発表年 2023年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関