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Data Article

A dataset for analyzing the climate change response of grain quality of 48 Japanese rice cultivars with contrasting levels of heat tolerance



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ABSTRACT

Climate change has a significant impact on rice grain appearance quality; in particular, high temperatures during the grain filling period increase the rate of chalky immature grains, reducing the marketability of rice. Heat-tolerant cultivars have been bred and released to reduce the rate of chalky grain and improve rice quality under high temperatures, but the ability of these cultivars to actually reduce chalky grain content has never been demonstrated due to the lack of integrated datasets. Here, we present a dataset collected through a systematic literature search from publicly available data sources, for the quantitative analysis of the impact of meteorological factors on grain appearance quality of various rice cultivars with contrasted heat tolerance levels. The dataset contains 1302 field observations of chalky grain rates (%) - a critical trait affecting grain appearance sensitive to temperature shocks - for 48 cultivars covering five different heat-tolerant ranks (HTRs) collected at 44 sites across

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Japan. The dataset also includes the values of key meteorological variables during the grain filling period, such as the cumulative mean air temperature above the threshold temperature (TaHD), mean solar radiation, and mean relative humidity over 20 days after heading, obtained from a gridded daily meteorological dataset with a 1-km resolution developed by the National Agriculture and Food Research Organization. The dataset covers major commercial rice cultivars cultivated in Japan in different environmental conditions. It is a useful resource for analyzing the climate change impact on crop quality and assess the effectiveness of genetic improvements in heat tolerance. Its value has been illustrated in the research article entitled "Effectiveness of heat tolerance rice cultivars in preserving grain appearance quality under high temperatures - A meta-analysis", where the dataset was used to develop a statistical model quantifying the effects of high temperature on grain quality as a function of cultivar heat tolerance.

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Specifications Table

| | |
|--------------------------|--|
| Subject | Agronomy and Crop Science |
| Specific subject area | Climate change impacts on agriculture; genetic variability in heat tolerance in rice; crop environmental responses |
| Data format | Raw, Filtered |
| Type of data | Tables, Figures, Chart, Reference list |
| Data collection | Chalky grain percentage (CG) and heading dates of major rice cultivars in Japan were obtained through a systematic literature search using three data sources: 1) NARO's Rice Cultivar and Characteristics Database; 2) four scientific databases (J-STAGE, CInii Research, SCOPUS, and AgriKnowledge); 3) Kochi Prefectural Agricultural Research Center's Performance Tests for Recommended Varieties of Rice data from 2013 to 2020. The gridded daily meteorological dataset with a 1-km resolution developed by NARO provided daily mean, minimum, and maximum air temperature, relative humidity, and solar radiation. |
| Data source location | The 1302 field observations were collected at 44 sites in 33 prefectures (out of 47), covering seven regions (out of eight) in Japan. Weather data were obtained from the gridded daily meteorological dataset with a 1-km resolution developed by NARO, which was created based on ground-based observations at around 1,300 sites (about every 17 km) across Japan. |
| Data accessibility | All articles provided the data is listed in the reference list file in the repository. Repository name: Mendeley data Data identification number: 10.17632/xwv7bpp5rn.2 Direct URL to data: https://data.mendeley.com/datasets/xwv7bpp5rn/2 |
| Related research article | Wakatsuki, H., Takimoto, T., Ishigooka, Y., Nishimori, M., Sakata, M., Saida, N., Akagi, K., Makowski D. (2024) Effectiveness of heat tolerance rice cultivars in preserving grain appearance quality under high temperatures in Japan - A meta-analysis, Field Crops Research [1]. |

1. Value of the Data

- The dataset includes 1,302 field observations of chalky grain content - a major rice quality criterion.
- It covers almost all standard cultivars registered in all regions in Japan except Hokkaido, with contrasted levels of heat tolerance (susceptible, moderately susceptible, intermediate, mod-

erately tolerance, and tolerant) and can be used to analyze the impact of weather conditions on chalky grain for the most important regions and rice variety of Japan.

- All the data were collected in open fields, without any additional artificial warming, in conditions resembling those observed on real farms. The data collection also includes critical meteorological variables and geographical information for each observation, making it ready to study quality-climate relationships.
- This dataset offers useful resources to validate models predicting rice grain quality, and conduct meta-analysis to quantify the climate change impact on crop quality [1].

2. Background

Climate change, specifically rising temperatures, has a negative impact on rice grain quality by increasing the chalky grain percentage (CG). Since the 2000s, heat-tolerant cultivars have been bred and released to reduce CG under high temperatures, but the ability of these cultivars to actually reduce CG has never been demonstrated. The aim of this dataset is to facilitate analysis of the effect of different weather conditions on CG, taking into account the heat tolerance of rice cultivars during grain filling.

3. Data Description

- (1) "CG_database_8.25.xlsx" is the main data spreadsheet file containing the values of the variables listed in "Meta-data_CGdatabase.xlsx".
- (2) "Meta-data_CGdatabase_8.25.xlsx" is a summary of the dataset that includes information such as the definition and unit of the variables used in "CG_database_8.25.xlsx".
- (3) [Table 1](#) is the list of cultivars used for the systematic literature search.
- (4) [Fig. 1](#) is the PRISMA diagram, depicting the systematic literature search processes.
- (5) [Table 2](#) is the list of cultivars for each heat tolerance rank (HTR) groups and their years of release, breeding institutes, and prefectures where these institutes are located, included in "CG_database.xlsx".
- (6) "Reference list.pdf provides a list of 49 studies identified from the search on the four scientific research databases considered.

Table 1

List of 63 cultivars used for the systematic literature search.

| | Cultivars |
|---|---|
| Standard cultivars registered by Ministry of Agriculture, Forestry, and Fisheries (MAFF) [2,3], | Akanezora, Akisayaka, Aoinokaze, Hatsuboshi, Hinohikari, Komanomai, Matsuribare, Sainokagayaki, Sasanishiki, Satojiman, Tomohonami, Kinuhikari, Koganebare, Sinrei, Tachiharuka, Akitakomachi, Haenuki, Hitomebore, Koshihikari, Mutsuhomare, Nikomaru, Nipponbare, Mizuhonokagayaki, Akisakari, Fukei227, Hanaeichizen, Koganemasari, Kokoromachi, Mineharuka, Natsuhonoka, Nishihikari, Satonouta, Shifukunominori, Tochiginohoshi, Tsuyahime, Natsuhonoka, Eminokizuna, Fusaotome, Otentosodachi |
| Other heat-tolerant cultivars | Akionami, Fufufu, Harumoni, Koisomeshi, Yumiazusa, Chihominori, Inahokkori, Koinoyokan, Akiharuka, Kumasannnochikara, Koshijiwase, Nijinokirameki, Tsukiakari, Toyama81, Tsuyakirari Emidawara, Kankinokaze, Genkitsukushi, Natsuhikari, Mie23, Oidemai, Sagabiyori, Sainokizuna, Yosakoibijin |

Table 2

Name of cultivars and their detailed information for each heat tolerance rank (HTR) group included in the main dataset file "CG_database.xlsx".

| HTR | Cultivar name | Year of release | Breeding Institute | Prefecture | |
|----------------------------|--------------------------------|--|---|---|---------|
| 3 | Akanezora ¹⁾ | 1986 | Aichi Prefectural Agricultural Research Center | Aichi | |
| | Akisayaka | 1996 | Fukuoka Prefectural Agriculture and Forestry Research Center | Fukuoka | |
| | Aoinokaze | 1986 | Aichi Prefectural Agricultural Research Center | Aichi | |
| | Hatsuboshi | 1972 | Aichi Prefectural Agricultural Research Center | Aichi | |
| | Hinohikari | 1986 | Miyazaki Agricultural Research Institute | Miyazaki | |
| | Matsuribare | 1990 | Aichi Prefectural Agricultural Research Center | Aichi | |
| | Sainokagayaki | 2000 | Saitama Agricultural Technology Research Center | Saitama | |
| | Satojiman | 2001 | Institute of Crop Science, NARO | Ibaraki | |
| 4 | Kinuhikari | 1983 | Central Region Agricultural Research Center (Hokuriku Research Station), NARO | Niigata | |
| | Koganebare | 1977 | Aichi Prefectural Agricultural Research Center | Aichi | |
| | Koisomeshi ³⁾ | 2015 | Western Region Agricultural Research Center, NARO | Hiroshima | |
| | Shinrei | 1974 | Miyazaki Agricultural Research Institute | Miyazaki | |
| | Tachiharuka | 2010 | Kyusyu Okinawa Agricultural Research Center, NARO | Fukuoka | |
| | Yumiazusa ²⁾ | 2014 | Tohoku Agricultural Research Center, NARO | Miyagi | |
| | 5 | Akitakomachi | 1984 | Akita Prefectural Agriculture, Forestry and Fisheries Research Center | Akita |
| | | Chihominori | 2012 | Tohoku Agricultural Research Center, NARO | Miyagi |
| Emidawara | | 2014 | Institute of Crop Science, NARO | Ibaraki | |
| Haenuki | | 1990 | Yamagata Integrated Agricultural Research Center | Yamagata | |
| Harumoni ⁴⁾ | | 2009 | Kyusyu Okinawa Agricultural Research Center, NARO | Fukuoka | |
| Hitomebore | | 1988 | Miyagi Prefectural Furukawa Agricultural Experiment Station | Miyagi | |
| Inahokkori | | 2011 | Western Region Agricultural Research Center, NARO | Hiroshima | |
| Kankinokaze | | 2012 | Kyusyu Okinawa Agricultural Research Center, NARO | Fukuoka | |
| Koshihikari | | 1953 | Fukui Agricultural Experiment Station | Fukui | |
| Mutsuhommarre | | 1980 | Aomori Agricultural Research Center | Aomori | |
| Nikomaru | | 2002 | Kyusyu Okinawa Agricultural Research Center, NARO | Fukuoka | |
| Nipponbare | | 1961 | Aichi Prefectural Agricultural Research Center | Aichi | |
| 6 | | Akiharuka | 2013 | Kyusyu Okinawa Agricultural Research Center, NARO | Fukuoka |
| | | Akisakari | 2009 | Fukui Agricultural Experiment Station | Fukui |
| | | Fukei227 | 2009 | Aomori Agricultural Research Center | Aomori |
| | Hanaechizen | 1988 | Fukui Agricultural Experiment Station | Fukui | |
| | Koganemasari | 1973 | Miyazaki Agricultural Research Institute | Miyazaki | |
| | Koinoyokan | 2009 | Western Region Agricultural Research Center, NARO | Hiroshima | |
| | Kokoromachi | 1993 | Miyagi Prefectural Furukawa Agricultural Experiment Station | Miyagi | |
| | Mineharuka | 2002 | Aichi Prefectural Agricultural Research Center | Aichi | |
| | Nijinokirameki | 2015 | Central Region Agricultural Research Center (Hokuriku Research st.), NARO | Niigata | |
| | Nishihikari | 1977 | Miyazaki Agricultural Research Institute | Miyazaki | |
| | Shifukunominori | 2015 | Tohoku Agricultural Research Center, NARO | Miyagi | |
| | Tochiginohoshi | 2008 | Tochigi Prefectural Agricultural Experiment Station | Tochigi | |
| 7 | Tsukiakari | 2013 | Central Region Agricultural Research Center (Hokuriku Research st.), NARO | Niigata | |
| | Tsuyahime | 2005 | Yamagata Integrated Agricultural Research Center | Yamagata | |
| | Tsuyakirari | 2012 | Kyusyu Okinawa Agricultural Research Center, NARO | Fukuoka | |
| | Eminokizuna | 2008 | Central Region Agricultural Research Center (Hokuriku Research st.), NARO | Niigata | |
| | Fusaotome | 1994 | Chiba Prefectural Agriculture and Forestry Research Center | Chiba | |
| | Genkitsukushi ⁵⁾ | 2005 | Fukuoka Prefectural Agriculture and Forestry Research Center | Fukuoka | |
| | Natsuhikari ⁶⁾ | 1980 | Kagoshima Prefectural Institute for Agricultural Development | Kagoshima | |
| | Natsuhonoka | 2009 | Kagoshima Prefectural Institute for Agricultural Development | Kagoshima | |
| Otentosodachi | 2006 | Miyazaki Agricultural Research Institute | Miyazaki | | |
| Yosakoibijin ⁶⁾ | 2014 | Kochi Prefectural Agricultural Research Center | Kochi | | |

¹⁾ Cultivars in plain text are standard cultivars designated to each HTR in the MAFF guideline [4].

²⁾ Cultivars in bold text are recently released cultivars registered in the RCC database with their HTR classified following the MAFF guideline.

³⁾ HTR based on [5].

⁴⁾ HTR based on [6].

⁵⁾ HTR based on [7].

⁶⁾ HTR based on [8].

4. Experimental Design, Materials and Methods

4.1. Inclusion and exclusion criteria

Studies obtained from the literature search were selected to facilitate the analysis of the effects of meteorological factors on grain quality of major commercial cultivars with different heat tolerance levels. We selected studies satisfying the following criteria:

- (1) Experiments were carried out in the open field without any warming treatments. Experiments using pots and/or glasshouse or polyhouse were excluded.
- (2) Studies should include the following data: CG, heading dates, and precise experimental field locations.
- (3) Cultivars whose heat tolerance ranks are not known were excluded.

4.2. Data collection

A systematic literature search was conducted using three different sources (Fig. 1).

1) NARO's Rice Cultivar and Characteristics (RCC) database (<https://inweb.narcc.affrc.go.jp/>)

The database contains breeding progress, morphological and ecological characteristics, and appearance and taste quality characteristics of over 500 MAFF-registered varieties. In December 2021, we searched this database for experiments involving 63 cultivars: 39 conventional cultivars

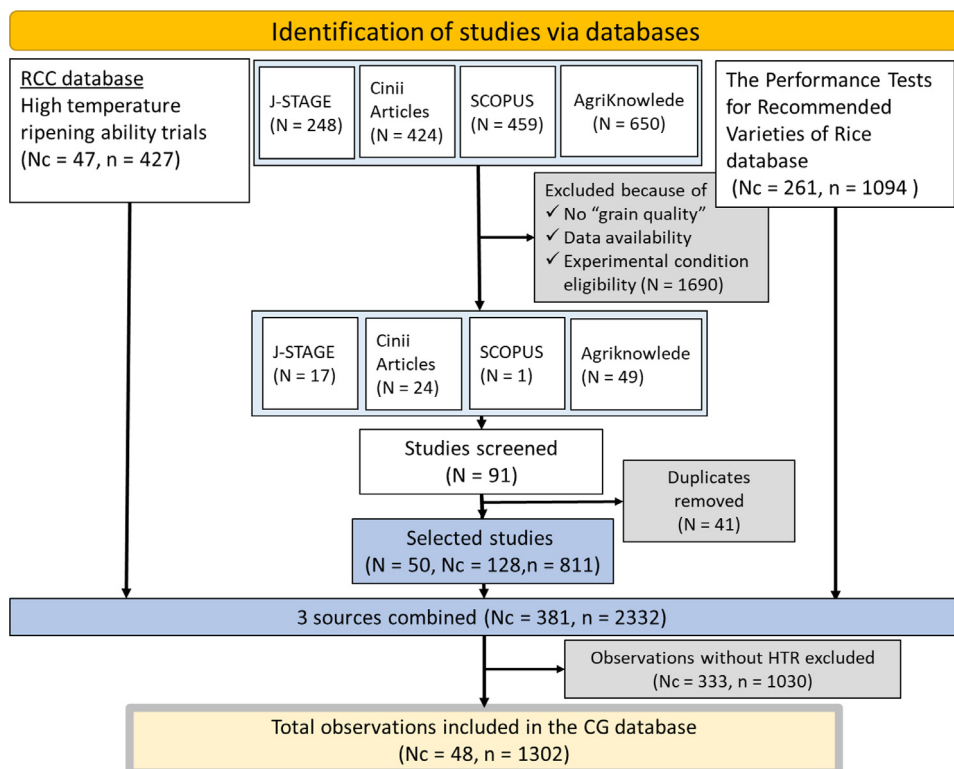


Fig. 1. A PRISMA diagram depicting data collection and selection processes. Nc is the number of cultivars, N is the number of studies, n is the number of observations.

of various heat tolerance ranks under the Plant Variety Protection and Seed Act (No. 83 of 1998) [4], and 24 heat-tolerant cultivars (Table 1). We then extracted those that met the inclusion criteria outlined in 2.1. This process yielded 427 observations for 47 cultivars.

2) Four databases containing peer-reviewed scientific publications and bulletins of national and prefectural agricultural research stations in Japan

- (1) J-STAGE (<https://www.jstage.jst.go.jp/browse/-char/en>)
- (2) CiNii Research (<https://cir.nii.ac.jp/?lang=en>)
- (3) SCOPUS (<https://www.scopus.com/>)
- (4) AgriKnowledge, a database for agricultural science and technology of Japan (<https://agriknowledge.affrc.go.jp/>),

In December 2021, we searched J-STAGE and CiNii Research using the search term “Kouon-tojuku” in Japanese, which means “grain filling under high temperatures,” and received 248 and 424 results, respectively. Applying the inclusion/exclusion criteria, we selected 17 and 24 papers from J-STAGE and CiNii Research, respectively.

The SCOPUS search was conducted in December 2021, using the following code:

```
PUBYEAR > 2001 AND (TITLE-ABS(("heat stress tolerance" OR "heat tolerance" OR "heat stress") AND ("genotyp*" OR "cultivar" OR "grain quality" OR "nutrient quality"))) OR AUTHKEY(("heat stress tolerance" OR "heat tolerance" OR "heat stress") AND ("genotyp*" OR "cultivar" OR "grain quality" OR "nutrient quality"))) AND (TITLE-ABS({greenhouse gas} OR {global warming} OR {climate change} OR {climatic change} OR {climate variability} OR {climate warming}) OR AUTHKEY({greenhouse gas} OR {global warming} OR {climate change} OR {climatic change} OR {climate variability} OR {climate warming})) AND NOT ((TITLE-ABS(MRV) OR AUTHKEY(MRV)))
```

MRV stands for Measurement, Reporting, and Verification, the process for quantifying greenhouse gas emissions, and was used with “NOT” to exclude papers that focused on climate change mitigation. The SCOPUS search yielded 459 results. However, only one study met the inclusion/exclusion criteria.

Additionally, in June 2022, we conducted a literature search in AgriKnowledge, using 63 cultivar names (Table 1) as a search string, and collected 650 articles, of which 49 studies met the criteria.

Selected papers from each database were gathered and checked for duplicates, yielding 50 studies with 811 CG observations of 128 cultivars.

(3) Kochi Prefectural Agricultural Research Center's Performance Tests for Recommended Varieties of Rice data from 2013 to 2020

The record of these variety trials contains 1094 sets of field observations of 261 cultivars.

The records obtained from the three independent data sources were combined (2332 observations), and cultivars with unknown HTR (1030 observations) were excluded, yielding 1302 observations of 48 cultivars (Fig. 1).

4.3. Data extraction

4.3.1. Site information

For each of the 1302 observations, we retrieved site information such as prefecture, municipality, latitude, and longitude (Meta-data) where the observations were collected. If latitude and longitude were not available, we used Google Map to identify them. The soil group at each site was retrieved if available in the literature, and if not, we extracted it referring to the Japan Soil Map by the soil-inventory project website (NARO, <https://soil-inventory.rad.naro.go.jp/>).

4.3.2. Crop information

In addition to the CG values and geographical information, the dataset contains sieve size for grain screening and CG measurement methods, such as “manual visual inspection” and “mechanical grain discriminator”. The standard errors and numbers of replicates were not available

in the selected studies and could thus not be extracted. In this study, the variable “CG” was defined as the total percentage of milky-white, basal-white, belly-white, and back-white grains. Wherever available, CG of these four different types of chalkiness were also recorded separately. The number of data with type-specific CG was 253, i.e. about 20% of all the records.

Of the 48 cultivars with known HTRs, 33 were listed in the MAFF guideline, 10 were rated in reference to the standard cultivars, and their HTRs were reported in the RCC database. HTRs of the other five cultivars were obtained from the literature [5–8] (Table 2). The 48 cultivars registered in our dataset belonged to HTRs ranging from 3 (susceptible) to 7 (tolerant) (Table 2). Currently, cultivars with HTRs higher than 7 or lower than 3 have not been registered.

4.3.3. Weather data

NARO's gridded daily meteorological dataset with a 1-km resolution [9] was used to extract weather data. For 20 days after heading, we averaged daily mean temperature, solar radiation (SR), and relative humidity (RH), a critical period impacting the prevalence of CG [10]. The incident SR was corrected using the shading ratio reported in each trial where shading treatments were enforced. Following previous research, we developed TaHD as a heat stress measure for rice quality, defined as the cumulative mean air temperature over the threshold temperature (T_b) for 20 days after heading. [9,11,12] as follows:

$$\text{TaHD} = \sum_{i=1}^{20} \max(Ta_i - T_b, 0)$$

Tai is the daily mean temperature on the i -th day from the heading date (Table 1). The value of T_b was set at 26°C in the analysis presented in the companion paper [1]. However, in agreement with previous studies [9,11,12], the database provides TaHD with different T_b from 24°C (TaHD24) to 28°C (TaHD28) (<https://data.mendeley.com/datasets/xwv7bpp5rn/2>).

Limitations

- The standard errors and numbers of replicates for the CG data were not available in the selected studies and could thus not be included in the dataset.
- CG data by different types, such as milky-white, basal-white, belly-white, and back-white grains, were available only for 20% of the observations.
- Most data came from cultivar trials conducted in experimental stations, where crops were grown under sufficient water and nutrients, as well as proper control over pests and diseases, but specific agronomic management data were not available.

Ethics Statement

The work does not involve any human subjects, animal experiments, or data collected from social media platforms.

Data Availability

A dataset for determining the dependence of rice grain quality of 48 Japanese cultivars with varying heat tolerance on weather conditions during grain filling (Original data) (Mendeley Data).

CRedit Author Statement

Hitomi Wakatsuki: Methodology, Formal analysis, Writing – review & editing; **Takahiro Takimoto:** Software, Data curation; **Yasushi Ishigooka:** Data curation; **Motoki Nishimori:** Vali-

dition; **Mototaka Sakata**: Resources; **Naoya Saida**: Resources; **Kosuke Akagi**: Resources; **David Makowski**: Formal analysis, Writing – review & editing; **Toshihiro Hasegawa**: Formal analysis, Writing – review & editing.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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