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Research

Cardinal Temperatures and Thermal Time for Germination of Sarawak Traditional Rice

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ABSTRACT

Germination of two rice landraces, namely Bario Sederhana and Biris, was determined from twelve temperatures (12.5 – 40 °C) in a series of incubation experiments. The cardinal temperatures and thermal time for germination were estimated from a 'broken-stick' linear model. Both landraces had a Tb of 10 °C, Topt between 32 – 33 °C, and Tmax of 43 °C. At the sub-optimal temperatures, the thermal time for germination was 62 oCd for Bario Sederhana and 53 °Cd for Biris. Within the supra-optimal range (Topt to Tmax), both landraces required 27-29 °Cd for seed germination. The maximum final germination for Bario Sederhana was 93% at 30 °C while Biris had 100% seeds population germinated at 27.5 °C.

Key words: Development, growing degree days, linear model, *Oryza sativa*, paddy

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INTRODUCTION

In rural regions of Sarawak, East Malaysia, traditional rice remains a popular choice among rice growers because it is pest-resistant, resilient to unploughed land environments, and requires minimum farm input. Thus, cultivation of traditional rice is prevalent in Sarawak with an estimation of at least 300 rice varieties identified (Khazanah Research Institute, 2018). Many of these varieties are said to possess exceptional quality in terms of taste (Wong *et al*., 2009), texture (Chih, 2016), aroma (Libin *et al*., 2012), and nutritional properties (Ronie *et al*., 2022). These varieties are sold as specialty rice and they fetch a premium price between MYR 8.00 to 19.50 per kilogram in the retail market (Lai *et al*., 2017). Coupled with high consumer demand for specialty rice, the emphasis on the production of specialty, premium rice products could increase farmers' profits and improve rural development. Some varieties originate from specific locations, with the quality derived from the origin, and as such are registered as Malaysia Geographical Indication. Examples of such varieties include the Bario and Biris rice.

Bario rice originates from the Kelabit Highland in Bario, Sarawak. The varieties of Bario rice are renowned for its finest grain qualities such as aroma, soft texture, taste, palatability, and nutrition (Wong *et al*., 2009; Thomas *et al*., 2013; Nicholas *et al*., 2014; Ronie *et al*., 2022). Its moderate glycemic index suggests that Bario rice has the potential to control blood glucose levels and thus can be marketed as a healthy food (Nicholas *et al*., 2014). Specifically, a commercially grown variety 'Bario Sederhana' is classified as medium grain rice with high protein and low-fat content, low gelatinization temperature, and high gel consistency which indicates a soft texture of cooked grain (Chih, 2016). This variety is suitable for health-conscious consumers who at the same time prefer food with excellent taste. On the other hand, Biris rice originates from the rice farms of Simunjan, Kota Samarahan, Sarawak. This variety produced an average grain yield of 2.2 tonnes per hectare with a stem height of 0.81 m (Nori *et al*., 2009). Biris rice is popular for its strong aroma and the grain is classified as very long and slender with a low percentage of chalkiness (Chih, 2016). Similar to Bario varieties, the cooked grains of Biris have a soft texture and are high in protein content. In addition, extracts from seedlings of Biris rice were reported to contain antioxidant properties that may have the potential to complement anti-cancer drugs, i.e., doxorubicin (Brandon *et al*., 2019).

In Sarawak, the majority of rice is grown rainfed on upland and flat terrains. Early crop establishment relies on an adequate population of seedlings that emerge following sowing. To achieve this, decision-making on suitable seeding rate is essential and can be influenced by seed germination performance. Provided that soil moisture is adequate, seed germination rate and count are mainly driven by temperature (Shaban, 2013; Nori *et al*., 2014). In general, seed germination accelerates with increasing temperature up to an optimum value, and any extremes of temperature can inhibit the germination process. For example, Tilebeni *et al*. (2012) reported no germination was observed at temperatures below 12 ºC and above 40 ºC on 15 rice cultivars. Furthermore, the accumulated heat units during a specific growth period, known as thermal time (ºCd), are utilized to measure the time required for seeds to germinate.

The calculation of thermal time requires cardinal temperatures (base, optimum, & maximum) to be determined from the relationship between temperature and germination rate (Angus *et al*., 1981). The base temperature (T_b) is the lowest temperature below which no germination occurs. The optimum temperature (T_{opt}) is where the fastest rate of germination is achieved in the shortest amount of time and the maximum temperature (T_{max}) is the extreme point where germination can take place.

Linear regression analyses of germination rate against temperatures with the intersection of the regression lines are commonly used to estimate cardinal temperatures (Angus *et al*., 1981; Cave *et al*., 2011; Draper and Smith, 1998). Nevertheless, field environments can only provide a limited range of temperatures. Specifically, in the tropical region, temperatures in the field below 25 ºC are not achievable and this will result in inaccuracy to calculate T_b because of a considerable extrapolation of the regression line. It is important to note that the prediction of T_b from linear extrapolation is affected by the number of temperatures at the sub-optimal. Therefore, incubation experiments can extend the temperature range to obtain a more accurate value of T_b and thermal time requirements (Angus *et al*., 1981).

Linear equations have been used to quantify cardinal temperatures for the germination of cultivated rice (Ali *et al*., 2003; Tilebeni *et al*., 2012) and weedy rice (Puteh *et al*., 2010). For these studies, cardinal temperatures reported T_b between 10 and 13 ºC, T_{opt} between 30 and 33 ºC, and T_{max} between 38 and 48 ºC for cultivated rice. In contrast, T_b, T_{opt}, and T_{max} for germination of weedy rice were 2-7, 28-37, and 42-43 ºC respectively. Typically, cardinal temperatures are species-dependent regardless of cultivars but the array of temperatures used was inadequate, and the thermal time (ºCd) requirement for germination was not quantified in the previous studies (Ali *et al*., 2003; Puteh *et al*., 2010; Tilebeni *et al*., 2012). Furthermore, the specific landraces of Bario Sederhana and Biris were not included in any of these previous studies. Therefore, the objectives of this study are to determine cardinal temperatures and thermal time for germination of Bario Sederhana and Biris rice from a series of incubator experiments.

MATERIALS AND METHODS

Source of seeds

The seeds of two traditional varieties of rice, namely Bario Sederhana and Biris were obtained from a farmer's field in Serian District, Sarawak. This planting location was outside of the historical origin of Bario Sederhana from Kelabit Highland in Bario and Biris from Simunjan District. Hence, the Bario Sederhana and Biris varieties used in this study are referred to as rice landraces because of their distinct identity, and adaption to local environments making them genetically diverse and associated with farmers' preferences (Villa *et al*., 2005).

Germination study

The experiment was conducted in three replicates with each consisting of 50 seeds of Bario Sederhana and Biris rice landraces. The seeds were put in disposable petri dishes containing wetted filter paper and were left to germinate in unlit incubators (Conviron G30 Model, Winnipeg, Canada) at twelve constant temperatures of 12.5 ºC, 15 ºC, 17.5 ºC, 20 ºC, 22.5 ºC, 25 ºC, 27.5 ºC, 30 ºC, 32.5 ºC, 35 ºC, 37.5 ºC, or 40 ºC. A mercury thermometer was placed inside the incubators to monitor the targeted temperature setting. Additional distilled water was added from time to time to ensure adequate moisture for the germination process. When the radicle protruded from the seed coat beyond 2 mm, the seeds were deemed as germinated. Seed germination was inspected twice per day during rapid germination times and regularly until the germination process ended (ISTA, 1993).