Evaluation of Gayo coffee germplasm on Hypothenemus hampei (Coleoptera: Curculionidae) resistances

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Abstract. The Gayo Experimental Station (GES) germplasm has the most complete collection of Arabica coffee in the world. The utilization of these collections to search coffee berry borer (CBB) resistant lines has not been carried out. This study aimed to evaluate 17 germplasm lines/varieties of Arabica coffee in GES against CBB resistance. Observation of CBB infestation level in the field was conducted at GES, Bener Meriah, Aceh. Each line used 10 trees and randomly selected 4 branches. Then the number of CBB-infested and healthy cherries were counted. At harvest time, were taken from each line 100 cherries randomly. Parameters observed were cherry weight, discus diameters, and cherries infested. Genetical resistance tests carried out at the plant protection laboratory of IIBCRI, Sukabumi, West Java. The parameter observed was the number of cherries infested. The results showed that CBB infestation level in germplasm was very low, caused by environmental factors that are not suitable for CBB development. There was a positive correlation between cherry discus diameters and CBB infestation rate. The results of genetic resistance testing in the laboratory showed that all of the evaluated Gayo arabica coffee lines/varieties showed a lightly susceptible response to CBB.

Keywords: Arabica coffee, coffee berry borer, infestation level, superior line

1. Introduction
Gayo coffee is known as coffee with excellent taste with a characteristic light acidity taste with a strong aroma, and a heavy body (good viscosity). Gayo coffee is Arabica coffee that grows in the Gayo highlands spread over three districts, namely Central Aceh, Gayo Lues, and Bener Meriah. The total area of Arabica coffee planted in Gayo highlands in 2011 was 91.471 ha [1]. All Arabica coffee produced from these three districts is considered Gayo coffee, most of which is exported to meet the needs of international consumers [2]. The development of Arabica coffee in the Gayo highlands cannot be separated from the duties and functions of the Gayo Experimental Station (GES), which is one of the experimental stations of the Aceh Assessment Institute for Agricultural Technology (AIAT), the Indonesian Agency for Agricultural Research and Development (IAARD).

The GES Arabica coffee germplasm has the most complete collection of Arabica coffee lines in the world. However, the utilization of the collection has not been carried out optimally. GES was built in 1976-1986 in cooperation between Indonesia and the Netherlands, has Arabica coffee germplasm plantations containing at least 40 lines/varieties from various regions in Indonesia and several countries.
such as Thailand, Australia, Brazil, India, Papua New Guinea, America, and others [2]. In 2010 two superior Arabica coffee varieties were released, namely Gayo 1 and Gayo 2.

One of the obstacles in coffee cultivation is the attack of pests and plant diseases. The coffee berry borer (CBB) *Hypothenemus hampei* is a major pest of coffee plants worldwide [3, 4, 5]. This pest has reduced coffee productivity in Uganda (80%), Colombia (60%), Jamaica (58–85%), Tanzania (90%), Malaysia (50–90%), and Mexico (60%) [6]. This pest attack not only reduces productivity but can also reduce coffee quality [7, 8, 6, 9]. Although national data of attack rate and yield losses are not yet available, the CBB infestation in some coffee plantation centers is very high. *H. hampei* infestation has caused yield losses of Arabica coffee in South Sulawesi 30-60% [10], and Simalungun Regency reached 51.6% [11]. Meanwhile, on Robusta coffee plantations in Lampung Province ranging from 6.30-20% [12], and on Liberica coffee in West Jabung Regency ranged from 8.20-17.76% [13].

CBB pests have become pests on all types of coffee grown at an altitude range of 500-1,000 m above sea level (asl) [8]. Meanwhile, according to Hulupi et al. [14], CBB pests generally attack coffee grown in the lowlands with an altitude of lower than 700 m asl. Several factors that support the high level of CBB attack are planting locations, ecosystem conditions, and cultivation techniques applied by farmers [15]. Arabica coffee plantations in the Gayo highlands generally have a wet climate with even distribution of rain throughout the year. This condition supports continuous flowering throughout the year, which causes feed for CBB to be always available [14]. In addition, the impact of global climate change causes an increase in air temperature in the central area of Arabica coffee production, which has the potential to increase the attack of the coffee berry borer (CBB) [15, 16]. Therefore, it is necessary to look for Arabica coffee plant varieties that have resistance to these CBB pests [15].

Considering the high loss of coffee yields due to CBB attacks, one of the main programs for breeding coffee plants is to obtain CBB resistant coffee varieties. Plant resistance is a form of expression of the relationship between host plants and insect pests whose interaction process is influenced by growing environmental factors. According to Sera et al. [17], the resistance reaction of the coffee genotype to CBB will differ depending on the environmental conditions in which it is cultivated. Lemma and Abewoy [18] reported that resistance to CBB indicated that Arabica coffee was more susceptible than Liberica coffee. CBB attacks on arabica coffee in the lowlands are twice as high as on Liberica coffee. There is not much information on research results that explain the mechanism of coffee resistance to CBB [17], and to date, no source of resistance to CBB has been found in the coffee gene pool [19].

Efforts to find genetic sources of Arabica coffee resistant to CBB to obtain new superior varieties must be done. The genetic diversity of Arabica coffee germplasm in GES is needed as the base material in assembling new superior varieties with the desired properties [20]. Given the enormous source of genetic diversity in the existing collections, the opportunity to obtain new superior Arabica coffee varieties that are resistant to CBB was very large. Therefore, it is important to evaluate Arabica coffee lines that have been planted in the GES germplasm for more than 20 years. The purpose of this study was to evaluate the CBB resistance of 17 Arabica coffee lines/varieties in GES.

2. Materials and methods

Field observations of the level of CBB infestation were carried out at the Gayo Experimental Station (GES) located in Pondok Gajah, Bandar District, Bener Meriah Regency, Aceh. While the evaluation of the genetic resistance of Arabica coffee from GES to CBB was carried out at the Plant Protection Laboratory of the Indonesian Industrial and Beverage Crop Research Institute (IIBCRI), Sukabumi, West Java. The study was conducted on 17 arabica coffee lines/varieties that had been grown for more than 20 years at GES (Table 1).

2.1. Evaluation of the level CBB infestation in arabica coffee germplasm in GES

Evaluation of CBB infestation was carried out at GES, which is located at 04'45'188 north latitude and 96'53'798 east longitude, at an altitude of 1.485 m above sea level (asl). The GES land has a volcanic soil structure and contains organic matter of more than 5%, effective depth is more than 100 cm, soil
pH is 5.5 - 6.5, the land slope is around 30%, rainfall ranges from 1,000 to 2,500 mm per year with the number of rainy days 143–170, temperature ranges from 13 - 26°C and relative humidity 20 - 75.8%.

Observations were made on 13 Arabica coffee lines and 4 varieties that had been released for comparison, namely Gayo 1, Gayo 2, USDA 762, and Line S 795 (Table 1). The selection of trees and branches observed followed the method of Soesanthy et al. [15]. Each line/variety used 10 trees and randomly selected 4 branches. Then the number of CBB-infested and healthy cherries were counted. At harvest time, were taken from each line 100 cherries randomly. Parameters observed were cherry weight, cherry discus diameters, and the number of infested cherries.

Table 1. Evaluated Arabica coffee lines/varieties in GES.

| No. | Lines/Varieties     | Originally plants | Year of planting | Number of collections |
|-----|--------------------|-------------------|------------------|-----------------------|
| 1.  | Ateng Super        | Aceh Tengah       | 1999             | 2,050                 |
| 2.  | P 88               | Thailand          | 1988             | 1,584                 |
| 3.  | C 41               | Australia         | 1988             | 2,411                 |
| 4.  | CTT                | Timor Leste       | 1988             | 702                   |
| 5.  | C 47               | Australia         | 1988             | 2,615                 |
| 6.  | CH 308             | Thailand          | 1988             | 1,987                 |
| 7.  | C 50               | Australia         | 1988             | 2,446                 |
| 8.  | BP 425             | Jember            | 1994             | 401                   |
| 9.  | C 48               | Australia         | 1988             | 1,627                 |
| 10. | C 49               | Australia         | 1988             | 750                   |
| 11. | Catimor Jaluk      | Jember            | 1991             | 868                   |
| 12. | Caturra Yellow     | Brazil            | 1991             | 900                   |
| 13. | SLN 9              | India             | 1992             | 150                   |
| 14. | Gayo 1 (Timtim)²,³ | Aceh Tengah       | 2005             | 816                   |
| 15. | Gayo 2 (Borbor)²,³ | Aceh Tengah       | 2005             | 720                   |
| 16. | USDA 762²          | USA               | 1994             | 50                    |
| 17. | Line S 795²,³      | Jember            | 1994             | 267                   |

² Arabica coffee varieties that have been released
³ Resistant variety [14]

2.2. Evaluation of resistance to CBB of Arabica coffee lines/varieties in the laboratory

2.2.1. Propagation and maintenance of test insects. CBB-infected coffee cherries were collected from the Pakuwon Experimental Station (PES), Sukabumi, West Java. Cherries were sterilized according to the method of Perez et al. [21]. These cherries were washed with soap for 15 minutes under running water, soaked in a 2% sodium hypochlorite solution for 10 minutes, then washed with distilled water. In the next step, the cherries were soaked in a 2% potassium sorbate solution and washed with distilled water. Cherries containing CBB were dried, then transferred to a plastic box with a gauze lid. Each plastic box was lined with a mixture of gypsum and activated charcoal to retain moisture and prevent the cherries from shrinking. Every three days the inside of plastic boxes was watered to keep them moist. Plastic boxes were placed on the treatment rack at room temperature.

2.2.2. Evaluation of Arabica coffee resistance to CBB. For each strain/variety evaluated, 100 green coffee cherries with fully formed endosperm were selected. The samples were taken randomly from 10 coffee trees. To remove the fungus carried from the field, cherries were sterilized according to the Perez et al. [21] method in the laboratory. Evaluation of resistance to CBB followed the method of Sera et al. [17]. Cherries tests were immersed in liquid paraffin to prevent CBB from entering through the base of the cherry or tearing cherry skin during harvesting. Cherries were placed in a petri dish (9 cm diameter, 1.1 cm high) which had been coated with 20 grams of sterile sand to make it easier for CBB to move in the petri dish.
The screening test for resistance to CBB of 17 Arabica coffee lines/varieties was carried out using the no-choice test followed the method of Soesanthy et al. [15]. The treatments were arranged using a Completely Randomized Design with 4 replications. Each replication used 20 cherries for each line/variety in a plastic container filled with 20 CBB beetles. The plastic containers were covered with black cloth and left for 14 days after the infestation (DAI). After being left for 14 days, then observations were made on the number of cherries infested by CBB. The resistance reaction was calculated according to the following classification: 0 = immune; 1 - 10% = resistant; 11 - 20% = moderately resistant; 21 - 30% = moderately susceptible; 31 - 49% = susceptible; >50% = lightly susceptible [14].

3. Results and discussion
3.1. CBB infestation in arabica coffee germplasm in GES
The results of observations on the level of CBB infestation in 17 arabica coffee lines/varieties in GES showed that the level of infestation was very low, with an infestation of 0.00 - 3.28% (Table 2). The low level of CBB infestation on Arabica coffee lines/varieties in GES is due to environmental influences. The GES Arabica coffee germplasm plantation is located at an altitude of 1,485 m asl, which is not suitable for CBB development. According to Susilo [8], the attack of H. hampei was higher at an altitude range of 500 - 1,000 m asl than at an altitude lower than 500 m asl or upper than 1,000 m asl. The CBB infestation was positively correlated with temperature and negatively correlated with altitude [22]. The optimum temperature for the CBB development ranges from 25-26°C [8]. The increasing of temperature in the coffee growing area resulted in a reduction in the yield and quality, increasing pest and disease outbreaks, increasing cost of production, and reduced area of production [23]. Therefore, the occurrence of the global warming process that drives climate change must be anticipated properly.

![Figure 1](image1.png)

**Figure 1.** The coffee berry borer life cycle (A); (B) entrance hole of CBB) (arrow) in the central discus of the developing green coffee cherries.

The results of observations on the morphological characters of Arabica coffee cherries that may be related to CBB resistance, namely cherry size, and discus diameter, indicate that there were variations between the observed lines/varieties. Cherry size did not correlate with CBB infestation level, but discus diameter indicated a positive correlation. Damon [24] stated that H. hampei prefers coffee cherries that have wider discus and smaller coffee cherries. From the observational data, it can be seen that the size of the discus diameter was positively correlated with the percentage of CBB infestations (Figure 2). P 88, C 48, and USDA 762 lines which had the largest discus sizes were attacked by CBB relatively higher
than the other lines/varieties. The wider diameter of the cherry discus will make it easier for CBB beetles to bor into the cherry than the smaller ones [8, 15].

![Positive correlation between discus diameter width and CBB infestation level](image)

**Figure 2.** Positive correlation between discus diameter width and CBB infestation level.

**Table 2.** Morphological characters and CBB infestation levels of 17 Arabica coffee lines/varieties.

| No. | Lines/ Varieties | Weight of 100 cherries (g) | Cherry weight (g) | Central discus diameters (mm) | CBB infestations (%) |
|-----|------------------|---------------------------|------------------|-----------------------------|----------------------|
| 1.  | Ateng Super      | 24.81                     | 1.72             | 2.9                         | 0.58                 |
| 2.  | P 88             | 20.33                     | 1.45             | 3.5                         | 1.37                 |
| 3.  | C 47             | 16.60                     | 1.06             | 2.6                         | 0.94                 |
| 4.  | C 41             | 16.41                     | 1.19             | 2.9                         | 0.17                 |
| 5.  | BP 542           | 19.93                     | 1.49             | 3.5                         | 0.00                 |
| 6.  | CH 306           | 17.93                     | 1.33             | 2.1                         | 0.20                 |
| 7.  | C 50             | 15.58                     | 1.06             | 2.5                         | 0.36                 |
| 8.  | CTT              | 17.89                     | 1.33             | 3.0                         | 0.61                 |
| 9.  | C 48             | 15.00                     | 1.26             | 3.1                         | 2.19                 |
| 10. | C 49             | 17.00                     | 1.15             | 2.4                         | 0.54                 |
| 11. | Catimor Jaluk    | 18.00                     | 1.07             | 2.3                         | 0.72                 |
| 12. | Catura Yellow    | 17.00                     | 1.09             | 2.7                         | 0.00                 |
| 13. | SLN 9            | 17.00                     | 1.27             | 2.2                         | 0.11                 |
| 14. | Gayo 1           | 21.45                     | 1.64             | 2.9                         | 0.22                 |
| 15. | Gayo 2           | 23.77                     | 1.61             | 3.1                         | 0.31                 |
| 16. | USDA 762         | 22.00                     | 1.71             | 3.5                         | 3.28                 |
| 17. | LINI S 795       | 18.00                     | 1.35             | 2.8                         | 0.98                 |

3.2. *Arabica coffee genetic resistance test against CBB in the laboratory*

The level of CBB infestation in genetic resistance testing of Gayo Arabica coffee with the no-choice method in the laboratory is shown in Figure 3. The CBB infestation rate in all Arabica coffee lines is very high, between 62.0 - 95.0%. The lowest CBB infestation rate occurred on the Catimor Jaluk line (62.0%) and the highest on the P 88 line (95.0%). Referring to the classification of resistance reactions
according to Hulupi et al.[14], all lines/varieties of Gayo Arabica coffee evaluated were lightly susceptible to CBB (> 50%).

The results of genetic resistance testing of Gayo Arabica coffee in this laboratory are different from the results of evaluating the level of CBB infestation in the field (Table 2). The results of this study are the same as those reported by Soesanthy et al. [15] that the percentage of H. hampei infestation in arabica coffee in the field at an altitude of 1,300 - 1,450 m (asl) was very low between 3.24 - 6.76%. However, after testing for genetic resistance in the laboratory, it showed that the CBB infestation rate was quite high, both from the choice and non-choice tests, namely 51.25% and 17.5%, respectively.

![Figure 3](image)

**Figure 3.** Percentage of CBB infestation in Arabica coffee lines/varieties in the laboratory

4. Conclusion
The level of CBB infestation in arabica coffee lines/varieties evaluated in the GES germplasm was low, due to the unsuitable cultivation environment for CBB development. The results of genetic resistance testing using the no-choice method in the laboratory showed that the percentage of CBB infestation in all tested lines/varieties was very high. All lines/varieties evaluated showed a lightly susceptible reaction to CBB.

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