The Abundance of Fruit Flies (Bactrocera Spp.) On Some Varieties of Mango from Three Selling Sources

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ABSTRACT
The fruit fly is one of the detrimental pests to mango production in Indonesia. Information about fruit fly species in the mango production areas is pivotal for analyzing pest risk assessment, developing appropriate standards for plant quarantine treatment, and managing its control programs. This study aims to analyze the fruit fly abundance and composition among three mango cultivars (“Gedong Gincu,” “Cengkir” and “Arumanis”) in Indramayu, Majalengka and Sumedang Regencies, Indonesia. The mangoes were selected randomly by hand collecting from trees, middlemen and traditional vendors. All collected fruits were transferred to the laboratory. The fruits were retained in the cages until the fruit fly imagoes emerged. The results showed that Bactrocera dorsalis (Hendel), Bactrocera carambolae Drew & Hancock, and an interspecific hybrid of both species were found on mangoes from all study sites. The Bactrocera umbrosa (Fabricius) was merely found on mangoes in Sumedang Regency. The B. dorsalis was the dominant species in all mango cultivars. The nutritional content of mangoes did not correlate with the abundance, species diversity and weight of fruit fly pupae.

Introduction
Mango (Mangifera indica L., Anacardiaceae) is commercially the most important fruit crop of Indonesia, accounting for more than 6.7% of the total mango production worldwide. In 2019, Indonesia produced 3.28 metric tons of mangoes from 202 thousand hectares of mango orchards. One of the mango production centers in Indonesia is located in West Java, including Sumedang, Indramayu, Cirebon and Majalengka Regencies. Several mango cultivars with high economic value are widely cultivated in those regions, including “Gedong Gincu,” “Arumanis” and “Cengkir.” These cultivars are highly preferred because they demonstrate various superior characteristics (Balai Penelitian Buah Tropika, 2017).

Compare to its land width potential, mango production in Indonesia is yet optimal. More than 300 insect species pest attack the vegetative and reproductive phases of the 31 mango crops in the world, including in Indonesia. Among insects, fruit flies are the main pests of mango fruit and cause a substantial decrease in mango quality and production (Siregar and Sutikno, 2015). The attack of fruit flies on mangoes can reduce its competitiveness in the global market and hamper export activities (Syahfari and Mujiyanto, 2013). Damage due to fruit fly attacks decreased mango quality before reaching its maturity. Yield losses due to fruit fly attacks may reach 100% (Susanto et al., 2017).

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Surveillance of fruit fly populations in mango is an important part of pest control. This process is pivotal to ensure mango quality conform with international standards, especially those for export consumption (ISPM 6, 2018; Syahfari and Mujiyanto, 2013). Rigorous identification is required to differentiate between species for pest risk assessment, to develop appropriate standards for plant quarantine treatment and to monitor of invasive species (Ebina and Ohto, 2006).

The *B. dorsalis* has been widely distributed in both Asia-Pacific and Africa (Salmah et al., 2017; Vargas et al., 2015; Vaysièr et al., 2015), whereas, *B. carambolae* has a narrower range in Southeast Asia. The *B. carambolae* has recently been reported to exist in South America (Leblanc et al., 2019; Marchioro, 2016; Vargas et al., 2015). Most research on fruit fly diversity is carried out on mango plantations or orchards. Since the mango distribution chain involves middlemen and traditional market sellers. Surveillance in those levels may provide important information to encourage mango quality control and limit the spread of those flies. Based on the description of the problem above, the study of the diversity of fruit flies on the several mango cultivars in different areas is necessary. This study aims to analyze the fruit fly abundance and composition among three mango cultivars (“Gedong Gincu,” “Cengkir” and “Arumanis”) in Indramayu, Majalengka and Sumedang Regencies Indonesia.

Materials and Methods

This study was conducted in three regencies in West Java, Indonesia: Sumedang, Majalengka and Indramayu, from October to December 2018. Mangoes with uniform sizes and similar levels of maturity were collected from the orchards, middlemen and traditional vendors. The mango (*Mangifera indica* L.) consisted of three cultivars: “Gedong Gincu,” “Cengkir” and “Arumanis.” Mangoes were collected once every month, for three consecutive months (October to December). Sampling in all locations was carried out on the same day. In each unit, 10 fruits were collected randomly, resulted in the total fruit per month was 270 individuals, and the total number of fruits in three months was 810 individuals. Fruits from the orchards were collected randomly from the trees, while those from middlemen and traditional vendors were selected from the stocks.

The selected mangoes were put in a sack or plastic bag and lined with cloth to reduce the amount of water due to respiration. All infested mango fruits were transferred to the Laboratory of Plant Pest, Padjadjaran University for the rearing and identification process. The fruits were retained in the cages with room temperature (22.2–28.5°C) and humidity (51–84%) until the adults’ fruit fly emerged. The emerged imagoes were reared until 14 days and then killed with a killing jar contain 70% of Etanol. The identification of fruit fly morphology was conducted based on different characteristics (abdomen, thorax and wing). Differences in wing characters were observed from the shape and venation of the wings. The characteristics of the wings, abdomen and thorax of each species were distinguished using a microscope. The results of observing fruit fly identification were compared to the description in the key manual (Choudhary et al., 2014; Astriyani, 2014; Drew, 2011). The process of comparing the identification results is carried out with the help of Lucid Key software.

Mango Nutritional Testing

Mango nutrition testing was carried out in the Test Services Laboratory, Faculty of Agricultural Industry Technology, Padjadjaran University in December 2018. This test was carried out on ripened mangoes free of fruit fly attack symptoms. The test of each cultivar was replicated three times. The chemical composition tested was done with the standard method as follows, the water content in gravimetric method, fat content in Soxhlet method (Zarnowski and Suzuki, 2004), protein content in Kjeldahl method (Magomya et al., 2014), the ash content in gravimetric method and carbohydrate content two methods namely enzymatic-gravimetric (Gordon et al., 2002), and in vitro methods (Christine et al., 2012).
Data Analysis

The calculation of the diversity of fruit fly species was carried out for each cultivar at each sampling location by using the Shannon-Wiener diversity and Simpson dominance indices (Astriyani, 2014), with the following formula.

\[ H' = \sum_{i=0}^{s} (pi) \log(pi) \]  

(1)

where:
- \( H' \) = Shannon-Wiener diversity index
- \( s \) = number of species in the community
- \( pi \) = proportion of total abundance represented by \( i^{th} \) species \( s \)

\[ D = 1 - (\sum(pi)^2) \]  

(2)

where
- \( D \) = Simpson Dominance Index
- \( pi \) = proportion of total abundance represented by \( i^{th} \) species \( s \)

The difference of fruit fly abundance and diversity among the locations were tested by one-way analysis of variance. The correlations between mango nutrition contents with fruit fly abundance and diversity as well as with pupa weight were evaluated by Pearson’s correlation. Analysis of variance and correlation test was performed using SPSS software version 25.0.

Results and Discussion

Fruit Fly Species Identification

The identification results showed that several species of fruit flies were found in the fruits. Bactrocera dorsalis, B. carambolae and interspecific hybrid between B. carambolae and B. dorsalis were found in mangoes from Indramayu, Majalengka and Sumedang Regencies. Interspecific hybrids are the offspring from interspecies mating. The B. carambolae and B. dorsalis are closely related species to allow for interspecific mating (Pramudi et al., 2013). Another fruit fly species, B. umbrosa, was found merely in Sumedang Regency. The B. umbrosa is a primary pest of a small number of Artocarpus species. It is an oligophagous pest infesting Moraceae fruits. The species is distributed throughout Southeast Asia and the West Pacific (Krosch et al., 2018, Vargas et al., 2015). Its presence in mango was also found in previous studies in Indonesia (Siregar and Sutikno, 2015; Susanto et al., 2018).

Bactrocera dorsalis and B. carambolae has morphologically different characteristics. The B. dorsalis (Figure 1) and B. carambolae (Figure 2) can be distinguished morphologically by observing their abdomen. On the abdomen of B. dorsalis, a black pattern forming the letter “T” is present, while a dark band is absent on the lateral side in IV terga (Figure 1c). Otherwise, a small black pattern forming a triangle is present on the lateral side of the terga. Similar to B. dorsalis, B. carambolae also exhibits a black pattern forming the letter “T” on its abdomen, but the black pattern on the lateral side at IV terga is more pronounced to form a rectangle (Figure 1c).

Apart from the abdomen, the morphology of the two species can also be distinguished by their wing characteristic. The B. dorsalis presents with wings that are sometimes confluent at R2 + 3 or overlapping on R2 + 3. The black band on the B. dorsalis costal line extends straight past the ends of R2 + 3 and R4 + 5 to the tips of the wings (Figure 1d). In contrast to B. dorsalis, the B. carambolae wing overlaps on R2 + 3, and the black band on the costal line extends past the ends of R2 + 3 and R4 + 5 and widened at the tips of the wings after passing R4 + 5 (Figure 2d).
The intermediate morphological characters were found between *B. carambolae* and *B. dorsalis*. The intermediate morphological character is shown from the morphological combination of the two species. According to Schutze et al. (2013) interspecific mating between *B. dorsalis* and *B. carambolae* may occur naturally. Approximately 67.8 ± 3.7% pairs of *B. dorsalis* and *B. carambolae* interbreed between species (Schutze et al., 2013). Hybrid offsprings may have intermediate mid-range variations of the wings, abdomen, black dots on the quadriceps and the size of the ovipositor (Ebina and Ohto, 2006; Juma et al., 2014). Variation of body pattern of F1 was intermediate of its parents while F2 demonstrated a wider variation (Ebina and Ohto, 2006). Wide variation means that there are some of the same patterns such as male elders, female elders or different interchangeable
patterns. This study found interspecific hybrid (mid morphology) of *B. carambolae* and *B. dorsalis*. This hybrid exhibits wing morphology similar to *B. carambolae*, while its abdominal morphology is a characteristic feature similar to *B. dorsalis* (Figure 3).

Morphological of *B. umbrosa* include the following characteristics: black colored scutum with yellow stripes on both lateral sides, median post sutural vittae absent on the scutum (Figure 4a), more than one transverse band from the costal border on the underside of the wing (Figure 4a and b) and the abdomen III–V is reddish-brown in color with a black color on the lateral side of the third group (Figure 4c). This fruit fly species exhibits different characteristics than the other *Bactrocera* species.

**Abundance and Distribution**

A total of 14,480 individual fruit flies were collected from three study sites. The *B. dorsalis* were the most common species found in all study sites accounting for 85% of total abundance. The other identified species were included *B. carambolae* (accounting for 14% of total abundance), interspecific hybrid species of *B. carambolae* and *B. dorsalis* and *B. umbrosa* with few individuals (Table 1). Among the mango cultivars, “Cengkir” demonstrated the highest infestation rate by all fruit fly types (2,277.7 individuals), whereas “Arumanis” exhibited the lowest infestation rate (1,235.3).
Table 1. Species and number of individual fruit flies attacking three cultivars of Mango from study sites collected by random sampling.

| Study sites | Selling level | Varieties          | Fruit flies abundances |
|-------------|---------------|--------------------|------------------------|
|             |               |                    | B. dorsalis | B. carambolae | Interspecific hybrid | B. umbrosa | total  |
| Sumedang    | Orchard       | Gedong Gincu       | 293         | 63           | 0                    | 0          | 356    |
|             |               | Cengkir            | 625         | 180          | 7                    | 0          | 812    |
|             |               | Arumanis           | 441         | 59           | 3                    | 0          | 503    |
|             | Middleman     | Gedong Gincu       | 94          | 31           | 0                    | 0          | 125    |
|             |               | Cengkir            | 262         | 80           | 16                   | 0          | 358    |
|             |               | Arumanis           | 400         | 100          | 4                    | 3          | 507    |
|             | Vendor        | Gedong Gincu       | 157         | 9            | 0                    | 0          | 166    |
|             |               | Cengkir            | 303         | 9            | 0                    | 0          | 312    |
|             |               | Arumanis           | 92          | 79           | 2                    | 0          | 173    |
| Majalengka  | Orchard       | Gedong Gincu       | 412         | 41           | 2                    | 0          | 455    |
|             |               | Cengkir            | 719         | 219          | 20                   | 0          | 958    |
|             |               | Arumanis           | 446         | 106          | 5                    | 0          | 557    |
|             | Middleman     | Gedong Gincu       | 244         | 45           | 2                    | 0          | 291    |
|             |               | Cengkir            | 486         | 94           | 3                    | 0          | 583    |
|             |               | Arumanis           | 254         | 65           | 4                    | 0          | 323    |
|             | Vendor        | Gedong Gincu       | 193         | 21           | 2                    | 0          | 216    |
|             |               | Cengkir            | 215         | 47           | 2                    | 0          | 264    |
|             |               | Arumanis           | 244         | 25           | 3                    | 0          | 272    |
| Indramayu   | Orchard       | Gedong Gincu       | 1398        | 65           | 2                    | 0          | 1465   |
|             |               | Cengkir            | 2086        | 144          | 1                    | 0          | 2231   |
|             |               | Arumanis           | 462         | 70           | 1                    | 0          | 533    |
|             | Middleman     | Gedong Gincu       | 553         | 65           | 7                    | 0          | 625    |
|             |               | Cengkir            | 737         | 234          | 11                   | 0          | 982    |
|             |               | Arumanis           | 381         | 76           | 2                    | 0          | 459    |
|             | Vendor        | Gedong Gincu       | 232         | 10           | 0                    | 0          | 242    |
|             |               | Cengkir            | 255         | 78           | 0                    | 0          | 333    |
|             |               | Arumanis           | 327         | 52           | 0                    | 0          | 379    |
| **Sum total** |              |                    | **12311**   | **2067**     | **99**               | **3**      | **14480** |

Table 2. Summary of F statistic followed by significance of fruit fly abundance and diversity among locations, selling levels and cultivars.

| Dependent variables | Location | Selling level | Cultivars |
|---------------------|----------|---------------|-----------|
|                     | F        | p             | F         | p         | F         | p         |
| B. dorsalis         | 3.04     | 0.067         | 5.31      | 0.012     | 1.27      | 0.300     |
| B. carambolae       | 0.28     | 0.760         | 4.20      | 0.027     | 6.37      | 0.006     |
| Interspecific hybrid| 0.40     | 0.674         | 2.27      | 0.125     | 3.02      | 0.067     |
| Diversity value     | 1.22     | 0.313         | 5.61      | 0.010     | 2.31      | 0.121     |

Statistically, there was no significant variation of the fruit fly abundance among the study sites. The abundance of B. dorsalis was significantly varied among selling levels (F = 5.31; P < .05, while that among the cultivars did not differ significantly. The abundance of B. carambolae was also significantly different between selling levels (F = 4.20; P < .05) and cultivars (F = 6.37; P < .01), while that of interspecific hybrid did not show a significant variation. The species diversity showed a significant variation among selling level (F = 5.61; P < .05) (Table 2). Although the infestation rate was the lowest in “Arumanis,” the distribution of infestation among selling levels was almost even (Figure 5). The infestation rate by B. dorsalis is high, even at the vendor level, and the number of individual fruit flies only decreased by less than 50%, while other cultivars demonstrate a decrease by more than 60%. The infestation rate by B. carambolae was also high, even at the vendor level and the number of individual fruit flies only decreased by less than 25%, while other cultivars decreased by more than 70%.
The results showed that the diversity value of fruit fly species in the “Gedong Gincu,” “Cengkir” and “Arumanis” cultivars at each sampling location was low. The low level of fruit fly diversity was due to the high numerical dominance of B. dorsalis. The “Cengkir” and “Arumanis” cultivars tended to be more infested with various fruit fly species than “Gedong Gincu” (Table 3).

**Table 3.** Fruit fly species diversities (H') and dominances (D) of fruit fly species at various sampling locations.

| Study sites          | Selling level | Cultivars   | H'  | D   |
|----------------------|---------------|-------------|-----|-----|
| Sumedang             | Orchard       | Gedong Gincu | 0.46 | 0.71 |
|                      |               | Cengkir     | 0.56 | 0.64 |
|                      |               | Arumanis    | 0.48 | 0.72 |
|                      | Middle man    | Gedong Gincu | 0.57 | 0.62 |
|                      |               | Cengkir     | 0.68 | 0.61 |
|                      |               | Arumanis    | 0.58 | 0.65 |
|                      | Traditional vendor | Gedong Gincu | 0.20 | 0.89 |
|                      |               | Cengkir     | 0.09 | 0.95 |
|                      |               | Arumanis    | 0.64 | 0.57 |
| Majalengka           | Orchard       | Gedong Gincu | 0.35 | 0.82 |
|                      |               | Cengkir     | 0.57 | 0.68 |
|                      |               | Arumanis    | 0.50 | 0.70 |
|                      | Middle man    | Gedong Gincu | 0.43 | 0.76 |
|                      |               | Cengkir     | 0.44 | 0.74 |
|                      |               | Arumanis    | 0.56 | 0.66 |
|                      | Traditional vendor | Gedong Gincu | 0.31 | 0.90 |
|                      |               | Cengkir     | 0.48 | 0.83 |
|                      |               | Arumanis    | 0.33 | 0.84 |
| Indramayu            | Orchard       | Gedong Gincu | 0.21 | 0.89 |
|                      |               | Cengkir     | 0.30 | 0.82 |
|                      |               | Arumanis    | 0.40 | 0.76 |
|                      | Middle man    | Gedong Gincu | 0.43 | 0.74 |
|                      |               | Cengkir     | 0.57 | 0.64 |
|                      |               | Arumanis    | 0.51 | 0.69 |
|                      | Traditional vendor | Gedong Gincu | 0.14 | 0.91 |
|                      |               | Cengkir     | 0.37 | 0.75 |
|                      |               | Arumanis    | 0.36 | 0.79 |
**Table 4.** Analysis of Mango nutritious contents (%) from study sites collected by random sampling.

| Variables     | Gedong Gincu | Cengkir | Arumanis |
|---------------|--------------|---------|----------|
| Water &superscript; | 85.83 ± 1.94<sup>a</sup> | 86.46 ± 1.40<sup>a</sup> | 86.12 ± 4.64<sup>a</sup> |
| Ash &superscript; | 0.28 ± 0.02<sup>a</sup> | 0.30 ± 0.02<sup>a</sup> | 0.32 ± 0.11<sup>a</sup> |
| Fat &superscript; | 0.70 ± 0.12<sup>a</sup> | 0.83 ± 0.18<sup>a</sup> | 0.94 ± 0.12<sup>a</sup> |
| Protein<sup>*</sup> | 0.19 ± 0.04<sup>a</sup> | 0.30 ± 0.02<sup>a</sup> | 0.24 ± 0.05<sup>a</sup> |
| Carbohydrate<sup>rs</sup> | 13.56 ± 1.92<sup>a</sup> | 12.47 ± 1.37<sup>a</sup> | 12.38 ± 4.46<sup>a</sup> |

*ns = not significant, * = p < 0.05, content of variable followed by different alphabet means that the statistical analysis is significant

**Table 5.** Average pupa weight (gr) of fruit flies from study sites collected by random samplings.

| Study sites | Gedong Gincu | Cengkir | Arumanis |
|-------------|--------------|---------|----------|
| Sumedang    | 0.0127       | 0.0123  | 0.0139   |
| Majalengka  | 0.0137       | 0.0128  | 0.0135   |
| Indramayu   | 0.0132       | 0.0130  | 0.0134   |
| Average     | 0.0132       | 0.0127  | 0.0136   |

**Nutritional Content of Mango**

The results of testing the nutritional content of mangoes showed that the percentage of nutritional content varied among the cultivars. The protein content of the “Cengkir” cultivar was the highest (0.30 ± 0.0%), while that in “Gedong Gincu” was the lowest (0.19 ± 0.04%). The water content of the “Cengkir” cultivar is also higher than the other two cultivars. The carbohydrate content in “Gedong Gincu” cultivar is higher than the other two cultivars. The ash and fat content in the “Arumanis” cultivar is higher than the other two cultivars. Statistical analysis showed that the difference in protein content between cultivars was significant, while the other parameters were not significant (Table 4).

Based on the results of the Pearson’s correlation test, the nutritional content of mango fruit including water, ash, fat, protein and carbohydrates contents with the abundance and diversity of fruit fly species in this study was not significant (P > .05). The weak correlation indicates the low effect of fruit nutrition on the abundance and diversity of fruit fly (Table 4).

**Relationship between Mango Nutrient Content and Pupae Weight**

The highest average pupa weight was found in “Arumanis” cultivar (0.0136 gr), and the lowest was found in the “Cengkir” cultivar (0.0127 gr) (Table 5).

**Discussion**

This study indicated that fruit fly infestation occurred on mango in all locations, ranging from orchards to vendors. This indicates a weak quality assurance process, which affects the distribution of fruit flies. Pest control should be applied before harvest and a strict selection process base on international standards should be presented at harvest to prevent pests from spreading.

High pests in the orchard are allegedly due to ineffective pest control and the lack of sanitation at the location of the land. The development of fruit flies continued to increase because the infected fruits ruin on the ground remains uncontrolled. Therefore, land sanitation must be improved to break the fruit fly life cycle and suppress their development (Ditlin Hortikultura, 2018). Proper sanitation in mango orchard may reduce the intensity of fruit fly attacks by up to 20% (Hasyim et al., 2008).
Our study found that *B. dorsalis* and *B. carambolae* are important pests in mango cultivation in West Java. This result is consistent with other studies in Asia and Africa region because *Bactrocera dorsalis* are classified as cosmopolitan species (Jayanthi et al., 2012; Salmah et al., 2017; Waterhouse, 1993). The *B. dorsalis* is a very important pest and is recognized worldwide as a quarantine pest infesting over 50 different kinds of tropical fruit and horticultural crops (Ekesi and Mohamed, 2011; Srimartpirom et al., 2018). Another species, *B. carambolae*, was detected in several Southeast Asia countries (Win et al., 2014). According to Wee (2000), this species has been discovered since the early 1990s through traps baited by methyl eugenol in the Malaysian ecosystem. This shows that natural crossovers can occur in nature. In addition, another study reported that catch using methyl eugenol succeeded in collecting 62% of interspecific hybrid of fruit flies.

The low diversity value of fruit flies infesting each mango cultivar was due to the dominance of a species. The dominance value of the fruit flies in all cultivars is close to one, indicating the existence of species domination (Rahayu et al., 2015). In each cultivar, a diversity variance is found where the “Cengkir” and “Arumanis” cultivars exhibit a diversity index value, which tends to be higher than the “Gedong Gincu” cultivars.

Our study collected a great number of *B. dorsalis* individuals in all fruits. *Bactrocera dorsalis* is a species with the highest abundance level among other fruit fly species in Indonesia (Pramudi et al., 2013). This species is widely distributed in very high populations and is polyphagous, able to take advantage of various species of fruit plants as hosts that are available all seasons. In addition, this fruit fly exhibits the largest host range and high adaptability to several abiotic factors (Ginting, 2009). A previous study also reported that *Bactrocera dorsalis* has a high population density in all research locations (Syaukani and Ali, 2016). The existence of this species corresponds with its host availability that supports its survival. The host plants were found in all research locations such as guava (*Psidium guajava*), star fruit (*Averrhoa carambola*), banana (*Musa paradisiaca*), watery rose apple (*Syzygium aqueum*) and vegetables. Some of those hosts are perennial plants such as banana, chili (*Capsicum frutescens*) and tomato (*Solanum lycopersicum*). Seven factors are interrelated in determining the degree of fluctuation of fruit fly species diversity, namely time, spatial heterogeneity, competition, predation, climate stability, cultivation techniques and productivity.

The preference of fruit flies to the “Cengkir” cultivar may associate with the high protein content in the fruit tissue. From these results, this study assumes that the high protein content attracts the presence of female flies to lay their eggs. In contrast with these results, the low number of individuals attacking “Arumanis” cultivar produces higher pupal weight. This may be due to competition among larvae in the former cultivar can hamper their growth. The assumption exists that the level of competition tends to affect pupal weight. The more larve abundance in the fruit leads the nutritional competition. The poor developmental conditions of fruit flies are characterized by insufficient of nutrient sources due to high larval competition, which affects the body size of the imago.

**Conclusion**

*Bactrocera dorsalis, B. carambolae* and an interspecific hybrid of both species were found on mangoes in Indramayu, Majalengka and Sumedang Regencies, Indonesia. The *B. umbrosa* was merely found on mangoes in Sumedang Regency. The *B. dorsalis* dominated the specimen of all mango cultivars. The nutritional content of mangoes did not correlate with the abundance, species diversity and weight of fruit fly pupae.

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Data availability statement

The authors state that all data generated or analyzed during this study are included in this article. The full data used to support the findings of this study are available from the corresponding author upon request https://repository.unpad.ac.id/frontdoor/index/index/docId/200569

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