Comparative effectiveness of three types of pheromones against *Rhynchophorus vulneratus* (Panzer) and *Oryctes rhinoceros* (L.) in Indonesia

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**Abstract.** *Rhynchophorus vulneratus* and *Oryctes rhinoceros* are two major pests that cause serious damage to coconut palms leading to a significant coconut yield loss. Several pheromones have shown the potential as lures for these insect pests. This study aimed to measure the effectiveness of Oricmas, Rhynchomonas, and Feromonas, the three types of pheromones, against *R. vulneratus* and *O. rhinoceros*. In this study, traps baited with each pheromone were installed at the four Research Stations of IPCRI in North Sulawesi, was infected by *R. vulneratus* and *O. rhinoceros*. Two locations were selected in each station, and at each location, three traps were installed with different pheromones. The research was carried out from April to September 2020. A total number of 3723 *R. vulneratus* and *O. rhinoceros* were trapped during the study. Oricmas pheromone showed the most effective to trap *R. vulneratus* and *O. rhinoceros* compared to Rhynchomonas and Feromonas. The number of *R. vulneratus* and *O. rhinoceros* trapped was 51.18% and 49.82%, respectively. Rhynchomonas demonstrated its effectiveness to trap *R. vulneratus*, while did Feromonas to *O. rhinoceros*. For monitoring and controlling *Rhynchophorus* and *Oryctes*, respectively. Oricmas could be used, while Rhynchomonas and Feromonas for monitoring and controlling *Rhynchophorus* and *Oryctes*, respectively.

**Keywords:** Pheromone types, palm weevil, rhinoceros beetle, coconut

**1. Introduction**

Coconut palm (*Cocos nucifera* L.) plays an important role in the life of people in many countries. It is a major source of income for ca. 23 million farmers worldwide [1]. In Indonesia, more than 95% of the coconut palm was cultivated by farmers. The area of coconut plantations in Indonesia is 3,417,951 ha, which is dominated by smallholder plantations covering an area of 3,385,085 ha (99.04%), large state plantations covering an area of 3,842 ha (0.11%), and large private plantations covering an area of 29,024 ha (1.02%) , with a total production of 2,840,148 tons, consisting of smallholder plantations of 2,807,930 tons (98.86%), large state plantations of 1,805 tons (0.08%), and large private plantations of 29,791 tons (1.05%) [2]. This production is still low compared to the average production of superior coconut palm with the potential production >3 tons/ha. Several factors can decrease coconut production, including pests and diseases factor.
Two of the major pests in Coconut are *Rhynchophorus vulneratus* (Coleoptera: Curculionidae), known as Asian Palm Weevil (APW), and *Oryctes rhinoceros* (Coleoptera: Scarabaeidae), known as Coconut Rhinoceros Beetle (CRB). These two types of pests can inhibit the development of coconut plants in Indonesia because they can cause a decrease in production and death of the affected plants. Beetles and larvae of *Rhynchophorus* can develop in stems, shoots, rachis, coconut inflorescences and early symptoms of attack are difficult to detect so this pest is difficult to control. Adult beetles *O. rhinoceros* fly into the coconut canopy at night and enter through one of the axils at the top of the canopy, making a noise while entering the leaf axil. Damage occurs to young leaf midribs, only few beetles are required to cause high losses. A heavy attack can cause death of the palm, at one year old or younger, the entry point could be at the base of the stem at ground level. Damage to the base of the frond or stem could result in the breaking of the frond. The beetle could damage four fronds in a week [1].

In Indonesia, previously known, there are three species of *Rhynchophorus*, namely *Rhynchophorus ferrugineus* (Olivier), *Rhynchophorus vulneratus* Panzer, and *Rhynchophorus bilineatus* (Montrouzier) [3, 4]. However, with the development of science and technology, molecular insect identification techniques have also been developed. Based on molecular identification, *R. vulneratus* Panzer and *R. ferrugineus* (Olivier) should be considered color morphs of the same species and be synonymized under the name *R. ferrugineus* (Olivier) [5]. Based on the palm weevil samples collected from several study locations, only two species exist in Indonesia, namely, *R. vulneratus* and *R. bilineatus* [6]. Based on the molecular-genetics study [7], they confirmed that the Palm Weevil *R. vulneratus* (Panzer 1798) is a valid species distinct from *R. ferrugineus* (Olivier 1790). It has been proven that *R. vulneratus* and *R. ferrugineus* are morphologically distinct species [8]. Therefore, in this study, we used *R. vulneratus* as a different species from *R. ferrugineus*. The economic significances of APW lie mainly in the infestation of young coconut plantations. Without prior warning, several crowns of the trees may collapse, and the palms die; examination of the growing points reveals that crowns have been bored by the larvae [4].

*O. rhinoceros* is commonly known by coconut farmers in Indonesia [1], spreads in almost all coconut plantations in Indonesia [9], S.E. Asia, and the islands of the S.W. Pacific, in all localities where coconut or other palms are grown [4]. This beetle caused significant losses because of the damage to young leaves, which is very influential on coconut production [1]. The control techniques proposed are utilizing natural enemies of Fungi *Metarhizium anisopliae*, Entomopathogen Virus: *Oryctes* Nudivirus (OrNv), utilizing pheromone-based traps, and other control techniques. Several pheromone research programs to identify and develop pheromones as tools in IPM programs, including *O. rhinoceros, R. ferrugineus, and R. vulneratus* were undertaken in Indonesia[10].

Male American palm weevils *Rhynchophorus palmarum* produced two sex-specific compounds, the major male-produced volatile was identified as (2E)-6-methyl-2-heptene-4-ol with the trivial name rynchophorol, which proved to be the essential component of the APW aggregation pheromone [11]. The male of palm weevils produces 4 -methyl -5- nonanol (ferrugineol) and 4-methyl -5-nonanone (femigineone), the first of which is an aggregation pheromone. Both *R. ferrugineus* and *R. vulneratus* produced and responded to the 4S, 5S-isomer of ferrugineol, and production and antennal response to 4S-ferrugineone exceeded that of its antipode in both weevils [10].

Male of *O. rhinoceros*, produce three sex-specific compounds, ethyl 4-methyl octanoate, ethyl 4-methyl heptanoate, and 4-methyl octanoic acid, the first of which is an aggregation pheromone. Infield trapping experiments (4S)-ethyl 4-methyl octanoate and the racemic mixture were equally attractive and ten times more effective in attracting beetles than ethyl chrysanthemumate, a previously recommended attractant. Results of this study indicate that there is potential for using ethyl 4-methyl octanoate in operational programs to control *O. rhinoceros* in oil palm plantations [12]. Traps containing aggregation pheromone, Ethyl 4-methyl octanoate, and old coconut wood in pheromone traps caught significantly more CRB than traps containing the pheromone or old coconut wood alone [13].

Pheromones are chemical signals released by certain organisms that may stimulate a response from another individual of the same species. Aggregation pheromone from the male adult CRB can attract both female and male [14]. In addition to the role of pheromones as a control tool, they can also be used to monitor the pest populations in the field as part of the control strategy. This study aimed to measure
the effectiveness of Oricmas, Rhynchomonas, and Feromonas, the three types of pheromones, against \textit{R. vulneratus} and \textit{O. rhinoceros}.

2. Material and methods

The research was conducted at the four Research Stations, namely: KP Mapanget, KP Paniki, KP Kaiwatu, and KP Kima Atas of Indonesian Palm Crops Research Institute (IPCRI) in North Sulawesi, Indonesia. The research was carried out from April to September 2020.

In this study, traps baited with each pheromone were installed at the four Research stations of IPCRI in North Sulawesi, Indonesia, naturally infected by \textit{R. vulneratus} and \textit{O. rhinoceros}. Two locations were selected in each station and at each location three traps were installed with different pheromones. Research location in KP Mapanget, the trap was installed on the mature palm of Hengniu hybrid, Raja Dwarf (GRA), Tebing Tinggi Dwarf (GTT) and Jombang Green Dwarf (GHJ), the distance between location is around 200-300 m. Research locations in KP Paniki the trap were install in young oil palm and Ima Hybrid. In KP Kaiwatu, the trap was installed on young Bido Tall and Hybrid coconut, while in KP Kima Atas, the trap was installed on composite coconut and Salak Dwarf (GSK) with the distance between location about 500 m. The distance between locations is about 100 m. The pest population was observed every two days, while the observation of palm damage was conducted before and after treatment. The position of each pheromone trap in the research location is as in Table 1.

| No. | Location | Coordinate                  | Vegetation  |
|-----|----------|-----------------------------|-------------|
| M1  | KP Mapanget, HengNiu (1) (O) | 01°30’56.3″N 124°56’03.8″E | Coconut     |
| M2  | KP Mapanget, HengNiu (2) (F) | 01°30’53.7″N 124°56’02.1″E | Coconut     |
| M3  | KP Mapanget, HengNiu (3) (R) | 01°30’54.8″N 124°56’04.5″E | Coconut     |
| M4  | KP Mapanget, GRA (4) (O) | 01°30’58.4″N 124°55’50.1″E | Coconut     |
| M5  | KP Mapanget, GTT (5) (F) | 01°30’56.8″N 124°55’51.0″E | Coconut     |
| M6  | KP Mapanget, GHJ (6) (R) | 01°30’59.4″N 124°55’48.2″E | Coconut     |
| P1  | KP Paniki, Sawit (1) (O) | 01°30’57.0″N 124°55’33.8″E | Oil Palm, corn, peanut |
| P2  | KP Paniki, Sawit (2) (F) | 01°30’57.2″N 124°55’36.2″E | Oil Palm, corn, peanut |
| P3  | KP Paniki, Sawit (3) (R) | 01°30’54.1″N 124°55’35.8″E | Oil Palm, corn, peanut |
| P4  | KP Paniki, IMA (4) (O) | 01°30’48.7″N 124°55’35.5″E | Coconut, corn |
| P5  | KP Paniki, IMA (5) (F) | 01°30’46.8″N 124°55’31.4″E | Coconut, corn |
| P6  | KP Paniki, IMA (6) (R) | 01°30’49.8″N 124°55’38.1″E | Coconut, corn |
| K1  | KP Kaiwatu, Bido (1) (O) | 01°29’53.7″N 124°53’47.4″E | Coconut, citrus, date palm |
| K2  | KP Kaiwatu, Bido (2) (F) | 01°29’51.3″N 124°53’48.1″E | Coconut, citrus, date palm |
| K3  | KP Kaiwatu, Bido (3) (R) | 01°29’55.9″N 124°53’48.4″E | Coconut, citrus, date palm |
| K4  | KP Kaiwatu, Hibrida (4) (O) | 01°29’48.7″N 124°53’50.2″E | Coconut, betel nut, corn |
| K5  | KP Kaiwatu, Hibrida (5) (F) | 01°29’45.7″N 124°53’50.9″E | Coconut, betel nut, corn |
| K6  | KP Kaiwatu, Hibrida (6) (R) | 01°29’43.9″N 124°53’53.3″E | Coconut, betel nut, corn |
| A1  | KP KimaAtas, Komposit (1)(O) | 01°32’38.0″N 124°54’42.6″E | Coconut     |
| A2  | KP KimaAtas, Komposit (2)(F) | 01°32’40.5″N 124°54’39.7″E | Coconut     |
| A3  | KP KimaAtas, Komposit (3)(R) | 01°32’40.5″N 124°54’44.3″E | Coconut     |
| A4  | KP KimaAtas, GSK (4)(O) | 01°32’54.8″N 124°54’38.5″E | Coconut, corn |
| A5  | KP KimaAtas, GSK (5)(F) | 01°32’56.6″N 124°54’39.9″E | Coconut, corn |
| A6  | KP KimaAtas, GSK (6)(R) | 01°32’58.9″N 124°54’36.9″E | Coconut, corn |

Notes: O = Oricmas; F= Feromonas; R= Rhynchomonas
3. Result and discussion

3.1. Population’s fluctuations of R. vulneratus weevil and O. rhinoceros’ beetle

The results of 160 days of observations showed that the number of R. vulneratus weevils trapped every day varied between 8.7 – 21.7 weevils or an average of 11.88 weevils/day with a mean number of female weevils always trapped higher than the male weevils (Figure 1), while the O. rhinoceros beetles trapped every day varied between 5.2 – 17.4 beetles or an average of 10.81 beetles/day (Figure 2). The population of R. vulneratus weevils trapped was slightly constant and tended to increase. On the other hand, the average population of O. rhinoceros beetles for 160 days of observation showed a decreased pest population after 90 days (3 months) of pheromone trap installation (Figure 3). It has been reported that ferrugineol-based pheromone traps trapped young, gravid and fertile female weevils; pheromone trapping can play a significant role in mass trapping programs, which to suppress the pest population in the field [15].

![Figure 1. Population fluctuation of R. vulneratus weevils trapped during 160 days using pheromones traps (Feromonas, Rhynchomonas, and Oricmas) in four Research Stations of IPCRI.](image1)

![Figure 2. Population fluctuation of O. rhinoceros beetles trapped during 160 days using pheromones traps (Feromonas, Rhynchomonas, and Oricmas) in four Research Stations of IPCRI.](image2)
3.2. Populations of R. vulneratus and O. rhinoceros beetles in four Research Stations

Table 2, showed that the R. vulneratus trapped in KP KimaAtas was 889 weevils, which is higher than in KP Mapanget (366 weevils), KP Kayuwatu (363 weevils), and KP Paniki (283 weevils). The R. vulneratus population between each location was highly dependent on the population of these pests in the field. From the 1901 R. vulneratus weevils trapped during the study, it was found that the trapped females (70.91%) were higher than the males (29.09%). The sex ratio (male: female) of R. vulneratus at each Research station varied from 1:2.21 to 1:2.63, similar to the sex ratio based on pheromones type that was varied from 1:2.14 to 1:2.65. Aggregation pheromones, Rhynchomonas, can capture 77.78% female and 22.28% male of Rhynchophorus [9]. The results of this study indicate that R. vulneratus weevils are more attracted to Rhynchomonas pheromone (48.29%) than Oricmas (43.44%) and Feromonas 8.26%.

The population of O. rhinoceros beetles was trapped from each Research Station is as follows: KP Kima Atas (587 beetles), KP Paniki (509 beetles), KP Kayuwatu (399 beetles, and KP Mapanget (327 beetles) (Table 2). The number of CRB trapped was lower than APW, indicating that APW is potentially starting to damage coconut palm at the Research Station of IPRCI. From the total number of 1822 O. rhinoceros beetles trapped during the study, the females trapped (56.70%) were higher than males (43.30%). Feromonas pheromone, are capable of capturing 57% female and 43% male of O. rhinoceros in a coconut plantation, in young oil palm plantation a total number 2201 CRB trapped (61.20% female and 38.80% male), and in mature oil palm plantation, a total number 751 CRB trapped (69.51% female and 30.49% male) [9]. The number of O. rhinoceros caught six months after application using the synthetic pheromone ethyl-4-methyl octanoate indicated that the pheromone was effectively in controlled O. rhinoceros pests. A total of 206 O. rhinoceros beetles (89 males and 119 females or 1:1.34) were trapped after 6 months of application in 6 ha of coconut plantation area. So the average number of O. rhinoceros caught is about 5.6 beetles/ha/month. The data showed that the number of female insects caught was more than that of the male insects. The same results were also observed by several countries that carried out the same test such as the Philippines, Malaysia, Thailand, India, and Sri Lanka using synthetic aggregation pheromones but with different trade names [14]. The type of pheromone used as a trap for the pest O. rhinoceros is classified as an aggregation pheromone. So, both female and male insects can be trapped.
The sex ratio of *O. rhinoceros* at each location varied from 1:1.22 to 1:1.57, different with the sex ratio based on pheromones type varied from 1:1.27 to 1:2.50. These data indicated that Rhynchomonas pheromones tend to capture more females of *R. vulneratus* weevils and *O. rhinoceros* beetles higher than Oricmas and Feromonas. About 85 percent of pheromone trap-captured female weevils were fertile and laid viable eggs, that indicating that they had already mated before entering the traps [15]. Therefore, the pheromone-based trap was very effective in cutting the continuity of the pest cycle on the field. Overall, based on location and pheromone type can be seen that the sex ratio of *R. vulneratus* higher than *O. rhinoceros* beetles except on Rhynchomonas pheromone. The results of this study indicated the *O. rhinoceros* beetle was more attracted to Feromonas pheromone (50.77%) than Oricmas (45.01%) and Rhynchomonas 4.23% (Table 2).

A total number of 3723 *R. vulneratus* weevils and *O. rhinoceros* beetles were trapped during the study. Oricmas pheromone showed the most effective to trap both pests, *R. vulneratus* and *O. rhinoceros*, compared to Rhynchomonas and Feromonas. The number of *R. vulneratus* and *O. rhinoceros* trapped was 43.45% and 45.01%, respectively (Figure 4). Rhynchomonas show its effectiveness to trap *R. vulneratus*, while did Feromonas to *O. rhinoceros*. For monitoring and controlling *R. vulneratus* and *O. rhinoceros*, Oricmas could be used, while Rhyncomonas and Feromonas for monitoring and controlling *R. vulneratus* and *O. rhinoceros*, respectively.

**Table 2.** Sex ratio of *R. vulneratus* and *O. rhinoceros* trapped based on location and type of pheromones.

| Location / Pheromones | Population of *R. vulneratus* | Sex Ratio of *R. vulneratus* | Population of *O. rhinoceros* | Sex Ratio of *O. rhinoceros* |
|-----------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|
| Location              | ♂ | ♀ | Total | ♂ | ♀ | Total | ♂ | ♀ | Total |
| KP KimaAtas           | 255 | 634 | 889 | 1 | 2.49 | 261 | 326 | 587 | 1 | 1.25 |
| KP Kayuwatu           | 100 | 263 | 363 | 1 | 2.63 | 172 | 227 | 399 | 1 | 1.32 |
| KP Paniki             | 84  | 199 | 283 | 1 | 2.37 | 229 | 280 | 509 | 1 | 1.22 |
| KP Mapanget           | 114 | 252 | 366 | 1 | 2.21 | 127 | 200 | 327 | 1 | 1.57 |
| Pheromone             |     |     |     |     |     |     |     |     |     |     |
| Oricmas               | 254 | 572 | 826 | 1 | 2.25 | 362 | 458 | 820 | 1 | 1.27 |
| Feromonas             | 50  | 107 | 157 | 1 | 2.14 | 405 | 520 | 925 | 1 | 1.28 |
| Rhynchomonas          | 249 | 669 | 918 | 1 | 2.69 | 22  | 55 | 77  | 1 | 2.50 |
| Total                 | 553 | 1348 | 1901 | 789 | 1033 | 1822 |
| Percentage            | 29.09 | 70.91 |     | 43.30 |     | 56.70 |

**Figure 4.** The number of *R. vulneratus* weevils and *O. rhinoceros* beetles trapped during 160 days using pheromones (Oricmas, Feromonas, and Rhynchomonas, at the four Research Stations of IPCRI.
3.3. Palm damage
Coconut damage due to *O. rhinoceros* varied among the four locations. The results showed that the *O. rhinoceros* attack varied from 0.07 – 0.53 cut/frond. After four months of using pheromones, the Coconut cultivars showed a decrease in the number of frond damage, except in Hybrid and GTT varieties, which both tend to increase (Figure 5). This trend was related to the resistance of the coconut to the attack of the pest, and future research needs to be conducted. The lowest damage was found in the Composite coconut, and the highest was in the Heng Niu hybrid coconut. Based on the theory, 2-3 actively eating beetle in a hectare can lead to the decrease of production to 18%. The result shows that the Pheromone-based trap can decrease to 0.23 cut/frond which can be estimated that the decrease in production will only <10% and the number of actively beetle is <1% [16].

![Figure 5. Palm damage (cut/frond) in several coconut cultivars at the Research Station of IPCRI.](image)

Note: M1,2,3=KP Mapanget, HengNiu; M4= KP Mapanget, GRA; M5= KP Mapanget, GTT; M6= KP Mapanget, GHJ; K1,2,3= KP Kaiwatu-Bido Tall; K4,5,6 = KP Kaiwatu, Coconut Hybrid; A1,2,3 = KP KimaAtas, Composite; A4,5,6 = KP KimaAtas, GSK.

**Conclusion**
A total number of 1901 *R. vulneratus* weevils and 1822 *O. rhinoceros* beetles (3723 weevils and beetles) were trapped during the study. Oricmas pheromone showed the most effective to trap both pests, *R. vulneratus* and *O. rhinoceros*, compared to Rhynchomonas and Feromonas. The number of *R. vulneratus* and *O. rhinoceros* trapped was 43.45% and 45.01%, respectively. Oricmas can be used to monitor and control both *R. vulneratus* and *O. rhinoceros*, while Rhynchomonas and Feromonas can be separately used to monitor and control *R. vulneratus* and *O. rhinoceros*, respectively.

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