The influence of cropping pattern of pepper with citronella and lemongrass to the insect diversity and insect pests population

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Abstract. Lemongrass and Citronella contain essential oils which are repellent against insect pests. Research on the cropping pattern of pepper with lemongrass and citronella was conducted to determine the influence of two essential oil plants on the diversity and population of insect pests of pepper plants. The research was conducted at the Sukamulya Experimental Garden, from 2018 to 2020 on a 3000 m² planting plot. The treatments of the cropping patterns tested included: 1) Climbing pepper, 2) Climbing pepper + Shrub pepper, 3) Climbing pepper + Citronella, 4) Climbing pepper + Lemongrass, 5) Climbing pepper + Shrub pepper + Citronella, 6) Climbing pepper + Shrub pepper + Lemongrass. Each treatment was repeated twice. Observation parameters were insect diversity and insect pests, the level of pest attack, and the number of plants attacked. The results obtained about 66 species of insects from 46 families and 9 orders. The insects associated with the pepper cropping pattern ecosystem were relatively evenly distributed in all treatments, except for treatment 3, where only 4 types of insect pests were found. Pests, especially Thrips sp., were distributed in all treatments, but in the combination treatment with citronella and lemongrass, the population of Thrips sp. relatively low.

1. Introduction
Pepper (Piper nigrum L.) is a spice crop which is mostly (96%) cultivated in the form of smallholder plantations, while the rest (4%) is in the form of large private plantations [1]. Although it is not native to Indonesia, this India’s originated plant grows and develops well and has an important role in the national economy. Pepper was the first Indonesian spice product which was traded to Europe via Arabic and Persian. Before the Second World War, Indonesia was listed as the world’s largest producer of pepper and supplied 80% of the world’s demand for pepper [2]. In 2016, the export volume of Indonesian pepper was recorded at 53,099 tonnes with a value of US $ 430,146,092 consisting of 20,292 tonnes of white pepper, 28,598 tonnes of black pepper, and 4,209 tonnes in other forms of pepper [1]. Pepper is used as a food spice in both the household sector and the food industry.

Pepper planting centers in Indonesia are located in Lampung, Bangka, West Kalimantan, East Kalimantan and South Sulawesi. The total area in 2020 is estimated to be 189,662 ha with a production of 89,902 tonnes. Compared to 2003, which reached 204,364 ha, the area in recent years has decreased [1]. Among the contributing factors of the decreased are the national and world economic conditions,
the political and security situation, and the price of pepper. These conditions, doubled with minimal cultivation techniques, cause pepper crop production to decline.

The minimum cultivation technique causes low productivity of Indonesian pepper that is 0.4-0.8 tonnes/ha which still far below the potential production of the pepper varieties which have been released (3-4 tonnes/ha) [3]. To increase the productivity, application of pepper cultivation technology such as aspects of plant material, nutrient and plant management, as well as proper management of pests and diseases attack must be considered. The application of this cultivation technology should be applied in pepper cultivation which requires climbing poles (dead or living stands) and in cultivation of shrub pepper which does not require climbing poles.

Cultivation of pepper generally applies a monoculture pattern that relatively has higher risk than other annual crop farming, both economic and natural risks. One of the efforts to reduce this risk is through the application of cropping patterns with other plants [4]. An aspect that needs to be considered in cropping cultivation techniques is the compatibility between staple crops and intercrops. Apart from being not detrimental in the competition for biotic and abiotic elements, the application of cropping patterns is also expected to suppress/avoid pests and diseases [5].

Cropping pattern is expected to be an effort to increase income from other commodities besides pepper. Pepper-based cropping patterns can be done by planting citronella or lemongrass. These two types of plants, apart from being a source of additional income, are also have function as insect pest repellent. The scent of fragrant that plants produce can disrupt the attractive scent released by the host plant so that the movement of pests towards the host plant can be diverted. Therefore, citronella’s oil is widely used in botanical pesticide formulations. According to Damanik [6], citronella farming is very profitable, which produce Rp 24,500,000 for 2 years. Maximum profit is obtained at the fourth harvest. Meanwhile, besides cultivating lemongrass as additional income, according to Prasetyo et al [7] it can also be used as an ingredient in botanical pesticides that are effective against pests such as Plutella xylostella. The aim of the study was to determine the effect of citronella and lemongrass on insect diversity and insect populations of pests and diseases in pepper.

2. Materials and methods
The research was conducted from 2017 to 2019 in the Sukamulya Experimental Garden, Sukabumi Regency, West Java. The pepper plants used were Climbing Pepper and Shrub Pepper of Natar 1 varieties, while the intercrops were citronella (Cymbopogon nardus) variety of G2 and lemongrass (C. Citratus).

The environmental design used was a randomized block design. The treatments tested were: (a) climbing pepper, (b) climbing pepper + shrub pepper, (c) climbing pepper + citronella, (d) climbing pepper + lemongrass, (e) climbing pepper + shrub pepper + citronella, and (f) Climbing pepper + shrub pepper + lemongrass. Each treatment was repeated twice. Climbing pepper was planted on land with a spacing of 2.5 m x 2.5 m using gliricidia climbing poles on an area of 2 x 3000 m². Shrub pepper intercrops were planted between climbing peppers with the same spacing of 2.5 m x 2.5 m. Citronella and lemongrass were planted between the climbing pepper and in rows of shrub peppers. The plot design of crop pattern can be seen in Figure 1. Fertilization of the pepper and intercrops based on the recommendations.

Observations were made on the diversity of insects, population and level of pest and disease attack, number of plants attacked by pests and diseases, and production of intercrops. Insect sampling was carried out using yellow sticky trap method. A yellow board wrapped in plastic and smeared with insect glue which were hung from climbing pepper plant 1.5 m above the ground. There were 3 traps hanging per treatment plot. The sample was taken to the Entomology laboratory in Balittro, Bogor for identification. Observation of the population and intensity of attacks on pests and diseases of pepper was carried out on 5 samples of pepper plants. Calculation pest attack (Thrips sp.) were conducted by counting the number of leaves that showing symptoms, namely fold at the edges and fold and dry. Meanwhile, pests and other diseases were analyse by calculating the population and intensity of attacks
on the sample trees. Observations of pepper and intercrop were carried out at the end of each season’s harvest.

Figure 1. The plot design of crop pattern

3. Results and discussion

The diversity of insects from the use of yellow sticky traps was obtained as many as 66 species of insects from 46 families and 9 insect orders associated with the pepper cropping pattern ecosystem. The general status of these insects was dominated by natural enemy groups consisting of parasitoid and predatory insects, followed by pest groups that were scattered in each type of treatment (Table 1). Others are in the form of insect pollinators and other insects. The population of small insects from the orders Diptera and Hymenoptera and generally consists of many species and possibly from different families, but in general these insects are parasitoid insects.

Based on the distribution of each species of insect between treatments, the cropping pattern is relatively evenly distributed, only in the treatment of climbing pepper cropping patterns with citronella the least insect species compared to other treatments, this is probably due to the influence of the aroma of citronella essential oil which is repellent to insects, especially insect pests. From the insect data obtained, it can be seen that the population of *Thrips* sp. the most dominant was found compared to other insects in all cropping patterns. The lowest thrips population was found in the cropping pattern of climbing pepper + shrub pepper + lemongrass compared to other cropping patterns.

Table 1. The diversity of insects associated with the pepper cropping ecosystem in the cropping pattern with citronella and lemongrass intercropping

| Ordo/Family/Species | A | B | C | D | E | F | General status |
|---------------------|---|---|---|---|---|---|----------------|
| Coleoptera          |   |   |   |   |   |   |                |
| Coccinellidae       |   |   |   |   |   |   | Predator       |
| - Species 1         |   | + |   |   |   |   | Predator       |
| - Species 2         |   |   |   |   |   |   | Predator       |
| - Scymnus sp.       | + | + | - |   | + | + | Predator       |
| - Cocccinella       | - | + | - | + | - | + | Predator       |
| Lycidae             |   |   |   |   |   |   |                |
| - Species 11        | + | - | - | - | - | - | Predator       |
| Scolytidae          |   |   |   |   |   |   |                |
| Taxon                      | Species 1 | Species 2 | Species 3 | Species 4 | Species 5 | Species 6 | Species 7 | Species 8 | Species 9 | Species 10 | Species 11 |
|---------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|
| Curculionidae             |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | +         | -         | -         |           |           |           |            |           |
| Staphylinidae             |           |           |           |           |           |           | -         |           |           |            |           |
| - Species 1               | +         | -         | -         | -         | -         | -         |           |           |           |            |           |
| - Species 2               |           |           |           |           |           |           |           |           |           |            |           |
| Chrysomelidae             |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | +         | -         |           |           |           |           |            |           |
| Elateridae                |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | +         | -         | +         | -         | +         |           |           |            |            |           |
| Scarabaeida               |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | +         | -         |           |           |           |           |            |           |
| Diptera                   |           |           |           |           |           |           |           |           |           |            |           |
| Dolichopodidae            |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +++       | +         | ++        | -         | ++        | +         |           |           |           |            |           |
| - Species 2               |           |           |           |           |           |           |           |           |           |            |           |
| Lonchaeida                |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         | +         | +         |          | -         | -         |           |           |           |            |           |
| Tephritidae               |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         | -         | +         | +         |          | -         |           |           |           |            |           |
| Drosophilidae             |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         | +         | +         | +         |          |           |           |           |           |            |           |
| Culicidae                 |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | +         | +         | -         |           |           |           |            |           |
| Muscidae                  |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | +         | -         | +         | -         | -         |           |           |           |            |           |
| Agromyzidae               |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | +         |          |           |           |           |           |            |           |
| Bombyliidae               |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | +         |          |           |           |           |           |            |           |
| Tipulidae                 |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               |           |           |           |           |           |           |           |           |           |            |           |
| Mycetophilidae            |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | +         | -         | -         | -         |           |           |           |           |            |           |
| Small Diptera             |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +++       | ++        | ++        | ++        | ++        | ++        |           |           |           |            |           |
| Tachinidae                |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | +         | -         | +         |          |           |           |           |            |           |
| - Species 2               |           |           |           |           |           |           |           |           |           |            |           |
| Asilidae                  |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         |          |           |           |           |           |           |           |           |            |           |
| Syrphidae                 |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         |           |           |           |           |           |           |           |           |            |           |
| Anthomyiidae              |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         | -         | -         | +         |           |           |           |           |           |            |           |
| Stratiomyiidae            |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | -         | -         | -         | +         |           |           |           |           |            |           |
| Opomyzidae                |           |           |           |           |           |           |           |           |           |            |           |
| - Opomyza sp.             |           |           |           |           |           |           |           |           |           |            |           |
| Chironomidae              |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | -         | +         | -         | -         | +         |           |           |           |           |            |           |
| Anthomyiidae              |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         |           |           |           |           |           |           |           |           |            |           |
| Hymenoptera               |           |           |           |           |           |           |           |           |           |            |           |
| Ichneumonidae             |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         | +         | +         | -         | +         | +         |           |           |           |            |           |
| - Species 2               |           |           |           |           |           |           |           |           |           |            |           |
| Braconidae                |           |           |           |           |           |           |           |           |           |            |           |
| - Species 1               | +         | ++        | -         | +         |          | -         |           |           |           |            |           |
| - Brachymeria sp.         |           |           |           |           |           |           |           |           |           |            |           |
| - Species 3               |           |           |           |           |           |           |           |           |           |            |           |
| Insect Order | Family | Species | Climbing Pepper (A) | Shrubs (B) | Citronella (C) | Lemongrass (D) | Citronella + Lemongrass (E) | Pest Combination (F) |
|-------------|--------|---------|---------------------|-----------|----------------|----------------|--------------------------------|---------------------|
| Sphingidae   | - Species 1 | +       | -                   | -         | -              | +              | -                              | -                   |
| Formicidae   | - Oecophylla smaragdina | -       | +                   | -         | -              | -              | -                              | -                   |
|             | - Species 2 | -       | -                   | -         | -              | -              | -                              | -                   |
|             | - Species 3 | -       | -                   | +         | -              | -              | -                              | -                   |
|             | - Species 4 | +++      | +++                 | +         | +              | +              | +                              | +                   |
|             | - Species 5 | -       | -                   | -         | +              | -              | -                              | -                   |
| Diaphorididae| - Species 1 | -       | -                   | -         | +              | -              | -                              | -                   |
| Hymenoptera  | - Species 1 | +++      | ++                  | +         | +++            | +++            | ++                             | Parasitoid           |
| Apidae      | - Species 1 | -       | +                   | -         | -              | -              | -                              | Pollinator           |
|              | - Species 1 | -       | -                   | -         | -              | -              | -                              | Pollinator           |
| Vespidae    | - Species 1 | -       | -                   | -         | -              | -              | -                              | Pollinator           |
| Encyrtidae  | - Species 1 | -       | -                   | +         | -              | -              | -                              | Parasitoid           |
| Bromidae    | - Species 1 | -       | -                   | -         | ++             | -              | -                              | Predator            |
| Tenthredinida| - Species 1 | -       | -                   | -         | +              | Pollinator     | Pollinator                     |                    |
|              | - Species 1 | -       | -                   | -         | +              | Pollinator     | Pollinator                     |                    |
| Mymaridae   | - Species 1 | -       | -                   | -         | +              | -              | -                              | Pollinator           |
| Heteroptera  | - Species 1 | +       | ++                  | -         | -              | -              | -                              | Parasitoid           |
| Miridae     | - Species 1 | -       | -                   | -         | +              | +              | -                              | Pest                |
| Cicadellidae| - Bothrogonia sp | +       | +                   | +         | +              | +              | +                              | Pest                |
| Flatidae    | - Species 1 | -       | -                   | -         | -              | -              | +                              | Pest                |
| Aphididae   | - Species 1 | -       | -                   | -         | -              | -              | +                              | Pest                |
| Isoptera    | - Species 1 | +       | +                   | -         | +              | +              | +                              | Pest                |
| Termitidae  | - Species 1 | +       | +                   | -         | +              | +              | +                              | Pest                |
| Thysanoptera| - Species 1 | +       | +                   | -         | +              | +              | +                              | Pest                |

Note: A = climbing pepper, B = climbing pepper + shrub pepper, C = climbing pepper + citronella, D = climbing pepper + lemongrass, E = climbing pepper + shrub pepper + citronella, F = climbing pepper + pepper shrub + lemongrass.

Thrips sp. is a pepper leaf sucker which is mainly found attack young leaves [8]. Symptoms of damage caused by Thrips sp. are silvery spots on the leaves and curl at the edges of the leaves and also roll upward. Thrips are not only found in pepper [9,8] but also in nutmeg plants, such as Liothrips karnyi [10].

The results of the observation of Thrips sp., which was caught in the yellow sticky trap (Figure 2), shows that the pest population was found in all cropping patterns both in monoculture pepper cropping and with intercropping. The highest population was in the climbing pepper (A) plot, followed by climbing pepper and shrub (B) plots, then it decreased in other cropping plots. The lowest population was in the plots of the climbing pepper combine with citronella that are (C) and (E) plots. This shows that there is a decrease in the population in the cropping pattern plots using citronella and lemongrass plants compared to the pepper cropping patterns without citronella and lemongrass plants, possibly due to the repellency properties of the citronella and lemongrass plants. Citronella is known to contain citronellal, geraniol and citronellol [11]. Citronellal and geraniol compounds are known to be repellent.
against insects, especially insect pests [12,13]. Likewise, lemongrass also contains citronellal and geraniol, in addition to large amounts of citric acid [14,15]. The results of observations on damage to pepper plants were relatively not different in all treatments except for the treatment of cropping patterns with citronella plant which appeared to have lower attacks.

Figure 2 shows the population of *Thrips* sp. caught in the yellow sticky trap in March 2018. It can be seen that the population of *Thrips* sp. in the treatment plot of pepper plants planted with citronella and lemongrass plants appeared much lower than that obtained in the treatment plot of pepper plants that were not planted with citronella or lemongrass. In general, the increase in the population of *Thrips* sp. seems to be influenced by climatic factors. Population of *Thrips* sp. usually increases in dry season conditions or in conditions of low rainfall and low rain frequency. This is fit with the statement that abiotic factors such as temperature, humidity and rainfall determine the development and abundance of the population of *Thrips* sp. [16,17].

![Figure 2](image-url)

**Figure 2.** Population of *Thrips* sp. on the trap of each pattern treatment

L = climbing pepper, LLP = climbing pepper + shrub pepper, LSW = pepper climbing + lemongrass, LSD = climbing pepper + lemongrass, LLPSW = climbing pepper + shrub pepper + citronella, LLPSD = climbing pepper + shrub pepper + lemongrass.

High population of *Thrips* sp. cause damage of pepper leaves which appearing to fold at the edges (Figure 3). On further attack, the pepper leaves curl, dry, and die. Considering the high population of *Thrips* sp. and its impact on pepper, control was needed which was carried out using botanical insecticides. After controlling, the population of *Thrips* sp. on the field decreased sharply. The results of subsequent insects collection using a yellow sticky trap showed that the thrips population was very low (<5 individuals per trap) and evenly distributed in all cropping patterns.

The population of *Thrips* sp in pepper in 2019 was relatively low and rarely found in pepper plants. However, its presence in the field can be seen from the symptoms on the leaves that appear to fold and dry at the edges. This Thrips attack needs to be monitored, especially during low/dry rainfall, because the population usually increases.

From this research, besides obtaining data on insects diversity, it was also obtained data on the yields of pepper and intercrops (citronella and lemongrass). Each cropping pattern treatment gave different results. In terms of additional yields, the climbing pepper cropping pattern alone had no additional yield apart from the climbing pepper. From the climbing pepper + shrub pepper pattern, there was an addition from the results of shrub pepper, while in the cropping pattern with citronella and lemongrass plants there were additions apart from the results of the intercrop plants as well as the pests control effect from citronella and lemongrass plants. The average yield of citronella was 1.4 - 2.0 kg/clump, while the yield of lemongrass was 1.7 - 4.5 kg/clump.
Figure 3. Pepper plants with symptoms of Thrips sp. attack (a), and young leave attacked by Thrips with insects in the leaf fold (b).

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