INSECT PESTS OF KALAMANSI CITRUS (*Citrofortunella microcarpa*) AND THEIR SYMPTOMS OF INFESTATION IN BENGKULU, INDONESIA

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ABSTRACT

Kalamansi citrus (*Citrofortunella microcarpa*) is one of many horticultural commodities cultivated in Bengkulu, Indonesia. Insect pests are organisms that interfere growth and economic value of crops such as citrus. Insect pests on citrus plants result in decreased production ranging from 50%–77% worldwide. Knowledge of types of pest insects and their natural enemies is very important to designing effective control strategies. This study aimed to identify insect pests associated with Kalamansi citrus in Bengkulu. The number of Kalamansi citrus sample plants observed was 20 (selected randomly) and the citrus plants observed were about six years age. The results showed that Kalamansi citrus was infested by four orders and eight families of insects, including Hemiptera: Pentatomidae (*Rhynchocoris poseidon* Kirk), Hemiptera: Aphididae (*Toxoptera citridicus* Kirk), Hemiptera: Pseudococcidae (*Planococcus citri* Risso), Hemiptera: Flatidae (*Metcalfa pruinosa* (Say), Thysanoptera: Thripidae (*Scirtothrips dorsalis* Hood), Lepidoptera: Gracillariridae (*Phyllocnistis citrella* Stainton), Lepidoptera: Papilionidae (*Papilio demoleus* L.), and Diptera: Tephritidae (*Bactrocera* spp.). The dominant pests on Kalamansi citrus belonged to the orders Diptera (fruit flies) and Hemiptera. Some insect pests attack oranges and cause direct damage to crops by eating the affected plant parts, whereas others act as vectors for viruses and other pathogens. Some insects eat leaves, flowers, and fruits directly.

Keywords: Entomopathogenic fungi, Kalamansi citrus, natural enemies, pest

ABSTRAK

Limau Kalamansi (*Citrofortunella microcarpa*) merupakan salah satu komoditi hortikultur yang ditanam di Bengkulu, Indonesia. Serangga perosak merupakan organisma yang mengganggu pertumbuhan dan nilai ekonomi tanaman seperti sitrus. Kerugian yang disebabkan oleh serangga perosak pada tanaman sitrus mengakibatkan penurunan dalam pengeluaran antara 50-77%. Pengetahuan tentang jenis serangga perosak dan musuh semulajadinya adalah sangat penting untuk mereka bentuk strategi kawalan yang berkesan. Kajian ini bertujuan untuk mengenal pasti serangga perosak Limau Kalamansi di Bengkulu. Sejumlah 20 tanaman Limau Kalamansi (dipilih secara rawak) yang berumur lebih kurang

enam tahun telah diperhatikan. Hasil kajian menunjukkan bahawa Limau Kalamansi diinfestasi oleh perosak dari empat order and lapan famili termasuk Hemiptera: Pentatomidae (*Rhyncocoris Poseidon* Kirk), Hemiptera: Aphididae (*Toxoptera citridicus* Kirk), Hemiptera: Pseudococcidae (*Planococcus citri* Risso), Hemiptera: Flatidae (*Metcalfa* pruinosa (Say) Thysanoptera: Thripidae (*Scirtothrips dorsalis* Hood), Lepidoptera: Gracillariridae (*Phyllocnistis citrella* Stainton), Lepidoptera: Papilionidae (*Papilio demoleus* L.) and Diptera: Tephritidae (*Bactrocera* spp.). Perosak yang dominan pada Limau Kalamasi ialah Diptera (lalat buah) dan Hemiptera. Sesetengah perosak serangga menyerang Limau Kalamansi dan menyebabkan kerosakan langsung pada tanaman dengan memakan bahagian tumbuhan yang terjejas, manakala yang lain bertindak sebagai vektor untuk virus dan patogen lain. Sesetengah serangga memakan daun, bunga dan buah secara langsung.

Kata kunci: Kulat entomopatogenik, Limau Kalamansi, musuh semulajadi, perosak

INTRODUCTION

Citrus plants have been cultivated widely in tropical and subtropical regions, with more than 137 countries generating around US$105 billion per year from citrus production (Food and Agriculture Organization of the United Nations, 2016 (FAO)). According to the FAO report, the United States, China, Brazil, Italy, and Mexico are the main producers of citrus. Kalamansi citrus (*Citrofortunella microcarpa*) or Kasturi lime is a type of citrus that is widely cultivated by the Bengkulu people. Its oranges smell good and have a sour taste. The Kalamansi citrus fruits are locally processed to make Kalamansi syrup (Widyastuti 2011).

Kalamansi oranges originate in the People's Republic of China and have spread widely to Southeast Asia, Malaysia, Indonesia, and other areas, such as Florida and Panama. Kalamansi oranges are declared superior products in Bengkulu because of their high demand in the market and fast crop period, which is six months after planting. Kalamansi oranges are the first fruit introduced in the "one village one product" program. Kalamansi oranges were introduced by the Baptist Foundation about 15 years ago and have been developed by the Kalamansi Culture Cooperative in the Bumi Ayu, Surabaya, and Air Sebakul areas, Bengkulu (Widyastuti 2011).

One of the problems associated with Kalamansi citrus cultivation in Bengkulu is the decreased harvest due to pests. Pests are one of the main obstacles to citrus production, (Gebreslasie & Meres 2018; Yosef et al. 2014). Pests that attack citrus plants include *Aleurothrixus floccosus* (Hemiptera: Aleyrodidae), *Planococcus citri* (Hemiptera: Pseudococcidae), *Papilio demodocus* (Lepidoptera: Papilionidae), *Icerya purchasi* (Hemiptera: Margarodidae), *Coccus hesperidum* (Hemiptera: Coccidae), *Phyllocnistis citrella* (Lepidoptera: Gracillariidae), *Trioza erytreae* (Hemiptera: Psyllidae), *Bactrocera* spp. (Diptera: Tephritidae), *Metcalfa pruinosa* (Hemiptera: Flatidae), *Toxoptera citricida* (Hemiptera: Aphididae), *Diaprepes abbreviatus* (Coleoptera: Curculionidae), and *Thaumatotibia leucotreta*, (Lepidoptera: Tortricidae). Smith and Pena (2002) and Megawati and Candra (2017) also reported other pests in citrus crops, among them *Diaphorina citri* (Hemiptera: Psyllidae), *Scirtothrips dorsalis* (Thysanoptera: Thripidae), *Aonidiella aurantii* (Hemiptera: Diaspididae), *Phyllocoptruta oleivora* (Acari: Eriophyidae), *Panonychus citri* (Acari: Tetranychidae).

Attacks by insect pests on citrus plants have been reported to decrease production, ranging from 50%–77% in Debub and *Anseba zoba* (the Eritrean highlands) (Hussain et.al. 2017). Knowledge of the types of insects and their natural enemies associated with this citrus

is essential for designing an effective control strategy. However, information on pests associated with Kalamansi citrus in Bengkulu has never been reported. Therefore, the identification of pests Kalamansi citrus in Bengkulu, Indonesia is needed for making control decisions and as a reference for further research on natural pest control in agriculture. Therefore, this study aimed to identify insects associated with Kalamansi citrus (*Citrofortunella microcarpa*) in Bengkulu.

MATERIALS AND METHODS

Research Sites

This research was conducted in Bentiring, Muara Bangka Hulu District, Bengkulu City, Bengkulu, Indonesia (Figure 1), at 28.2 m above sea level, with the coordinates 3°46'1734 "S102°18'29,783" E. This research was conducted from January to June 2021.

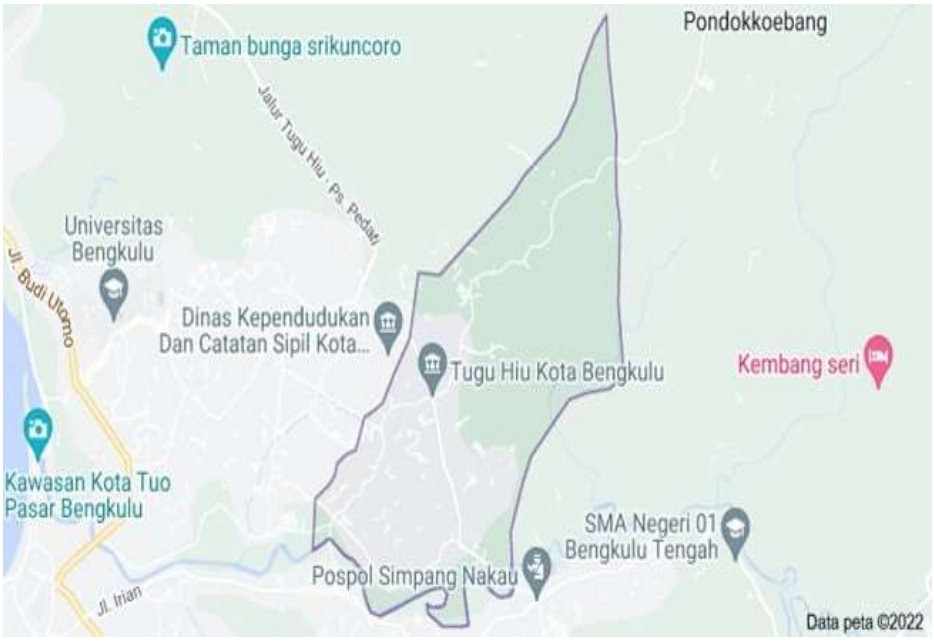

Figure 1: Map showing the location of the riset

(Source: *https://www.google.com/maps/place/Bentiring*)

Observation of Attack Symptoms and Pest populations

The *C. microcarpa* citrus plants observed were about 6 years of age. The plants had been previously planted with a spacing of 3 × 3 m in a land area of ±1 ha. The plant height ranged from 2 to 3 m. A sampling of pests and natural enemies in the field using direct observation of plant parts, namely the stems, twigs, fruits, and leaves, and sampling was carried out randomly. The number of samples of citrus plants observed in the location was 20.

Species Identification

The pests obtained were identified using the insect identification book by Borror et al. (1996), NPPC (2017) and pictures were taken. Observation of attack symptoms was carried out directly by observing the presence of pests on plant parts such as flowers, fruit, leaves, and plant shoots. The symptoms were photographed using a digital camera. The Kalamansi citrus

plant pests were collected, placed in plastic jars, and brought to the laboratory for further identification. They were observed under a compound microscope and the pest population found was recorded and counted during the observation. Data obtained from field observations were grouped, tabulated, and interpreted.

RESULTS

Pest Spesies Composition

The results showed that Kalamansi citrus was attacked by 4 orders and 8 families of insects, including Hemiptera: Pentatomidae (*Rhyncocoris poseidon* Kirk), Hemiptera: Aphididae (*Toxoptera citridicus* Kirk), Hemiptera: Pseudococcidae (*Planococcus citri* Risso), Hemiptera: Flatidae (*Metcalfa pruinosa* (Say) Thysanoptera: Thripidae (*Scirtothrips dorsalis* Hood), Lepidoptera: Gracillariridae (*Phyllocnistis citrella* Stainton), Lepidoptera: Papilionidae (*Papilio demoleus* L.), and Diptera: Tephritidae (*Bactrocera* spp.). The dominant pests on Kalamasi citrus were Diptera (fruit flies) and Hemiptera (Table 1). Their presence was checked by using parameters such as parts of the plant they feed.

Table 1. Pest insects found in Kalamansi citrus were collected during the study

No	Species	Order	Family	Number (individual)	Parts of the plant they influence
1	*Rhynchocoris poseidon*	Hemiptera	Pentatomidae	12	Young shoots, fruits
2	*Toxoptera citricidus*	Hemiptera	Aphididae	45	Young leaves
3	*Planococcus* sp.	Hemiptera	Pseudococcidae	10	Young leaves, stems, fruits
4	*Metcalfa pruinosa*	Hemiptera	Flatidae	10	Young leaves, stem
5	*Scirtothrips* sp.	Thysanoptera	Thripidae	3	Flower buds, leaves, young fruits
6	*Phyllocnistis citrella*	Lepidoptera	Gracillariidae	4	Young leaves
7	*Papilio demoleus*	Lepidoptera	Papilionidae	2	Young leaves
8	*Bactrocera* spp.	Diptera	Tephritidae	56	Fruit

DISCUSSION

All of the above pests (Table 1) interfere with the productivity of Kalamansi citrus plants. Some insect pests attack oranges and cause direct damage to crops by eating the affected plant parts, whereas others act as vectors for viruses and other pathogens. Some insects eat leaves, flowers, and fruits directly, causing a decrease in the productivity of citrus plants (Kumar et al. 2015). The number of insect pests under the Hemiptera order is around 38% which was pests on citrus plants (Kamaruddin et al. 2022).

Rhynchocoris poseidon (Hemiptera: Pentatomidae)

The color of the imago is green and the eggs are white. The development of this pest consists of five stages. The eggs hatch in about a week. The young nymphs remain clustered for a short time and then begin attacking the young shoots and fruit kalamansi, maturing at about 6–8 weeks. In the first stage, the nymphs are black, yellow, white, and orange. In later stages, they look more like an imago and are generally green with black markings (Figure 2.) The female imago lays eggs 2–3 times, and the number of eggs produced is about 15, depending on local climatic conditions, or 1–3 generations per year. Generally, the fallen fruit has brown spots around the puncture mark, caused by secondary infection by microorganisms, and has

a brownish color in the middle. The skin of the fruit also changes color and causes shrinkage of the seed cotyledons. This ladybug secretes foul substances from the pores on each side of the body (NPPC 2017).

Figure 2. *Rhynchocoris poseidon* (a,c.f. Nymph, b, g. Imago, d. Symptoms of *R. poseidon* attack on citrus fruits, e. the first stage nymph

These ladybugs suck the citrus juices by sticking their stylet into the shoots, leaves, and fruits. Both the imago and nymphs of these insects suck the juices from young citrus shoots and fruits. Young shoots become speckled and growth is stunted as a consequence, whereas fruits fall from the tree. Fruits that have been attacked show brown spots on the skin, making it difficult to market them. The fruits are mostly attacked when under ripe, causing the fruit to change color prematurely and fall off. When larger fruits are attacked, they are internally damaged (dry and brownish).

***Toxoptera citricidus* (Hemiptera: Aphididae)**

Aphids are very small insects, 2 mm long. Life cycle, from the birth of young aphids to one week of imago. Aphids have a wingless and wingless form. A winged form appears when crowding occurs to allow populations to disperse (Tennant 2009).

Toxoptera citricidus is a sucking insect found attached in groups under young lime leaves and new shoots. Lime aphids are black, often found in dense populations on young shoots of citrus trees, and do not attack older leaves. The nymph stage is reddish brown. Both the imago and nymphs of this pest suck the juices from the young shoots, causing the leaves to become damaged and yellow, as a result of which shoot growth is disturbed (Figure 3). Aphids also produce honeydew, in which a sooty dew grows that looks like a thin layer of black powder on leaves, shoots, and fruit. However, the significant damage caused by aphids is indirect. The citrus aphids are mainly vectors of the citrus tristeza virus, one of the most important citrus diseases in Southeast Asia. Aphids spread the virus by sucking on infected plant fluids and transferring them to healthy plants.

Figure 3. *Toxoptera citricidus* attached under young lime leaves

***Planococcus* sp. (Pseudococcidae: Hemiptera)**

Mealybugs reduce plant vigor by sucking plant juices. The nymphs and their imagos absorb the soft juices of leaves and shoots, causing curling, defoliation, and death of shoots. Fruits infested with mealybugs also show damage. However, the most significant economic damage from mealybugs is caused by their emitting honeydew that invites sooty dew, spoiling the fruit and reducing its selling value (Ashraf et al. 2014). The affected leaves and shoots change shape and twist into knots, the leaves curl, and the fruit falls out due to the end of the fruit stem eating. Mealybug colonies are found on twigs and fruits. Imago *Planococcus* sp. lays eggs in the sac. After the eggs hatch into yellow crawlers with red eyes, moving toward the fruit and leaves, the next stage is the migration down the stem. These pests cause damage to nurseries and mature plants (Figure 4).

Figure 4. Colony of *Planococcus citri* mealybugs. a. fruit, b. twig

***Metcalfa pruinosa* (Hemiptera: Flatidae)**

Metcalfa pruinosa reduces the vigor (vitality) of plants, directly causes stunted plants, and plants also wither, and indirectly causes sooty dew from the excretion of honey (Figure 5). After the eggs hatch, a large number of first instar nymphs fall from tree branches and move to nearby herbaceous plants. The fallen nymphs spread to the surrounding vegetation or plants, making it difficult to control them. The imago returns to the tree for oviposition, but it is not

well targeted for imago control because the damage caused by the imago was less than the nymph, and the imago can easily fly when sprayed chemically.

The orange planthopper *M. pruinosa* has caused serious economic in the countries where it is found. In Italy, the yield loss from the soybean crop was reported to be 30%–40%. *M. pruinosa* polyphage species has become a problem in various crops and fruit trees such as ginseng, sesame, grape, pear, persimmon, apple, mulberry, and timber trees, such as *Robinia pseudoacacia, Castanea crenata, Styrax japonicus, Diospyros lotus,* and *Acer palmatum*; shrubs and herbs, such as *Hibiscus syriacus, Rhamnus davurica*, and *Lycium chinense* (Kim et al. 2014; Lee et al. 2019; Park et al. 2019; Preda & Skolka 2011; Seo et al. 2019).

Effective targets for chemical control of *M. pruinosa* are the first instar nymphs that clumped together around trees. The waxy filaments produced by nymphs can be good indicators of *M. pruinosa* nymph abundance (Strauss 2010) but are difficult to detect in newly hatched early instar nymphs because of their very small body size and low wax secretion, so when white wax nymphs are detected, the nymphs already damaged crops (Kim et al. 2011; Kim et al. 2019).

Figure 5. *Metcalfa pruinosa* a. symptoms of an attack on leaves and fruit, b. attack on the fruit stalk

***Scirtothrips* sp. (Thysanoptera: Thripidae)**

Thrips are very small, and less than 0.1 cm long. The imago thrip has two pairs of narrow wings that are lined with hair. The thrips life cycle is as follows: Egg, 1st instar, 2nd instar, prepupa, pupa, and imago. The eggs are laid in plant tissue and hatched about five days later (Prakash 2012). Damage symptoms due to thrips attack, nymphs, and imago suck the fluid from flower buds and leaves kalamansi were fully developed, as well as young fruits. A parallel white stripe between the veins and a whitish silvery ring around the neck of the fruits are characteristic of thrip infestation.

Thrips suck the juices of citrus plants and prefer young plant tissues, such as shoots, flowers, and young fruit. Immature thrips attack the skin of the fruits and cause scarring. The typical pattern of thrips attacks is a ring of scar tissue at the end of the fruit (Figure 6). The second instar thrips damage the skin of the fruits by puncturing and sucking fluid from the surface of the cells of the fruit. In addition to eating developing fruit, thrips also attack young shoots (Prakash 2012).

Figure 6. Symptoms of thrips attack citrus fruits a. ring of scar tissue at the end of the fruit, b. scarring

***Phyllocnistis citrella* (Lepidoptera: Gracillariidae)**

Leaf miner larvae attack the shoots or young leaves so that leaf growth is disturbed. The symptoms that arise are in the form of ulcers that cause leaf curl or leaf malformation, which reduce the ability of photosynthesis and cause some leaves to stop growing. Typical leaf miner damage includes silver or yellowish leaves, or wavy lines on the lower leaf surface. The leaf-cutting larvae tunnel or mine through the leaves, following a characteristic wavy path just below the leaf surface (Figure 7).

Imago is nocturnal, so it was rarely seen, occasionally flying when the leaves were disturbed. Eggs were laid singly on the underside of the leaves. Newly- emerged leaves were a preferred nesting site. When they hatch, the larvae slit into the leaves, making mines (Prakash 2012). The larvae mine near the leaf margins, causing the leaf edges to fold. Pupation occurs at the edges of the leaves. The pupa remains in the mine until an imago appears. The total life cycle was approximately 2–3 weeks. Each larva has its own tunnel. Usually, each leaf has only one miner, but in cases of heavy infestations, there may be several mines per leaf. This leaf mining causes the leaves to curl upwards and look distorted. Symptoms of damage to lime leaf miners are mainly a problem in young plants (nurseries) because they inhibit growth. Mature plants are more resistant to attack. The feeding activity of lime leaf miners causes permanent twisting and curling of leaves and can inhibit the growth required for development (Prakash 2012).

The lime leaf miner (*P. citrella*) is a silvery white or gray moth. Leaf miner larvae feed on the epidermis of the leaves, producing silver mines, generally on the underside of the leaves. Often, small larvae are found in them. The damage caused to young plants is more severe than to old plants. Severe attacks can cause severe leaf defoliation (Kumar et al. 2015).

Figure 7. Symptoms of leaf miner attack citrus fruits, a. Leaf malformations, b. lines on the lower leaf surface

***Papilio demoleus* (Papilionidae: Lepidoptera)**

Larvae attack citrus plants, heavy attacks cause defoliation. The larvae feed on the young leaves of citrus plants, which is more damaging to young plants than to older trees (Figure 8). Severe infestations by these pests to nurseries and young plants lead to complete defoliation of the plant. Larvae are dark brown with irregular whitish marks on the dorsal side of the abdomen (Tennant 2009; Kumar et.al. 2015).

Figure 8. *Papilio demoleus.* a. The larvae feed on the young leaves of citrus plants, b. Larvae

***Bactrocera* spp. (Diptera: Tephritidae)**

Larvae cause fruit damage, so they are not suitable for consumption. Larvae (maggots) eat and develop into ripe fruit. The affected fruit falls to the ground. Infested fruit can easily be distinguished by the presence of a round, rotting mark where the fruit fly pierced (Figure 9).

Figure 9. Symptoms of *Bactrocera* spp. on citrus fruits, a. fruit falls, b. imago *Bactrocera* spp.

Fruit flies are economically the most important insect pests on fruit in Southeast Asia, and can cause losses of 90%–100%, also preventing the development of export markets. Countries that do not have fruit flies want to stay pest free. They usually impose strong quarantine restrictions on fruit imports from countries where fruit flies are found. Fruit flies are widespread in tropical Asian countries. Imago mates at dusk and the female lays eggs right on the rind. Under optimal conditions, a female can lay more than 3000 eggs during its lifetime. The eggs hatch into larvae, which then slit into the fruit. Adult larvae emerge from the fruit, fall to the ground, and form a brown pupa. The fruit fly can be distinguished from the common fly by its triangular-shaped abdomen and the venation shape of its wings. Fruit flies lay their eggs under the ripe skin of the fruit by inserting their ovipositor into the fruit. The pupation is yellowish-brown and appears as an imago after 7–10 days (Kumar et al.2015). Symptoms of damage to the oviposition point can be observed on the top of the fruit; then, the fruits show round, brown, hard spots 1–2 mm in diameter just under the skin. The maggots eat the inside of the yellow fruit prematurely and fall off. The fallen fruit has a brown-black, dry, or rotting puncture mark; the maggots then pop out of the hole. The affected part of the fruit becomes dry and then rots (NPPC 2017).

CONCLUSIONS

The types of insects and their natural enemies associated with this citrus is essential for designing an effective control strategy. Some insect pests attack oranges and cause direct damage to crops by eating the affected plant parts, whereas others act as vectors for viruses and other pathogens. Some insects eat leaves, flowers, and fruits directly.

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AUTHORS DECLARATIONS

Conflict of Interest
The authors declare that they have no conflict of interest.

Ethics Declarations
No ethical issue is required for this research

Data Availability Statement
My manuscript has no associated data

Authors' Contributions
Sempurna Ginting conceived this research and designed experiments; Sempurna Ginting, Djamilah and Pryatiningsih participated in the design and interpretation of the data, performed experiments and analysis; Sempurna Ginting wrote the paper and participated in the revisions of it. All authors read and approved the final manuscript. All authors read and approved the final manuscript.

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