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RESEARCH PAPER

The effect of biopesticide and combined fertilization in promoting plant health and growth of tomato cultivated on peat soil in West Kalimantan

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ABSTRACT

The demand for horticultural products that are cultivated organically has increased. However, the susceptibility of plants to pests and diseases becomes an obstacle in organic crop cultivation. The use of biopesticides can be a solution to overcome these problems with the added benefit due to its environmental friendly and sustainable aspect. The purpose of this study was to determine the effect of biopesticides and combined fertilization in promoting plant health and enhancing tomato growth on the peat soil. This study used a randomized complete block design with two factors and three replications. The first factors were four combined fertilizations (K), namely: K1: 100% organic fertilizer+local microorganisms; K2: 75% inorganic fertilizer+Petrobio, K3: 75% inorganic fertilizer+M-Dec, and K4: 100% inorganic fertilizer. The second factors were three types of pesticides (S), namely: S1: homemade biopesticides, S2: industrial biopesticides containing active ingredient Eugenol 188,4 g L^{-1}, and S3: chemical pesticides containing active ingredient fipronil 50 g L^{-1}. The observed data were analyzed statistically using Analysis of Variance (ANOVA) and further tests were carried out using Duncan's Multiple Range Test (DMRT) at the 5% level. The results showed that the tuba roots and betel leaves used in biopesticides had different effects on controlling fruit flies and leafminer caterpillars, as well as anthracnose disease. The application of chemical pesticides influenced the lowest infestation of fruit flies and leafminer caterpillars, while homemade and industrial biopesticides, as well as chemical pesticides had the same effect in reducing the intensity of anthracnose. In conclusion, a combination of 100% inorganic fertilizer+industrial biopesticides and 75% inorganic fertilizer+Petrobio gave greater tomato yields. Biopesticides could sustain organic crop cultivation in peatlands considering the ingredients availability, affordable, and easy application.

Key words: betel leaf, biopesticides, tomato, tuba root

INTRODUCTION

Market demand on organic vegetables increases lately. This can be seen from the high preference of consumers on organic products in the regional, national, and international levels. The good education level of communities and the negative impact on residue of pesticides in agricultural products lead to improve consumer awareness on how important to consume organic products (Directorate of Processing and Marketing of Agricultural Products, 2006; Mayrowani, 2012; Rais & Darwanto, 2016).

Now and on, organic agricultural products seem to be expected to contribute in improving gross domestic product (GDP) of Indonesia. Indonesia has many resources including up to 20% of tropical agricultural land with incredibly diverse germplasm as well as many sources of organic fertilizer or organic matter. The trend of organic farming in Indonesia is continuing to increase. In 2002, International Federation of Organic Agriculture Movement (IFOAM) stated that only 40,000 ha (0.09% of the agricultural land) has been utilized for organic farming in Indonesia. Alliance of Indonesian Organic (AOI), which is a member of IFOAM, recorded that the area of organic farming in Indonesia in the year of 2010 was 238,872.24 ha. The previously mentioned data showed that there has been a robust increase of organic farming area by nearly 600% over a period of 8 years (Alliance of Indonesian Organic (AOI), 2011).

West Kalimantan is one of the Indonesian provinces which has potential to become one of the areas for developing organic agricultural products including vegetables. Horticultural products including vegetables can be best grown in peat soil. Peat soil was dominantly found in this province. The total area of peat soil in West Kalimantan is approximately 1,729,980 ha and up to 40.16% (694,714 ha) is feasible for agricultural

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land.

Peatland is categorized as marginal land; nevertheless, by several years intensive cultivation, fibrist peat soil (raw) can turn into saprist peat soil (ripe) that is very potential for growing vegetables (Agus & Subiksa, 2008). The characteristics of peat soil properties in this study area is classified as acidic soil. Total macro nutrients in the peat soil are commonly high, but in organic forms (Andriesse, 1988; Stevenson & Fitch, 1986). Most macro nutrients such as N, P, K, Ca and Mg are in unavailable forms for plant in the peat soil (Mutalib et al., 1991). Hence, in this study, the combination of organic and inorganic (N, P, and K) fertilizers are applied to enhance plant growth and yield.

Plant pests and diseases are one of the most critical problems faced by organic vegetables farming, especially in the newly opened area (Wulandari & Wahyudi, 2014). The natural balance of pest's population and the natural enemies can be overpopulated due to monoculture farming. In order to maintain the balance of the agricultural ecosystem, application of eco-friendly controlling methods is strongly needed, and one of which is biopesticide.

Some plants have been reported to be potentially used as biopesticide, and two of the plants are derris (tuba plant) and betel. The root of derris (*Derris elliptica* (Wallich) Benth) contains rotenone, deguelin, elliptone, and toxicarole that are toxic to some plant pests (Setiawati et al., 2008; Setiawati et al., 2015). Betel leaves (*Piper betle* Linn.) contains various active ingredients as biofungicide such as hydroxychavicol, chavicol, chavibetol, estragole, eugenol, methyl eugenol, carvacrol, terpenes, and sesquiterpenes (Ariyanti et al., 2012; Arsensi, 2012; Dwianggraini et al., 2013; Maryani & Lusi, 2004; Siamtuti et al., 2017; Wardani, 2009). In addition, there are several ingredients for making biopesticides such as galangal, turmeric, garlic, lemongrass, and shallot that contain active ingredients and function as fungicide, insecticide, and bactericide (Gunnars, 2021; Petre, 2019; Sharma et al., 2018). Whereas, local microorganisms (LOM) comprise natural ingredients and function as plant pests and diseases control (Roeswitawati et al., 2018).

In West Kalimantan, both of derris and betel can be easily found in the backyard or as the hedgerows in the vegetable farm. However, there is no report on the capability of the extracts of these two plants as biopesticide for controlling plant pests and diseases of tomato in West Kalimantan. This research was performed to identify the capability of biopesticide developed from derris and betel leaves extract and fertilizer combination for controlling plant pests and diseases of tomato as well as improving the yield of tomato plant.

MATERIALS AND METHODS

Research Site. This research was conducted on hemic peat soil (Histosols) with semi-ripe decomposition rate in Siantan Hulu, Pontianak Utara Sub Districts, West Kalimantan (0.001793, 109.341974).

Research Design. This research was arranged in a randomized complete block design with two factors and three replications. The first factors were four levels of combined fertilizations (K), i.e. K1: 100% organic fertilizer (40 tons ha^{-1} cow manure + 40 tons ha^{-1} bokashi) + 250 L ha^{-1} local microorganism, K2: 75% inorganic fertilizer (1.5 tons ha^{-1} NPK) + 10 tons ha^{-1} chicken manure + 1.5 tons ha^{-1} Petrobio (Petrokimia Kayaku, Indonesia), K3: 75% inorganic fertilizer (1.5 tons ha^{-1} NPK) + 10 tons ha^{-1} chicken manure + 250 L ha^{-1} M-Dec (Balai Penelitian Tanah, Badan Litbang, Kementerian Pertanian), and K4: 100% inorganic fertilizer (2 tons ha^{-1} NPK) + 10 tons ha^{-1} chicken manure. Whereas, the second factor was kinds of pesticides (S), i.e. S1: homemade biopesticides (biopesticide made from local ingredients using conventional method), S2: industrial biopesticide containing active ingredient Eugenol 188,4 g L^{-1} (NASA, Indonesia), which was available on the market, and S3: chemical pesticides containing active ingredient fipronil 50 g L^{-1} (BASF, Indonesia). Chicken manure was not used in K1 treatment due to the issue of chemical use in chicken feed industries, while the treatment was meant to be fully organic, and LOM in this treatment was also used for the same reason. Petrobio and M-Dec were used in K2 and K3, respectively, as an addition for 75% dosage of inorganic fertilizer. While Petrobio was added in its original formulation, M-Dec was given by diluted 5 g in 1 L to give a concentration of 250 L ha^{-1} (1.25 kg ha^{-1}). Negative control was not used in this experiment. Trial plots were planting beds of 0.8 × 6 m, the distance between the beds was 0.7 m.

Plant Nurseries. Tomato seeds (Permata variety) (East West Seed, Indonesia) were soaked in water at 40 °C for 15 min, before being sown on a-square-meter of peat soil previously added with 5 kg of ash and 5 kg of cow manure. After 10 days, each seed was put into black polybags size of 8 × 4 cm placed in a shady place and watered daily to maintain soil moisture.

Field Preparation. Agricultural lime (dolomite) was applied in the planting beds at a dose of 1000 kg ha^{-1}, chicken manure, cow manure and ash were applied at a dose of 500 kg ha^{-1} each, evenly distributed on the surface of the beds one day before covering the beds using silver black plastic mulch.

Plant Maintenance. Transplanting was done three weeks after sowing. The space of the planting holes on the planting beds was 60 × 40 cm. Weeding was manually carried out every 10 days throughout the experimental period to keep the plants free of weeds.

Biopesticides Production and Application. There were two types of homemade biopesticides used in this experiment, i.e. bioinsecticide and biofungicide (Ariyanti et al., 2012; Arsensi, 2012; Kardinan, 2001; Setiawati et al., 2008; Setiawati et al., 2015; Siamtuti et al., 2017). The ingredients used as bioinsecticide were 1 kg of tuba root, ¼ kg of galangal, ¼ kg turmeric, and ¼ kg garlic. These ingredients were ground with a mortar, then put in a bucket mixed with 10 L of water and incubated for 3 days before ready to use. Meanwhile, biofungicide was made from 1 kg of betel leaf, ¼ kg of lemongrass and ¼ kg of shallots that were treated with a similar process as bioinsecticide.

Biopesticide was applied by adding 240 mL of it into 15 L of water, added with 15 g of detergent as emulsifier, stirred homogeneously and sprayed on plants every 3 days. Meanwhile, LOM was applied by mixing 5–10 mL of the solution with 1 L of water, drenched on the plants and media. Watering was conducted simultaneously with planting and repeated once a week.

Plant Pests and Disease Intensity. The effectiveness of biopesticides against plant pests was assessed by observing the average of pests and disease intensity of three major tomato pests and disease (Setiawati et al., 2001), i.e. fruit flies, leafminer and anthracnose. Fruit flies attack was assessed using the formula:

$$I = \left[\frac{a}{N}\right] \times 100\%$$

I = absolute plant damage intensity (%);
a = number of attacked fruit;
N = number of fruits observed.

Leafminer attack was assessed using the formula:

$$I = \left\{\frac{\Sigma n_i v_i}{Z \times N}\right\} \times 100\%$$

Meanwhile, anthracnose was assessed using the formula:

I = relative plant damage intensity (%);
n_i = number of leaves with a damage scale of v_i;
v_i = the value of the scale of damage of i;
Z = the highest damage scale;
N = number of leaves observed.

The damage scale values (v) for the pest are as follows:

$$I = \left\{\frac{\Sigma n_i v_i}{Z \times N}\right\} \times 100\%$$

As for the disease are as follows:

I = disease severity (%);
n_i = number of fruits with a damage scale of v_i;
v_i = the value of the scale of damage of i;
Z = the highest damage scale;
N = number of fruits observed.

0 = no attack;
1 = 0–25% of plant parts affected;
2 = 26–50% of plant parts affected;
3 = 51–75% of plant parts affected;
4 = 76–100% of plant parts affected.

0 = no attack;
1 = 0–10% of plant parts affected;
2 = 11–20% of plant parts affected;
3 = 21–40% of plant parts affected;
4 = 41–60% of plant parts affected;
5 = 61–100% of plant parts affected.

Agronomic Properties. This study focused on the effect of application of biopesticides, inorganic and organic fertilizers, and local organisms in order to improve tomato growth and yields. The agronomic properties of tomato plants were measured through: 1) plant height, 2) fruit weight, and 3) yield ha^{-1}. The data were taken once the tomato plant reached 70 days-old. Yield data were collected from the accumulation of the first harvest (70 days after sowing, DAS) and the second harvest (77 DAS).

Data Analysis. Observational data on the pests and disease intensity and plant agronomic characteristics were analyzed using analysis of variance (ANOVA). If there was a significant difference ($P< 0.05$), the data was further analyzed using Duncan's Multiple Range Test (DMRT) at 5% of significant level.

RESULTS AND DISCUSSION

Effect of Organic Pesticides and Organic Fertilizers on the Tomato Plant Pests and Diseases. Two kinds of pests and one disease were found during observation, i.e. fruit flies, leafminer caterpillars, and anthracnose disease. Symptoms produced by fruit fly attack were characterized by a discoloration on the fruit surface, around the oviposition sting (Figure 1A). At the early stage of invasion, the egg emission might be observed under the fruit skin. The leafminer caterpillar showed symptoms such as sunken lesions on fruit or mining activity on leaves and stems which was caused by larvae feeding activity (Figure 1B). The anthracnose disease was recognized by symptoms of depressed, circular lesions about 0.5 inch (1.2 cm) in diameter appearing on ripe fruit. With age, the lesions become brown (Figure 1C).

The effect of combined application of biopesticides, organic fertilizers and local organisms on the pests and disease of tomato plants were presented in Figure 2. Homemade biopesticides (S1) as well as industrial biopesticides (S2) were generally less effective than chemical pesticides (S3) in controlling fruit flies. The results showed that the average infestation of fruit flies was higher in the treatment of homemade biopesticides and industrial biopesticides, compared to the chemical pesticides (Figure 2A).

The effect of fertilizer and pesticide treatments on the intensity of leaf miner attacks was similar with those of fruit flies attacks (Figure 2B). The average infestation of leafminer on plants treated with homemade biopesticides (S1) and industrial biopesticides (S2) was higher than those treated with chemical pesticides (S3). Homemade and industrial biopesticides were less effective in controlling leafminer larvae that live and feed in leaf burrows. These larvae feed in their burrows until all that is left on the leaves is the epidermis.

The effect of fertilizer and pesticide treatment on disease severity of fruit rot (anthracnose) showed that there was no difference between the treatment of organic pesticides and chemical pesticides ($P< 0.05$), except for the K1S1 treatment which showed a fairly high disease severity (15.83%). This result showed that the use of homemade biopesticide combined with 100% organic fertilizer resulted in the highest disease severity of anthracnose (K1S1). Interestingly, biopesticides also gave the lowest severity of anthracnose if K2 (75 % of inorganic fertilizer + Petrobio) was given as the fertilization. Treatment of other biopesticides, namely K2S1 (3.92%), K3S1 (0.83%), and K4S1 (2.50%) had the same disease severity compared to chemical pesticides, namely K1S3 (1.62%), K2S3 (10.20%), K3S3 (0.83%), and K4S3 (0.83%) (Figure 2C).

Homemade biopesticides as well as industrial biopesticides are generally less effective in controlling fruit flies and leafminers compared to chemical pesticides. It is suspected that this is due to mode of actions of their active ingredients. Rotenone contained in the tuba roots, although it is a broad-spectrum poison, works as a stomach and contact poison (Setiawati et al., 2008; Setiawati et al., 2015), while the larvae of fruit flies and leaf miner attack plants by living and eating in plant tissues that cannot be reached by the active ingredient. Fruit flies are unlikely to be affected by direct spray since it is actively flying and will perch on plants to lay eggs once conditions permit. In addition, chemical pesticides which were applied are suspected to be more effective at repelling fruit fly imago due to the strong odor of the substance that was able to repel pests from approaching crops and infecting tomato fruits.

Betel leaf has shown potential as a biopesticide to control fruit rot disease in tomatoes. It can be seen in Figure 2C, treatment of S1 (homemade biopesticide) gave the lowest disease severity of fruit rot when combined with treatment of K2 (75% of inorganic fertilizer + Petrobio). Meanwhile, it produced no significant difference in disease severity of tomato fruit rot compared to chemical pesticides when combined with treatment of K3 (75% of inorganic fertilizer + M-Dec)

Figure 1. Symptoms of pest and disease on tomato plants. (A) Fruit fly; (B) Leafminer; (C) Anthracnose.

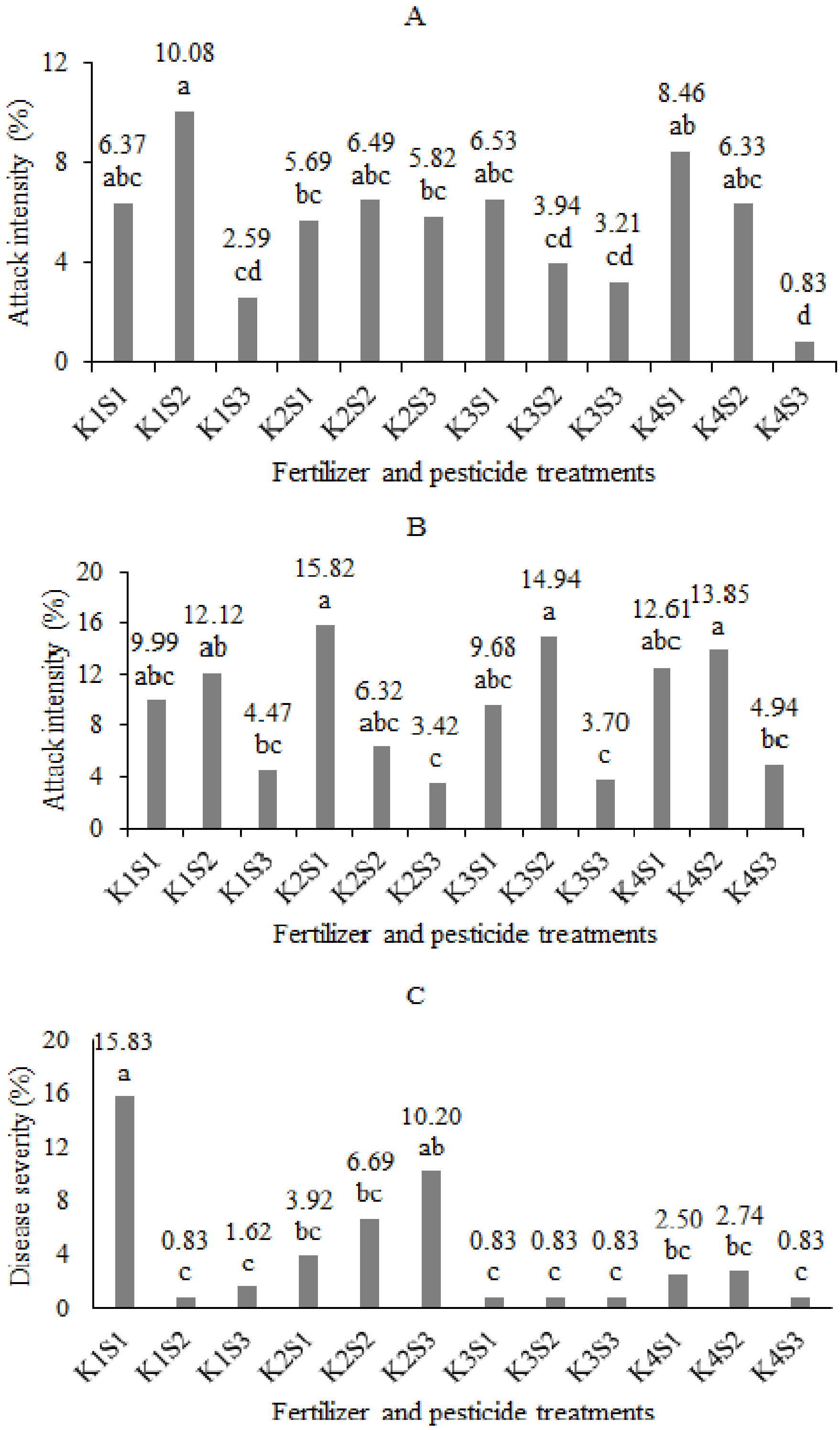

Figure 2. The effect of various fertilizer and pesticide treatments on attack intensities of (A) Fruit flies; (B) Leafminer; (C) Disease severity of anthracnose on tomato plants. Bars with no common letters are significantly different (*P* <0.05). (K1) 100% organic fertilizer + local microorganism; (K2) 75% of inorganic fertilizer + Petrobio; (K3) 75% of inorganic fertilizer + M-Dec; (K4) 100% of inorganic fertilizer. (S1) Homemade biopesticide; (S2) Industrial biopesticide; (S3) Chemical pesticide.

or K4 (100% of inorganic fertilizer). Wati et al. (2014) reported that betel leaf and n-Heksana formulation effectively suppressed the growth of anthracnose in chili. The natural ingredient was known to contain essential oil compounds, saponins, flavonoids and polyphenols used as a fungicide. Saponins and flavonoids have antifungal activity and represent the first chemical barriers to pathogen infection (Rubio-Moraga et al., 2013).

The overall results showed that chemical pesticides performed better in controlling fruit flies and leafminers, while homemade biopesticides have the potential to control fruit rot. Although biopesticides have limitations in pest control, it has some values to support organic vegetable cultivation. Therefore, it is feasible to be adopted. From an economic point of view, biopesticides have advantages over chemical pesticides, which can be produced by farmers at low cost. Thus, the lower harvest output can be compensated by the lower production inputs. In West Kalimantan, the main ingredients of biopesticides can be found easily in the farmer's backyards. More importantly, biopesticides have environmental friendly characteris-

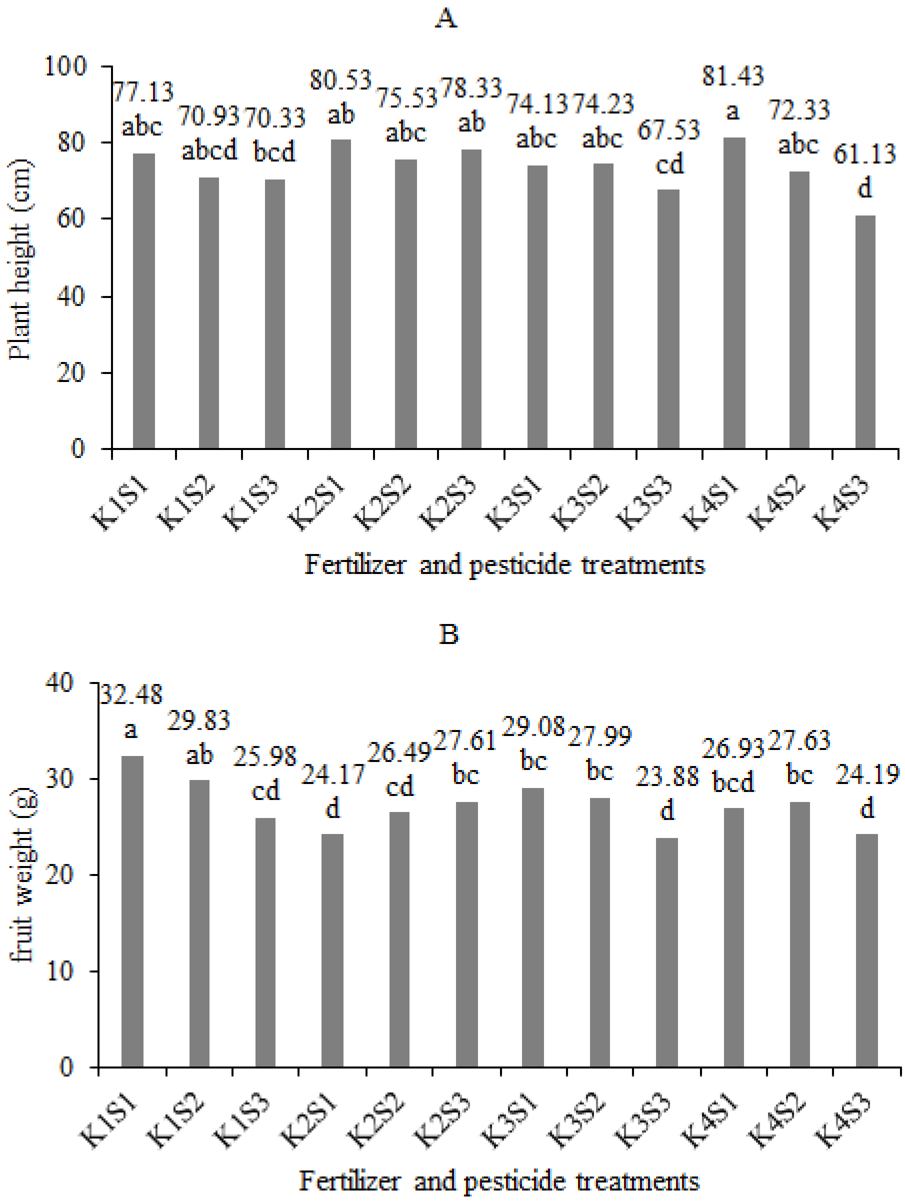

Figure 3. Effect of various fertilization and pesticide treatments on (A) Tomato height; (B) Fruit weight; (C) Tomato yield. Bars with no common letters are significantly different (*P*< 0.05). (K1) 100% organic fertilizer + local microorganism; (K2) 75% of inorganic fertilizer + Petrobio; (K3) 75% of inorganic fertilizer + M-Dec; (K4) 100% of inorganic fertilizer. (S1) Homemade biopesticide; (S2) industrial biopesticide; (S3) Chemical pesticide.

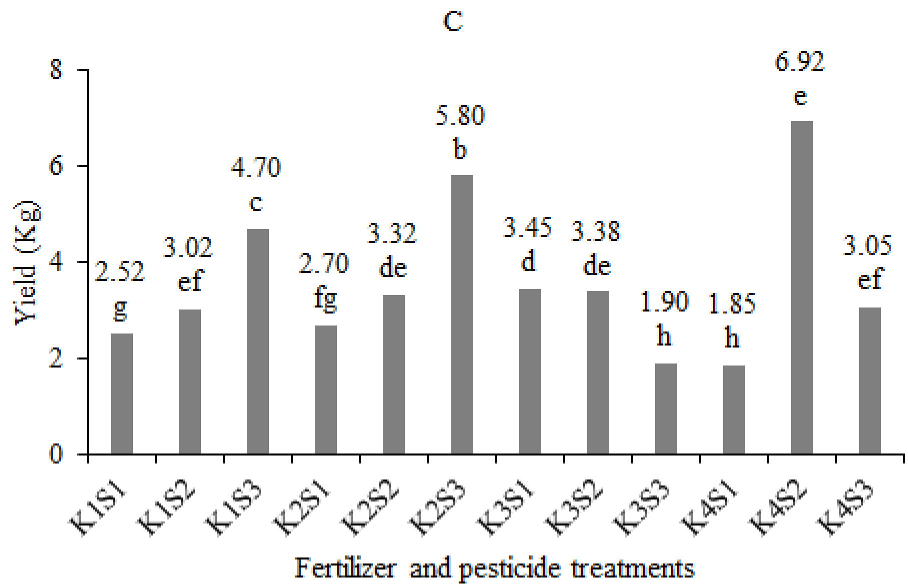

Figure 3. Continued. Effect of biopesticides and organic fertilization on agronomic characteristics of tomato plants. (A) Plant height; (B) Fruit weight; (C) Yield. Bars with no common letters are significantly different ($P < 0.05$). (K1) 100% organic fertilizer + local microorganism; (K2) 75% of inorganic fertilizer + Petrobio; (K3) 75% of inorganic fertilizer + M-Dec; (K4) 100% of inorganic fertilizer. (S1) Homemade biopesticide; (S2) Industrial biopesticide; (S3) Chemical pesticide.

tics which are very important for human health (Rais & Darwanto, 2016).

Effect of Biopesticides and Organic Fertilization on Agronomic Characteristics of Tomato Plants. The results of the effects of biopesticides and organic fertilization on the agronomic properties of tomato plants were presented in Figure 3. The results showed that the type of fertilization treatments affected plant height, fruit weight, and the yield of tomato plants. Figure 3A showed that treatment K2 (75% inorganic fertilization + Petrobio) produced the highest average plant height compared to other fertilization treatments (K1, K3, and K4). The average plant height of K2 was 78.13 cm, while the average plant height of K1, K3, and K4 were 72.80, 71.97, and 71.63 cm, respectively.

Observation on fruit weight showed that the heaviest weight of fruit was the average result of treatment K1 (100% organic fertilization), which was 29.43 g (Figure 3B). Meanwhile, the average fruit weight of K2, K3, and K4 treatments were 26.09, 26.99, and 26.35 g, respectively. The results indicated that the 100% organic fertilization was the best in increasing fruit weight of tomato plants. However, the highest fruit weight did not produce the highest yield since treatment K1 (100% organic fertilization) produced less fruits compared to the 100% inorganic fertilization (K4).

Observations on tomato yield, accumulation of the first and second harvests, showed treatment K4 (100% inorganic fertilization) produced similar results with treatment K2 (75% inorganic fertilization + Petrobio), which was 3.94 kg. Meanwhile, the yield of treatment K1 (100% organic fertilization) and K3 (75% inorganic fertilization + M-Dec) were 3.41 and 2.91 kg, respectively. The result showed that Petrobio has the potential to partially substitute the use of inorganic fertilizer, whereas M-Dec as well as the 100% organic fertilization cannot be used to replace inorganic fertilizer if we aim for the high yields.

CONCLUSION

The use of biopesticides, both homemade and industrial ones, had the same effectivity as chemical pesticides in controlling anthracnose attacks on tomato plants. However, biopesticides were less effective in controlling fruit flies and leafminers. K4S2 treatment, a combination of industrial biopesticide and inorganic fertilizer, gave the highest yield of tomato, which suggested that the industrial biopesticide could be a good alternative to replace chemical pesticides while dependency to inorganic fertilizer was difficult to avoid. In terms of accessibility, homemade biopesticides had the potential to support organic crop cultivation in peatlands of West Kalimantan, due to the availability of ingredients, affordable, and easy application.

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AUTHORS' CONTRIBUTIONS

DPW and AU are contributed equally to the research since the start of the experiment up until the writing of the manuscript. However, DPW and AU did contribute specifically on some processes. The design of the experiment was planned by DPW and the observation and data collection were performed by AU. Other works, such as field assistance, data analysis, data interpretation, and manuscript writing were done by both authors. Then, all the authors have read and approved the final manuscript.

COMPETING INTEREST

The authors declare that there is no competing interest.

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