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Diversity And Infestation Intensity Of Bactrocera Spp. In Local Red Chili (*Capsicum annuum* L.) Varieties In West Sumatra

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Abstract

Red chili (*Capsicum annuum* L.) is an essential horticultural product in West Sumatra both commercially and culturally,. Sadly, its output has experienced a substantial decline recently, primarily as a result of increased biotic pressures, particularly from tephritid fruit flies (Bactrocera spp.). This study aimed to clarify the diversity and infestation intensity of Bactrocera species, as well as their correlation with regional chili types and four important chili-producing regencies. Using morphological taxonomic keys, species were identified during the October 2024 to March 2025 period by extensive field surveys and Lynfield trapping techniques. Three species of Bactrocera were identified: *B. umbrosa* (0.3%), *B. carambolae* (0.8%), and *B. dorsalis* (98.9% of all catches). Across all sites, the species composition showed substantial pest dominance, especially of *B. dorsalis*, but low overall biodiversity. Agam had the most diversity, although Simpson, Evenness, and Shannon diversity indices differed by location. Strong positive correlations between *B. dorsalis* density and infestation rates of both plants (r = 0.70) and fruit (r = 0.68). Likewise, there were notable positive relationships between altitude and infection intensity (plant r = 0.88; fruit r = 0.73), indicating that mid- to high-altitude study zones had higher levels of pest activity. Kuhay showed significant resilience, but Rawit and Keriting were the most susceptible of the four chili types. These results emphasize the necessity of incorporating agroecological context and varietal resistance into targeted integrated pest management (IPM) methods for upland chili systems, as well as the dominance of *B. dorsalis* as a pest concern.

Keywords: altitude; Bactrocera spp.; Lynfield; and red chili

Introduction

The agricultural sector is very strategic, is the basis of the people's economy in rural areas, controls the lives of the majority of the population, and absorbs more than half of the global total workforce (BPS, 2022). Indonesia is known as an agricultural country because the topographical and natural conditions are potentially fertile for the cultivation of a wide range of agricultural commodities (Mariyono, 2017; Anwarudin et al., 2019). West Sumatra province is located in the lowlands and highlands, so it is suitable for vegetable-growing areas and the agricultural sector is one of the mainstays of economic growth, with a contribution to the gross regional domestic product of 21.71% (BPS, 2022) and accounts for 50.69% of West Sumatra's population (BPS West Sumatra, 2020). Twelve districts of the province have some major vegetable crops such as bitter melon, bitter gourd, cucumber, and chili pepper. Red chili is one of the market demands urgently for horticultural products (Kate & Laird, 2019).

Chili (*Capsicum annuum* L.) is an annual herbaceous plant that belongs to the genus Capsicum under the Solanaceae family (Perry & Flannery, 2007; Baenas et al., 2019). There are more than 400 different varieties of chili found all over the world and are grown in about 140 countries. Indonesia is the third red chili producer in the world (Sundari et al., 2021). Therefore, chili production in Indonesia is increasing year by year from 2021 to 2023 with a total production of 2.74, 3.02, and 3.05 million tons including big chilis, curly chilis, and cayenne peppers (Liu, 2022; FAOSTAT, 2024). Meanwhile, West Sumatra province was Indonesia's fifth-largest red chili production (Khairat et al., 2024) and showed the highest consumption of chilies, namely 0.59 kg/capita/month in 2021 (Lukas et al., 2023). According to Badan Pusat Statistik Provinsi Sumatera Barat, (2024) reported that chili production in 2023, Agam Regency produced 42,002 tons followed by Solok at 41,168 tons, Tanah Datar at 22,261 tons, and Padang Pariaman at 2,006 tons that these districts and cities occupied 50% of the total chili production out of 19 districts and cities. Apart from that, West Sumatra province has diverse local chili varieties as many as 14 local chilies from 9 regencies/cities (Chili Kawek, Kampung Manangah, Local Maninjau, Lotanbar, Local Sijunjung, Local Dharmasraya 1 and 2, Local Tanah Datar, Local Pesisir Selatan, Ateng Maninjau, Kampung Solok Selatan, Kuhay, Ateng Pasaman Barat, Akar) genetic resources have deep potentials fruit fly resistance and are bringing high economic value (Suliansyah, Ekawati, & Hariandi, 2023). A subsequent study by Budiyanti et al. (2024) stated that there were twenty-three of these genotypes are curly chili types grown by farmers in their original locations. The dendrogram showed that the 23 chili genotypes were retrieved into four main groups with genetic similarity coefficient values ranging from 0.67 to 0.97 or a diversity of features of 0.03–0.33 (30%).

In West Sumatra, the chili peppers are predominantly cultivated in open field systems in upland and lowland areas. Sadly, *Bactrocera* genus are one of the most significant pests affecting the yield and quality of chili peppers (Hasinu et al., 2020). Budiyanti et al. (2019) reporteded that there were three species of fruit flies found in four vegetables in Padang, viz. *B. cucurbitae*, *B. carambolae*, *B. dorsalis* and Bactrocera species. Consequently, direct crop loss is caused by maggots feeding which chili fruits are perishable, reducing productivity due to shed prematurely and revenues for farmers (Rwomushana et al., 2019). In Indonesia, the conditions allow a chili host for the development of various types of fruit flies and the amount of injury can reduce production by 30 to 90,1 percent (Hasinu et al., 2020; Jamaluddin et al., 2020). On the contrary, indirect loss results when quarantine restrictions on fruit fly-infested produce limit exports to lucrative markets abroad (Heather, 2008). Countries spend millions of dollars each year on control and have trade sanctions imposed by rigorous treatment of products before export (Dhami et al., 2016). Notably, fruit flies can carry viruses from several genera and families, including Dicistroviridae, negev-like virus clades, Thika virus clades, Solemoviridae, Narnaviridae, Nodaviridae, Iflviridae, Orthomyxoviridae, Bunyavirales, Partitiviridae, and Reoviridae (Zhang et al., 2022).

Unfortunately, chili productivity in West Sumatra province fell steadily for three years 2020-2022 reaching 11.16, 10.4, and 9.6 tons/ha, which is still less half than the optimal productivity of 20–22 tons/ha (Agustina et al., 2022; BPS, 2022). Additionally, fruit flies are one of the species that have a strong negative impact on chili production (Mayasari et al., 2019; Hasinu et al., 2020). To combat this threat, a thorough assessment is necessary to determine the interaction between pest diversity, environmental conditions, and chili varietal resistance (ISPM, 2018; Syahfari & Mujiyanto, 2013). Nevertheless, the above pieces of information have not been officially reported in West Sumatra province. This study aimed to (1) characterize the diversity of *Bactrocera* spp. in different agroecological zones, and (2) analyze their correlation with the infestation rates across four prominent local chili varieties.

Research Method

Survey sites

This research was conducted on the 4 regencies/cities in West Sumatra province (Agam; Solok; Padang Pariaman; and Tanah Datar) with a total of 33 sites from October 2024 to March 2025 and altitudes ranging from 15 to 1571 meters. Survey activities for local chili varieties were conducted in four regencies/cities such as Agam regency (Altitude range from 0 to 2891m asl), Solok (Altitude range from 329 to 1,458m asl), Tanah Datar (Altitude range from 400 to 1000m asl), and Padang Pariaman (Altitude range from 10-1000m asl). According to the altitude classes of Michael, (2019), 0 – 600 is lowland, 600 – 1500 is pre-mountainous, 1500 – 1800 is low mountain, 1800 – 2700 is mid-mountain, 2700 – 3300 is high mountain and 3300 – >3300 is sub-alpine.

Sampling

Fruits were collected, transported, and incubated in the lab using the previously published procedures in each sample region (Copeland et al., 2002). The inspection of local chili fields was counted randomly at the same time as the survey. Criteria sites were determined purposively based on three criteria: Secondary information of local chili varieties from previous studies (Suliansyah, Ekawati, & Hariandi1, 2023), cultivation area is greater or less than 400 meters square, and fruits at generative phase in which fallen fruits without decomposition or attack by soil organisms were occasionally collected from the ground. The material used a variety of pepper chili plants owned by farmers in each chili plantation. Chili host plants were identified in the field using the manuals of (Budiyanti et al., 2024). Altitude and GPS coordinates were noted for every sampling location (Choudhary et al., 2015; Astriyani, 2014; Drew, 2011).

Fruit fly trapping and identification

One modified Lynfield trap were installed at the center of each of the diagonal rectangle sample plots in a chili plantation at a height of 1.5 m from the ground supported by wood stakes. Traps were placed at 7:00 a.m. and taken at 5:00 p.m. All treatment solutions were prepared, soaked in cotton wick for 24 hours, and equipped in Lynfield trap. Petrogenol 800 L (Methyl eugenol) were dropped into cotton as much as with a dose of 1.5 ml/trap (Mayasari et al., 2019). To conserve dead fruit flies, a liquid preservative was used to prevent decay and desiccation of about 15 mL of a 70% ethanol solution (Bronnec & Alexeyev, 2022). Lynfield traps can be made locally by using abandoned packaged water bottles. Following the removal of the plastic label from these bottles, heated GI wire is used to puncture four holes in the direction of the label's upper 5 cm band, each measuring 6 to 8 mm and just large enough to allow fruit flies to enter. Then, at the top of the plastic container is equipped with a hook. The hook were modified from the rope to make it easier for the trap device to be installed on the branch of the host tree they were further equipped using GI-wires for hanging. Each modified trap were labeled with identities; trap numbers, research locations, the date for trap setting (Gupta & Regmi, 2022). Dead fruit flies were taken with tweezers and put into a film bottle containing 70% alcohol and then labeled. After that, samples were further identified at Andalas University's Faculty of Agriculture's Insect Bioecology Laboratory.

Morphological identification of *Bactrocera spp*.

The general features of the fruit fly *Bactrocera* sp.'s thorax, abdomen, and wings were used for morphological identification. Morphological characteristics of the type of fruit flies found was done by referring to the fruit fly pest identification book written by Suputa et al. (2006), an image by AQIS (2008) (Astriyani et al., 2016) by observing the matching of all the visible fruit fly characteristics, and key identification of the fruit fly is as follows Larasati et al. (2016).

Statistical analysis

In order to ensure that infestation rates were sufficiently representative of the field, we calculated the fruit infestation (%) and plant infestation (%) following formula (Kakar et al., 2014). The calculation of the diversity index of fruit fly species will be carried out for each cultivar at each sampling location by using Shannon- Wienner formula (Magurran, 1988) and Evenness formula (Pielou, 1966). Duncan's various range tests were used to compare and categorize the average number of captures made by each trap. Descriptive statistics and Pearson correlation analysis were used to evaluate relationships between fruit fly counts, infestation levels, altitude, and chili variety. Graphs and heatmaps were created to illustrate trends. Version 25.0 of the SPSS program was used to conduct analysis of variance (ANOVA).

Results and Discussion

Trapping number of *Bactrocera spp.*

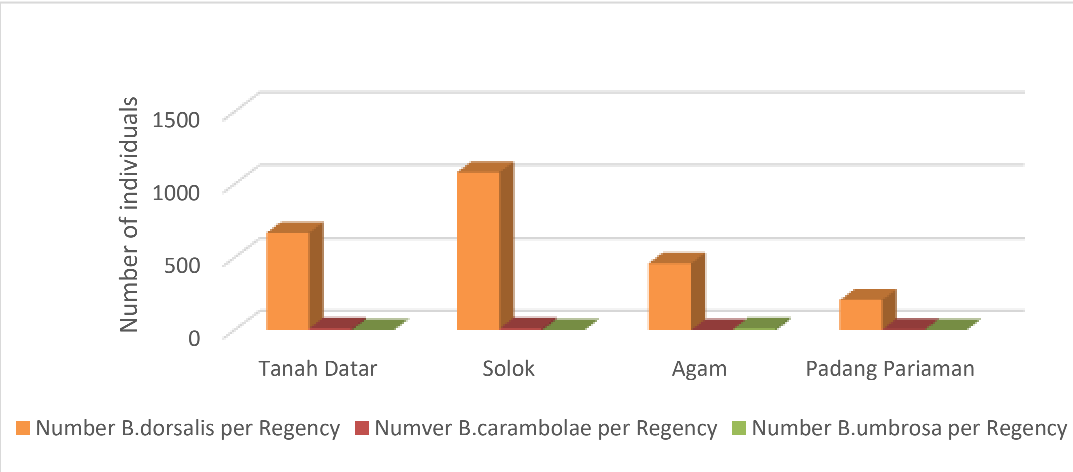

Figure 1. Relative abundance of *Bactrocera spp*. across four regencies

Important markers of pest dynamics and the financial effect of these pests on agricultural output are the variety and makeup of fruit fly (*Bactrocera spp*.) populations in West Sumatra. Three main Bactrocera species were found in red chili (*Capsicum annuum* L.) fields in this study incluuding *B. dorsalis*, *B. carambolae*, and *B. umbrosa*. Nonetheless, two main species were found, specifically *B. dorsalis* and *B. carambolae*, which the most common and dominant species at all trap locations (Figure 2) was *B. dorsalis*, accounted for up to 98.9%, or 2417, of all fly captures in 2048. It consistently accounted for the largest percentage of flies caught; in Solok, some sites reported trap captures of over 452 individuals per trap. *B. carambolae*, on the other hand, was much less common and only sometimes observed; it frequently co-occurred with *B. dorsalis* but never took over. With 20 individuals, or 0.8% of the total, this species was mostly found in mid-altitude regions, especially in Tanah Datar and Solok. Rarely, Bactrocera species found, especially *B. umbrosa*, which accounted for 0.3% with 9 individuals.

According to observations, *Bactrocera spp*. diversity in red chili fields in West Sumatra was low in species richness but high in pest pressure, mostly due to *B. dorsalis*'s dominance. Numerous ecological or environmental reasons, specifically different farming patterns and altitude changes. High-altitude locations (<1500 m) are found in Solok, Tanah Datar, and Agam; these locations may accelerate the pace of population expansion for some species while favoring those that can withstand cold. This result supported the findings of Odanga et al. (2018) and Geurts et al. (2014), which demonstrated that fruit infestation levels varied with *B. dorsalis* population variation, reaching their greatest at lower elevations and relatively low at higher elevations (>1500 asl). Moreover, species richness and trap attractiveness were probably influenced by the availability of alternative host plants (such as mango, guava, tomato, and eggplant) in the surrounding vegetation (Ye & Liu, 2007). Furthermore, Tan & Nishida (2012) mentioned that methyl eugenol was also very specific attraction to male *B. dorsalis* but less effective for non-responsive species, which might result in an underestimating of variety. Another aspect that the discovery of *B. umbrosa*, albeit in small quantities due to many causes. According to White (1992) and Leblanc et al. (2012) that *B. umbrosa* was not commonly associated with chili as a major host for oviposition, this close contact could have drawn adult flies that strayed into traps. Jackfruit trees and other Artocarpus species were planted next to or beside chili patches in a number of the investigated areas where habitat overlap was present. Furthermore, *B. umbrosa* may be inadvertently trapped even if it was not very sensitive to methyl eugenol, particularly if there was a large population density in neighboring host trees (Drew et al., 2005; Tan & Nishida, 2012).

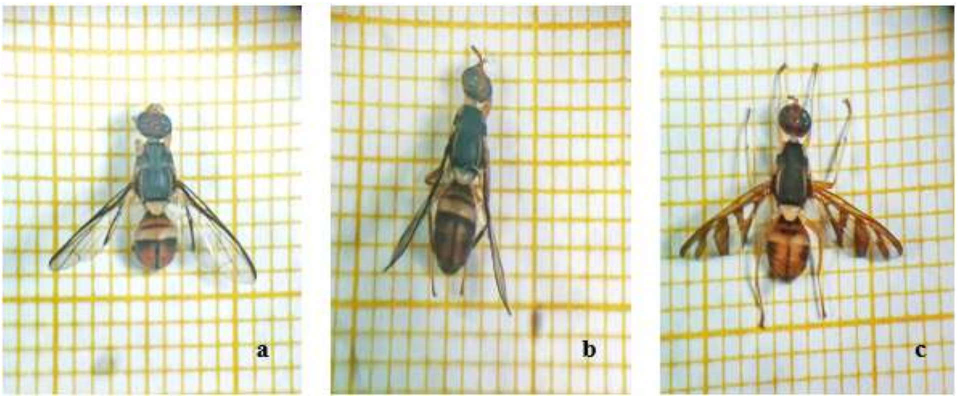

Figure 2. Morphological character of *Bactrocera dorsalis* (a), *Bactrocera carambolae* (b), and *Bactrocera umbrosa* (c) Diversity of *Bactrocera spp*.

Location	Species Identified	Total Individuals	Shannon Index (H′)	Simpson Index (1-D)	Evenness (E)
Tanah Datar	*Bactrocera dorsalis, Bactrocera carambolae*	678	0.077	0.029	0.111
Solok	*Bactrocera dorsalis, Bactrocera carambolae*	1090	0.052	0.018	0.075
Agam	*Bactrocera dorsalis, Bactrocera umbrosa*	469	0.095	0.038	0.137
Padang Pariaman	*Bactrocera dorsalis, Bactrocera carambolae*	211	0.054	0.019	0.077

Table 1. Species identified and biodiversity indices calculated per location

To evaluate the organization of the *Bactrocera* communities in each location, diversity indicators such the Shannon Index (H′), Simpson Index (1−D), and Evenness (E) were computed based on Table 1. Agam had the highest Shannon Index (H′) at 0.095, suggesting a more evenly distributed community structure. Conversely, Solok and Padang Pariaman showed minimal species diversity, as evidenced by their low H′ values (0.052 and 0.054, respectively). Because *B. dorsalis* dominated these areas, community evenness was diminished. Furthermore, a similar pattern was seen in the Simpson Index (1−D), where Solok had the lowest diversity (0.018) and Agam once more had the most (0.038). This confirmed the finding that a single species monopolized trap captures in Solok, creating a very unequal society. These variations were further emphasized by the Evenness (E) statistic. Tanah Datar (0.111) and Agam (0.137) had the most evenness, indicating a more equal distribution of individuals across species. Since Solok had the lowest evenness (0.075), the conclusion that there was a lack of balance and species domination is supported.

There are notable ecological differences in the diversity and evenness of *Bactrocera spp*. may be related to habitat features and farming methods. Agam had the most species variety of the locations, which may be a result of a more varied habitat or a wider range of host plants. On the other hand, Solok had the lowest Shannon and Simpson indices, a very low evenness score, and the greatest number of fruit flies. In systems that are controlled by monocultures or have reduced ecological diversity, this suggests that one species likely *B. dorsalis* dominates and can outcompete others. This result was supported by Vargas et al. (2015) fruit fly populations that live in heavily maintained orchards with a single host predominant have shown similar trends. Additionally, research findings were in line with prior study Schowalter (2016), reduced ecosystem stability and resilience are frequently linked to lower diversity and evenness, which may have an impact on the dynamics of pest outbreaks. Furthermore, prior research highlighting the sympatric distribution of *B. dorsalis* and *B. carambolae* in Southeast Asia is consistent with their co-occurrence in the majority of locations (Vargas et al., 2012).

Relationship between *Bactrocera spp*. infestation level and chili varieties

Table 2. Fruit flies infestation range by five local chili varieties

Chili Variety	Infested Plant % (mean ± SD)	Infested Fruit % (mean ± SD)	n
Akar	62.2 ± 23.2	4.5 ± 2.3	9
Keriting	73.0 ± 19.3	3.3 ± 2.6	10
Kopay	52.5 ± 67.2	4.7 ± 5.9	2
Kuhay	21.7 ± 9.8	0.5 ± 0.2	6
Rawit	62.5 ± 24.9	3.1 ± 3.1	6
Sig	0.005	0.077	

The statistical Table 2 showed that there were five native chili types including Akar, Keriting, Rawit, Kopay and Kuhay. These findings suggested a significant difference between chili variety and infestation intensity at 0.005%. Keriting, Rawit, and Akar recorded the highest average infested plant 73, 62.5, and 62.2% respectively. Moreover, Kopay and Akar varieties displayed the highest fruit infestation with 4.7 and 4.5, respectively. Conversely, Kuhay had significantly lower infestation levels, with an average of just 0.5 infested fruits and 21.7% infested plant.

These findings suggested a clear correlation between variety and infestation intensity. The level of fruit fly infestation varied markedly among the five chili varieties observed: Akar, Keriting, Rawit, Kopay, and Kuhay. This variation indicated potential genetic or morphological factors influencing susceptibility or resistance to fruit fly attacks. The Akar and Keriting varieties recorded the highest average number of infested level, suggesting that these varieties were highly attractive or susceptible to fruit fly oviposition. This findings were interpretated that their fruit morphological traits such as thin skin, pungency, or fruit size may be contributing factors, as reported in previous studies linking host fruit characteristics to *Bactrocera spp*. Preference (Ekesi et al. 2007; Abdullah et al. 2021; Syamsudin et al., 2022). In contrast, the Kuhay variety displayed the significantly lowest infestation levels both plant and fruit, indicating Kuhay possesses traits associated with resistance or low attractiveness to fruit flies. Such traits may include tougher pericarp, smaller fruit size, lower volatile emission, or other defensive plant chemistry (White, 1992; Syamsudin et al., 2022).

Correlation between *Bactrocera spp*. infestation level and Regencies

Rates of infestation vary greatly by location and type of chili in Figure 3. Whereas fruit infection varied from 0.2% to 8.9%, plant infestation ranged from 5% to 100%. Tanah Datar, Agam, and Solok regency were among the pre-mountainous sites with the highest infection, whereas Padang Pariaman had the lowest infestation. Solok (pre-mountainous) recorded the highest infested plant (88%) and fruit (6.64%). Conversely, Padang Pariaman showed the lowest both infestation level (41.43%) and (1.83%). Suggesting a strong link with infestation that was probably caused by multiple reasons.

Solok and Agam nevertheless documented significant damage in their investigation, suggesting a strong link with infestation that was probably caused by a variety of reasons. This might suggest that other interrelated variables were at work and that fly abundance was not the only factor driving infestation. Susceptible chili cultivars (Akar, Keriting) that may have physical or chemical characteristics that draw ovipositing females were mostly planted in highly infected sites at high elevations (Ali et al., 2020). Additionally, localized factors including sun exposure, wind buffering, and valley effects may provide microhabitats that were favorable for fruit fly survival and reproduction, even if altitude typically lowers average temperature (Ekesi, 2007). According to further research, the prevalence and proportion of *B. dorsalis* infestations lessen pest pressure at higher elevations (1500 m.a.s.l.) (Odanga et al., 2018) and were almost nonexistent above 1700 m (Finnie et al., 2021). However, Ye & Liu (2007) found that the primary factor affecting the population's high and low is the host. The findings of Hassani et al. (2022), which highlight how altitude indirectly affects fruit fly population dynamics through modifications in abiotic variables and host diversity, corroborate this conclusion. Highland areas' surrounding vegetation and host diversity included a variety of alternative host plants, including oranges, tomatoes, papayas, eggplants, and rose apples, which may support *Bactrocera spp*. populations even in colder climates (Leblanc et al., 2012). Because of lower temperatures and host availability, it may be assumed that higher altitudes often report decreased pest pressure from *Bactrocera spp*. (Vargas et al., 2015; Ian M. White, 1992). On the other hand, fruit fly reproduction is best at lower elevations (Ye & Liu, 2007).

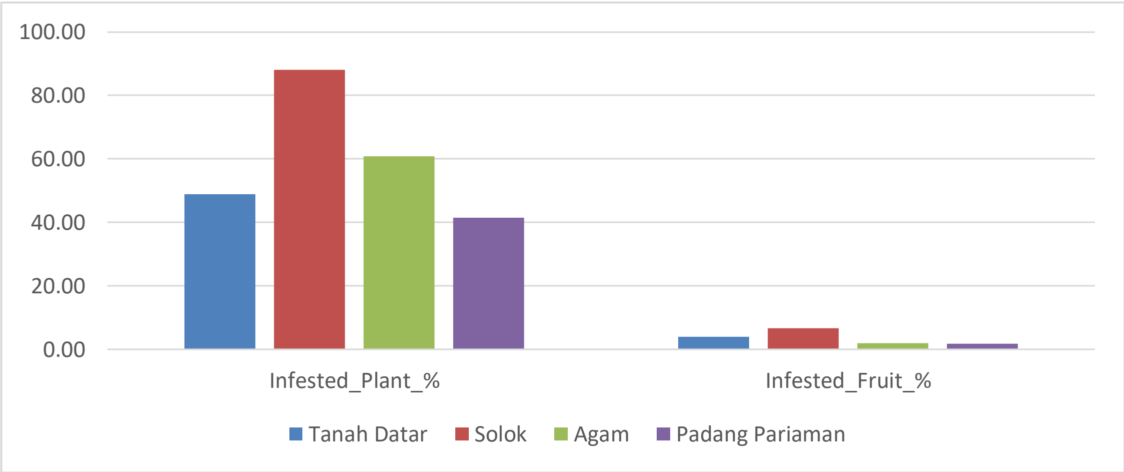

Figure 3. Percent infestation levels in four regencies

Conclusion

The conclusion of this study is: 1). the diversity of *Bactrocera spp*. was low and *B. dorsalis* was the most dominant species across four regencies; 2). The correlation between *Bactrocera spp*. diversity and infestation levels, regencies and red chili varieties in West Sumatra was influenced by a number of ecological factors, host preferences, the efficacy of control strategies, and agricultural practices; 3). These findings underscore the significance of incorporating varietal resistance screening into pest management frameworks in highland chili systems.

Further research is required to investigate the precise interactions between *Bactrocera spp*. and their environments to improve pest control efforts in this region.

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