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Effects of Seasonal Transitions on Population Dynamics of Fruit Flies in *Capsicum annuum* and *Solanum lycopersicum* in Batu City, Indonesia

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Abstract. Fruit flies remain a persistent threat to horticultural production, especially in tropical regions where seasonal shifts can significantly affect their population dynamics. This study investigated the species composition, diversity, and environmental drivers of fruit fly populations infesting *Capsicum annuum* and *Solanum lycopersicum* over a one-year period in Batu City, Indonesia. Using weekly sampling across four seasonal phases—dry-to-rainy transition, rainy season, rainy-to-dry transition, and dry season—fruit fly specimens were collected, reared, and identified. Environmental variables, including temperature, humidity, rainfall, light intensity, and pesticide application frequency, were monitored and analyzed in relation to fruit fly abundance using Principal Component Analysis (PCA) and multiple linear regression. A total of four species were recorded: *Bactrocera carambolae*, *Bactrocera dorsalis*, *Atherigona* sp, and *Silba* sp, with the latter representing a new regional record for East Java. Population peaks occurred during the rainy season and its transitional periods, while significant declines were observed during the dry months. Regression models revealed that temperature and humidity supported population growth, whereas pesticide use had a consistently suppressive effect—particularly for *B. dorsalis* and *Atherigona* sp. However, the models explained only 20–50% of the variation, suggesting that additional ecological factors may be at play. These findings deepen our understanding of fruit fly ecology in tropical systems and highlight the importance of integrating climatic and agronomic data in pest management strategies. The discovery of *Silba* sp. further enriches current biogeographical knowledge and signals the need for adaptive, interdisciplinary approaches to sustainable pest control.

Keywords: fruit flies; seasonal shift; population dynamics; environmental drivers diversity

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INTRODUCTION

Fruit flies are among the most destructive and invasive pests affecting horticultural crops, notably *C. annuum* and *S. lycopersicum*, where they lead to considerable economic losses (Bhoye, 2024; Bulawan et al., 2022; Rattanapun et al., 2021; Augustin et al., 2022). Infestations by fruit flies lead to substantial economic impacts through both reductions in yield quality and quantity and increased control costs (Tarimo et al., 2023; Lello et al., 2023). Fruit fly numbers in Indonesia and similar tropical regions tend to shift with the seasons, largely due to changes in weather—things like rainfall, temperature, and humidity—which in turn shape how larvae grow and mature inside fruit hosts (Zhao et al., 2024). Their infestation reduces both the yield and quality of harvests while also driving up pest control expenses due to larval damage inside the fruits (Tarimo et al., 2023; Lello et al., 2023). *Atherigona orientalis* has adapted to shifting climates, enabling it to spread into new areas, including parts of Korea and Greece (Colberg et al., 2024; Roditakis et al., 2023). Climate shifts have made 85% of land habitats more suitable for invasive pests (Cao & Feng, 2024), accelerating their global spread (Indriyanti et al., 2012). In Indonesia, *Bactrocera* infestations can lead to yield losses of up to 40% during the rainy season and around 1–2% during dry periods (Indriyanti et al., 2014).

Despite existing research, there is limited specific information on the patterns of fruit fly population fluctuations in relation to seasonal transitions, particularly in *C. annuum* and *S. lycopersicum* crops. This study set out to identify the species of fruit flies infesting two specific host plants, evaluate their diversity, and examine the extent to which environmental conditions shape their population dynamics across different seasons and transition periods. Gaining insight into these patterns helps address a key gap in current scientific understanding—particularly in the context of sustainable pest management. Knowing when population peaks occur can also support more precise pesticide use, making control measures both more effective and less harmful to the surrounding environment. Identifying any previously unrecorded species could also indicate emerging threats, requiring adjustments to current management efforts.

METHODS

Study Area

The study was conducted over 12 months in three agricultural plots of each of *C. annuum* and *S. lycopersicum*, each measuring 1,500 m², situated in the farming area of Sumberejo Village, Batu City, Indonesia (7°51'40.30" N, 112°30'54.80" E, elevation 890 m a.s.l.). The climatic conditions define distinct seasons and transitional periods, namely: dry to rainy season (August- October 2022), rainy season (November-December 2022 and January- February 2023), rainy to dry season (March-April 2023), and dry season (May-July 2023). These crops were selected due to their economic significance and prominence as primary vegetable commodities for local farmers.

Sampling Procedures

Environmental data, including temperature, humidity, light intensity, wind speed, and rainfall, were recorded weekly at midday (12:00–14:00), concurrently with fruit sampling. Fruit samples showing fruit fly infestation symptoms were collected weekly using gloves and stored in paper bags. Infested fruits of *S. lycopersicum* were placed in 650 ml paper bowls, whereas *C. annuum* fruits were stored in microwave boxes measuring 17 cm × 11 cm × 3.5 cm (top) and 15 cm × 9.5 cm × 3.5 cm (bottom). The bottom of each container was layered with sterilized sand mixed with fine sawdust and moistened with sterile water to facilitate pupation. Larvae and pupae were inspected every three days for two weeks following field collection.

Species Identification

Fruit flies emerging from fruit samples were identified as species using the key to Tephritidae. (Australia, 2018) Lonchidae (Reimann & Rulik, 2024; Rodrigues & González, 2022; Arimoto et al., 2020) and Muscidae (Roditakis et al., 2023; Mouttet & Taddei, 2024; Magoai & Muller, 2024). Fruit fly species were identified at the Biology Laboratory of Brawijaya University and confirmed at the Pests and Diseases Laboratory of the Faculty of Agriculture, Gadjah Mada University, and Museum Zoologicum Bogoriense BRIN. Fruit fly specimens and parasitoid species were kept at the Biology Laboratory of Brawijaya University.

Data Analysis

Total abundance, species richness, species evenness, and Simpson and Shannon indices were calculated for each season and transition using PAST 4.13. A normality test was performed with Shapiro-Wilk. Differences in mean fruit fly abundance between seasons and transitions were analyzed using ANOVA, followed by Tukey's test. The relationship of environmental factors and frequency of pesticide spraying to the fruit fly population was analyzed for each season and transition with Principal Component Analysis (PCA) in R statistical program. In addition, multiple regression analysis was used to build regression models.

RESULTS AND DISCUSSION

Fruit Fly Species Diversity Associated with *C. annuum* and *S. lycopersicum* Across Seasonal and Transitional Phases

This study successfully identified four fruit fly species infesting the fruits of *C. annuum* and *S. lycopersicum*, namely *Atherigona* sp, *B. dorsalis*, *B. carambolae*, and *Silba* sp. While the first three species were detected on both crops, *Silba* sp. was found exclusively on *C. annuum*. The presence of *Silba* sp. constitutes a novel record for East Java. Previous findings have reported *Silba adipata* in Bali (Yuliadhi et al., 2024; Widaningsih et al., 2024; Merta et al., 2024), *S. adipata* in Rembang, Central Java (Ningtyas et al., 2023), and *Silba capsicarum* in Bogor, West Java (Macgowan & Rauf, 2019).

In total, 33,915 individual fruit flies were collected, with nearly equal distribution between the two host plants, 16,960 on *C. annuum* and 16,955 on *S. lycopersicum*. Population dynamics exhibited a seasonal fluctuation pattern influenced by climatic changes. Table 1 provides the diversity of fruit flies in *C. annuum* and *S. lycopersicum*. Fruit fly abundance rose steadily during the shift from dry to rainy conditions, reaching its highest point in the rainy season, then declined as the climate dried—most sharply during the peak of the dry period. This pattern held for both crops.

Species richness remained relatively low throughout the year, with only three to four dominant species observed, likely due to environmental constraints such as limited host plant availability in agricultural settings (Dionysopoulou et al., 2020; Facon et al., 2021), as well as physical pest control practices like pesticide application (De Araujo et al., 2021). However, species evenness remained relatively stable across all seasons, indicating a degree of fruit fly adaptability to seasonal environmental changes.

Simpson's diversity index revealed low dominance during the transition from dry to rainy season. In contrast, lower Simpson values during the rainy season and the following transition suggest increased dominance by specific species, particularly *Atherigona* sp. During the dry season, species dominance shifted, with *B. dorsalis* becoming more prevalent on *C. annuum* and *B. carambolae* on *S. lycopersicum*. Shannon's diversity index appeared to support these findings, as species richness remained notably low—likely due to the narrow taxonomic range identified during field sampling.

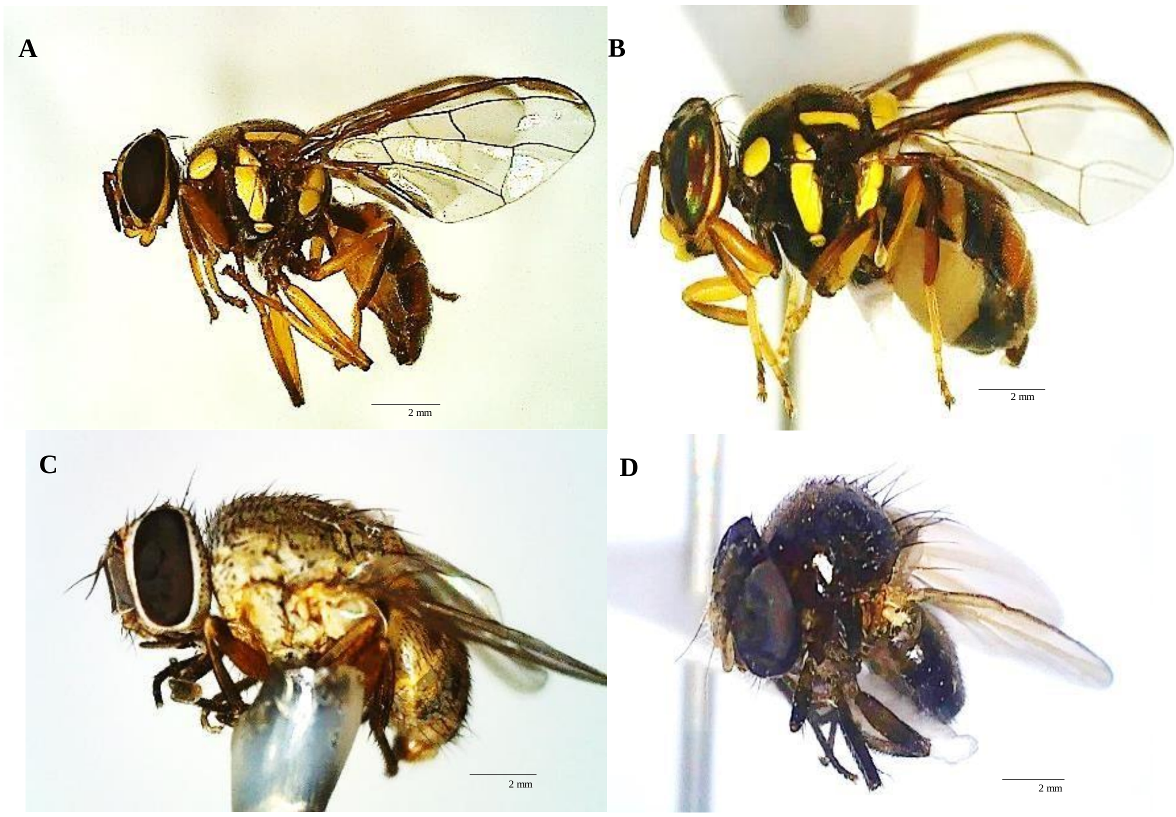

Figure 1. Morphology of (A) *B. dorsalis*; (B) *B. carambolae*; (C) *Atherigona* sp; and (D) *Silba* sp.

Table 1. The Biodiversity Indices of the Fruit Flies in *C.annuum* and *S. lycopersicum* Fruits

Variable	Season	Fruit Flies Diversity Indices	
		C. annuum	***S. lycopersicum***
Abundance	Dry to Rainy	4465	4097
	Rainy	4643	4371
	Rainy to Dry	4937	5217
	Dry	2915	3270
Richness	Dry to Rainy	0.4	0.2
	Rainy	0.4	0.2
	Rainy to Dry	0.4	0.2
	Dry	0.4	0.2
Evenness	Dry to Rainy	1	0.9
	Rainy	0.9	0.7
	Rainy to Dry	0.9	0.9
	Dry	0.9	1
Simpson’s Index	Dry to Rainy	1.4	1
	Rainy	0.7	0.4
	Rainy to Dry	0.7	0.6
	Dry	0.7	0.6
Shannon's index	Dry to Rainy	1.4	1
	Rainy	1.2	0.8
	Rainy to Dry	1.3	1
	Dry	1.2	1.1

Table 2. Comparison of Average Weekly Fruit Flies in *C. annuum* and *S. lycopersicum* Fruits Based on One-way ANOVA at Each Transition of the Season

Season	***C. annuum***				***S. lycopersicum***		
	B. carambolae	*B. dorsalis*	*Atherigona* sp	*Silba* sp	*B. carambolae*	*B. dorsalis*	*Atherigona* sp
Dry to Rainy	24.82^{c}	33.16^{b}	46.15^{c}	18.48^{b}	28.09^{b}	18.52^{b}	50.92^{b}
Rainy	9.41^{a}	20.60^{a}	67.41^{d}	20.56^{b}	16.54^{a}	8.58^{a}	65.94^{c}
Rainy to Dry	30.52^{d}	54.67^{c}	14.97^{a}	30.26^{c}	59.07^{d}	28.44^{c}	105.70^{d}
Dry	17.74^{b}	34.82^{b}	29.85^{b}	7.21^{a}	35.41^{c}	18.51^{b}	29.92^{a}

Note: Different superscript letters in each column with an average value indicate a significant difference ($p < 0.05$; Tukey test)

When comparing seasonal averages (Table 2), notable differences emerged in population sizes across all species observed. *B. carambolae* populations were highest during the transition from rainy to dry season, displaying an upward trend from the rainy months toward the dry period, while populations remained low from dry-to-rainy transition through the rainy season. Meanwhile, *B. dorsalis* exhibited a relatively stable pattern, peaking during the rainy-to-dry season transition, with significant variation across most seasons except between the dry season and the subsequent transition.

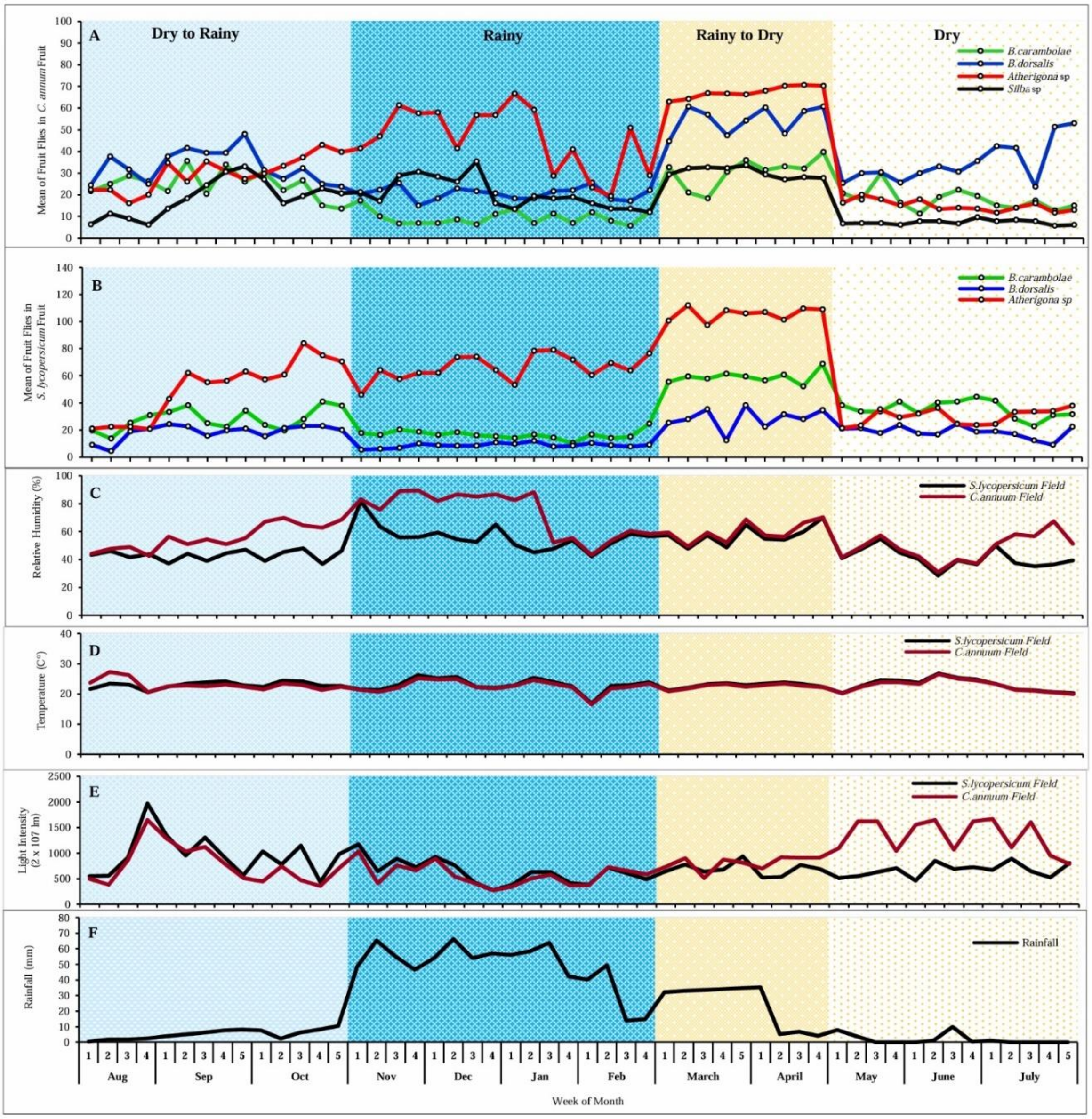

Figure 2. Illustration of average weekly population patterns of fruit flies on dry to rainy, rainy, rainy to dry, and dry seasons in *C. annuum* and *S. lycopersicum* fruits (A-B) based on climatic conditions on fields (C-F). (A) Illustration of seasonal patterns *of B. carambolae*, *B. dorsalis*, *Atherigona* sp, and *Silba* sp on *C. annum* fruit. (B) Illustration of seasonal patterns of *B. carambolae*, *B. dorsalis*, and *Atherigona* sp on *S. lycopersicum* fruit. (C) Relative humidity. (D) Temperature. (E) Light intensity. (F) Rainfall. The colours represent the local seasons that occur in the agricultural landscape of Sumberejo Village, Batu City. From left to right are: (light blue) transition season from dry to rainy, (blue) rainy season, (light yellow) transition season from rainy to dry, and (light yellow with a dotted pattern) dry season.

Atherigona sp. populations surged sharply but briefly during the rainy season in *C. annuum* and during the rainy-to-dry transition in *S. lycopersicum*. Variation of seasons appeared to impact the average abundance differently between the two crops; *C. annuum* tended to peak during the rainy season, whereas *S. lycopersicum* reached higher numbers during transitional climate phases. Unlike the other species, *Silba* sp. populations on *C. annuum* showed little seasonal variation, staying relatively stable year-round—though a modest increase was noted during the transition from rainy to dry periods. No statistically significant changes were noted for this species between the dry-to-rainy transition and the rainy season.

The pattern of key environmental conditions corresponding with shifts in fruit fly population dynamics is illustrated in Figure 2. Notably, the rainy season appeared to coincide with substantial increases in population density, marking it as a particularly influential phase. Figures 2A and 2B, tracking population trends from August to July on *C. annuum* and *S. lycopersicum*, respectively, clearly show population surges during the rainy-to-dry seasonal transition.

Relative humidity (Figure 2C) remained elevated during the rainy season, dropping sharply in the dry season, thereby creating highly favorable conditions for fruit fly development. Relative humidity is a key environmental factor influencing fruit fly development, with elevated levels typically supporting more rapid growth and improved survival rates (San et al., 2021; Fiaboe et al., 2021). As shown in Figure 2D, temperature remained fairly stable over the year, dipping slightly in the rainy season—a period that also aligned with heightened insect activity. According to Figure 2E, light intensity was generally higher during dry periods and the seasonal shifts between extremes, though levels dropped as rainfall began to increase. Meanwhile, Figure 2F shows that precipitation was highest in the rainy season and strongly aligned with rises in fruit fly populations before declining under drier conditions.

Environmental and Seasonal Drivers of Fruit Fly Population Dynamics

Principal Component Analysis (PCA) was utilized to examine how environmental factors influence the fluctuation of fruit fly populations on *C. annuum* and *S. lycopersicum* across seasonal cycles. This analysis incorporated key environmental variables, including humidity, temperature, rainfall, light intensity, and the frequency of pesticide application. Species distribution patterns appeared to vary considerably across seasons, likely reflecting interactions with dynamic and shifting environmental conditions over time. PCA was conducted separately for each fruit fly species observed on *C. annuum* and *S. lycopersicum* (Figure 3).

On *C. annuum*, the PCA indicated that the population of *B. carambolae* (Figure 3.1A) accounted for 60.5% of the variation in the dataset. During the transition from dry to rainy season, this species appeared positively associated with warmer temperatures and stronger light intensity—factors generally conducive to adult activity and reproduction. Although humidity and rainfall supported larval growth, prolonged or excessive precipitation likely hindered reproductive success in adults. Similar patterns were observed in *Sarcophaga dux*, where larval development accelerated under rainy conditions compared to summer (Babu et al., 2024). Although elevated humidity facilitated larval development, high rainfall likely inhibited reproductive success by limiting adult flight activity and reducing the availability of suitable oviposition sites (Sontigun et al., 2018). A negative correlation was also observed with frequent pesticide applications. In the dry season, moderate temperatures and intense light appeared to support *B. carambolae* survival, while reduced rainfall and pesticide use contributed to lower environmental pressure on populations.

In comparison, *B. dorsalis* (Figure 3.1B) explained 60.1% of the data variation. During the dry-to-rainy transition, its population was weakly positively correlated with temperature and light while showing negative correlations with humidity and rainfall. Notably, pesticide application frequency was positively associated with both humidity and rainfall levels. In the rainy season, *B. dorsalis* populations declined, exhibiting negative correlations with all environmental variables. As the climate shifted from the rainy to the dry season, temperature and light began playing a more prominent role, fostering conditions favorable to species development. During the dry period, elevated temperatures and increased sunlight likely stimulated reproductive activity. In contrast, lower humidity, decreased rainfall, and ongoing pesticide use appeared to place stress on the population, limiting its growth.

For *Atherigona* sp. on *C. annuum* (Figure 3.1C), the PCA explained 63.5% of the variation. During the dry-to-rainy transition, this species was positively correlated with temperature, light, and humidity while showing negative associations with rainfall and pesticide use. During the rainy season, population levels were strongly influenced by high humidity, frequent rainfall, and pesticide use. In contrast, higher temperatures and increased light appeared to have a negative effect. Overall, the population seemed to thrive under moist, cooler conditions, while warmer, brighter environments were less favorable for its growth. In the dry season, population correlations with all variables were generally weak, indicating suboptimal environmental conditions for this species.

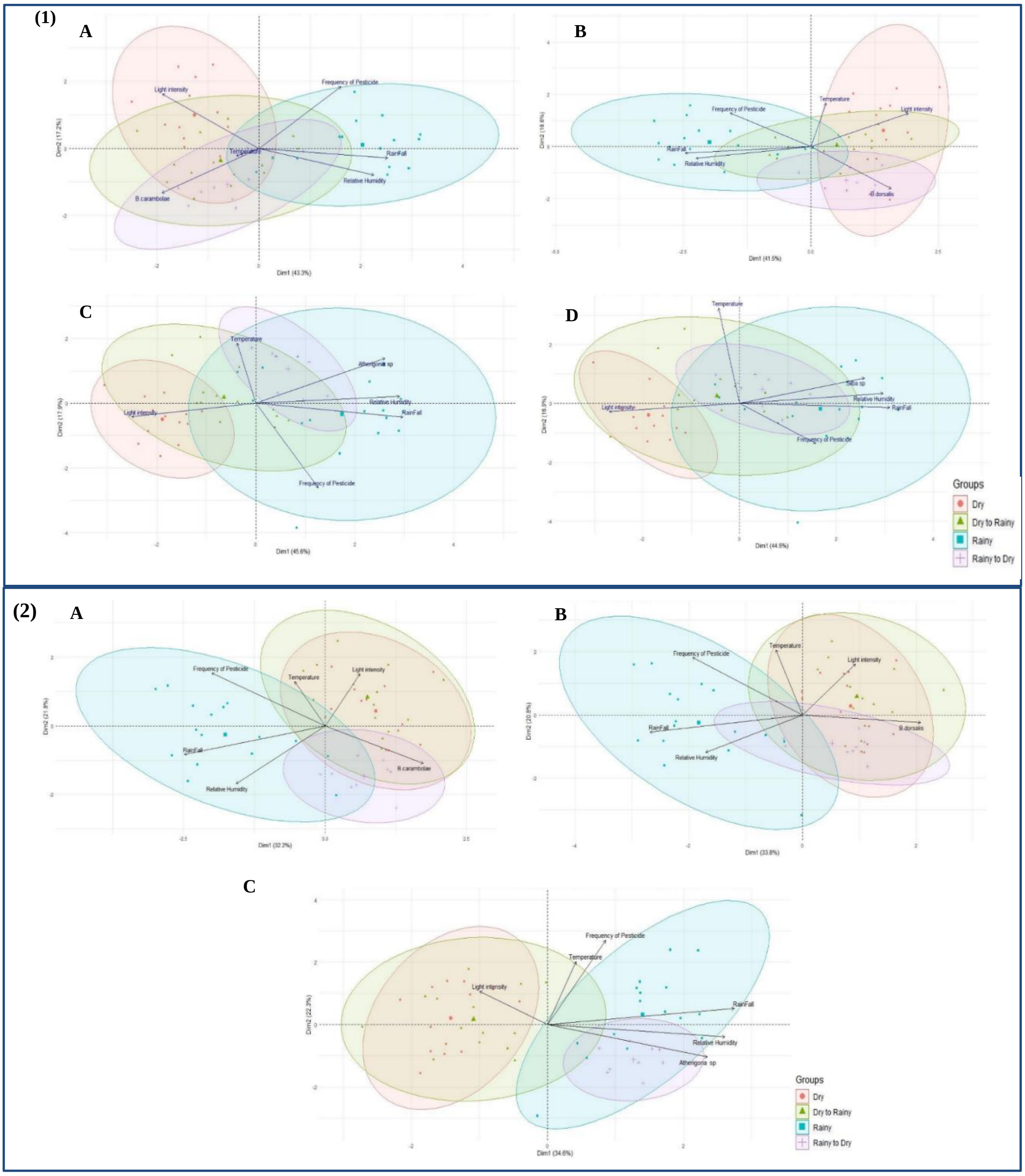

Figure 3. Principal Component Analysis (PCA) of Environmental Factors and Frequency of Pesticide Spraying on Fruit Flies Species Population in *C. annuum* (1) and *S. lycopersicum* (2) Fruit. PCA for (A) *B. carambolae*, (B) *B. dorsalis*, (C) *Atherigona* sp, (D) *Silba* sp. The dry season is colored pink with a round marker, the dry to rainy season is colored green with a triangle marker. The rain is colored with a rectangular marker, and the rain to dry is colored purple with a plus marker.

Analysis of *Silba* sp. on *C. annuum* (Figure 3.1D) accounted for 61.4% of the dataset variation. During the transition from dry to rainy season, the population of *Silba* sp. correlated positively with humidity and rainfall but negatively with temperature and light intensity. No strong relationship was observed between its population and pesticide application frequency. During the rainy season, strong positive links with humidity and rainfall continued to dominate, while temperature, light, and pesticide use were negatively associated with population levels. These patterns stayed fairly consistent as the seasons changed and carried into the dry season, where only light showed a slight positive effect while the other factors maintained their negative influence.

For *S. lycopersicum*, the PCA (Figure 3.2A) revealed that *B. carambolae* populations explained 54% of the variation. During the dry-to-rainy transition, the population was strongly positively correlated with temperature and light and negatively correlated with humidity, rainfall, and pesticide applications. As the rainy season went on, the dampening effects of humidity and rainfall became more pronounced, while the earlier positive influence of temperature and light seemed to lose strength in shaping population trends. However, as the weather shifted from rainy to dry, this pattern flipped again—reaching a peak in the dry season, when temperature and light emerged as the main factors supporting population growth. Rainfall and humidity continued to show strong negative correlations during this period.

For *B. dorsalis* on *S. lycopersicum* (Figure 3.2B), 54.6% of the variation was explained. During the dry-to-rainy transition, strong positive correlations were observed with temperature and light, while rainfall, humidity, and pesticides showed negative relationships. In the rainy season, negative correlations dominated all environmental variables except for weakly positive associations with temperature and light. As the season transitioned to dry, positive correlations with temperature and light strengthened again, while negative correlations with other variables began to diminish. In the dry season, temperature and sunlight became key factors in supporting B. dorsalis populations, while the dampening effects of humidity and pesticide use were less noticeable. Interestingly, it was the high temperatures during this period that had the biggest impact on how abundant the species became—populations actually peaked during the dry months (Odanga et al., 2020; Faryad et al., 2023; Li et al., 2024). A temperature range of 20–30°C has been cited as optimal for B. dorsalis development and survival (Fiaboe et al., 2021).

The PCA of *Atherigona* sp on *S. lycopersicum* (Figure 3.2C) accounted for 56.9% of the variation. During the dry-to-rainy season transition, correlations with temperature, light, and humidity were weak. During the rainy season, *Atherigona* sp populations appeared to be closely linked to elevated humidity, intense rainfall, and frequent pesticide exposure. In contrast, temperature and light had only minimal suppressive effects. As conditions began to shift, the influence of humidity and rainfall gradually weakened but remained present. Once the dry season set in, rising temperatures and stronger sunlight became more clearly linked to a drop in population. Meanwhile, the earlier positive influence of pesticide use also lessened. The steep drop in both humidity and rainfall likely made it harder for *Atherigona* sp to adapt, leading to a noticeable decline in their numbers.

A multiple linear regression analysis was carried out to assess the environmental impact on the seasonal fluctuations in the populations of four fruit fly species associated with *C. annuum* and *S. lycopersicum* (Figure 4). The research focused on four important seasonal phases: The dry to rainy season transition, the rainy season, the rainy to dry season transition, and the dry season.

The regression model in *C. annuum* (Figure 4.1.) for *B. carambolae* indicated a significant positive association with temperature, while pesticide application emerged as the strongest negative factor. Although relative humidity and rainfall had negative coefficients, their influence was not statistically significant. The model has an R^2 of 0.296, meaning the model explained 29.6% of the population variance. This relatively modest explanatory power suggests the need to consider additional ecological variables, such as host availability (Costa et al., 2023; Kitano et al., 2018), natural enemies (Costa et al., 2023), and fruit fly migration behavior (Jose et al., 2018).

For *B. dorsalis* on *C. annuum*, pesticide application had the most pronounced negative impact, while temperature and rainfall exhibited weaker, yet still negative, effects. Only 20.5% of the population variance could be explained by the variables included. The low predictive accuracy suggests that ecological context and additional environmental interactions should be factored into future models. Among the species analyzed, *Atherigona* sp. was particularly sensitive to environmental variation. The regression analysis showed that humidity, temperature, and rainfall were significant predictors of its population dynamics, which means that favorable abiotic conditions play a significant role in population growth. On the flip side, the use of pesticides had a significant negative impact, with a value of reflecting how much it limited their numbers with an R^2 value of 0.481. This model explained 48.1% of the variation, making it comparatively stronger than those for the other species.

For *Silba* sp. on *C. annuum*, both humidity and temperature showed positive correlations with population size, whereas pesticide application had a mild negative effect. Rainfall also contributed positively, though its impact was smaller. The regression model has an R^2 of 0.491. This indicates that approximately 49.1% of the population variance could be accounted for, suggesting the model provides reasonably good predictive power regarding environmental influence on *Silba* sp. dynamics.

Regression Models on *S. lycopersicum* (Figure 4.2.) for *B. carambolae* experienced population growth from humidity and temperature, but pesticide use and rainfall negatively affected it. The model has an R^2 value of 0.325. This model accounted for about 32.5% of the variation in *B. carambolae* populations, though other ecological aspects—such as habitat structure and alternative hosts—should be considered for a more complete understanding.

The model for *B. dorsalis* on *S. lycopersicum* indicated that humidity and temperature positively influenced population growth. The abundance of this species showed negative relationships with rainfall and pesticide use. Light intensity had a minimal effect as with other species. The model captured 40.4% of the variation, reinforcing the role of pesticide management and microclimatic monitoring in pest control strategies.

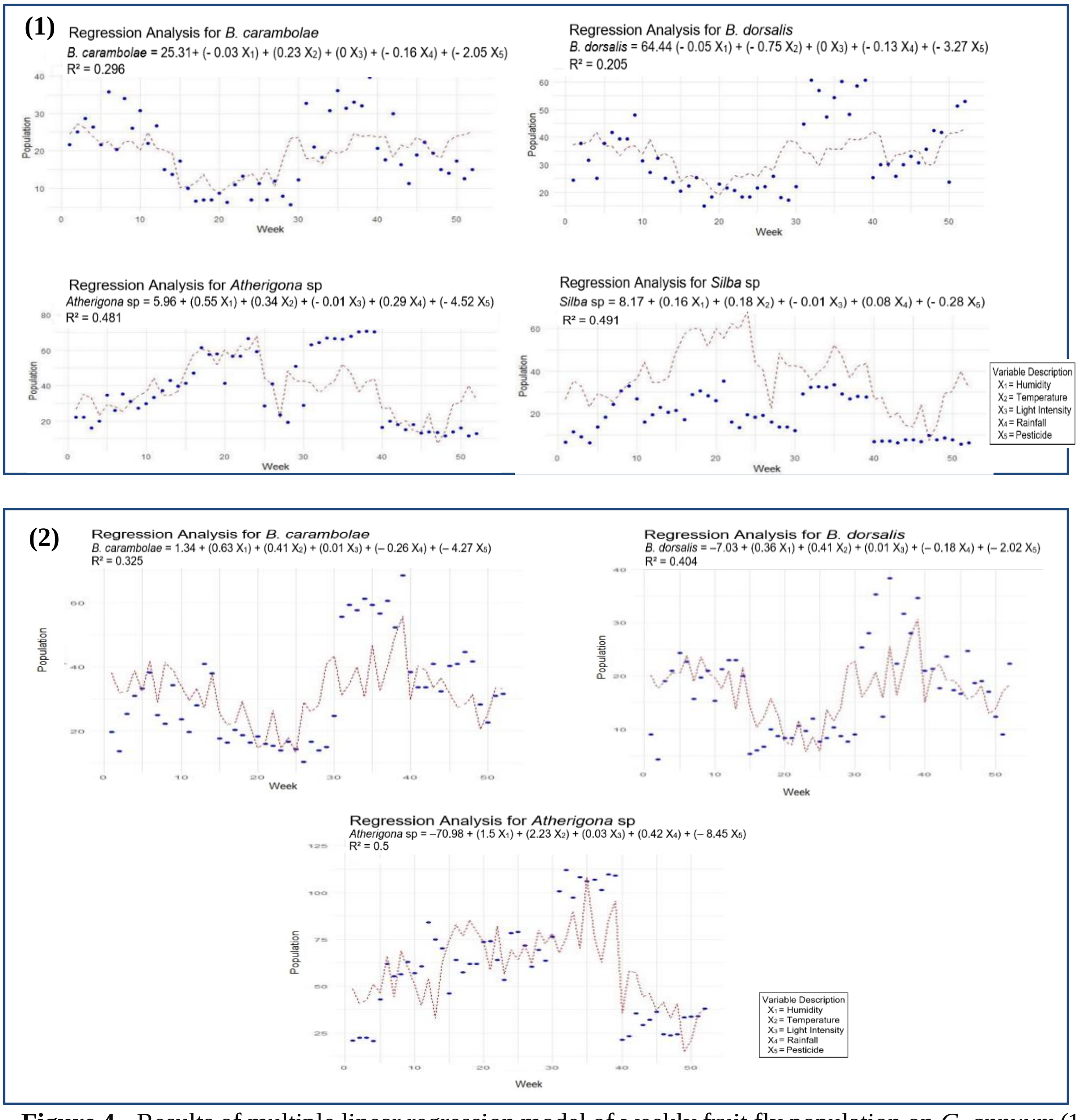

Figure 4. Results of multiple linear regression model of weekly fruit fly population on *C. annuum* (1) and on *S. lycopersicum* (2) across different seasons and its transition from dry to rainy, rainy season, rainy to dry, and dry seasons with environmental factors of temperature, humidity, light intensity, rainfall and frequency of pesticide spraying.

Finally, the regression for *Atherigona* sp. on *S. lycopersicum* highlighted humidity and temperature as dominant drivers of population increase. The population received modest positive effects from rainfall and light intensity, but pesticide use negatively affected the population the most. The regression model explained up to 50% of the population variation and suggests that *Atherigona* sp. thrives under high humidity and warm temperatures, particularly in the absence of intensive pesticide use.

The results of this study suggest that environmental variables—namely temperature, relative humidity, light intensity, rainfall, and pesticide usage—have a notable influence on fruit fly population dynamics in *C. annuum* and *S. lycopersicum*. Regression analysis showed that species such as *B. carambolae* tended to thrive under higher temperatures and humidity, while pesticide application remained the most consistent factor in suppressing their numbers. These findings are consistent with those of He et al. (2024), who noted that tephritid fruit fly populations respond strongly to environmental conditions—thriving in warm, humid settings, while heavy rainfall can disrupt larval development and reduce adult activity.

In this study, pesticide use clearly stood out as a major limiting factor for population growth. The effectiveness of pesticides depends on the application methods and the level of resistance in the pest population. The USDA APHIS (2023) also stressed the need for integrated pest management approaches and the need to use pesticides responsibly in order to minimize the potential harm to the environment and human health. Moreover, environmentally friendly alternatives—such as biological control agents—offer promising potential for managing fruit fly populations in a more sustainable manner (He et al., 2024). Beyond these patterns, the study contributes to our understanding of how tropical insect populations respond to both natural and human-driven changes. The appearance of *Silba* sp. in a previously undocumented area points to the potential for range expansion by weaving together climatological and agronomic data, The research also shows how valuable interdisciplinary approaches can be for managing pests in complex agroecosystems.

CONCLUSION

The findings from this study provide new insights into fruit fly diversity and distribution on two commonly cultivated crops. Three species — *B. carambolae*, *B. dorsalis*, and *Atherigona* sp. — were observed infesting both *Capsicum annuum* and *Solanum lycopersicum*. In contrast, *Silba* sp. was found exclusively on *C. annuum*. This marks the first documented occurrence of *Silba* sp. in East Java, adding to the regional species record.

The transition period from the dry to the rainy season appeared to support the highest diversity, especially on *C. annuum*, where Shannon and Simpson indices both reached 1.4. Meanwhile, diversity dropped to its lowest on *S. lycopersicum* during the rainy season, with index values of 0.8 and 0.4, respectively. Population trends over the course of a year reflected clear seasonal influences. Numbers generally climbed during the wet season and its transitional phases, then dropped steeply in the dry season. Temperature and humidity seemed to favor population growth, while pesticide use consistently limited the numbers of *B. dorsalis* and *Atherigona* sp.

Still, the regression models explained only part of the story — between 20% and 50% of the observed variation. This suggests that other factors may be equally important. Future work should look more closely at elements such as host plant availability, natural enemies, and habitat micro-conditions. Long-term studies and DNA-based identification tools are also recommended to better understand interannual patterns and to confirm species identity, particularly for newly observed species like *Silba* sp.

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