

ANALYSIS OF INSECT BEHAVIOR UNDER COMPOST TYPE AND DOSE VARIATION IN THE GENERATIVE PHASE OF MARIGOLD (*Tagetes erecta* L.)

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Article Info	ABSTRACT
Article history: Received 16 February, 2026 Revised 17 March, 2026 Accepted 2 April, 2026 *Corresponding Email: farendragiri.2021@student.uny.ac.id	This study aimed to determine the effect of the variation and dose of compost fertilizer from market organic waste MOL (local microorganisms) on the foraging rate and flower handling time of insects during the generative phase of marigold plants. This research used an experimental method with two factors: the variation of MOL in compost production and the dose of the compost fertilizer. The MOL activators used for composting were fruit MOL, vegetable MOL, a combination of fruit and vegetable MOL, as well as EM4 and water as controls. Data were collected using focal sampling and analyzed using quantitative descriptive methods. The results showed that the foraging rate on marigold flowers was dominated by <i>Apis mellifera</i>, <i>Trigona sp.</i>, and <i>Luthrodes pandava</i>. The highest foraging rate for <i>Apis mellifera</i> was observed in the 400-g treatment of compost made with a combination of fruit and vegetable MOL; the highest rate for <i>Trigona sp.</i> was found in the 400-g treatment of vegetable MOL compost; and <i>Luthrodes pandava</i> tended to have a low foraging rate across all treatments. For flower handling time, <i>Apis mellifera</i> was highest in the fruit-and-vegetable MOL treatment at 200 g, <i>Trigona sp.</i> was highest in the fruit-and-vegetable MOL at 200 g, and <i>Luthrodes pandava</i> was highest in the fruit MOL and vegetable MOL treatments at both 200 and 400 g. Insect behavior was influenced by the surrounding climatic factors as well as by the quality and quantity of flowers produced by the marigold plants as a result of fertilizer application. Keywords: MOL; compost; marigold; insect behavior

Introduction

The market is a center for the daily buying and selling of processed food products. Most market organic waste is not yet optimally managed, so it only ends up at waste disposal sites. The accumulation of this waste can cause various negative environmental impacts, such as unpleasant odors, degradation of water and soil quality, and the potential to become a source of disease (Purba *et al.*, 2024). Market organic waste can be converted into various useful products, such as raw material for local microorganisms (MOL) and organic fertilizer. MOL is a solution produced from the fermentation of organic matter that contains microorganisms useful for accelerating the decomposition of organic matter (Kurniawan, 2018).

Fruit and vegetable waste have different nutrient contents, which can create differences in the quality of the MOL produced. This MOL can be used to accelerate composting through decomposition. Compost from various types of MOL can have diverse nutrient contents. This is because the nutrient content of fruits and vegetables differs, which can cause differences in the microbes during the decomposition of organic matter (Khafidiyanto *et al.*, 2014). Compost has been shown to be effective in supporting the growth of various types of plants. Compost can accelerate the growth period of plants, including the growth of roots, stems, leaves, and flowers (Sudirman *et al.*, 2022). Therefore, the quality of MOL from fruits and vegetables can also affect the quality of the resulting compost.

Marigold (*Tagetes erecta* L.) is a flowering plant that can act as a refugia agent because it has a distinctive aroma and striking color, so it attracts various types of insects (Kurniati, 2021). The use of compost and marigold is an ideal combination to support environmentally friendly and sustainable

agriculture. Compost helps plant growth without damaging the soil, while planting marigold acts as a natural protector of the main crop from pest insects without the need for chemical pesticides. Planting marigold as a crop-top plant also significantly affects pollinator insects on the main crop (Aminatun *et al.*, 2023).

Differences in fertilizer type and dose can affect plant growth as well as the quality of flowers and fruit. Excessive addition of N reduces the quality and quantity of flowers (Gao *et al.*, 2023). This fertilization factor can affect insect behavior in the form of foraging rate and flower handling time. These two insect behaviors are strongly influenced by the quality and quantity of flowers. Through these behaviors, the rate of insect visitation in pollinating marigold can be determined.

Based on the description above, variations in the type and dose of compost can affect the nutrient content of the soil, the growth rate of marigold, flower quality, and the diversity and behavior of insects visiting the plants. Insect behavior is an important subject in ecological studies because it can indicate the stability of a community (Arifta, 2016). By determining the visitation rate and visit duration of insects, the effectiveness of flower-pollinating insects relative to the availability of floral resources that meet the insects' needs can be determined.

To date, few studies have examined the effect of fertilization on insect behavior, especially foraging rate or flower handling time. Foraging rate is defined as the number of food sources successfully obtained or processed per unit time (Afrian *et al.*, 2020). This foraging rate is a quantitative parameter often used to assess the efficiency of insects in exploiting resources in their environment. Visit duration is the length of time an insect spends exploiting resources (Afrian *et al.*, 2020).

Based on the description above, this study aimed to determine the effect of variations in the type and dose of compost from market organic waste on the foraging rate and flower handling time of insects visiting marigold flowers, given the limited information on the effect of fertilizer on insect activity.

Methods

The research was conducted at the Biology Garden of FMIPA UNY from January to April 2025. This study was carried out as an experiment with two factors: MOL variation and fertilization dose. The MOL variation was used as an activator during fertilizer production, using fruit MOL, vegetable MOL, fruit-and-vegetable MOL, as well as EM4 and water. The doses used were 200 g and 400 g, each with three replications.

Observation of the foraging rate of insects with potential as marigold flower pollinators used the focal sampling method (Aminatun *et al.*, 2023). Foraging rate, or the insect visitation rate, is the number of flowers visited per minute (Tarigan *et al.*, 2022). Data were collected using a stopwatch for insects that landed on flowers. Observations were made by walking around the plots on a schedule of morning (07:00–09:30), noon (11:00–13:30), and afternoon (15:00–17:30), twice a week for one month after the marigold flowered.

The data obtained from each observation were calculated and identified using the foraging rate and flower handling time formulas. The unit used for the number of visits per unit time is a count, whereas the unit for visit time per flower is seconds (Tanjung *et al.*, 2019). The results of the analysis are presented as tables and diagrams and described based on the results obtained.

Results and Discussion

Based on the research, the generative phase of marigold was dominated by pollinating insects of the order Hymenoptera, although insects from other orders also visited the flowers. Three types of pollinating insects with the highest number of individuals were found, namely *Apis mellifera*, *Trigona sp.*, and *Luthrodes pandava*. These three species are insects with potential as marigold flower pollinators.

Foraging Rate per Minute

Apis mellifera showed a very high result in the positive control treatment, far exceeding the dose and MOL variation treatments. This shows that the condition of the marigold plants and flowers in the positive control treatment (NPK fertilizer) produced the highest number of flower visits compared with the others, namely 16 flowers per minute. This is because marigold growth in the positive control treatment was the fastest. This rapid growth can promote a greater increase in the number of flowers on the plant (Nugroho *et al.*, 2019).

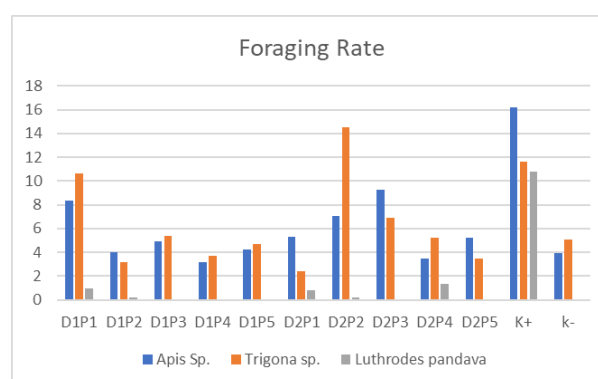


Figure 1. Foraging rate of the dominant insects

In general, the 400-g compost dose, especially with vegetable MOL and fruit-and-vegetable MOL, tended to show a higher foraging rate for the dominant insects than the 200-g dose; however, this response did not occur for all species or MOL types. A higher fertilizer dose most likely provides more optimal nutrient availability for the marigold plants. This increased nutrient availability can result in stronger plant growth, more flowers, and potentially increased production of nectar, pollen, and attractive volatile compounds (Tarigan *et al.*, 2022).

Apis sp. showed a visitation rate that varied depending on the fertilizer treatment. The fruit-and-vegetable MOL treatment at 400 g showed a relatively high visitation rate. This shows that the combination of fruit and vegetable MOL at a higher dose can increase the attractiveness of marigold flowers to *Apis sp.* by improving the quality of its floral resources. *Trigona sp.* also showed the highest visitation activity in the vegetable MOL treatment at 400 g, indicating that vegetable MOL at a higher dose is effective in increasing the attractiveness of marigold flowers to *Trigona sp.* *Trigona sp.* actively forages from morning to afternoon, with peak activity at midday (Wulandari *et al.*, 2017).

Meanwhile, *Luthrodes pandava* tended to have a relatively low foraging rate. This is closely related to its relatively longer flower handling time compared with *Apis sp.* and *Trigona sp.*, so the foraging rate of *Luthrodes pandava* is also smaller than that of other pollinators. *Luthrodes pandava* visited only certain treatments. This may indicate that *Luthrodes pandava* tends to prefer flowers that produce resources suited to its needs, for example in the fruit MOL and vegetable MOL treatments. *Luthrodes pandava* is a small butterfly with a proboscis proportional to its size. This short proboscis is a physical limitation, so it forages on flowers with easily accessible nectar (Chaudhary, 2020). This also leads to a longer visit duration, so the foraging rate tends to be lower.

Apis mellifera and *Trigona sp.* showed the highest foraging rates in the fruit-and-vegetable MOL treatment at 400 g and the fruit treatment at 400 g. In the fruit treatment at 200 g, the result was too high; this is because in that treatment there were plants that did not grow well, so insects only landed briefly without many visiting. The fruit-and-vegetable MOL treatment at 400 g had the highest foraging result for the dominant pollinators, so this MOL type has potential in attracting pollinating insects. Differences in visit duration (handling time) per flower among species affect the visitation rate, namely the number of flowers that can be visited per unit time (A'yunin *et al.*, 2019). The more flowers visited, the more efficient a pollinator species is. However, this also depends on the amount of pollen per visit

successfully transferred to the female flower's stigma (Artz & Nault, 2011). Therefore, visiting more flowers allows pollination to be more even, but the nutrient content of the flowers is not necessarily fully exploitable by the pollinators.

Flower Handling Time

Based on the results, *Luthrodes pandava* did not visit all treatments. This may be because *Luthrodes pandava* only visits flowers that are attractive to it, with strong flowers and stalks that can support its body. The insect came only to the fruit MOL, vegetable MOL, EM4 MOL (low), and positive control treatments. This indicates that *Luthrodes pandava* was attracted to marigold flowers in the fruit MOL and vegetable MOL treatments, at both 200-g and 400-g doses, with a high flower handling time. This indicates that these flowers contain substances attractive enough to be taken and consumed by *Luthrodes pandava* in fairly large amounts. *Luthrodes pandava* was also present in the EM4 treatment at 400 g, but only at a small value, indicating that this treatment also contained resources needed by *Luthrodes pandava* but offered fewer of them. Based on the results, the longer an insect visits a flower, the fewer flowers are visited per unit time (A'yunin et al., 2019).

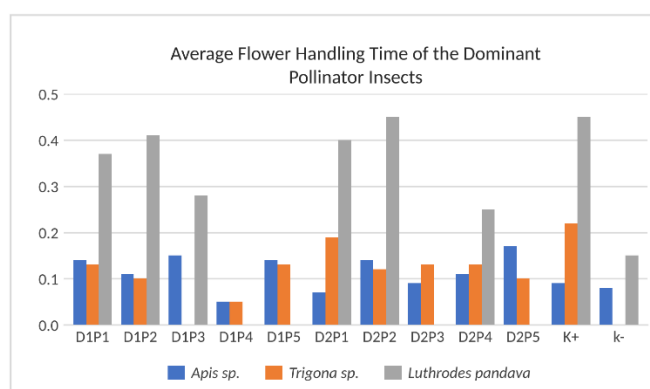


Figure 2. Flower handling time of the dominant insects

Apis mellifera generally showed the lowest flower handling time among the three dominant species. The highest flower handling time for *Apis mellifera* was seen in the fruit-and-vegetable MOL treatment at 200 g. The increase in flower handling time in this treatment shows that the combination of fruit-and-vegetable MOL at 200 g can produce marigold flowers with the most attractive or efficient characteristics for *Apis mellifera* to visit as a nectar source. An increase in flower handling time can be interpreted as an indication of increased nectar quality or more abundant and higher-quality pollen. When flowers offer greater resources per visit, honeybees tend to spend more time collecting them, maximizing the efficiency of resource acquisition before moving to another flower. The attraction of pollinators to flowers depends on the available nectar volume and sugar concentration (A'yunin et al., 2019). In the EM4 treatment at 200 g, the flower handling time was very low for *Apis mellifera*, indicating that the flowers in this treatment were less attractive, with suboptimal or quickly depleted resources, encouraging the insect to move on quickly. This low flower handling time shows that the flower was not rewarding.

Trigona sp. showed a varied flower handling time, with the highest value in the fruit-and-vegetable MOL treatment at 200 g. This shows that fruit-and-vegetable MOL at 200 g can optimize the floral resources of marigold for stingless bees. This increase in flower handling time may be caused by an increase in the quality and quantity of nectar and pollen produced by marigold flowers in that treatment. *Trigona sp.* spent more time per flower than *Apis mellifera*, so *Trigona sp.* needs more time to exploit the nectar resources of marigold flowers. The lowest flower handling time for *Trigona sp.* was also found in the EM4 treatment at 200 g, which may indicate that in that treatment the quality and quantity of nectar and pollen were suboptimal, so the insect moved on more quickly. The higher the

nectar volume, the longer a pollinator visits a flower; this may be the reason *Trigona sp.* visited flowers longer in certain MOL treatments (A'yunin *et al.*, 2019).

In essence, pollinators prefer larger flowers and a greater number of flowers. Based on the calculation of the number of flowers and flower diameter, the results were not significantly different. Another factor that attracts insects to flowers is nectar quality (nectar sugar concentration and composition) and quantity (nectar volume) (Vaudo *et al.*, 2022). Plants exposed to fertilizer did not produce significantly more flowers, but they produced a greater amount of pollen and nectar per flower than unfertilized plants (Russo *et al.*, 2023). Thus, plants may prioritize floral rewards for insects over floral display.

Variations in compost dose and MOL type applied indirectly affect the foraging rate and flower handling time of insects because of a connected causal chain. Compost at an optimal dose increases macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) in the soil (Rahyuni *et al.*, 2023). Nitrogen plays an important role in the vegetative growth of plants, phosphorus is crucial in the flowering process, and potassium contributes to fruit quality (Elvina *et al.*, 2023). Healthier and more vigorous plants tend to produce more flowers of better quality. This increase in the quality and quantity of floral resources, or a stronger signal, makes plants more attractive and provides a greater reward for foraging insects (Nitarini & Sataral, 2022). This can explain why foraging rate and flower handling time tended to be higher at higher doses for certain species, especially the main pollinators. Increased nutrients from compost not only make plant growth faster but can also change the plant's attractant profile, such as floral scent and the quality and quantity of nectar. The movement of pollinators from flower to flower is a function of the quantity and quality of nectar (Knopper *et al.*, 2016).

The use of market organic waste compost together with marigold as a refugia agent is an ideal combination to support environmentally friendly and sustainable agriculture. The synergy between compost and marigold can create an integrated agroecosystem. Using compost and marigold can reduce chemicals in agriculture, such as chemical fertilizers and pesticides, so that the environmental ecosystem is better maintained. Refugia plants can be used as an alternative in cultivation strategies based on biodiversity (Septariani *et al.*, 2019). The use of refugia plants around agricultural areas has a positive impact by providing shelter, food sources, or other resources for natural enemies such as predators, so that the conservation of natural enemies is well established (Arianto *et al.*, 2022).

Table 1. Results of environmental abiotic factor measurements

Time	Humidity (%)	Light Intensity (lux)	Wind Speed (m/s)	Temperature (°C)
Morning	78.1	4753.8	0.0	30.2
Noon	62.1	8672.5	0.1	32.5
Afternoon	68.9	3205.1	0.1	31.5

During the observations, moderate to heavy rain often occurred. This climatic factor can disrupt insect activity. Directly, high rainfall reduces the insect population because some individuals are washed away by the heavy rain (Sofyan *et al.*, 2019). Erratic rain also affects the diversity and activity of insects because during rain, insects are inactive and shelter from the raindrops (Nisa *et al.*, 2025). One environmental factor that reduces insect activity is high rainfall (Hidayat *et al.*, 2022). This occurs because heavy rain that saturates the soil can cause the death of insects, and insect eggs and nymphs on plant stems also die, washed away by the rain. Excessive rainfall can also reduce pollinator activity (Chen *et al.*, 2025).

Climatic factors are important factors that affect plant growth. This is because the climatic factors of temperature, air humidity, and light intensity are important in plant physiological processes such as the transpiration rate and photosynthesis rate (Sumarlin *et al.*, 2018). Various weather factors, such as temperature, light intensity, wind, and relative humidity, have been reported to affect insect activity and behavior. This is because insects are classified as cold-blooded organisms (poikilotherms), so their

internal body temperature depends greatly on and fluctuates with the external environmental temperature (Taradipha *et al.*, 2018). Therefore, climatic factors are important and interrelated between plant growth and the increase in the insect diversity index occurring in that environment.

Edaphic or soil factors greatly affect plant growth. This is because the main requirements that ensure plant life come from the soil, such as nutrients, water, and air, so the level of soil fertility greatly affects plant growth (Mus'af *et al.*, 2019). Other examples of edaphic factors that affect plant growth are soil temperature, soil pH, and aeration. The use of fertilizer on plants will certainly affect the edaphic factors of the soil, because fertilizer contains nutrients and changes the soil pH and temperature. These differences in edaphic factors can be one cause of the differences in insect behavior occurring at fertilized locations or on fertilized plants.

Conclusion

Based on the research results, it can be concluded that for the foraging rate, *Apis mellifera* was highest in the fruit-and-vegetable MOL treatment at 400 g and *Trigona sp.* in the vegetable MOL treatment at 400 g, whereas *Luthrodes pandava* tended to have low results. This insect behavior is strongly influenced by the quality and quantity of the plant's flowers and by environmental climatic factors.

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