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The effects of flowering trap crops on diversity and longevity of pollinator insect visitation on chili plants

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Abstract. *Aminatun T, Budiwati, Rahmawati YF, Widiyanti DN, Fahdah LA. 2023. The effects of flowering trap crops on diversity and longevity of pollinator insect visitation on chili plants. Biodiversitas 24: 887-893.* Red chili (*Capsicum annuum*) is a significant agricultural commodity with flowerage and fruit quality affected by pollinator insect visitation. However, research on the effect of flowering trap crops on the diversity and visitation of pollinator insects in chili has never been investigated. Therefore, the study aimed to analyze the effect of flowering trap crops on the visitation of pollinator insects on chili plants. The research was conducted at the experimental garden of the Faculty of Agriculture, Gadjah Mada University in Banguntapan, Bantul. The independent variable was the trap crops: marigold (with repellent odor) and sunflower (without repellent odor). Each treatment consisted of 5 replicate plots, with an area of 4 m^2 per plot and random plot placement. The observations of pollinator insects were carried out for seven days during the blossoming period, including diversity, number of insect visits, and longevity. Different tests were carried out using ANOVA to determine whether there were differences between the treatments. The results showed that the trap crop treatment of marigolds had a higher diversity index and evenness index of pollinator insects visiting chili plants than the other treatments. The longevity of pollinator insects on control chili plants showed a higher result than chili plants treated with flowering trap crops, although it was not statistically significant. Meanwhile, the use of trap crops (marigold, *Tagetes erecta*) significantly resulted in the best chili products. This means that trap cropping with marigolds which, based on the results of previous studies, was effective in controlling insect pest populations, does not inhibit the visit of pollinator insects on chili flowers. In the future, marigold has the potential to become an effective trap crop to increase the productivity of chili plants.

Keywords: Marigold flower, repellent odor, sunflower

INTRODUCTION

Pollinator insects contribute significantly to global food production, which has an impact on crop yields and quality (van der Sluijs and Vaage 2016; Mallinger et al. 2021), so for sustainable agriculture, a pollinator-friendly agricultural system is needed to conserve pollinators (Sawe et al. 2020; Kumsa and Ballantyne 2021).

Many agricultural commodity plants have hermaphrodite flowers with an anther structure that forms a cone so that vibration is needed to release pollen from the pistil (Aminatun et al. 2019). Although this plant can self-pollinate, cross-pollination with the help of insects is needed to enhance the fruit's quality and quantity (Lumentut 2022). An example of such a plant is chili (*Capsicum annuum*). Chili is an important agricultural commodity because of its abundant benefits and high economic value (Olatunji and Afolayan 2018; Glodjinon et al. 2021). Therefore, the barriers to pollinator insect activity on chili flowers can affect fruit quality and productivity (Aminatun et al. 2019).

Each pollinator insect requires a different duration of time in search of nectar. They need time to study flower morphology (Baur et al. 2019). The diversity and visiting behavior of pollinator insects affect the effectiveness of pollination, which can increase crop yields (Bartomeus et al. 2014; Levenson et al. 2022).

The existence of pollinator insects in agricultural habitats is influenced by several factors, including habitat availability. Habitat maintenance for pollinators on farms can be done through perennial flower strips around farmlands (Kremen et al. 2018; Von et al. 2022). Protection of pollinator diversity by trap crop wildflower strips also affects the lower pest abundance with increasing natural enemies (Christmann et al. 2021). Thus, trap cropping is a technique used to attract insect pests so as not to attack the main crop; it plays a role in natural pest control, which allows multitrophic interactions between main crops, pests, natural enemies, and various types of secondary plants that function as the barrier (Parolin et al. 2012).

Based on the explanation above, the use of trap crops can affect the visit of insect pests, natural enemies, and pollinators. The selection of a flowering trap crop can be an alternative in natural pest control because it can invite natural enemy insects to come. For example, from the results of research on upland rice cultivation with various barrier plants treatments such as trap crops, namely natural weeds, marigolds (*Tagetes erecta*), and sunflowers, the lowest frequency of pests and natural enemies' visits on rice plants occurred in the trap cropping of marigold flowers (Aminatun et al. 2020). This means that marigold inhibits the visit of insect pests and natural enemies on the canopy of rice plants, given the barrier, compared to other treatments. This is due to the odor of marigold flowers as a repellent for insects. The results of the olfactometer test showed that these volatile compounds effectively repel insect pests, so intercropping using repellent plants effectively reduces insect pest visitation because the insects avoid this specific area (Iamba et al. 2020; Niu et al. 2022). Thus, repellent substances that are effective in preventing insect pests in plants may also prevent pollinators. So far, no research has been found on the comparison between flowering trap crops that contain repellent substances and those that do not. Therefore, in this study, marigold flowers were chosen as plants with repellent odor and sunflowers with no repellent odor. The study used chili plants because it is an important agricultural crop, and based on previous research (Aminatun et al. 2019), the blossoming process and productivity are strongly influenced by the visitation of pollinator insects. Thus, the study aimed to analyze the effect of flowering trap crops (marigold and sunflower) on the visitation of pollinator insects on chili plants.

MATERIALS AND METHODS

Study area

The research was a field experiment at the Experimental Garden of the Faculty of Agriculture, Gadjah Mada University (UGM), Banguntapan, Bantul. This study employed a completely randomized design with the following treatments: (1) PK is a treatment plot code with marigold trap crops; (2) PM is the code for the treatment plot with sunflower trap crops; and (3) P0 is the treatment plot code without trap crop (control). Each treatment consisted of five replications, so there were a total of 15 experimental plots.

Procedures

Preparation

This stage included making plot boards with codes according to the treatments, preparing the experimental ground by plowing and cleaning the ground from plant residues and roots, then proceed with basic fertilization (manure) before planting, and preparing marigold and sunflower seeds in the greenhouse which were planted together with chili seeds in the treatment plots.

Plot layout drawing

The plots measuring 2x2 m^2 were created with a space between plots of 2 m. The chili plants were planted in the space of approximately 30x30 cm in each plot, which means there will be 16 chili plants in each plot, in both control and treatment plots. The trap crops were planted around the chili plots, with a space between plants of 30 cm and the space from the chili plots is 50 cm. The treatment plots were arranged randomly (Figure 1).

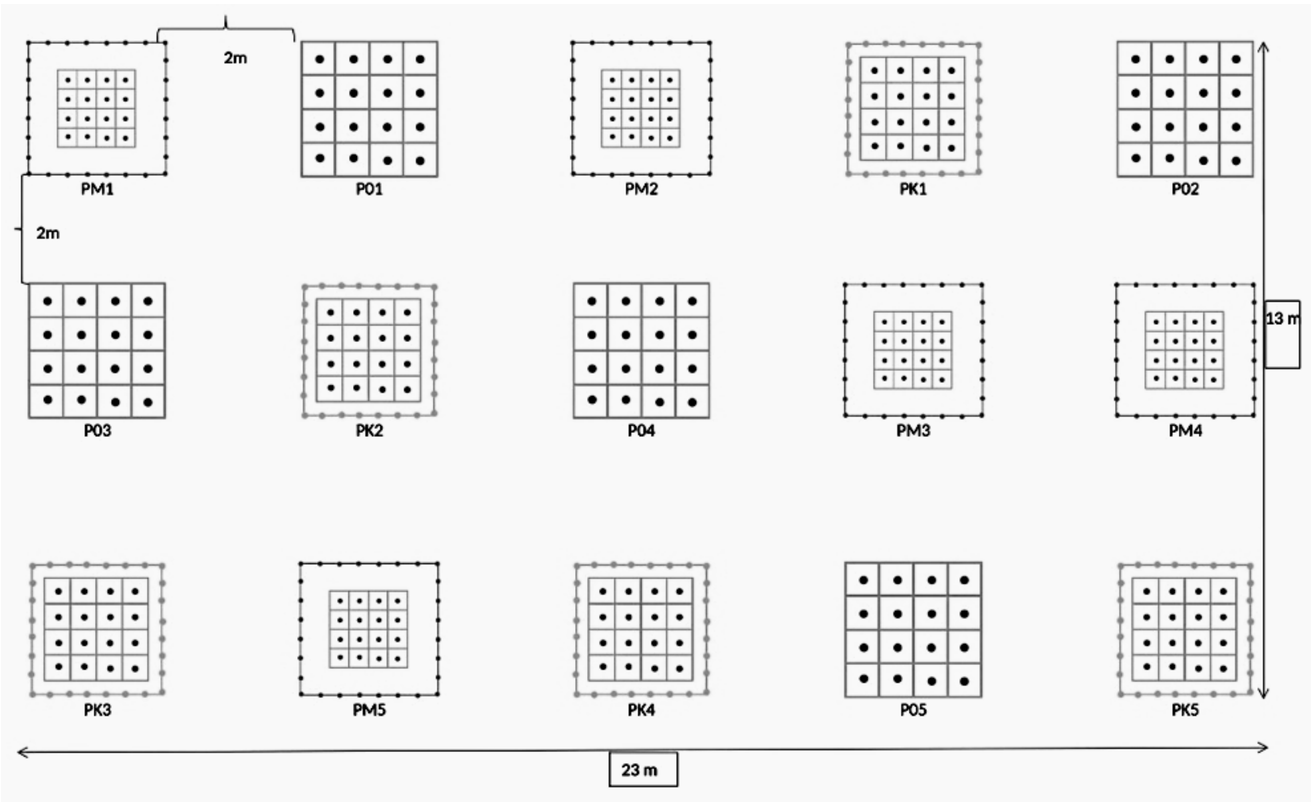

Figure 1. The layout of chili plant experimental ground. Note: PO: Control Treatment; PK: Marigold Trap Crop Treatment; PM: Sunflower Trap Crop Treatment; ● : Chilli Plants; —●—●—●— : Trap Crop

Crop maintenance (fertilizing, watering, and weeding)

Basic fertilizer (manure) was given seven days before sowing the seeds on each plot, as much as 5 kg for each plot. The next fertilization (urea) was carried out one and two months after the first fertilizer or basic fertilizer. The dose used is 2 tbsp urea for 6 liters of water, then applied to the entire plot. The plants were watered every day to maintain humidity and aeration, while weeding was carried out every 2 weeks. Pest control was done mechanically (handpicking), and the natural mechanisms have not interfered. All of crop maintenance activities (fertilizing, watering, and weeding) are applied equally for each of the conditions.

Data collection

The observation of pollinator insect diversity was carried out for seven days on chili plant flowers and trap crops. The observations were conducted using the scan sampling method (Martin and Bateson 2007) by walking around the planting plot for 15 minutes every hour with 5-minute intervals in the morning (07:00-09:00 am and 10:00-12:00 am) and in the afternoon (1:00-4:00 pm). There will be 2 observers in each part of the observing time.

The visitation included the number of pollinator insect visits, length of visit per flower (longevity/handling time), and the total time of visit per plant (Akter et al. 2017). The observation used the focal sampling method (Martin and Bateson 2007) by observing one individual from each pollinator insect species at each observation.

During the observation, the species and the number of pollinator insects that were visiting chili plants' flowers and trap crops' flowers were recorded. The identification of pollinator insect specimens was based on Bolton (1994) (Yata and Morishita 1981; Tsukada 1985; Holloway 1988; Vockeroth and Thompson 1992; Goulet and Huber 1993; Robinson et al. 1994; Michener 2007). To see the effect of pollinators' visitation on plant productivity, the chilies harvested were identified based on the average weight and length of chili peppers per treatment plot. The average weight and length of chili peppers were measured during the chilies harvest. These measurements of weight and length use digital scales and a ruler.

Data analysis

Diversity index (H')

The pollinator insect diversity index was measured using the Shannon-Wiener diversity index, as follows;

$$H' = \sum pi\ (\ln pi)$$

$$pi = n/N$$

Where:
H : Diversity Index,
pi : Proportion of ith species in the community,
n : Individual abundance of morphospecies i,
N : Total individual number of all species.

The calculation results of insect abundance are categorized into three as follows Table 1.

Evenness Index (E)

The evenness index of pollinator insects was measured using Simpson's evenness index, which measures the proportion of each species in a population at a certain place and time (Table 2).

$$E' = H' \ln(S)$$

Where:
E' : Evenness index,
H' : Diversity Index,
ln : Natural logarithm,
S : Number of species found

One-way ANOVA

The SPSS 16 program was used to help analyze the effect of trap cropping on diversity, the number of visits, and the longevity of pollinator insects on the flowers of chili plants and trap crops. The normality test doesn't show any data due to the method of this research is a completely randomized design.

RESULTS AND DISCUSSION

The diversity of pollinator insects visiting the flowers

There were 11 types of pollinator insects found on chili plant flowers during the 7-day observation (Table 3). This marigold trap crop was visited by a larger number and more varied insects when compared to the sunflower trap crop. Meanwhile, in the control group, the diversity of pollinator insects and the total number of insects were the lowest compared to other treatments. It is important to increase the number of pollinator insect visits on chili plants with trap crop treatment because they significantly affect the harvest quality of various crops (Bartomeus et al. 2014; Elisante et al. 2020; Dymond et al. 2021). The diversity of pollinator species in both treatments is higher than that in the control treatment. This indicates that marigold and sunflower trap crops are able to carry out their functions to attract pollinator insects (Frankie et al. 2019; Zhang et al. 2020).

Table 1. Category of insect diversity index

Diversity value (H′)	Category
$H' \leq 2$	Low Diversity
$2<H'\leq3$	Moderate Diversity
$H'\geq3$	High Diversity

Table 2. Category of insect evenness index

Evenness value (E′)	Category
$E' \leq 0.3$	Low Evenness
$0.3<H'\leq0.6$	Moderate Evenness
$H'\geq0.6$	High Evenness

Marigold crop trap was visited by a more diverse and larger number of pollinator insects than chili plants (Table 3). This indicates that pollinator insects are more attracted to the marigold flowers than the chili flowers. Its shape, length, color, smell, nectar, and pollen are factors influencing the insects' interest (Yan et al. 2016). The other factor is the easiness of getting the nectar because pollinator insects have short tongues and are small in size (Hicks et al. 2016). Although the marigold flower has a repellent odor (Iamba and Homband 2020; Niu et al. 2022), it is somehow restrictive because, at certain concentrations, it is repellent to certain types of pollinators but can also attract pollinators. Ants will visit less if the nectar is repellent (Ballantyne and Willmer 2012; Stevenson et al. 2017). Repellent nectar will reduce the duration of visits and the volume of nectar taken by pollinator insects but increase the frequency of insect visits (Pattrick et al. 2017).

In this study, there are five families of pollinator insects visiting the marigold trap crop, namely Apidae (*Apis dorsata* and *Apis cerana*), Curculionidae (*Hypomeces squamosus*), Nymphalidae (*Acraea terpsicore*), Anthoporidae (*Xylocopa confusa*) and Papilionidae (*Papilio demoleus*). Meanwhile, the sunflower trap crop was visited Apidae (*Apis dorsata* and *Apis cerana*), Curculionidae (*Hypomeces squamosus*), Nymphalidae (*Junonia atlites*, *Morpho polyphemus*) (Table 3).

The insect mostly found in both trap crops belongs to Apidae family (*Apis cerana).* As many as 30 and 46 insects were found in marigold and sunflower trap crops, respectively. This finding is in accordance with the results of previous studies showing that pollinator insects that mostly visit chili plant flowers are from the families of Apidae (*Trigona* and *Apis*) and Formicidae (*Camponotus*) (Putra et al. 2016; Aminatun et al. 2019). It is also in line with the statement that traps crops can attract insects to visit because they need them for alternative habitats as well as foraging, mating, and resting (Leksono et al. 2019). From various studies, it was found that the majority of large plants were assisted by various insects for pollination (Rader et al. 2015; Ollerton et al. 2018; Tanda 2021; Wojcik 2021).

Based on the comparison of the diversity index between insect pollinators visiting chili plants, marigold flowers (in the marigold trap crop), and sunflowers (in the sunflower trap crop), the diversity index of pollinator insects visiting the marigold trap crop is the highest, while sunflower trap crop is the second, and the chili plant with no trap crop is the lowest (Table 4). The difference in diversity is due to the flower's looks, including its design (color, shape, and accessibility) as well as the spatial and temporal position of the flowers (Michael et al. 2017).

The evenness index of insect pollinators visiting chili plants with the marigold trap crop is the highest, while the chili plant flower in the control group obtained the lowest index. These indexes show the evenness of distribution between species in a community. The index will be high if all species in a sample are similar in abundance (Strange and Tripodi 2019). The high evenness index in the marigold trap crop treatment shows that the pollinator insects are truly diverse because no particular species dominate. The insects can use the chili plants to increase populations together with equal opportunities, so there is no dominance of one type against another.

Table 3. Diversity of types and total number of pollinator insects visiting the flowers which all plots were observed equally every day for 7 days

Variety of pollinator insects		The number of pollinator insects visiting the flowers during the treatment				
		PO	PK		PM	
Family	Spesies	Chili	Chili	Marigold	Chili	Sunflower
Apidae	*Apis dorsata*	10	4	10	6	-
Apidae	*Apis cerana*	24	30	3	46	1
Curculionidae	*Hypomeces squamosus*	1	9	17	2	2
Nymphalidae	*Junonia atlites*	-	-	3	2	1
Nymphalidae	*Morpho polyphemus*	-	-	2	1	-
Nymphalidae	*Acraea terpsicore*	-	2	7	-	-
Nymphalidae	*Hypolimnas bolina*	-	-	3	-	-
Anthoporidae	*Xylocopa confusa*	1	1	37	-	2
Papilionidae	*Papilio demoleus*	-	1	5	-	1
Andrenidae	*Andrena cineraria*	-	-	3	-	-
Vespidae	*Vespa affinis*	-	-	3	-	-
Total		36	47	120	57	7

Note: PO: Control Treatment; PK: Marigold Trap Crop Treatment; PM: Sunflower Trap Crop

Table 4. Diversity and Evenness Indexes of Pollinator Insects

Index	Flowers of plants with treatment					Category
	Control-chili (P0)	Chili-marigold (PK)	Marigold (PK)	Chili-sunflower (PM)	Sunflower (PM)	
Diversity	0.82	1.11	1.82	0.97	1.54	Low
Evenness	0.60	0.62	0.79	0.60	0.96	High

Note: PO: Control Treatment; PK: Marigold Trap Crop Treatment; PM: Sunflower Trap Crop

An interesting phenomenon is shown by the diversity and evenness indexes of trap crop flowers. The evenness index of pollinator insects of marigold flowers is lower than the index of sunflowers. However, when marigold serves as a trap crop of the chili plant, this flower obtains the highest evenness index (Table 4). It indicates that marigold flowers can increase the evenness of pollinator insect diversity in chili plants because the presence of pollinator insects is strongly influenced by the availability of flowers in a habitat (Koneri et al. 2020). Thus, the availability and diversity of flowers will greatly affect the diversity of pollinator insects (Kleiman et al. 2021). The marigold flower will increase the variety of flowers in the planting plot. In other words, the marigold flower is suitable to be used as a trap crop.

Pollinator insect visitation

The visitation of pollinator insects is shown from the number of visits and the average longevity, which are calculated and presented in Table 5. The high longevity average may positively influence the increase in the harvest (Yourstone et al. 2021). This table shows that the average longevity of pollinator insect visits on chili plant flowers in the control group is the highest because there was no trap crop that is more attractive and planted purpose for pollinator insects around the chili plant (Yourstone et al. 2021) so that more pollinator insects aim to visit the chili plant flowers.

The average longevity of insect visits on marigold flowers is higher than on chili flowers because pollinator insects tend to choose marigold that is visually more attractive and colorful (Gurung et al. 2020). In addition, the marigold plant belongs to the Asteraceae family, which is one of the favorite flowers for insects, especially Hymenoptera, Lepidoptera, and Diptera (Klumpers et al. 2019). There will be more pollinator insects visiting if the flowers are attractive (Yourstone et al. 2021).

Furthermore, the average longevity of insect visits on chili flowers is higher than on sunflowers. It is due to the density and abundance of flowers that may influence the diversity of pollinator insects and the longevity of visits (Wratten et al. 2012). Although sunflowers are attractive and have a particular characteristic that may attract pollinator insects (Adeoye and Pitan 2020), the presence of pollinator insects is also influenced by the number of flowers. In contrast, the lack of flowers will lead to a low frequency of pollinator insect visits.

Based on the results of ANOVA on the visitation of pollinator insects on chili plants between treatments, there is no significant difference in longevity, but there is a significant difference in the number of pollinator insect visits. The sig. value at the longevity of 0.120 is greater than the reference value of 0.05 (sig. >), for the number of visits significant difference was found with p value 0.021 (sig. <). There is no significant difference because the longevity values of pollinator insects in each treatment show not much difference (Table 5). The abundant and attractive flowers (Wratten et al. 2012; Gurung et al. 2020) may distract pollinator insects, thus not concentrating on one type of flower. Although they do not lead to different results of longevity average, the abundant and attractive flowers are factors causing a significant difference in the number of insect visits (Perrot et al. 2019).

Table 6 shows the most potential chili harvest with marigold plants as the trap crop. This is possible because the abundant and attractive flowers in the marigold trap crop attract more pollinator insects than the flowers in the control treatment. The pollinator insect visits positively impact the increase in harvest (Yourstone et al. 2021). However, based on the data presented in Table 5, the duration of insect visits on chili plants with marigold trap crops is no longer than the duration of its visits in the control treatment. Therefore, there might be another factor influencing pollination, namely wind. Wind pollination has a significant impact on harvest increase. Based on a study, wind pollination may contribute up to 30% of harvest increase (Yourstone et al. 2021). This is also due to the effectiveness of the marigold crop trap in controlling insect pest populations (Iamba et al. 2020).

Table 6. The amount of chili harvested from each treatment

Average	PO	PK	PM
Weight	1.49 grams	1.83 grams	1. 57 grams
Length	8.2 cms	7.9 cms	8. 41 cms
Total	215 grams	271 grams	444 grams

Note: PO: Control Treatment; PK: Marigold Trap Crop Treatment; PM: Sunflower Trap Crop

Table 5. The pollinator insect visitation on chili plant flowers

Pollinator insect		Average length of pollinator insect visits (second)				
		PO	PK		PM	
Family	Species	Chili	Chili	Marigold	Chili	Sunflower
Apidae	*Apis dorsata*	37.1	14.75	77.9	41.33	-
Apidae	*Apis cerana*	22.9	19.83	17.66	22.73	15
Curculionidae	*Hypomeces squamosus*	600	66.66	106.88	365	10
Nymphalidae	*Junonia atlites*	-	-	3	50	2
Nymphalidae	*Morpho polyphemus*	-	-	24.33	-	-
Nymphalidae	*Acraea terpsicore*	-	14	63.57	-	-
Nymphalidae	*Hypolimnas bolina*	-	-	73	-	-
Anthoporidae	*Xylocopa confusa*	300	32	88.64	-	15.5
Papilionidae	*Papilio demoleus*	-	13	19.4	-	2
Andrenidae	*Andrena cineraria*	-	-	136	-	-
Vespidae	*Vespa affinis*	-	-	36.33	-	

Note: PO: Control Treatment; PK: Marigold Trap Crop Treatment; PM: Sunflower Trap Crop

According to ANOVA on the productivity of chili plants, the value of sig. is smaller than 0.05 (0.002). This shows that the trap crop treatment on chili plants may positively affect the chili harvest, and marigold is a potential trap crop. Marigold flowers attract pollinator insects, so planting this crop in agricultural areas may increase harvests (Kachhawa et al. 2020). Marigold trap crops may result in better harvests because the diversity and evenness indexes of this trap crop are higher than those of another trap crop. The indexes affect the chilies harvested, as shown by the average weight of chilies planted with the marigold trap crop.

The results of this present study show that the marigold trap crop has the highest diversity and evenness indexes because more pollinator insects visit this flower. However, this flower attracts more insects than the chili plant flowers, and as a result, the pollinator insects visiting the chili plant flowers are less in terms of diversity and evenness. In terms of longevity, the control chili plant has the highest longevity rate compared to chili plants with trap crops, although the value is not statistically significant. Meanwhile, planted with the marigold trap crops, the chili plants produce the best products. In line with previous studies, marigold trap crops are effective in controlling insect pest populations but do not prevent pollinator insects to visit. In the future, marigold plants can potentially become an effective trap crop to increase the productivity of chili plants.

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