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Prevalence and abundance of cowpea *Vigna unguiculata* (L.) Walp insect flower visitors as possible pollinators

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Abstract
The study assessed the prevalence and abundance of insects on cowpea flowers in some farms in some districts in the Central Region of Ghana. Two research questions were answered and two null hypotheses tested. Survey was conducted in ten farms. Farms were visited between 6.00am and 12.00pm to observe insects on the flowers during this period. Insects were observed on stigma, anther and inside flowers. Samples of insects were collected using sweep net for identification. Insects were identified up to order and in some cases species level. Data was analysed using Chi square (χ^2) by employing use of contingency tables. Insects observed on the flowers were *Apis mellifera*, *Ceratina* sp., thrips, crickets, flies, butterflies/moths, *Megachile* sp., *Lasioglosum* sp., ants, wasps, *Xylocopa calens, and* beetles. The most prevalent insects were butterflies/moths and the most abundant were thrips. Differences between the numbers of insects on flowers in all the farms put together were statistically significant (χ^2 = 23,051.985; DF = 11; p<0.05). The findings suggest that the insects observed on the flowers are probable pollinators and hence must be preserved.

Keywords: Prevalence, abundance, insect visitors, *Xylocopa calens*, hymenoptera, observed

Introduction

There exist a number of interactions between plants and animals. At the basic level, animals breathe in oxygen and exhale carbon dioxide. Plants take in carbon dioxide and release oxygen back into the atmosphere. Animals need plants for food and shelter. Plants need animals for seed dispersal and pollination. Some animals eat plants whereas others eat other animals. Plants use nutrients that are deposited back into the soil when animals die and decompose. Animals need clean water, and they are able to get it when forests and wetlands filter water to make it clean.

Just as animals in general interact with plants in several ways, insects also interact with plants in different ways. In some cases insects may serve as protectors, dispersers, or fertilizers for plants while plants may be sources of food/energy or nest location for insects (Calatayud, *et al*., 2018) [4]. Thus, Plant-insect interactions can be mutualistic, antagonistic, or commensalistic (Calatayud, *et al*., 2018) [4], which may lead to food production in agriculture, horticulture, and forestry.

One major plant-animal relationship with tremendous benefit to both plants and animals is pollination. Actually, pollination is an essential ecosystem service that enhances the reproductive capacity of natural and agricultural plants, resulting in food security, improvement of livelihoods, and conservation of biological diversity (Anonymous, 2006 cited in Dukku & Mukaddas, 2019) [8]. As many species of insects visit flowers to seek nectar or pollen, they transfer pollen grains and thereby contribute to pollination.

Though, pollination is known to be so beneficial to plants and animals, in cowpea it is known to be mainly self-pollination. For examples, Ige, *et al.* (2011) [20] observe that cowpea is self-pollinating and pollination usually occurs in flowers before they open. They further intimated that enclosure of the pistil and stamen within the keel enhances self-pollination. Therefore, pollen grains are transferred from the anther to the stigma causing pollination (Ige, *et al*., 2011) [20]. It is however established that cowpea flowers produce nectar which attracts insects to them.

During the process of feeding, the hairs on the insects brush the anthers and pollen adheres to them. These pollen grains are transferred to another flower (Ige, *et al*., 2011) [20]. Thus, though self-pollination is the norm in cowpea, the crop still benefits from the activities of animal pollinators, especially in genotypes that produce male sterile flowers (Dukku & Mukaddas, 2019) [8]. Rachie *et al.* (1975) [15] also established that self-pollination is hindered in some cowpea genotypes due to the fact that the anthers remain trapped in the corolla as the stigma emerges and grows beyond the reach of the anthers.

Since cowpea pollen grains are heavy and sticky they cannot be readily transferred by wind. Hence, it can be argued that insects transfer cowpea pollen grains, leading to cross pollination (Ige, *et al*., 2011) [20]. No doubt, Blackhurst and Miller (1980) [3] estimated that the rate of cross-pollination in cowpea is between 1% and 10%.

A further prove of insects implicated in cowpea cross-pollination can be traced to the fact that a number of insects have been cited to visit cowpea flowers. For example, butterflies, houseflies (*Musca domestica*), honeybees (*Apis mellifera*) (Ige, *et al*., 2011) [20], *Apis mellifera* L., Carpenter bees (Xylocopa aestuans (Linnaeus) and Xylocopa sp.), Painted Lady butterfly (*Vanessa* sp.), Blue Pansy butterfly (Precis orithya (Linnaeus)), Cabbage white butterfly (Pieris brassicae), Large Copper butterfly (*Lycaena* sp.), Cute butterfly (Skipper) (*Parnara* sp.), Long-tailed blue butterfly (Lampides boeticus (Linnaeus), Swallowtail lemon butterfly (Papilio demoleus (Linnaeus)), Yellow Butterfly (Colias erate (Esper), Robber fly (*Efferia* sp.), Dronefly (Eristalis tenax (Linnaeus)), Hoverfly (Didea fasciata (Macquart)) and Tachinid fly (*Archytas* sp.) were among the insects observed on cowpea flowers as cowpea flower visitors/pollinators. (Nghia, & Srivastava, 2015) [14], flies (Dipterans), wasps (Hymenoptera) bees such as Lasioglossum sp (Hymenoptera: Halicitidae; Halicitinae), *Apis mellifera* adansoni (Hymenoptera: Apidae), *Ceratina* sp (Hymenoptera: Apidae; Xylocopinae), Megachile sp. (Hymenoptera: Megachilidae; Megachilinae), and *Xylocopa calens* (Hymenoptera: Apidae; Xylocopinae), thrips, lepidopterans and ants (Hordzi, 2011) [9] were all observed on various parts of cowpea implicating them in cross-pollination.

Despite the fact that a lot of work has been done on types of insects that visit cowpea flowers as well as their roles and influence on pollination, not much has been done on the prevalence and abundance of these insects. Therefore, this study aims at assessing the prevalence and abundance of insects on cowpea flowers and predict their possible pollination in some farms in some districts in the Central Region of Ghana.

Two research questions were answered by the findings of the study, they are:

1. What are the insects that visit cowpea flowers in the survey area?
2. What are the most prevalent insects observed on cowpea flowers from the survey area?

The following null hypotheses were tested:

H_{01}: There is no statistically significant difference in the number of insects observed on various parts of the flowers of cowpea in the survey area.

H_{02}: There is no statistically significant difference in the abundance of insects observed on cowpea flowers in the survey area

Research Methodology

A survey was conducted in 10 cowpea farms located in areas located in Agona West Municipality, Agona East District, Gomoa Central District and Effutu Municipality of the Central Region of Ghana. The survey was conducted between 3rd and 18th April, 2023, during the major season farming. Farms were selected at least 1km away from each other along major lorry roads. Farms were between five (5) to hundred (100) meters from the road side. Farms chosen for insect observation had almost half or more of plant population flowering. Cowpea flowers are known to open between 6.00am and 12.00pm (Ige *et al*., 2011) [20], 6.00am and 1.00pm (Dukku & Mukaddas, 2019) [8]. Hence, farms were visited between 6.00am and 12.00pm to observe insects on the flowers during this period. Each farm was visited two times, in two weeks interval. Three days were used for each visitation (first and second visitations respectively). Thus between two to three farms were visited each day.

Insects visiting the stigma, anther and entering the flowers were observed and counted. Samples were collected using sweep net for identification purpose.

Data analysis: Insects collected were identified up to order and in some cases up to species level. In order to determine how prevalent the insects were, the number of farms from which each species was observed was determined. Chi square (χ^2) analysis of the number of each species on various parts of the flowers and total number of each species was done. This was to determine the abundance of each species on various parts of the flowers and the abundance of the insects in general from the survey area. Chi square analysis employed the use of contingency Tables.

Results

Table 1: Insects observed on cowpea flowers and prevalence in the research area

Type of insect	Number of farms		Order	Family	Genus	Species
	No	%				
Apis mellifera	6	60	Hymenoptera	Apidae	*Apis*	*A. mellifera*
Ceratina sp.	4	40	Hymenoptera	Apidae	*Ceratina*	
Thrips	10	100	Thysanoptera	Thripidae	*Thrips*	
Crickets	1	10	Orthoptera			
Flies	9	90	Diptera			
Butterflies/ moths	10	100	Lepidoptera			
Megachile sp.	3	30	Hymenoptera	Apidae	*Megachile*	*Megachile sp.*
Lasioglosum sp.	6	60	Hymenoptera	Apidae	*Lasioglosum*	*Lasioglosum* sp
Ants	2	20	Hymenoptera	Formicidae		
Wasp	1	10	Hymenoptera			
Xylocopa calens	1	10	Hymenoptera	Apidae	*Xylocopa*	*X. calens*
Beetles	1	10	Coleoptera			

The insects observed on the cowpea flowers from the survey area are *Apis mellifera*, *Ceratina* sp., thrips, crickets, flies, butterflies/moths, *Megachile* sp., *Lasioglosum* sp., ants, wasps, *Xylocopa calens, and* beetles.

According to Lennon *et al*. (2004) [22], geographic variation in numbers of species per unit area (Species richness) is one of the most conspicuous patterns in biodiversity. They added that understanding relationships of species richness among different groups of organisms is a major task of conservation biologists and ecologists. From Table 1, butterflies/moths and thrips were the most observed, for that matter most prevalent insects (100% or all farms) on cowpea flowers in the survey area, followed by flies (in 90% of farms), *Apis melifera* and *Lassioglosum* sp. (in 60% of farms), *Ceratina* sp. (in 40% of farms), *Megachile* sp. (in 30% of farms), ants (in 20% of farms), crickets, wasps, *Xylocopa calens* and beetles (in 10% of farms each). Interestingly, all the above insects one way or the other have been cited to be doing pollination in cowpeas and other plants. For example, Varatharajan 1 *et al.* (2016) [19] indicated that by virtue of their pollen feeding habit, thrips (Thysanoptera) visit flowers of plants during anthesis and carry appreciable number of pollen grains and incidentally transfer them on to the stigma during their inter and intra movement between the flowers/florets/inflorescence. Varatharajan1 *et al.* (2016) [19] went on to say that a study reveals that the body setae of thrips favour fine attachment of pollen. The floral reward enhances the breeding potential of thrips and in return the flower is pollinated by the pollinivorous physopodans (Thrips).

Acceding to Dingha *et al.* (2021) [7], different bee species have been reported worldwide as cowpea pollinators. These include species such as the honeybee (*Apis mellifera* Linnaeus (Asiwe, 2009) [1], species of the genus *Xylocopa* (Asiwe, 2009, Kouam, *et al*., 2012; Wousla *et al*., 2019; Stefanie *et al*., 2015) [1, 12, 21, 16] bumblebees (*Bombus* sp.) (Vaz *et al*., 1998) [20] and species of the Megachilidae family (Kouam *et al*., 2012; Wousla, *et al*., 2019) [12, 21]. In the same way, in this study bees such as *Apis mellifera*, *Ceratina* sp., *Megachile* sp., *Lasioglosum* sp. and *Xylocopa calens* were actively observed on the cowpea flowers. Lazaridi *et al*., (2022) [13], observed ants exclusively visited the extrafloral nectaries located on the stipels of trifoliolate leaves and on the inflorescences' stalks. Lazaridi *et al*., (2022) [13], further, observed two species of butterflies, *Carcharodus alceae* and *Lampides boeticus* visiting cowpea flowers either for nectar or foraging. Nghia, & Srivastava (2015) [14] also observed a number of butterflies and bees including *Ceratina* sp. on cowpea flowers. In this study also, butterflies/moths and ants were observed on cowpea flowers.

Kevan (1999) [11] thinks that the great majority of pollinators are insects, including bees, wasps, flies, beetles, butterflies, and moths. Thus, these insects are flower visitors that eventually lead to pollination. In this study also, wasps, flies and beetles were observed alongside other insects visiting cowpea flowers.

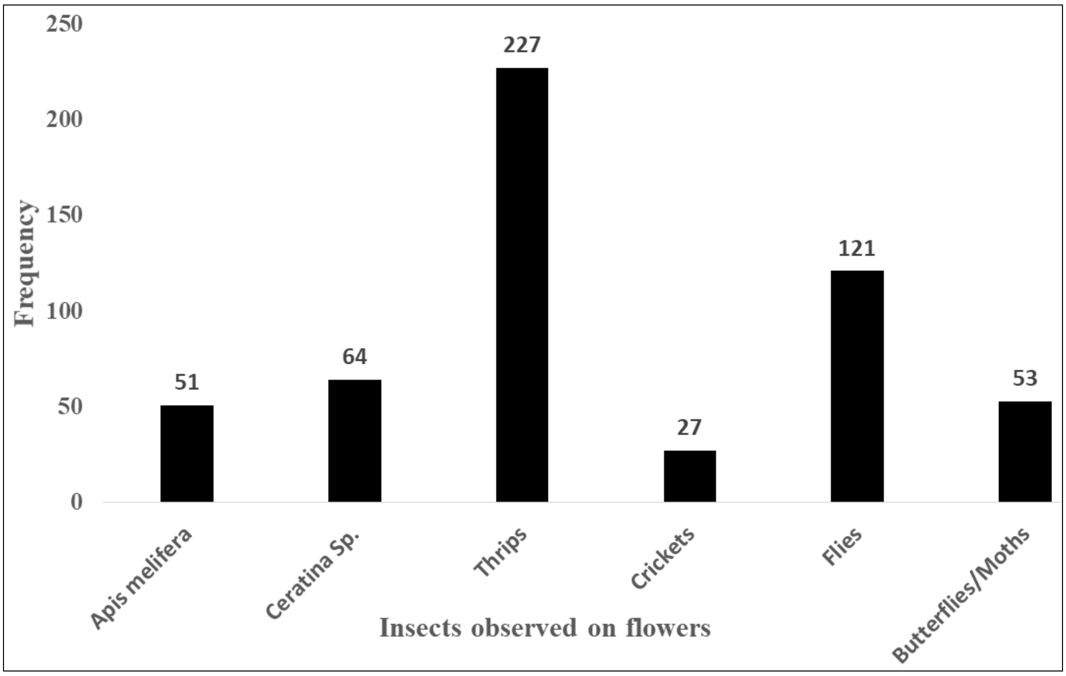

Fig 1: Total number of insects observed on cowpea flowers in farm 1

Over all, the most common insect on cowpea flowers in Farm 1 was thrips, followed by flies, *Ceratina* sp., butterflies/ moths, *Apis melifera*, and crickets (Figure 1). The differences in the numbers were statistically significant (χ^2 =301.26; DF = 5; $p<0.05$), implying that the differences were real. Thus, the null hypothesis was rejected and the alternate hypothesis accepted.

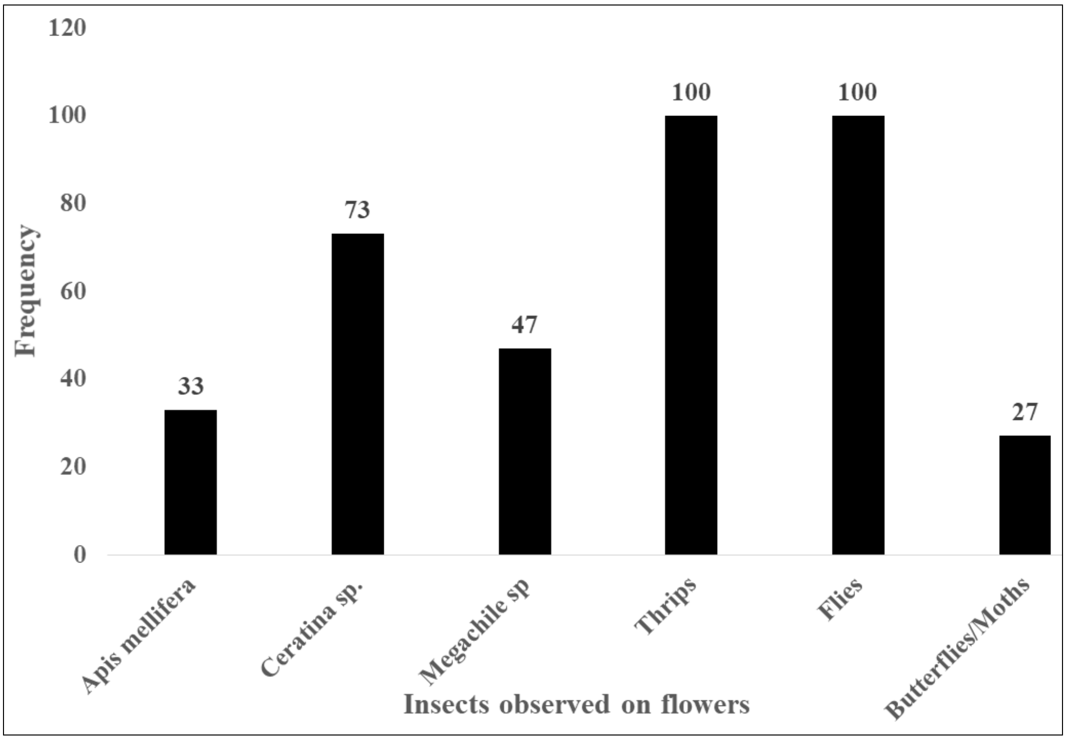

Fig 2: Total number of insects observed on cowpea flowers in farm 2

Data in Figure 2 points to the fact that in Farm 2, the highest number of insects found on flowers were thrips and flies (100 each), followed by *Ceratina* sp. *Mecgachile* sp., *Apis melifera* and butterflies/moths. The differences between the numbers were statistically significant (χ^2 = 83.52; df = 5; *p*<0.05). Therefore, in this case also the null hypothesis is rejected, indicating that the differences were real.

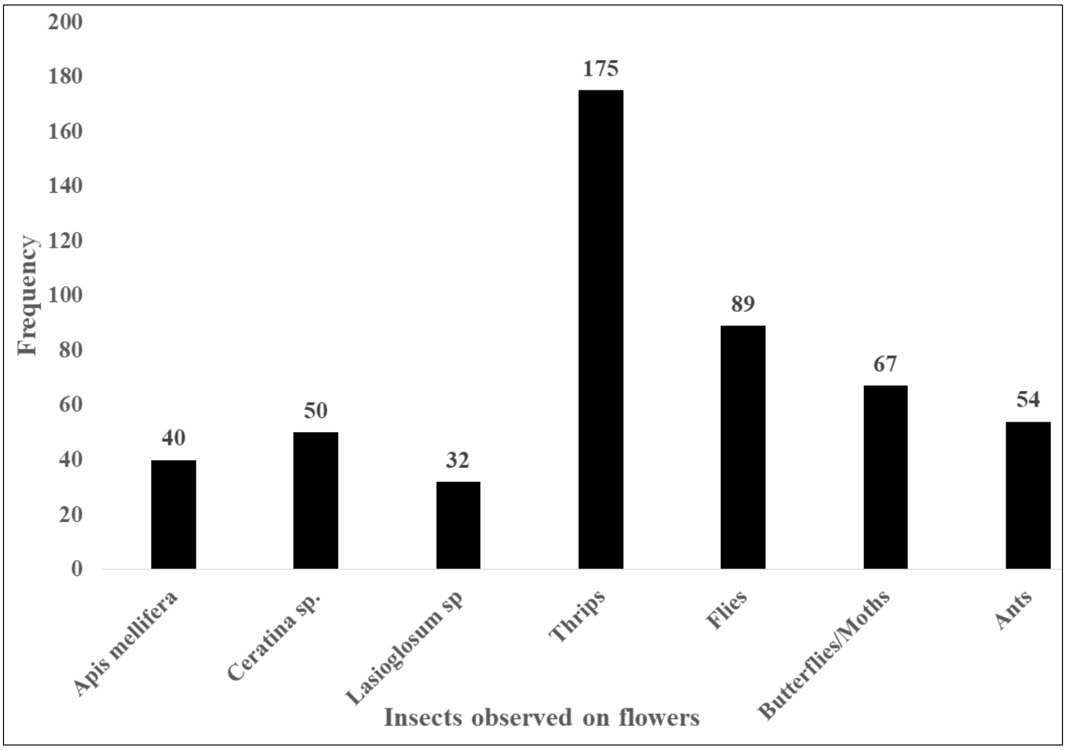

Fig 3: Total number of insects observed on cowpea flowers in farm 3

In Farm 3 also thrips were the most common insects, followed by flies, butterflies/moths, ants, *Ceratina* sp., *Apis melifera*, and *Lassioglosum* sp (Figure 3) Differences in the numbers were statistically significant (χ^2 = 198.18; df = 6**;** *p*<0.05). The fact that the differences between the figures were statistically significant points to the fact that the null hypothesis was rejected and thus suggesting that there were actual differences among the figures.

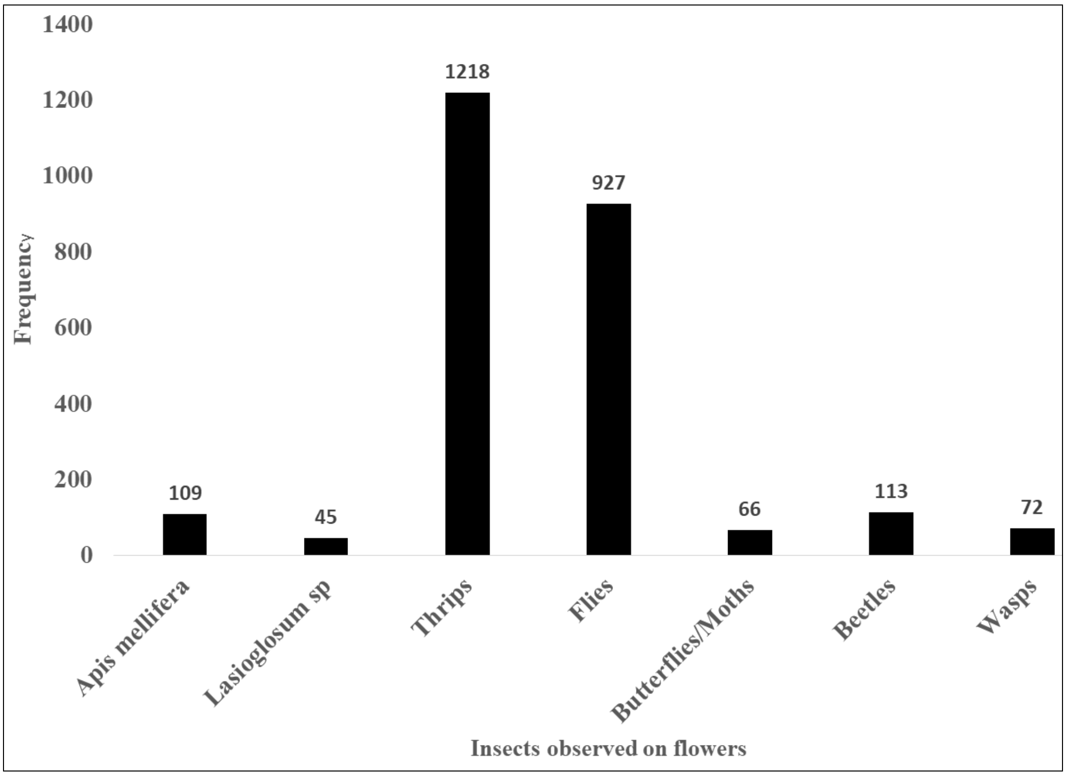

Fig 4: Total number of insects observed on cowpea flowers in farm 4

In Farm 4, again thrips were the most common insects observed with total number of 1218 followed by flies with total number of 927. All the other insects observed recorded numbers less that 120 (Figure 4). Once again the differences between the numbers were statistically significant (χ^2 = 3,980.37; DF = 6; $p<0.05$) and thus null hypothesis rejected.

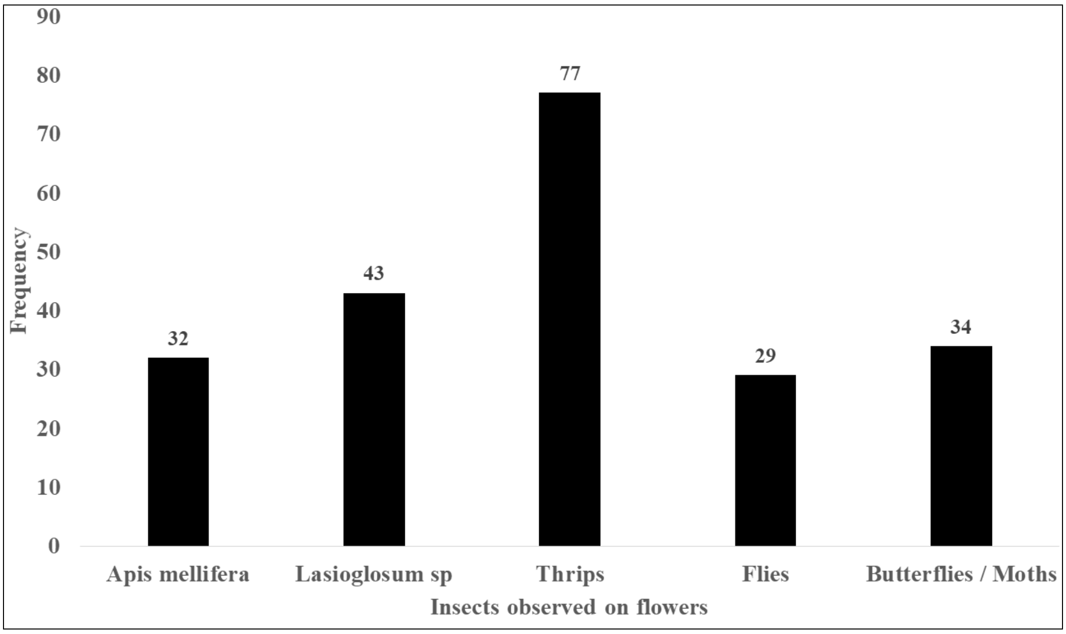

Fig 5: Total number of insects observed on cowpea flowers in farm 5

Six different types of insects were observed on flowers in Farm 5. Again the one with highest numbers was thirps (77) followed by *Lassioglosum* sp. (43) while others recorded numbers less than 40 (Figure 5). Differences in the numbers were however, statistically significant (χ^2 = 35.50; DF = 5; $p<0.05$) pointing out that the null hypothesis was rejected.

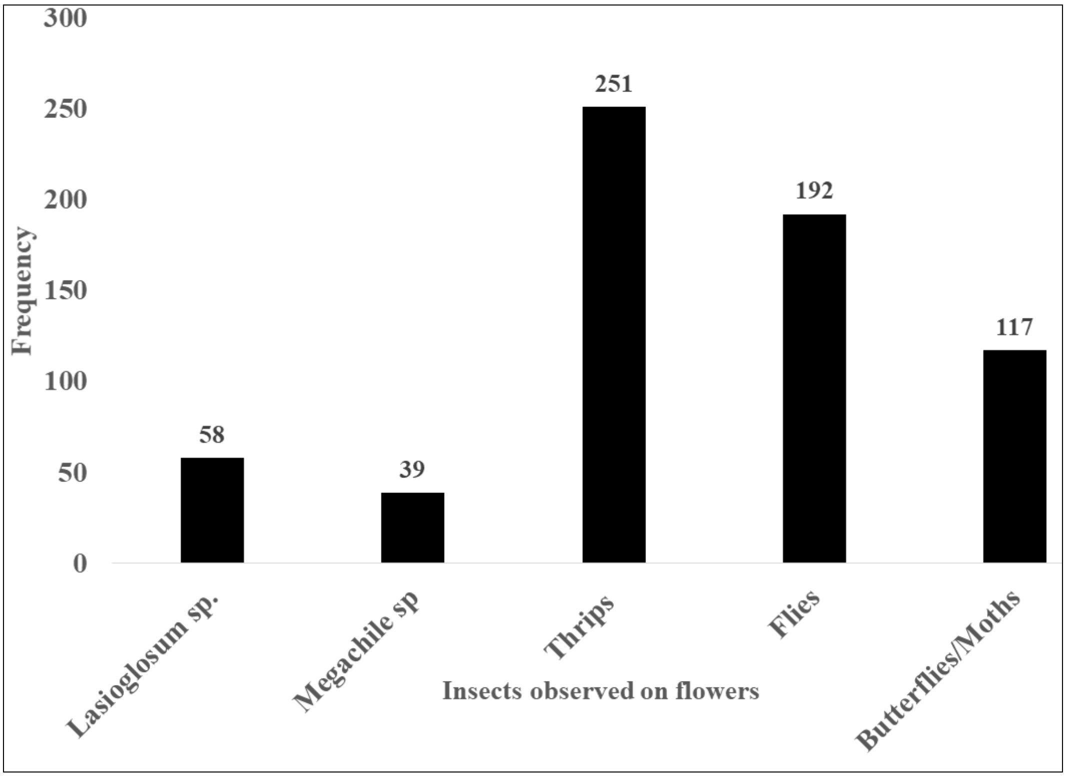

Fig 6: Total number of insects observed on cowpea flowers in farm 6

Five insects were observed in Farm 6. Out of these thrips recorded 251, followed by flies (192(, butterflies/moths (117), *Lassioglosum* sp. (58) and *Megachile* sp. (39). In this case also, the differences between the numbers were statistically significant (χ^2 = 180.65**;** DF = 4; p<0.05). Thus, the differences were real.

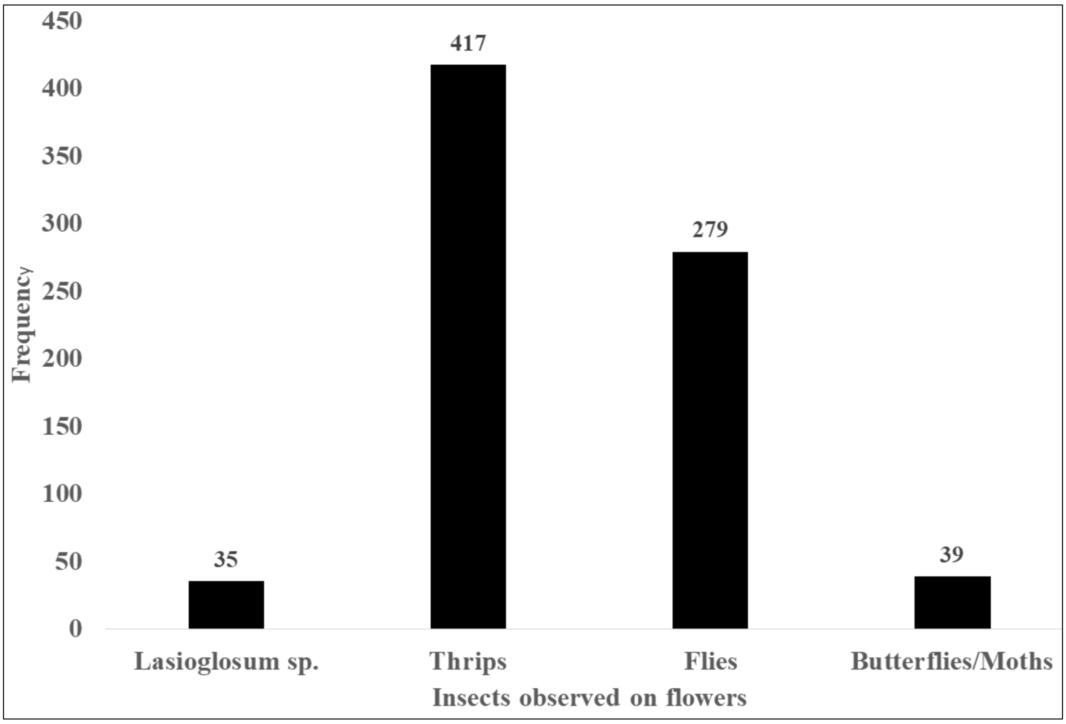

Fig 7: Total number of insects observed on on cowpea flowers in farm 7

For Farm 7 (Figure 7), four (4) insects were observed on the flowers. Again the commonest of them was thrips (417), followed by flies (279), butterflies/moths (39) and *Lassioglosum* sp. (35). Here also the differences between the numbers were statistically significant (χ^2 = 551.95; df = 3; p<0.05).

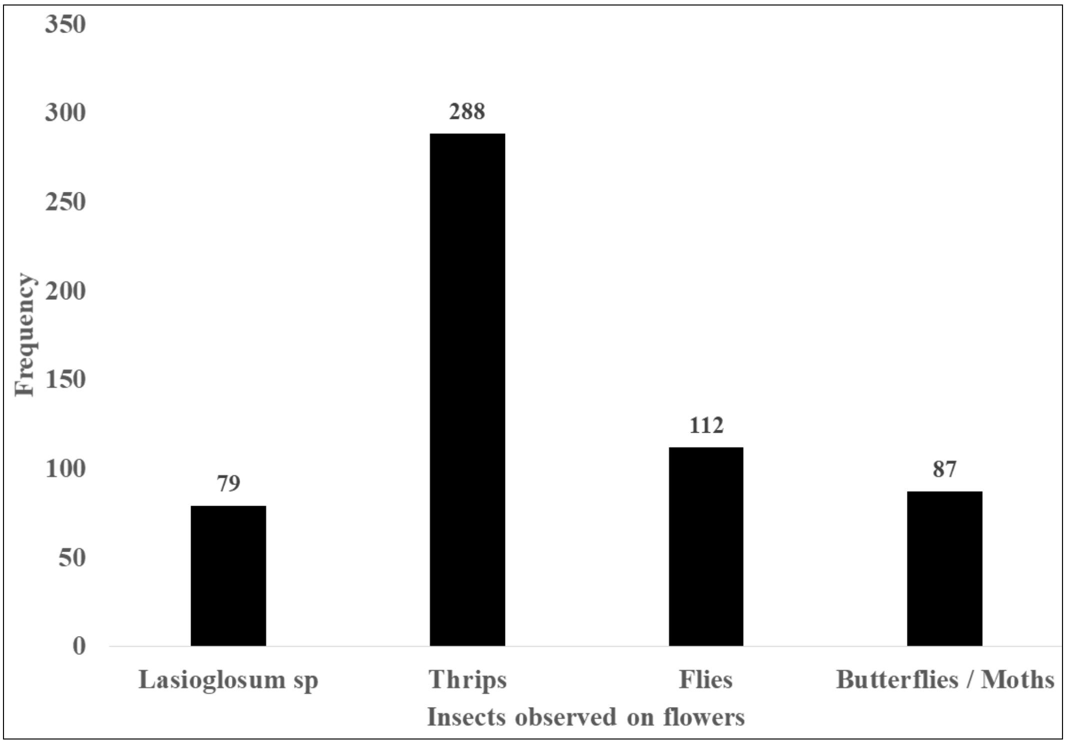

Fig 8: Total number of insects observed on on cowpea flowers in farm 8

From Figure 8, it is clear that four insects were observed in Farm 8 also, where thrips were the commonest (2880 followed by flies (112(, butterflies/moths (87) and *Lassioglosum* sp. (79). As usual, the differences in the numbers were statistically significant (χ^2 = 206.43; df = 3; p<0.05) and the null hypothesis rejected.

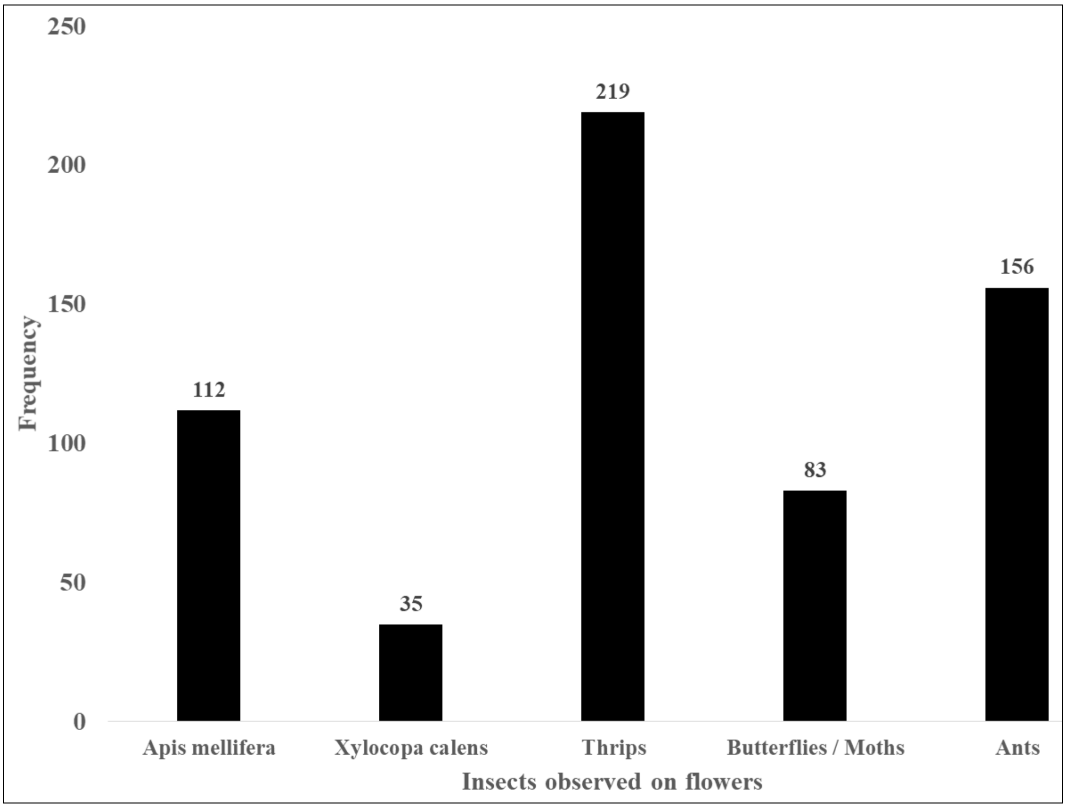

Fig 9: Total number of insects observed on on cowpea flowers in farm 9

In farm 9 (Figure 9), five insects were observed on the flowers. Again, the commonest was thrips (219), followed by ants (156), *Apis melifera* (112), butterflies/moths (83) and *Xylocopa calens* (35). Differences between the numbers were statistically significant (χ^2 = 163,21; DF = 4; p<0.05). obviously, the null hypothesis was rejected pointing out real differences among the figures.

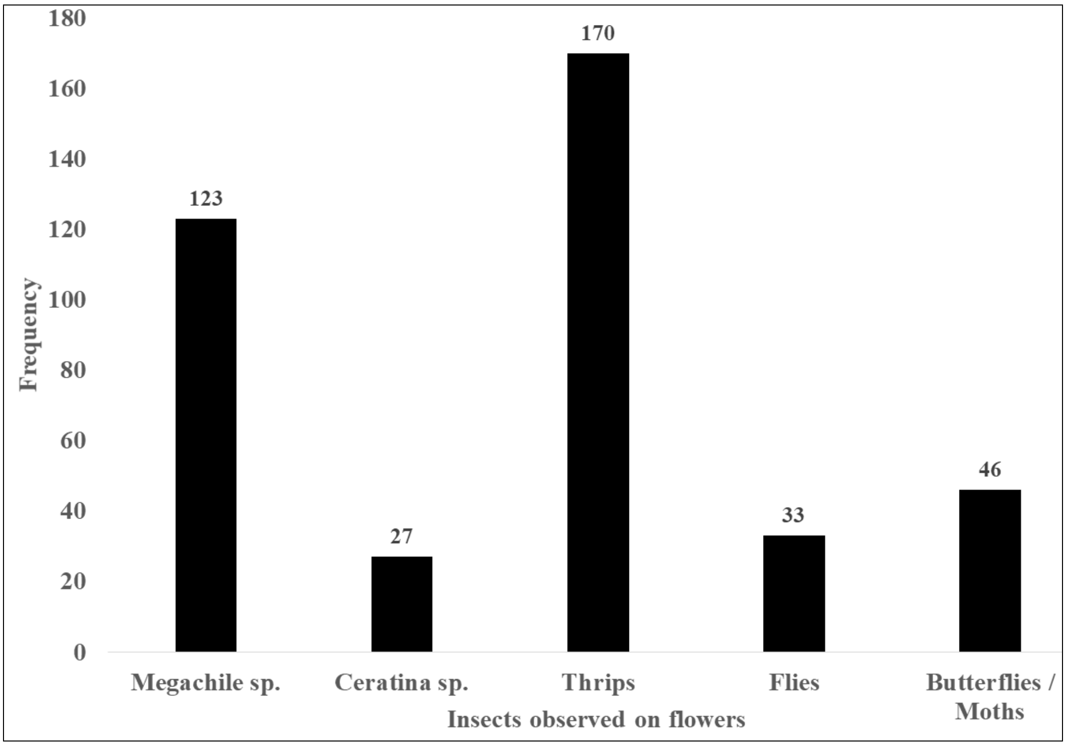

Fig 10: Total number of insects observed on cowpea flowers in farm 10

Five insects were observed on flowers in Farm 10 also (Figure 10). Once again thrips was the most common (170), followed by *Megachile* sp. (123), butterflies/moths (46), flies (33) and *Ceratina* sp. (27). The differences between the numbers were statistically significant (χ^2 = 202.05; DF = 4; p<0.05). Therefore, here also the null hypothesis was rejected.

Table 2: Abundance of insects observed on cowpea flowers in the survey area

Type of insect	Position on flower							
	On petals		On tip of stigma		Inside flower		Total	
	Freq	% Freq	Freq	% Freq	Freq	% Freq	Freq	% Freq
Apis mellifera	70	0.84	274	3.31	35	0.42	379	4.57
Ceratina sp.	43	0.52	128	1.54	43	0.52	214	2.58
Thrips	1,188	14.33	2,419	29.18	532	6.42	4,139	49.93
Crickets	13	0.16	7	0.08	7	0.08	27	0.33
Flies	857	10.34	1,009	12.17	64	0.77	1,930	23.28
Butterflies / moths	314	3.79	256	3.09	49	0.59	619	7.47
Megachile sp.	43	0.52	156	1.88	10	0.12	209	2.52
Lasioglosum sp.	64	0.77	198	2.39	76	0.92	338	4.08
Ants	62	0.75	41	0.49	112	1.35	215	2.59
Wasp	45	0.54	12	0.14	15	0.18	72	0.87
Xylocopa calens	11	0.13	17	0.21	7	0.08	35	0.42
Beetles	56	0.68	51	0.62	6	0.07	113	1.36
Total	2,766	33.37	4,568	55.10	956	11.52	8,290	100
	DF = 22; χ^2 =903.15						DF = 11; χ^2 = 23,051.985	

Results from Table 12 point to the fact that the most abundant insect species on flowers in the survey area was thrips ((49.93%), followed by flies (23.28%), and butterflies/moths (7.47%). The abundance of all the other insects observed was less than five per cent on the flowers in all the farms put together. The differences between the numbers on various parts of the flowers were statistically significant (χ^2 =903.15; DF = 22; p<0.05). Similarly, the differences between the numbers of insects on flowers in all the farms put together were statistically significant (χ^2 = 23,051.985; DF = 11; p<0.05). The fact that the differences in the numbers were statistically significant suggest that the differences between the numbers of insects visiting different parts of the flowers were not due to chance but real. The same can be said about the abundance of the insects. Thus, results from Figures 1 to 10 and Table 2 agree that the most abundant insect observed on flowers in farms sampled was thrips, followed by flies, butterflies/moths, *Apis mellifera*, *Lasioglosum* sp., *Ceratina* sp., ants and others.

In terms of the mechanism of pollination, pollen grains must be transferred from the anther to the stigma. Thus, it is presupposed that insects found on anthers would pick pollen grains and when they visit stigmas they would drop them for pollination to occur. For this study, thrips were once again the insects most visiting anthers (14.33%) followed by flies (10.34%), butterflies/moths (3.79%) and the rest which recorded less than one per cent. Again, thrips were the most abundant insects on the tip of stigmas of flowers (29.18%), followed by flies (12.17%), *Apis mellifera* (3.31%), butterflies/moths (3.09%), *Lasioglosum* sp. (2.39%), *Megachile* sp. (1.88%), *Ceratina* sp. (1.54%), and the others with less than one per cent. These results point to the fact that thrips might be the insects picking pollen grain most from the flowers and at the same time dropping pollen grains on tip of stigmas, followed by flies. However, while butterflies might be third most important insect collecting pollen grains they might be fourth in depositing pollen grains on stigmas, while *Apis mellifera* might be third. This suggests that if visitation will have corresponding deposition of pollen grains on the stigmas, then thrips might be first, followed by flies, *Apis mellifera*, butterflies/moths, *Lasioglosum* sp. *Megachile* sp. *Ceratina* sp. and the other insects.

Members belonging to the order hymenoptera are one group of insects best known for pollination. For example, honeybees, bumblebees, and solitary bees rely on nectar and pollen grains provided by flowers. It is documented that honeybees have specialized legs that rake pollen grains from the whole body and collect them in pollen baskets on the tibia. Their fur consists of hairs with hooks and teeth that allow the transport of many pollen grains (Tautz, 2008) [8]. In this study, efforts were not made to observe pollen grains on the body of the bees collected and identified (*Apis mellifera*, *Ceratina* sp., *Lasioglosum* sp., *Megachile* sp. and *Xylocopa calens*). However, some other studies point to the fact that these bees are cowpea pollinators ((Ige, *et al*., 2011; Wousla *et al*., 2019; Kouam *et al*., 2012; Dingha *et al*., 2021; Bebeli, *et al*., 2020) [20, 21, 12, 7, 2]. In this study, *Apis mellifera* was observed from 6.00am to 12.00pm just as documented by Ige *et al*. (2011) [20].

According to Cembrowski (2013) [5] it can be deduced from literature that ants can help or hinder pollination processes. However, overall flower-visiting ants most commonly have a non-significant net effect on plant fitness. Despite the fact that ants can directly harm flowers or indirectly affect pollination by consuming floral nectar or harassing pollinators, they can also benefit plants by attacking florivores or predators of pollinators (Cembrowski, 2013) [5]. Though their secretions often kill pollen grains, sometimes ants can act as pollinators themselves (Cembrowski, 2013) [5]. Ants visit the inflorescences of the same species only to promote cross-pollination, a process known as “geitonogamy”. However, ants may visit different inflorescences of different plants in the field. Ants' cross-pollination may have caused ants to coevolve with the pollinating flowers (Das & Das, 2023) [6]. These submissions suggest that ants observed inside flowers of cowpea in this study might be performing one of the outlined functions. However, the exact role was not studied.

Considering visitation into the inside of the flowers, once again thrips scored the highest figure (6.42%) followed by ants (1.35%) and the others recording less than one per cent. Meanwhile, Varatharajan *et al.* (2016) [19] clearly stated that thrips (Thysanoptera) are one of the pollinating insect groups. By virtue of their pollen feeding habit, thrips visit the flowers during anthesis and carry appreciable number of pollen grains and incidentally transfer them on to the stigma during their inter and intra movement between the flowers/florets/ inflorescence (Varatharajan *et al*., 2016) [19].

The implication is that thrips act as pests when they eat pollen grains. However, as they enter flowers to eat pollen grains, some of the grains stick to their bodies and eventually cross-pollinate other plants when they visit to feed on pollen grains. However, in this study, the feeding process and pollination activities of thrips were not studied. But it can be established that thrips played major roles on flowers in the research area.

Conclusion

The study aimed at assessing the prevalence and abundance of insects on cowpea flowers in some farms in some districts in the Central Region of Ghana. From the findings it is clear that the common insects found on cowpea flowers in the research area were *Apis mellifera*, *Ceratina* sp., thrips, crickets, flies, butterflies/moths, *Megachile* sp., *Lasioglosum* sp., ants, wasps, *Xylocopa calens, and* beetles. Butterflies/moths and thrips were the most prevalent **(**most observed**)** insects on cowpea flowers in the survey area, followed by flies, *Apis melifera* and *Lassioglosum* sp., *Ceratina* sp., *Megachile* sp., ants, crickets, wasps, *Xylocopa calens* and beetles. The findings also point to the fact that there were statistically significant differences in the number of insects observed on various parts of the flowers of cowpea in the survey area. Furthermore, there were statistically significant differences in the abundance of insects observed on cowpea flowers in the survey area.

Recommendations

It is hereby recommended that since insects such as *Apis mellifera*, *Ceratina* sp., thrips, crickets, flies, butterflies/ moths, *Megachile* sp., *Lasioglosum* sp., ants, wasps, *Xylocopa calens, and* beetles are very common on cowpea flowers in the research areas and they have been implicated in pollination in other studies, ways should be found by farmers to prevent their destruction on farms. The emphasis will be on applying pesticides at times that the said insects are not very active on cowpea flowers, especially periods beyond 1.00pm. It is also recommended that practices such as bush burning by hunters as well as slash and burn by farmers should be stopped to prevent destruction of such insects. Finally, the biology of the said insects should be studied by entomologists in order to commercially produce them to augment the numbers in the wild.

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