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RESEARCH ARTICLE

Field management practices and altitudes drive the abundance of ladybird beetles (Coleoptera: Coccinellidae) in cultivated cucurbit crops in Morogoro, Tanzania

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ABSTRACT

Ladybird beetles are helpful insects in agricultural ecosystems affected by locally accepted agroecological techniques. Conventional farming practices are known to harm these insects, which led to the exploration of agroecology as an alternative. From May to November 2021, yellow pan traps, hand picking, and hand netting were utilized in cultivated cucurbits such as *Cucumis sativus, Citrullus lanatus*, and *Cucurbita moschata*. The study found 222 ladybird beetles from nine genera and twelve species. The Plateau had 64.9% ladybirds, 46.4% in conventional fields, and 18.47% in agroecological fields. Mountain fields supplied 35.1%, conventional fields 24.77%, and agroecological fields 10.36%. Conventional plateau fields favoured *Cheilomenes sulphurea*, while agroecological fields selected *Hippodamia variegata*. *Cheilomenes lunata* dominated traditional fields in mountainous areas and agroecological fields. Ladybird beetles were more abundant in conventional fields across all seasons and agroecological zones, which were influenced by seasons, management strategies, and elevations. The present study found negative associations between ladybird abundance and maximum temperature, minimum temperature, mean temperature, number of flowers, and relative humidity. Mountainous precipitation increased ladybird abundance. This study shows how management practices, agroecological zones, and seasons affect ladybird populations, which can inform pest management strategies in agricultural systems and help conserve beneficial ladybird beetles.

Keywords: Cucurbits, Ladybird beetles, Management practices, Insect pest.

INTRODUCTION

Conventional farming practices in agriculture significantly impact biodiversity loss (Tscharntke et al., 2021; Marini et al., 2011). They involve standardizing and expanding farms and landscapes and clearing natural habitats (Vásquez et al., 2022). Using agrochemicals and machinery further worsens the situation (Molina-Guzmán & Ríos-Osorio, 2020; Ushanev et al., 2020). One of the most notable features of conventional farming is the excessive use of pesticides, favourably identified as the primary cause of declining insect populations in agricultural areas (Samways et al., 2020; Brühl et al.,2021). Studies by Norris (2008) and Hooper et al. (2012) have shown that this decline is mostly due to insecticides' lethal and sub-lethal effects. Additionally, herbicides used in conventional farming alter habitat features, reducing habitat suitability and composition for insect communities, including natural enemies. Conventional farming also leads to habitat depletion, resulting in decreased availability of essential resources like food, shelter, and reproductive areas for natural enemies (Puech et al., 2014; Chabert & Sarthou, 2020; Mabin et al., 2020).

Agroecological practices are increasingly seen as an effective solution to mitigate the negative impacts of conventional farming on insect communities (Samways et al., 2020; Deguine et al., 2021). Agroecology emphasizes ecological principles to support sustainable farming, encompassing crop diversification, reduced chemical inputs, cover cropping, and agroforestry (Altieri, 1995; Gurr et al., 2017). These practices create a favourable environment for beneficial insects in agricultural fields, ultimately increasing their populations. However, it is essential to acknowledge that the response of insect communities varies depending on the degree of integration of field management practices, insect taxa, and local climatic conditions.

Understanding how insect populations respond to various field management practices across diverse climatic conditions is crucial to promoting the sustainable coexistence of farming and insect biodiversity and optimizing the integration of agroecological principles into agricultural landscapes. The degree of integration of agroecological field management practices can significantly impact the abundance and distribution of beneficial insects. Research indicates that a higher degree of agroecological integration, such as organic farming with diversified cropping systems, supports a more diverse and abundant insect fauna (Bianchi et al., 2006; Batáry et al., 2017). However, the specific combination of these field practices within agroecology may vary among small-scale farmers, resulting in varying impacts on insect abundance (Bianchi et al., 2013; Chaplin-Kramer et al., 2015). For example, certain crop combinations may provide more suitable habitats and food resources for beneficial insects, promoting their populations more effectively than other combinations (Bianchi et al., 2013).

Furthermore, the impact of agroecological practices on insect abundance can be influenced by local climatic conditions. For instance, agroecological farming systems may be more effective in promoting insect biodiversity and ecosystem services in regions with moderate climates than in areas characterized by extreme temperature fluctuations or arid conditions (Zhang et al., 2020; Rusch et al., 2021). Different insect taxa can exhibit varying responses to agroecological practices. Some studies have shown that certain groups of insects, such as natural enemies like parasitoids and predators, may benefit from the increased habitat and food resources provided by agroecological farming systems (Rusch et al., 2015; Martin et al., 2019), while other studies have reported reduced populations of some insect groups in agroecological farms (Liu et al., 2018; Davis et al., 2020).

In the Morogoro region, farmers have adopted a wide range of agroecological management practices (Constantine et al., 2021). For decades, these agroecological practices have been used to manage crops across the mountainous and plateau areas of the Morogoro region. In these areas, ladybird beetles represent a significant group of natural enemies for managing aphids, coccids, and mites in crop fields (Kibulei et al., 2023). However, information regarding the effects of these agroecological field management practices on the abundance and distribution of ladybird beetles has largely remained unknown. Further research is needed to understand how different agroecological practices affect the ladybird beetle population and their potential contributions to pest management.

Therefore, this study focuses on investigating the influence of field management practices on the abundance of ladybird beetles associated with cucurbit crops cucumber *(Cucumis sativus L.),* watermelon *(Citrullus lanatus [Thunb.] Matsum and Nakai),* and squash *(Cucurbita moschata D).* The results of this study provide valuable information that could be used to design sustainable conservation measures for coleopteran natural enemies.

MATERIALS AND METHODS

Study site

The Morogoro region, which is located in the twilight zone between S5°58' and S10°0' latitude and E35°25' and E38°30' longitude, was the site of the study. To create experimental plots, two agroecological zones were chosen. The plateau and the mountainous zone were these regions. The average annual rainfall in the plateau zone, which is 300–600 meters above sea level, is between 700 and 200 millimetres. The mountainous region, on the other hand, is 600 meters above sea level and experiences annual rainfall averaging between 800 and 2500 millimetres. Ten plots (each 45 m × 45 m) were made for the study, five of which were used for conventional farming and five for agroecological farming. Each plot was divided into three subplots, each of which was planted with one of the three cucurbit crops: squash (*Cucurbita moschata* D.), watermelon (*Citrullus lanatus* [Thunb.] Matsum & Nakai), and cucumber (*Cucumis sativus* L.). 50 by 60 cm, 1 by 1.5 m, and 1 by 1.5 m, respectively, were the spacings between the crops.

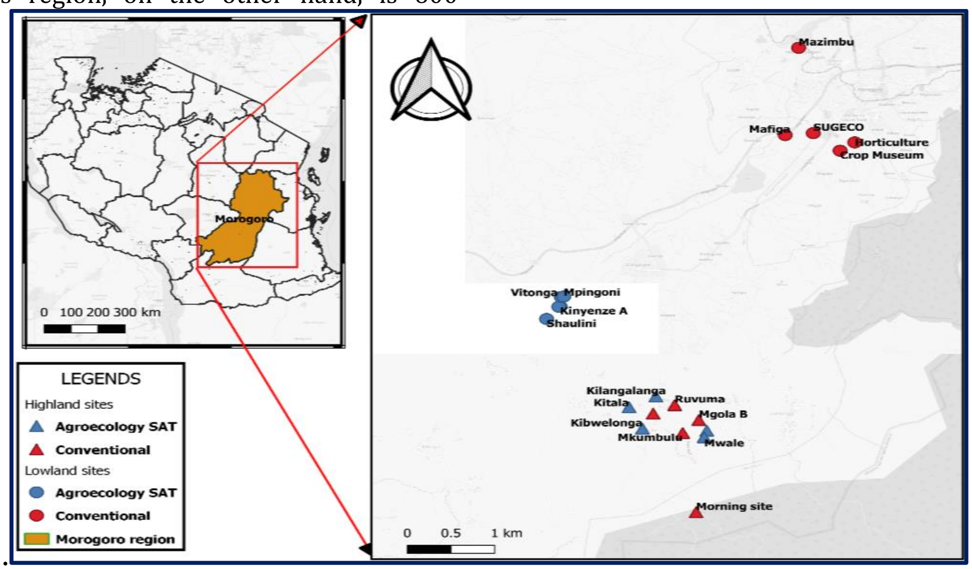

Figure 1. Experimental plots located across the two agroecological zones of the Morogoro 2 regions (Kibulei et al., 2023).

Sampling approach

Ladybird beetles were systematically collected every week in Morogoro for a total of seven weeks, spanning two distinct periods of cucurbit cultivation (May–June and October–November 2021). The methods employed for collecting specimens encompass sweep netting, pan traps, and handpicking. Anbalagan et al. (2016) employed sweep nets, pan traps, and handpicking as methods. Each management implemented five experimental plots in every agroecological zone, with each plot spanning an area of 2,025 square metres. Within each plot, three different cucurbit species (cucumber, watermelon, and squash) were cultivated, with each species occupying an area of 675 square metres. We preserved ladybird beetles from each cucurbit species in plastic vials with 100% alcohol to facilitate identification. The taxonomic identification was conducted at the entomology laboratory of Sokoine University of Agriculture (SUA) using a binocular stereomicroscope and systematic keys available online (Johari et al., 2020).

Data collected

Records were kept of ladybird beetles caught per trap per week. The Tanzania Meteorological Authority (TMA) at SUA station provided rainfall (mm), temperature (°C), and relative humidity (%RH). However, cucurbit flowers were counted weekly.

Statistical analysis

Excel spreadsheets organized data on the abundance of ladybird species associated with cucurbit crops. The population abundance values obtained were analyzed using R software to determine statistical differences in abundance between species, seasons, crop species, and insect species management practices. The means were compared using the post-hoc Tukey test.

RESULTS

Abundance of ladybird beetles

During this study, a total of 222 ladybird beetles were recorded from nine (9) genera, including *Cheilomenes*, *Harmonia*, *Epilachna*, *Hippodamia*, *Creoceris*, *Aulacophora*, *Raphidopalpa*, *Leptaulaca*, and *Aspidomorpha,* in twelve (12) different species. Of these, 64.9% were collected from the Plateau Zone, and 35.1% from the Mountain Zone. Within the Plateau Zone, 46.4% were collected from conventional Cucurbit fields, and the remaining 18.47% were collected from agroecological Cucurbit fields. The remaining 35.1% were collected in mountain areas, with 24.77% being conventionally collected in Cucurbit fields and the remaining 10.36% in agroecological Cucurbit fields.

Effect of management practices on the abundance of dominant ladybird beetle species

The results indicate that the richness of ladybug species was significantly impacted by the interaction between crop seasonal management practices and species in agroecological zones (p<0.05), (**Table 1**). In all zones and seasons, except for the plateau zone in the mountainous zone, the number of ladybird beetles was higher in conventional fields than in agroecological fields, as illustrated in **Figure 2**.

Table 1. Analysis of variance for agroecological zones, season, management strategies, and crop species on ladybird beetle abundance from May to November 2021.

Factors	Statistics		
	d.f	F value	P value
Agroecological zone (A)	1	9.879	0.002*
Season (S)	1	1.14	0.286ns
Management practices (M)	1	23.751	0.000*
Crop species (C)	2	0.647	0.524ns
A x S	1	0.001	0.974ns
A x C	1	0.585	0.445ns
A x M	2	0.484	0.617ns
S x C	1	12.977	0.000*
S x M	2	0.686	0.504ns
C x M	2	0.323	0.724ns
A x S x M	1	6.26	0.013*
A x S x C	2	0.443	0.642ns
S x C x M	2	0.198	0.82ns
A x C x M	2	0.09	0.914ns
A x S x C x M	2	0.063	0.939ns

*Indicates significant and ns shows not significant, d.f indicates the degree of freedom. * P< 0.01* * * p<0.001

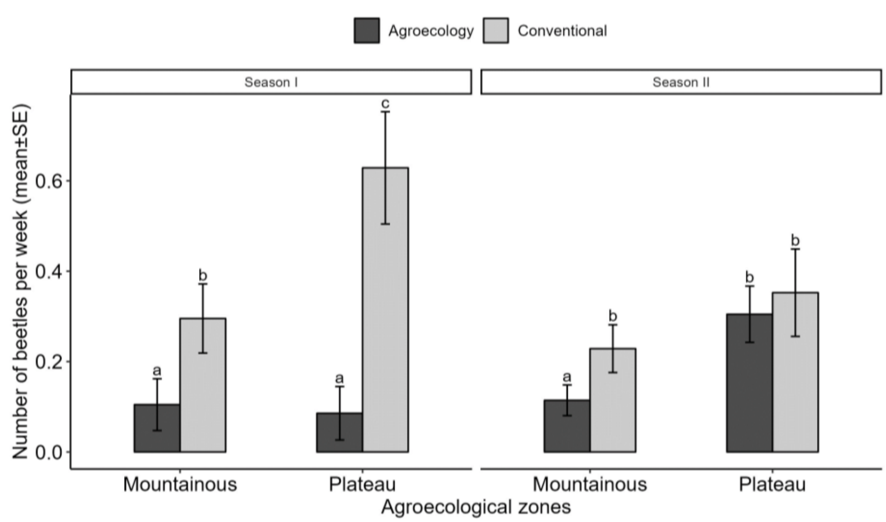

Figure 2. The abundance of dominant ladybird beetle species between two cucurbit cropping seasons in different management practices across agroecological zones of the Morogoro. Note: Bars with different letters denote significant differences, p < 0.05.

Influence of environmental factors on the abundance of dominant ladybird beetle species

Spearman correlation between weather variables and the abundance of ladybird species in the agroecological zones of the Morogoro region were presented in **Table 2**.

The abundance of ladybird beetles was found to be negatively correlated with maximum temperature, minimum temperature, mean temperature, number of flowers and relative humidity in plateau and mountain areas ($P > 0.05$), while precipitation in mountainous regions showed a positive correlation with the species ($P<0.05$).

Temporal and Spatial variability ladybird beetle species

The findings suggest a significant variation in the number of ladybugs depending on different management techniques used in each zone. In the plateau zone, the population of ladybugs on conventional fields was highest during Season II (October-November) but decreased towards the end of November. In Season I (May-June), the population increased towards June and then decreased. On the other hand, the ladybug population showed similar seasonal trends in Season I, with the highest frequency in October during Season II, which decreased towards November (**Figure 3**).

Table 2. Influence of environmental factors on the abundance of dominant ladybird beetle species with weather variables and number of flowers

Parameters	**Abundance**	
	Mountainous	**Plateau**
No of flowers	0.03ns	0.07ns
Maximum temperature	-0.05ns	$-3.6e^{-3}$ns
Minimum temperature	0.01ns	0.02ns
Mean temperature	0.07ns	0.02ns
Relative humidity	0.03ns	-0.04ns
Rainfall	0.11*	-0.02ns

Correlation is significant ***p<0.001; *p<0.05; ns = correlation is not significant

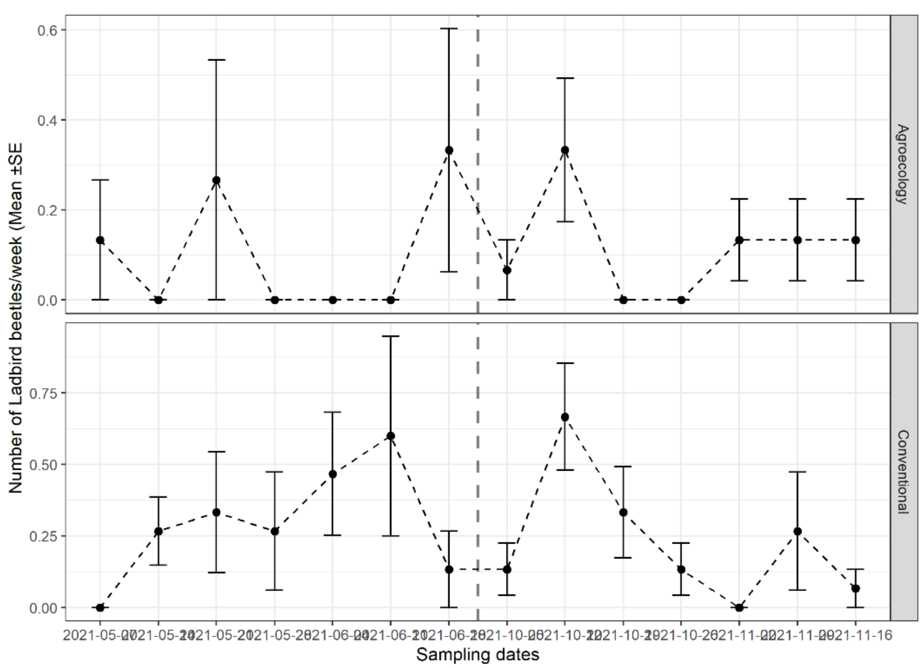

Figure 3. Temporal variability of ladybird beetles in the plateau zones across the two management practices from May to November 2021. *Note:* SE stands. The dashed lines separate seasons.

According to the results, the frequency of ladybird beetles varies greatly based on the management practices in each zone (**Figure 4**). In mountainous regions, the ladybird population on conventional fields was highest during Season II (October-November) and declined towards the end of November. During Season I (May-June), the population increased towards June and then decreased. Similarly, the ladybug population showed similar seasonal trends during Season I, with the highest frequency in October during Season II, which decreased towards November. According to the results, the frequency of ladybird beetles varies greatly based on the management practices in each zone, as shown in Figure 4. In mountainous regions, the ladybird population on conventional fields was highest during Season II (October - November) and declined towards the end of November. During Season I (May - June), the population increased towards June and then decreased. Similarly, the ladybug population showed similar seasonal trends during Season I, with the highest frequency in October during Season II, which decreased towards November.

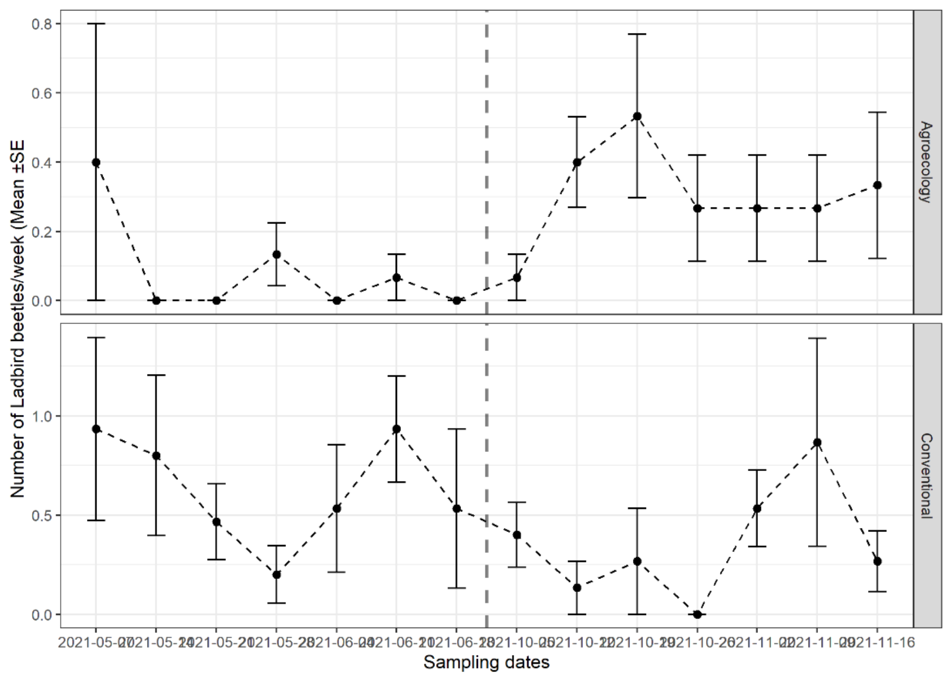

Figure 4. Temporal variations of ladybird beetles in the mountainous regions under two different management approaches between May and November 2021. *Note:* SE stands for Standard Error. The dashed lines separate seasons.

Relative abundance of ladybird beetles across agroecological zones and management practices by Heat map

In the heatmap, the population of ladybird beetles varied depending on the field type and geographic region. In conventional fields in the plateau zone (**Figure 5**). *C. sulphurea* was the most abundant species, followed by *Cheilomenes lunata* and *C. sexmaculata*. Meanwhile, in agroecological fields in the same zone, *H. variegata* was more abundant, followed by *L. fisicollis*. In mountainous zones, *C. lunata* was the most abundant species in fields under conventional practices, while *C. sulphurea* followed closely behind. On the other hand, in fields under agroecology in the mountainous zone, *C. lunata* was the most abundant species.

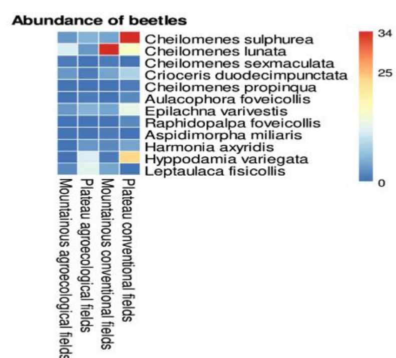

Figure 5. Heat maps show ladybird beetles' relative abundance across agroecological zones and management practices. The color code indicates relative abundance, ranging from blue (low abundance) to reddish (high abundance)

DISCUSSION

Changes in the populations of many insect species are dependent on various factors, such as management practices, elevation, and season (Hodgson et al., 2011; Makwela et al., 2019; Habel et al., 2019; Baldacchino et al., 2014). In particular, Ladybugs are affected by biotic and abiotic factors (Faheem et al., 2019; Reddy & Sreedevi, 2016). In a study conducted on gourd cultivation in the Morogoro region, it was observed that the abundance of most ladybird beetles was higher in conventional fields than in agroecological fields. This could be due to the more intensive management practices employed in conventional farming (Krauss et al., 2011; Lu et al., 2015). Similar results have also been found by Wenda et al. (2018) and Török et al. (2021), who reported a higher abundance of ladybirds on conventional fields.

However, some studies show that ladybugs are more common in agroecological farming practices in cotton fields than in conventional cotton fields (Bengtson et al., 2005; Lu et al. 2015; Liere et al., 2017). In the Morogoro region study, a higher frequency of ladybirds was observed in fields in high plateau than in fields in mountainous areas, which could be due to food availability and prevailing weather conditions on conventional fields in plateau zones (Guo & Gan, 2014; Török et al., 2021). This result is consistent with Wenda et al. (2018) and Török et al. (2021), who observed a higher frequency of ladybirds in plateau and mountain fields on conventional fields than in agroecological fields.

The study also found that weather variables significantly impact dominant ladybird species. Among the dominant ladybug species, *H. variegata* positively correlated with relative humidity and temperature but did not correlate with precipitation and the number of flowers (Bajia & Singh, 2014). Meanwhile, *C. lunata* only correlated with the mean temperature, and *C. sulphurea* correlated with none. This shows that changes in temperature and relative humidity significantly impact ladybug abundance, consistent with the findings of Bhati et al. (2016), and Makwela et al. (2019).

In conclusion, the abundance of ladybugs associated with cultivated squash plants varies according to the Morogoro region's management practices, season, and agroecological zones. Ladybugs experienced significant variability in abundance in management practices in different agroecological zones of the region. This is related to the variability of weather conditions, food abundance, and the diversity of inherent adaptive properties of surrounding vegetation between species in different agroecological zones. Insect turnover was due to abundant food and the favourable microclimate in conventional farming practices, as Bhati et al. (2016) and Shah et al. (2015) reported.

CONCLUSION

Our research has revealed that when cultivating pumpkin crops in plateaus and mountains, agroecological farming practices result in fewer predatory ladybirds than conventional farming. Additionally, we found that pumpkin crops with low populations of natural enemies are more suitable for low-intensity agroecological farming. Despite having more natural predators, conventional farming tends to have a more abundant presence of ladybugs. Our findings suggest that using natural enemies to control agricultural pests could be viable. However, it is crucial to note that ladybirds, parasitic wasps, and other natural enemies rely on natural vegetation as a source of food and habitat. While having a large population of predatory ladybugs can assist in controlling pests, their numbers cannot be artificially increased beyond a certain point.

DISCLOSURE STATEMENT

The author declares no competing interests.

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