Journal of
Current Opinion in Crop Science

Journal homepage: www.jcocs.com; ISSN(O):2583-0392

RESEARCH ARTICLE

Diversity of Ladybird Beetle Communities (Coleoptera: Coccinellidae) under different Cucurbit Farming practices in Morogoro, Tanzania

Ernest Kibulei[1,2]*., Sija Kabota[1,3]*., Jackline Bakengesa [1,4] and Abdul Kudra[1]

[1]Department of Crop Science and Horticulture, Sokoine University of Agriculture, Morogoro, Tanzania.
[2]Department of crop development, Ministry of Agriculture, Dodoma, Tanzania.
[3]Research, Consultancy, and Publication Unit, National Sugar Institute Kidatu-Morogoro, Tanzania.
[4]Department of Biology, University of Dodoma (UDOM), Dodoma, Tanzania.

Edited by:
Dr. K. Ashokkumar, Ph.D.,
SA & AS, GRI-DU, Dindigul, Tamil Nadu, India.

Reviewed by:

Dr. G. Rajadurai, Ph.D.,
Tamil Nadu Agricultural University,
Coimbatore, TN, India.

Article history:

Received: April 24, 2023
Accepted: June 25, 2023
Published: June 30, 2023

Citation:

Kibulei, E., Kabota, S., Bakengesa, J., & Kudra, A. (2023). Diversity of ladybird beetle communities (Coleoptera: Coccinellidae) under different cucurbit farming practices in Morogoro, Tanzania. *Journal of Current Opinion in Crop Science, 4*(2), 76-88.

*Corresponding author e-mail address: ernest.kibulei@kilimo.go.tz (Ernest Kibulei)

ABSTRACT

The farmers' friends, ladybird beetles, serve as predators to keep the plant-feeding insects from reaching damaging population levels and could be helpful in pest management. Farming strategies that retain biodiversity could be a viable option for pest management in agricultural systems. The current study examines the effects of various management practices on ladybird beetle diversity in cucurbit crops in both conventional and agroecological contexts. Trapping and netting were used to collect data on the diversity of these ladybird beetles in 2021. Collected data were analyzed using R software to determine both alpha and beta diversity. In the plateau and mountainous zones, 222 predatory ladybird beetles were collected, with nine genera and 12 species classified. *Cheilomenes lunata* (28.82 %) was the most prevalent of the nine (9) genera in terms of the total number of individuals, followed by *Cheilomenes sulphurea* (20.72 %) and *Hippodamia variegata* (15.90 %). The plateau zone collected 64.86 % of the total, while the mountainous zone comprised 35.14%. These findings are important in the decision-making and effective biological control and management of cucurbit crop pests. This study will help to gain insights into ecological balance and pest management.

Keywords: Agroecology, Beetles, Biological control, Conservation, Conventional, Diversity Predators, Ladybird.

INTRODUCTION

Agriculture is among the major drivers of biodiversity change worldwide (Duru et al., 2015; Garbach et al., 2014; Kleijn et al., 2011). It either reduces or increases the diversity and abundance of insect communities in agricultural landscapes (Gaspar et al., 2022). The change in biodiversity in the agricultural landscape may affect the delivery of crucial ecosystem services such as pollination and predation (Lundgren et al., 2015). These two ecosystem services are crucial in maintaining plant community stability and crop production sustainability in the agricultural landscape (Wickramasinghe et al., 2004; Kremen & Miles, 2012).

The intensification of agriculture represents a severe threat to the delivery of critical ecosystem services (Emmerson et al., 2016). Remarkably, the intensification of conventional farming, which involves excessive use of agrochemicals such as pesticides and fertilizers, has been associated with significant declines in insect communities and disruption of ecosystem processes (Norris, 2008; Hooper et al., 2012). Numerous studies have highlighted the negative impacts of conventional farming on insect communities (Kleijn et al., 2011; Duru et al., 2015; Reddy & Giraddi, 2019), as it contributes to more than 50% of losses in insects' abundance and diversity, underscoring its detrimental effects on both insect biodiversity and crop production (Cardinale et al., 2012; Emmerson et al., 2016). The impact of conventional farming on important insect taxa, such as pollinators and predators, is of great concern due to the potential decline in pollination services and biological pest control in agricultural landscapes (Albert et al., 2017).

Among predators, ladybird beetles (Coleoptera: Coccinellidae), also known as ladybugs or ladybirds, are important natural enemies of insect pests (Almeida et al., 2011; Giorgi et al., 2010; Pervez et al., 2020). They are globally recognized as essential biological pest control agents for many insect pests, including aphids and coccids (Rusch et al., 2010; Farooq et al., 2020; Che et al., 2021). However, conventional farming practices such as excessive use of insecticides and expansion of cleared land for farming have been shown to negatively affect these beneficial insect groups (Viglásová et al.,2017). Conventional farming practices have been found to disrupt the population dynamics and community structure of ladybird beetles by reducing their abundance and diversity (Crowder & Jabbour, 2014). As a result, suppressing insect pest populations becomes less effective (Yasmeen & Dugaje, 2020), leading to increased reliance on chemical pesticides and potentially negative consequences for human health and the environment (Wagner, 2020).

Furthermore, conventional farming contributes to habitat loss leading to reduced suitable habitats for ladybird beetles (Patil et al.,2019; Honek et al., 2019; Honek et al., 2016) and restricted accessibility of resources necessary for their survival, including food, shelter, and breeding sites (Puech et al., 2014; Chabert & Sarthou, 2020; Mabin et al., 2020). Consequently, ladybird beetle communities may experience reduced diversity and abundance, compromising their ability to provide biological pest control services in crop fields (Kleijn et al., 2011; Duru et al., 2015).

There is a growing recognition of the need to transition towards more sustainable and ecologically friendly farming practices to address these challenges (Brühl & Zaller, 2019). For example, agroecological farming emphasizes enhancing ecosystem services such as pollination, nutrient cycling, and biological pest control (Brühl et al., 2019; Kehoe et al., 2021). By adopting agroecological principles, farmers can reduce their reliance on agrochemicals, promote biodiversity conservation, and restore ecological processes in agricultural landscapes (Helfenstein et al., 2020). While agroecological farming is generally perceived as an alternative to conventional farming with the potential to boost the diversity and abundance of insect communities in crop fields (Landis et al., 2000; Tschumi et al., 2015), there is a need for further investigation and understanding of its impacts on specific insect groups such as ladybird beetles, as numerous contradictory findings have been reported in previous studies (Costamagna & Landis, 2006; Hatten et al., 2007; Liere et al., 2017).

The impacts of agroecological farming on insect communities can vary between locations depending on the intensity and complexity of the management practices adopted, as well as the insect taxa interaction (Costamagna & Landis, 2006; Liere et al., 2019). Ladybird beetles are among the common insects in many agricultural landscapes of Morogoro, Tanzania (Schabel, 2006). The agricultural fields in the Morogoro region have been under a wide range of locally adopted agroecological management practices for decades (Constantine et al., 2021). To what extent these locally adopted agroecological practices affect the diversity and assemblage of ladybird beetle communities in cucurbit crops remains unknown. This study aimed to unravel the extent to which the locally adopted agroecological management practices affect the diversity and assemblage of ladybird beetle communities by quantifying the diversity and pattern of species assemblages in cucurbit crops under two contracting farming systems (Conventional vs. Agroecology) in Morogoro. The findings of this study serve to provide baseline information on the performance of locally adopted management practices on improving the diversity of natural enemies in the agroecosystem.

MATERIALS AND METHODS

Study site

The study was carried out in the Morogoro region. The region is located S5°58'- S10°0' and E35°25'- E38°30' of the transitional belt (URT, 2002). The study established experimental plots in the mountainous and plateau agroecological zones. The average rainfall is 700-1200 mm in the plateau zone, 300-600 m above sea level. The mountainous zone, 600 m above sea level, receives 800 to 2500 mm of rain annually. A total of 10 plots (45 m x 45 m) were established at least 50 m apart each in each agroecological zone (**Figure 1**). Five plots were managed under conventional farming in each zone, and the remaining five were managed under agroecological farming. Each plot was subdivided into three subplots in which three cucurbit crops; cucumber (*Cucumis sativus* L.), watermelon (*Citrullus lanatus* [Thunb.] Matsum and Nakai), and squash (*Cucurbita maxima* L.) were planted at a space of 50 cm by 60 cm,1 m by 1.5 m and 1m by 1.5 m respectively.

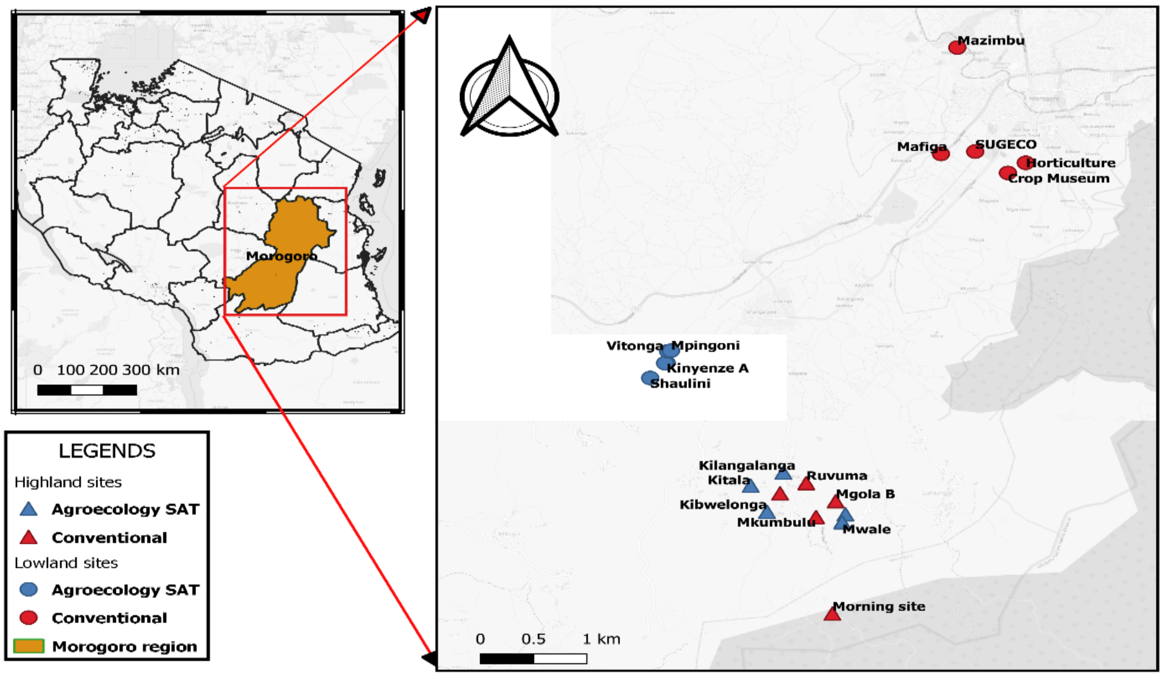

Figure 1. Location of experimental plots across the two agroecological zones of the Morogoro regions.

Sampling approach

Ladybird beetles were sampled on a weekly basis for seven consecutive weeks in each of the two cucurbit growing seasons (May-June and October-November, 2021) of Morogoro. The collection methods involved sweep netting, pan trapping, and handpicking. Handpicking was used in addition to sweep netting and pan trapping, as mentioned in Anbalagan et al. (2016). The sampling was carried out in five experimental plots per management within each agroecological zone, and each plot covered an area of approximately 2,025 square meters where three cucurbit species (cucumber, watermelon, and squash) were grown at $675m^2$ each. The ladybird beetles collected from each cucurbit species were preserved in plastic vials containing 100% alcohol for later identification. The taxonomic identification was performed at the entomology laboratory of Sokoine University of Agriculture (SUA) using a binocular stereo-microscope and systematic keys published online by Johari et al. (2020).

Data collection

Weekly catches of ladybird beetles were recorded as the number of beetles per trap/week. Weather parameters such as rainfall (mm), temperature (^{o}C), and Relative humidity (%RH) were also obtained from Tanzania Meteorological Authority (TMA) at SUA station. In contrast, the number of cucurbit flowers was also recorded once per week.

Data analysis

Alpha diversity

The diversity of ladybird beetle within management practices was assessed using alpha diversity indices including the Shannon, ($H' = \sum_{i=1}^{S} \frac{ni}{N} \ln \frac{ni}{N}$), Simpson, ($D = 1/(\sum_{i=1}^{S} \frac{ni}{N}(\frac{ni-1}{N-1}))$), and the evenness index of Pielou;- (J = H/In S). The species richness index of Margalef ((DMg =(S-1/lnN)) was used to highlight the richest management practices in terms of the number of ladybird beetle species across agroecological zones. In these formulae, ni is the number of individuals of the i species in the sample, N is the total number of individuals in the assemblage, and S is the number of species. R software version 4.2.3 produced these ecological community study indices.

Beta diversity

Beta diversity determines ladybird beetle species composition between management strategies. Sorensen's coefficient [Sc=(a+b)/(2c+a+b)] quantified ladybird beetle distribution. a and b are the unique species in the first and second sites, respectively, while c is the shared species. Sorensen's coefficient ranges from 0 (highest b diversity, no species shared between locations) to 1.0 (lowest, all species shared).

RESULTS

The abundance of Ladybird beetles associated with cucurbit crops

In total, 222 ladybird beetles were collected during the entire study period. Specimen belonged to twelve species; *Cheilomenes sulphurea* (Olivier), *C. lunata* (Chevrolat), *C. sexmaculata* (Fabricius), *C. propinqua* (Mulsant), *C.duodecimpunctata* (L.), *A. foveicollis* (Lucas), *Epilachna varivestis (*Mulsant*),* *Raphidopalpa foveicollis* (Lucas), *Aspidimorpha miliaris* (Fabricius), *H. axyridis* (Pallas), *Hippodamia variegata* (Goeze), *Leptaulaca fisicolli* (Weise) from nine (9) genera; Cheilomenes, Crioceris, Aulacophora, Epilachna, Raphidopalpa, Aspidimorpha, Harmonia, Hippodamia, Leptaulaca.

Of the total catch, 64.86%of the beetles were collected from the plateau zone, and the remaining 35.14% were collected from the mountainous zone (Table 1). Seventy-one per cent of the total catches were collected from fields under conventional practices, and the remaining 28.9% were from agroecological practices. Among ladybird beetle species collected, *C. lunata* was the most abundant species accounting for 28.8% of the total catch, followed by *C. sulphurea* (20.7%) and *H. variegate* which counted for 15.8% of the total catches. The remaining ladybird beetle species constituted the remaining 34.7%.

Table1. The total number of ladybird beetle species associated with cucurbit species under different management practices across the two agroecological zones of the Morogoro region from May to November 2021.

Zones	Plateau		Mountainous			
Beetle species	Conventional	Agroecology	Conventional	Agroecology	Total	%
C. sulphurea	34	5	4	3	46	20.7
C. lunata	16	3	34	11	64	28.8
C. sexmaculata	0	0	1	1	2	0.9
C. duodecimpunctata	8	1	4	3	16	7.2
C. propinqua	1	0	0	0	1	0.5
A. foveicollis	2	1	0	0	3	1.4
E. varivestis	13	5	4	3	25	11.3
R. foveicollis	2	0	0	0	2	0.9
A. miliaris	0	0	1	0	1	0.5
H. axyridis	4	3	2	0	9	4.1

H. variegate	23	11	1	0	35	15.8
L. fisicollis	0	12	4	2	18	8.1
TOTAL	103	41	55	23	222	100
%/management	46.4	18.5	24.8	10.4	100.0	
Total / zone	144		78		222	
% / zone	64.86		35.14		100	

Effects of Management Practices, season, crop species and Agroecological Zones on the Diversity of ladybird beetle communities

Shannon and Inverse Simpson Diversity of ladybird beetle communities

Results showed that interaction between agroecological zones, season, and management practices had significant effects on the Shannon and inverse Simpson diversity of ladybird beetle communities ($p<0.05$) (Table 2). During the May-June season, the Shannon diversity was significantly higher in the conventional fields than in agroecological fields in the plateau but did not differ significantly in the mountainous zone. However, in the October-November season, no significant difference in Shannon ladybird beetle diversity was observed between managements across the two agroecological zones (**Figure 2**).

Similar patterns were also observed for the inverse Simpson diversity index. Throughout the May to June season, the conventional fields significantly outperformed the agroecological fields in terms of inverse Simpson diversity in both the plateau and mountainous zone. However, during the October-November season, the difference was not significant between the two management practices across the agroecological zones (**Figure 3**).

Table 2. Analysis of variance for the effect of agroecological zones, season, Management practices and crop species on the Shannon and inverse Simpson diversity of ladybird beetle communities from May to November 2021.

Factors	d.f	SHANNON		INVERSE SIMPSON	
		F value	P value	F value	P value
Agroecological zone (A)	1	2.447	0.118ns	9.544	0.0021*
Season (S)	1	7.180	0.008*	1.528	0.216ns
Management practices (M)	1	11.315	0.001*	24.06	<0.0001*
Crop species (C)	2	1.920	0.147ns	0.6148	0.541ns
A x S	1	1.420	0.234ns	0.013	0.9105ns
A x C	1	0.829	0.363ns	0.399	0.5277ns
A x M	2	2.751	0.064*	0.3005	0.7405ns
S x C	1	5.045	0.025*	13.67	0.0002*
S x M	2	0.008	0.992ns	0.535	0.5855ns
C x M	2	0.502	0.605ns	0.426	0.6532ns
A x S x M	1	3.870	0.049*	6.572	0.0105*
A x S x C	2	0.957	0.385ns	0.378	0.6851ns
S x C x M	2	0.436	0.647ns	0.118	0.8891ns
A x C x M	2	0.893	0.410ns	0.112	0.8937ns
A x S x C x M	2	0.349	0.706ns	0.056	0.9453ns

Keys: * indicates significance, ns shows no significance and d.f indicates the degree of freedom

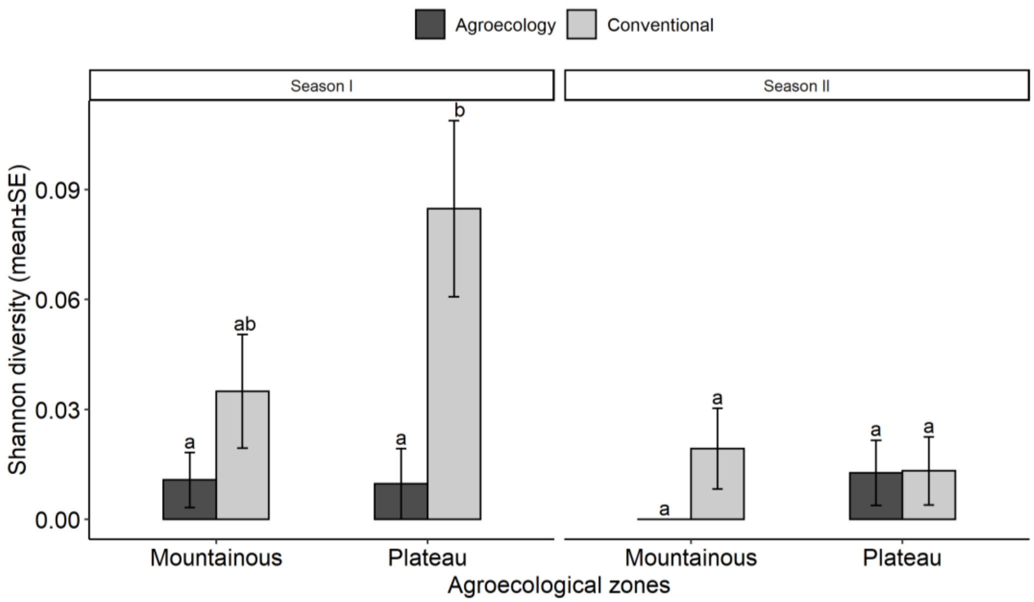

Figure 2. Shannon diversity of ladybird beetle communities in cucurbit crops under different management practices across the two agroecological zones of the Morogoro region from May to November 2021. Bars with different letters denote significant differences at $p < 0.05$. SE stands for Standard Error.

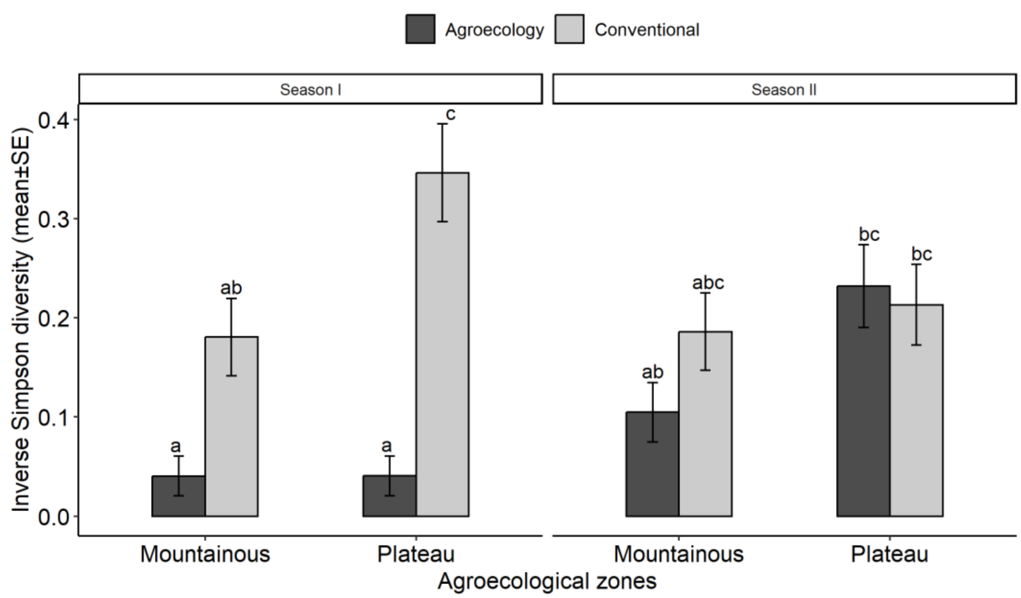

Figure 3. Inverse Simpson diversity of ladybird beetles in cucurbit crops under different management practices across the two agroecological zones of the Morogoro region from May to November 2021. Bars with different letters denote significant differences at $p < 0.05$. SE stands for Standard Error

Species Richness and Evenness of ladybird beetle communities

Results from Table 4 show that the interaction between agroecological zones, season, and management practices significantly affected species richness and evenness of ladybird beetle communities ($p<0.032$). During the May-June season, the ladybird beetle communities in conventional fields were significantly richer in ladybird beetle species than those in agroecological fields in both the plateau and mountainous zones. In the October-November season, the ladybird beetle communities in the conventional fields were also significantly richer in ladybird beetle species than those in agroecological fields in the mountainous zone. However, no significant difference in species richness between managements was observed in the plateau zone (**Figure 4**).

Regarding species evenness, during the May-June season, the ladybird beetle communities were more evenly distributed in the fields under conventional practices than agroecological practices in the plateau zone. However, such distribution did not differ significantly in the mountainous zone. A similar trend was also observed in the October to November season, where the distribution of ladybird beetle communities between management practices did not differ significantly across the two agroecological zones (**Figure 5**).

Table 4. Analysis of variance for the effect of agroecological zones, season, Management practices and crop species on species richness and Evenness of ladybird beetle communities in Morogoro from May to November 2021.

Factors	d.f	SPECIES RICHNESS		EVENNESS	
		F value	P value	F value	P value
Agroecological zone (A)	1	9.464	0.002*	2.010	0.157ns
Season (S)	1	0.608	0.436ns	6.401	0.012*
Management practices (M)	1	24.789	0.000*	11.729	0.001*
Crop species (C)	2	0.851	0.427ns	1.423	0.242ns
A x S	1	0.065	0.798ns	1.021	0.313ns
A x C	1	0.513	0.474ns	0.928	0.336ns
A x M	2	0.492	0.612ns	2.423	0.089*
S x C	1	13.944	0.000*	4.854	0.028*
S x M	2	0.488	0.614ns	0.187	0.829ns
C x M	2	0.409	0.664ns	0.633	0.531
A x S x M	1	7.015	0.008*	4.626	0.032*
A x S x C	2	0.519	0.595ns	0.589	0.555ns
S x C x M	2	0.117	0.889ns	0.595	0.552ns
A x C x M	2	0.113	0.893ns	1.209	0.299ns
A x S x C x M	2	0.095	0.910ns	0.159	0.853ns

Keys: * indicates significance, ns shows not significant and d.f indicates the degree of freedom

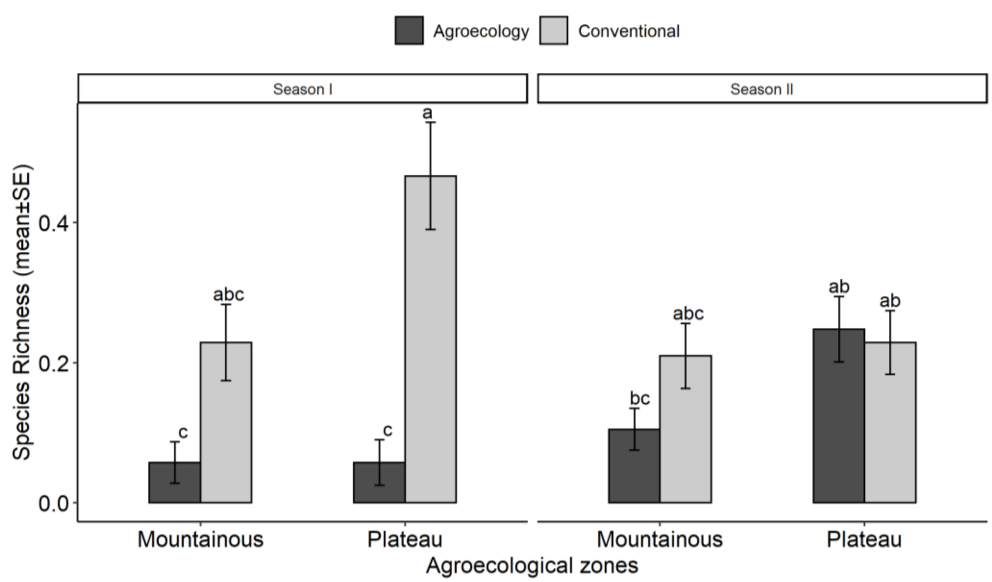

Figure 4. Ladybird beetle species richness in cultivated cucurbit crops under different management practices across the two agroecological zones of the Morogoro region from May to November 2021. Bars with different letters denote significant differences at $p < 0.05$. SE stands for Standard Error.

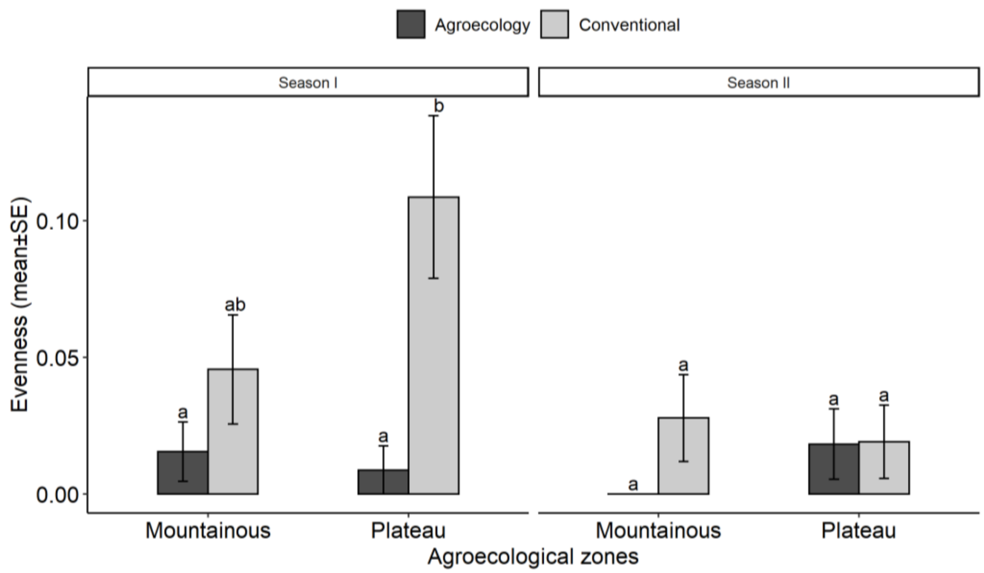

Figure 5. Evenness of ladybird beetle species in cucurbit crops under different management practices across the two agroecological zones of the Morogoro region from May to November 2021. Bars with different letters denote significant differences at $p < 0.05$. SE stands for Standard Error.

The influence of weather parameters on the diversity of ladybird beetle communities

Results showed that the species richness in the mountainous zone had a strong negative correlation with rainfall. However, other indices in the plateau and mountainous zones were not correlated with weather parameters or the number of flowers (**Table 5**).

Composition of ladybird beetle communities in different management practices across agroecological zones

Results showed that high Sorensen values (Sc values ranging from 0.56 to 0.78), indicating major variations in species composition between management practices across the two agroecological zones. In both agroecological zones, fields with agroecological practices were very different in terms of species composition from those with conventional practices (**Table 6**).

Table 5. The influence of weather parameters and the number of flowers on the alpha diversity of ladybird beetle communities across agroecological zones of the Morogoro region

Zone	Parameters	Shannon	Simpson	Richness	Evenness
Mountainous	Number of flowers	-0.02ns	-0.03ns	0.04ns	0.05ns
	Max temperature	-0.08ns	0.05ns	-0.04ns	-0.04ns
	Min-temperature	-0.06ns	-0.02ns	0.02ns	-0.02ns
	Mean-temperature	-0.07ns	0.07ns	-0.08ns	-0.07ns
	Relative Humidity	0.05ns	0.03ns	-0.03ns	<0.03ns
	Rainfall	0.02ns	-0.11*	-0.03ns	0.04ns
Plateau	Number of flowers	-0.04ns	0.07ns	0.05ns	-0.03ns
	Max temperature	-0.07ns	<0.07ns	0.01ns	0.01ns
	Min-temperature	-0.07ns	-0.02ns	0.04ns	-0.02ns
	Mean-temperature	-0.07ns	-0.02ns	0.03ns	<-0.06ns
	Relative Humidity	-0.06ns	0.04ns	0.06ns	-0.02ns
	Rainfall	-0.03ns	0.02ns	0.03ns	-0.02ns

Note, * indicates significance, ns shows no significance

Table 6. Sorensen values of predatory ladybird beetle composition studied at different management practices in the two agroecological zones of the Morogoro region.

Zone/Farming system	Plateau Conventional	Mountainous Conventional
Mountainous Conventional	0.69	
Mountainous Agroecology	0.56	0.75
Plateau Agroecology	0.78	0.81

DISCUSSION

Diversity and Composition of ladybird beetle communities under different management practices

The insect communities in agricultural landscapes can be influenced by management practices (McLaughlin and Mineau, 1995; Boutin et al.,2009; Fanfarillo et al., 2022). However, the extent of such influence can vary depending on the insect's taxonomical or functional group, landscape complexity, and the intensity of certain key elements in farming methods (Garratt et al., 2011; Batáry and Tscharntke, 2022). Coleoptera, a diverse group of natural enemies, has shown contradictory responses to management practices in various studies depending on the functional group or taxa (Puech et al., 2014; Török et al., 2021). In line with these findings, our study revealed a significantly higher abundance and diversity of ladybird beetle communities in conventionally managed fields than in agroecological fields. We recorded a total of 71.1% of ladybird beetles in fields managed conventionally, whereas only 28.9% were found in agroecological fields. Similarly, the Shannon, inverse Simpson, evenness, and richness indices were consistently higher in conventional fields than agroecological ones. However, we arbitrarily implicate this diverse community as we cannot be certain for sure as the number of samples collected during the study period was very small. Additionally, the Sorensen index indicated major variations in species composition between the two management practices, highlighting major differences in the composition of ladybird beetle communities.

The unexpectedly higher abundance and diversity of ladybird beetle communities in conventionally managed fields compared to the agroecological managed fields can be attributed to the use of synthetic pesticides in conventional fields, which could have indirectly benefited ladybird beetles. Studies indicate that frequent use of insecticides in conventionally managed fields has been implicated in reducing ladybird beetle prey abundance and resource competition (Sánchez-Bayo, F. 2021; Török et al., 2021), allowing the ladybird beetles to thrive more in conventional fields than in agroecological fields. Our findings concur with those of Török et al. (2021), who found higher species richness and abundance of cereal leaf beetles in conventionally managed fields than in organic fields. This study suggests that insufficient use of synthetic insecticides in conventional fields and their short-term effect on ladybird beetle abundance indirectly supported the higher number and diversity of ladybird beetle species in conventional fields.

Our study also found a significant influence of agroecological zones and cucurbit cropping seasons on the abundance, diversity, and composition of the ladybird beetle communities. The plateau zone was the most diverse, populated, and species-rich zone than the mountainous zone, with more ladybird beetle species recorded during May- July than in the October- November cropping season. The low diversity of ladybird beetle in highland areas may be attributed to their habit of hibernating in high mountains (Ceryngier, 2015; Arya and Tamta, 2016).

Our findings contradict the study by Johnson et al. (2017) which found that agroecological practices such as crop rotation and reduced pesticide use significantly increased the abundance and species richness of ladybird beetles in crop fields. The study attributed this effect to enhanced prey availability and diverse habitats. Similarly, a study by Smith et al. (2019) also discovered that agroecological farms had higher diversity and abundance of ladybird beetles than conventional farms. The study implicated the presence of flower-rich habitats and agroecological practices as important factors supporting the ladybird beetle population. In contrast, our study collaborates with a study by Davis et al. (2020) who also reported a decline in ladybird beetle abundance and diversity in agroecological farms. The study speculated that factors such as regional variations, complex interactions among species, and unpredictable environmental conditions could contribute to inconsistent outcomes.

The influence of weather conditions and the floral resources on the diversity of ladybird beetle communities

The difference in agroecological zones may have an impact on a range of environmental variables, such as temperature, precipitation, and relative humidity (Faizul et al., 2011). These parameters, in combination with floral resources, can impact the survival, reproduction, and distribution of Coleoptera species within the agricultural landscape (Jiang et al., 2019; Afaq and Kumar, 2021; Porhajašová and Babošová, 2022). During our investigation, we found that weather variables had limited influence on the diversity of ladybird beetle communities. Specifically, we observed a strong negative correlation between rainfall and beetle richness in the mountainous zone. However, we did not observe any correlations between other remaining alpha diversity indices or the number of flowers with the weather parameters in all agroecological zones. The study by Subba and Gosh (2016) reported that the activity of the ladybird population decreases with the rise of temperature, relative humidity and rainfall.

CONCLUSION

We cannot certainly confirm the influence of management practices on the diversity of ladybird beetles across the agroecology of Morogoro as the sample collected was small. However, our results insufficiently showed higher species diversity in the plateau zone than in mountainous zones. Furthermore, conventional fields were more diverse in specie than agroecology in both altitudes. Therefore, this study provides the first baseline ecological information on the diversity of ladybird beetles in different management practices at the plateau and mountainous zone of the Morogoro region in Tanzania. The findings of this study represent an asset for understanding ladybird beetles' communities associated with cucurbit crops and strengthening understanding of the best way to manage agroecosystems and ultimately conserve the flora and fauna of the natural enemies. We also recommend further research on the diversity of these insects as our study was limited by sample size.

DISCLOSURE STATEMENT

The author declares no competing interests

REFERENCES

Afaq, U., & Kumar, G. (2021). Is developmental rate polymorphism constant? Influence of temperature on the occurrence and constancy of slow and fast development in Zygogramma bicolorata Pallister (Coleoptera: Chrysomelidae). Journal of Thermal Biology, 100:103-043.

Albert, L., Franck, P., Gilles, Y., & Plantegenest, M. (2017). Impact of agroecological infrastructures on the dynamics of Dysaphis plantaginea (Hemiptera: Aphididae) and its natural enemies in apple orchards in Northwestern France. *Environmental Entomology, 46*(3), 528-537.

Almeida, L. M., Corrêa, G. H., Giorgi, J. A., & Grossi, P. C. (2011). New record of predatory ladybird beetle (Coleoptera, Coccinellidae) feeding on extrafloral nectaries. *Revista Brasileira de Entomologia, 5*(5), 447-450.

Anbalagan, V., Paulraj, M. G., Ignacimuthu, S., Baskar, K., & Gunasekaran, J. (2016). Natural enemy (Arthropoda-Insecta) biodiversity in vegetable crops in Northeastern Tamil Nadu, India. *International Letters of Natural Sciences*, *53*,1-7.

Aya, M. K., Tamta, P., & Dayakrishna (2016). Study on distribution and diversity of beetles (Insecta: Coleoptera) in different elevational zones of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India. *Journal of Entomological and Zoological Studies, 4*, 311-316.

Batáry, P., & Tscharntke, T. (2022). Scale-dependent effectiveness of on-field vs. off-field agri-environmental measures for wild bees. *Basic and Applied Ecology, 6*(2), 55-60.

Boutin, C., Martin, P. A., & Baril, A. (2009). Arthropod diversity as affected by agricultural management (organic and conventional farming), plant species, and landscape context. *Ecoscience, 16*(4), 492-501.

Brühl, C. A., & Zaller, J. G. (2019). Biodiversity decline as a consequence of an inappropriate environmental risk assessment of pesticides. *Frontiers in Environmental Science*, *7*, 177. https://doi.org/10.3389/fenvs.2019.00177

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature, 486* (7401), 59-67.

Ceryngier, P. (2015). Ecology of dormancy in ladybird beetles (Coleoptera:

Coccinellidae). *Acta Societatis Zoologicae Bohemicae, 79*(1/2), 29-44.

Ceryngier, P., Roy, H. E., & Poland, R. L. (2012). Natural enemies of ladybird beetles. Ecology and behaviour of the ladybird beetles (Coccinellidae), 375-443. https://doi.org/10.1002/9781118223208.ch8

Chabert, A., & Sarthou, J. P. (2020). Conservation agriculture as a promising trade-off between conventional and organic agriculture in bundling ecosystem services. *Agriculture, Ecosystems and Environment, 292*, 106815. https://doi.org/10.1016/j.agee.2019.106815

Che, L., Zhang, P., Deng, S., Escalona, H. E., Wang, X., Li, Y., & Liang, D. (2021). New insights into the phylogeny and evolution of lady beetles (Coleoptera: Coccinellidae) by extensive sampling of genes and species. *Molecular Phylogenetics and Evolution*, 15(6),107-045.

Costamagna, A. C., & Landis, D. A. (2006). Predators exert top-down control of soybean aphids across a gradient of agricultural management systems. *Ecological Applications, 16*(4),1619-1628.

Crowder, D. W., & Jabbour, R. (2014). Relationships between biodiversity and biological control in agroecosystems: current status and future challenges. *Biological Control, 7*(5), 8-17

Davis, B., Hilton, H. W., Bennett, A. B., & Groves, R. L. (2020). Lady beetle abundance differs between organic and conventional farms, but does not consistently align with biocontrol services. *Journal of Pest Science*, *93*(1), 49-62.

Duru, M., Therond, O., Martin, G., Martin-Clouaire, R., Magne, M. A., Justes, E and Sarthou, J. P. (2015). How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agronomy for sustainable development* 3(5):1259-1281.

Emmerson, M., Morales, M. B., Oñate, J. J., Batary, P., Berendse, F., Liira, J., & Bengtsson, J. (2016). How agricultural intensification affects biodiversity and ecosystem services. *Advances in Ecological Research, 5*(5), 43-97.

Faizul, H., Sardar, A. M., Kausar, S., & Shamsur, R. (2011). Diversity and distribution of ladybird beetles in District Dir Lower, Pakistan. *International Journal of Biodiversity and Conservation 3*(12), 670-675.

Fanfarillo, E., Calabrese, D., Angiolini, C., Bacaro, G., Biagiotti, S., Castagnini, P., ... & Maccherini, S. (2022). Effects of conventional and organic management on plant and insect communities in a traditional elephant garlic crop. *Community Ecology, 23*(3), 417-427.

Garbach, K., Milder, J. C., Montenegro, M., Karp, D. S., & DeClerck, F. A. J. (2014). Biodiversity and ecosystem services in agroecosystems. *Encyclopedia of Agriculture and Food Systems, 2*, 21-40.

Garratt, M. P. D., Wright, D. J., & Leather, S. R. (2011). The effects of farming system and fertilisers on pests and natural enemies: a synthesis of current research. *Agriculture, Ecosystems and Environment, 141*(3-4), 261-270.

Gaspar, H., Loureiro, J., Castro, H., Siopa, C., Castro, M., Casais, V., & Castro, S. (2022). Impact of local practices and landscape on the diversity and abundance of pollinators in an insect-dependent crop. *Agriculture, Ecosystems and Environment, 326*,107804. https://doi.org/10.1016/j.agee.2021.107804

Helfenstein, J., Diogo, V., Bürgi, M., Verburg, P., Swart, R., Mohr, F., & Herzog, F. (2020). Conceptualizing pathways to sustainable agricultural intensification. *Advances in Ecological Research*, *63*, 161-192. https://doi.org/10.1016/bs.aecr.2020.08.005

Helfenstein, J., Diogo, V., Bürgi, M., Verburg, P., Swart., Hemsley, J. A., & Holland, J. M. (2021). Does the non-native Harlequin ladybird disrupt the feeding behaviour of the native two-spot ladybird? *Bulletin of Entomological Research, 111*(6),741-745.

Honěk, A., Brabec, M., Martinková, Z., Dixon, A. F., Pekar, S., & Skuhrovec, J. (2019). Factors determining local and seasonal variation in abundance of Harmonia axyridis (Coleoptera: Coccinellidae) in Central Europe. *European Journal of Entomology, 1*(16), 93-103.

Honek, A., Martinkova, Z., Dixon, A. F., Roy, H. E., & Pekár, S. (2016). Long-term changes in communities of native coccinellids: population fluctuations and the effect of competition from an invasive non-native species. *Insect Conservation and Diversity, 9*(3), 202-209

Hooper, D. U., Adair, E. C., Cardinale, B. J., Byrnes, J. E., Hungate, B. A., Matulich, K. L., & O'Connor, M. I. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature, 486*(7401), 105-108.

Jiang, J., Zhang, Z., Yu, X., Yu, C., Liu, F., & Mu, W. (2019). "Sublethal and transgenerational effects of thiamethoxam on the demographic fitness and predation performance of the seven-spot ladybeetle *Coccinella septempunctata* L. (Coleoptera: Coccinellidae)." *Chemosphere, 216*, 168-178.

Johari, A., Oktafiani, D. W., & Dewi, R. S. (2020). The presence of ladybug beetle (Coleoptera:

Coccinellidae) as a predator on agriculture in Jambi region. *Journal of Entomological Research, 44*(1), 45-50.

Johnson, R., Zaid, & Dangle, J. L. (2017). Agroecology: A pathway to sustainable food systems. *Advances in Agronomy,* 144, 1-92.

Kehoe, R., Frago, E., & Sanders, D. (2021). Cascading extinctions as a hidden driver of insect decline. *Ecological Entomology, 46*(4),743-756.

Kleijn, D., Rundlöf, M., Scheper, J., Smith, H. G., & Tscharntke, T. (2011). Does conservation on farmland contribute to halting the biodiversity decline? *Trends in Ecology and Evolution*, *26*(9), 474-481.

Kremen, C., & Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecology and Society.* *17*(4), 40. http://dx.doi.org/10.5751/ES-05035-170440

Landis, D. A., Wratten, S. D., & Gurr, G. M. (2000). Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology, 45*(1),175-201.

Liere, H., Egerer, M. H., & Philpott, S. M. (2019). Environmental and spatial filtering of ladybird beetle community composition and functional traits in urban landscapes. *Journal of Urban Ecology, 5*(1), juz014. https://doi.org/10.1093/jue/juz014

Liu, Y., Zhu, L., & Zhou, X. (2018). Agroecological practices enhanced natural enemies and reduced pests in apple orchards in China. *Journal of Applied Ecology*, 55(5), 2352-2362.

Mabin, M. D., Welty, C., & Gardiner, M. M. (2020). Predator richness predicts pest suppression within organic and conventional summer squash (*Cucurbita pepo* L. Cucurbita: Cucurbitaceae). *Agriculture, Ecosystems and Environment, 287*, 106689. https://doi.org/10.1016/j.agee.2019.106689

McLaughlin, A., & Mineau, P. (1995). The impact of agricultural practices on biodiversity. *Agriculture, Ecosystems and Environment, 55*(3), 201-212.

Mokam, D. G., Djiéto-Lordon, C., & Bilong, C. F. (2014). Patterns of species richness and diversity of insects associated with cucurbit fruits in the southern part of Cameroon. *Journal of Insect Science, 14*(1), 248. https://doi.org/10.1093/jisesa/ieu110

Norris, K. (2008). Agriculture and biodiversity conservation: opportunity knocks. *Conservation letters, 1*(1): 2-11. doi: 10.1111/j.1755-263X.2008.00007.x

Patil, P. B., & Gaikwad, S. M. (2019). Diversity and association of ladybird beetles with the agricultural crops. *Journal of Emerging Technologies and Innovative Research, 6*(5), 457-459.

Pervez, A., Yadav, M., & Khan, M. (2020). Diversity of predaceous coccinellid beetles (Coleoptera: Coccinellidae) in Uttarakhand, North India. *Journal of Mountain Research, 1*(5), 7-20.

Porhajašová, J. I., & Babošová, M. (2022). Impact of arable farming management on the biodiversity of Carabidae (Coleoptera). *Saudi Journal of Biological Sciences, 29*(9), 103371. Doi: 10.1016/j.sjbs.2022.103371

Puech, C., Baudry, J., Joannon, A., Poggi, S., & Aviron, S. (2014). Organic vs. conventional farming dichotomy: does it make sense for natural enemies? *Agriculture, Ecosystems and Environment, 194*, 48-57.

Puech, C., Baudry, J., Joannon, A., Poggi, S., & Aviron, S. (2014). Organic vs. conventional farming dichotomy: does it make sense for natural enemies. *Agriculture, Ecosystems and Environment, 194*, 48-57. https://doi.org/10.1016/j.agee.2014.05.002

Reddy, B. T., & Giraddi, R. S. (2019). Diversity studies on insect communities in organic, conservation and conventional farming systems under rain-fed conditions. *Journal of Entomology and Zoology Studies, 7*(3), 883-886.

Rusch, A., Valantin-Morison, M., Sarthou, J. P., & Roger-Estrade, J. (2010). Biological control of insect pests in agroecosystems: effects of crop management, farming systems, and semi natural habitats at the landscape scale: a review. *Advances in Agronomy, 10*(9), 219-259.

Sánchez-Bayo, F. (2021). Indirect effect of pesticides on insects and other arthropods. *Toxics, 9*(8), 177.

Sánchez-Bayo, F., & Wyckhuys, K. A. (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation, 2*(32), 8-27.

Schabel, H. G. (2006). Forest entomology in East Africa: forest insects of Tanzania. Springer Science and Business Media.

Smith, H. G., Öckinger, E., & Rundlöf, M. (2019). Organic farming increases both the number and abundance of generalist predator species in agricultural landscapes. *Journal of Applied Ecology,* 56(1), 235-244.

Subba, B., & Ghosh, S. K. (2016). Population dynamics of lady bird beetle and spiders in relation to weather factors in tomato (*Lycopersicon* *esculentum* L.). *Life Sciences International Research Journal*, *3*(1), 35-37.

Török, E., Zieger, S., Rosenthal, J., Földesi, R., Gallé, R., Tscharntke, T., & Batáry, P. (2021). Organic farming supports lower pest infestation, but fewer natural enemies than flower strips. *Journal of Applied Ecology, 58*(10), 2277-2286.

Tschumi, M., Albrecht, M., Entling, M. H., & Jacot, K. (2015). High effectiveness of tailored flower strips in reducing pests and crop plant damage. *Proceedings of the Royal Society B: Biological Sciences, 282*, 20151369. https://doi.org/10.1098/rspb.2015.1369

Viglásová, S., Nedvd, O., Zach, P., Kulfan, J., Parák, M., Honk, A., & Roy, H. E. (2017). Species assemblages of ladybirds including the harlequin ladybird Harmonia axyridis: a comparison at large spatial scale in urban habitats. *Bio Control, 62*, 409-421. https://doi.org/10.1007/s10526-017-9793-0

Wagner, D. L. (2020). Insect declines in the Anthropocene. *Annual Review of Entomology, 6*(5), 457-480.

Yasmeen, S., & Dugaje, P. (2020). Holistic Survey on predatory Ladybird beetle diversity at selected regions of Nashik District (Maharashtra), India. *International Journal of Biological Innovations, 2*(1), 52-62.