Population Densities and Species Richness of Hymenoptera, Araneae, and Coleoptera Communities Associated with Cucurbit in Different Altitudes of Morogoro, Tanzania

***Lyimo, L.D.[a], J.A. Bakengesa[a,b], P.M. Bwire[a] and S.A. Kabota[a,c]**

[a]Department of Crop Science and Horticulture, Sokoine University of Agriculture (SUA), P.O. Box 3005 Chuo Kikuu, Morogoro, Tanzania,
[b]Department of Biology, University of Dodoma (UDOM), P.O. Box 338, Dodoma, Tanzania,
[c]Academic, Research and Consultancy Section, National Sugar Institute (NSI), P.O. Box [illegible], Kid[illegible] Morogoro, Tanzania

*Corresponding author e-mail: *liberatus.lyimo@sua.ac.tz*

Abstract

The influence of altitudes on the community structure of insects was investigated in 10 localities from two agroecological zones in Morogoro, Tanzania. The nonparametric estimator, coupled with the species accumulation curve based on Chao estimator, was used to estimate species richness. Three orders with 33 families were collected from 360 pitfall traps with 2133 individuals recorded. The average abundance of anthropods was significantly higher in the Plateau zone (47.78±3.02) compared to the mountainous (14.84±[illegible]). Kruskal-Wallis test (χ2 _18.11 df 9 p = 0.03) revealed a significant difference among the sites studied with a higher abundance and species richness recorded at Sugeco (545) followed by [illegible] (310), the other sites ranged between 67 to 278 individuals. The common anthropods found in both zones are Formicidae, Lycosidae, Scarabidae, Agelenidae, Chrysomelidae, and Carabidae. All localities reached an asymptote with more than 95% sampling efforts. The insect groups studied were species-rich, except at Ruvuma and crop museum. The relative abundance [illegible]sed with increasing elevation, which could be attributed to weather conditions.

Keywords: Population density, Abund[illegible]ion, insect, agroecological, cucurbit

Introduction

Insects are keystone species th[illegible] invaluable ecosystem services (Pywell *et al.,* 2015; Potts *et al.,* 2016). The[illegible] pollination services and pest suppression (Uhler *et al.,* 2021), acting as bio-indicators, exploiters, and dispersers of organic matter in the environment, forming a crucial link in the food supply chain (Duelli *et al.,* 1999). An ideally functioning agroecosystem requires providing the services mentioned above, which are of economic value (Uhler *et al.,* 2021). Species richness, or the total number of species in a community, positively correlates with the likelihood that they have complimentary spatio-temporal features and functions (Loreau *et al.,* 2001). The insurance hypothesis proposed by Yachi and Loreau (1999) argued that the coexistence of biodiversity protects ecosystems from declining functioning because many species guarantee that some will continue serving even if others flop.

Regardless of the importance of insects in an ecosystem, insect pests increasingly pose severe limitations to vegetable and fruit production in tropical and subtropical regions (Reddy, 2013; Campos and Ortiz, 2020). Approximately 50% of crop loss in Africa is associated with the high infestation rates of insect pests from the stage of sowing to storage (Scholtz and Mansell, 2017). Climate variability increases the infestation rate (Oerke, 2006; Phophi *et al.,* 2020), favouring breeding and conquest of novel insect species. Moreover, a recent prediction of temperature in Africa (Biber-Freudenberger *et al.,* 2016) reveals that pests will continue to be accountable for crop losses (Botha *et al.,* 2020). Weather patterns directly change insect pests' distribution, development, and population dynamics and facilitate the spread of indigenous and invasive species (Reddy, 2013; Pulatov *et al.,* 2014; Mafongoya *et al.,* 2019; Botha *et al.,* 2020). Phophi *et al.* (2020) reported that temperature is the primary driving factor that provides optimal conditions for pests to thrive, causing severe crop destruction. This situation anticipates increasing the burden in developing countries as a large share of their budget will be allocated to food importation rather th[illegible] developmental issues. Fruit flies and fal[illegible] armyworms are good examples of invas[illegible] pests in Africa, devastating fruit and cereal industries and leaving farmers with huge los[illegible] For instance, cucurbit production in Tanzania has recently been severely infested by f[illegible] flies, reducing its quality and hence income [illegible] rural and urban farmers who rely on exporting cucurbits to nearby countries like Kenya [illegible] Southern Sudan.

Various studies reported crop losses associated with insect pests infestation (Sasson[illegible] 2012), e.g., insect feeding preferences (Mok[illegible] *et al.,* 2014), climate change and insect development (Mafongoya *et al.,* 2019; Phophi *et al.,* 2020), and approaches to manage th[illegible] (Banwo and Adamu, 2003; Botha *et al.,* 20[illegible] Grové, 2022). Handful reports focused [illegible] the relative abundance, and species diver[illegible] of insect communities exist, particula[illegible] in Tanzania, e.g., Mokam *et al.* (2014) [illegible] Cameron, Arnold *et al.* (2021) and (Moham[illegible] 2013) in Tanzania, and Alao *et al.* (2017) in Nigeria. Moreover, the effect of altitude on [illegible] distribution of insect pests is not well address[illegible] particularly in Tanzania.

The African economy is highly dependent on agricultural production, of which more than 60% of its people depend directly on agriculture. The sector contributes approximately 17% of the GDP (Worldbank, 2021). Given the central role of agriculture in developing countries and the effects of climate changes in this era (Battisti and Naylor, 2009), there is a need to understand insect pest abundance, distribution, and species richness in different agroecological zones. This will help formulate and propose the first line of defense to minimize crop losses caused by insect pests and identify ecological tools to balance insect pest population in particular landscape.

Moreover, monitoring insect abundance and richness in changing agricultural landscapes is increasingly essential to ensure environmental, ecological, and biological resilience (Duelli *et al.,* 1999). According to Alao *et al.* (2017), understanding the relative abundance of insect pests is a critical factor for successfully implementing insect pest management. We hypothesized that the agricultural landscape [illegible]es the abundance and pattern of species [illegible] of insects associated with cucurbit [illegible] the Eastern part of Tanzania.

[illegible]ls and methods

[illegible]ion of the study sites

The study was conducted from March-[illegible]er 2021 in ten localities from two agricultural landscapes (Plateau and Mo[illegible]inous) (Table 1). The sites include Crop Muse[illegible], Horticulture Unit, Sugeco, Mafiga, [illegible]bu located in the plateau zone. While [illegible]e, Mkumbulu, Morning Site, Mgola, and [illegible]uyuma are in mountainous zones (Fig. 1[illegible] agricultural landscapes differed in their [illegible]hic and climatic characteristics (Table [illegible] The plateau zone has an altitude range [illegible] 300-600m above sea level with annual rainfall between 700-1200mm per annum and an [illegible] temperature of 29ºC per annum. While the mountainous zone has an altitude above [illegible]0m[illegible] sea level with annual rainfall between [illegible]0mm per annum and a yearly range temperature of ~23ºC. All sites are found in [illegible]ogoro region located between latitudes [illegible]0°0' and longitude E35°25'-38°30', and receive bimodal rainfall, with prolonged rainy occurring between March-May, while short rainfall fall between October – December (Mziray *et al.,* 2010).

Planting material and experimental design

Three crop species belonging to the family Cucurbitaceae, i.e., cucumber, watermelon, and squash, were studied. These crops are commonly grown in the Morogoro region due to conducive weather and high market demand. Triplicate species were grown per location with

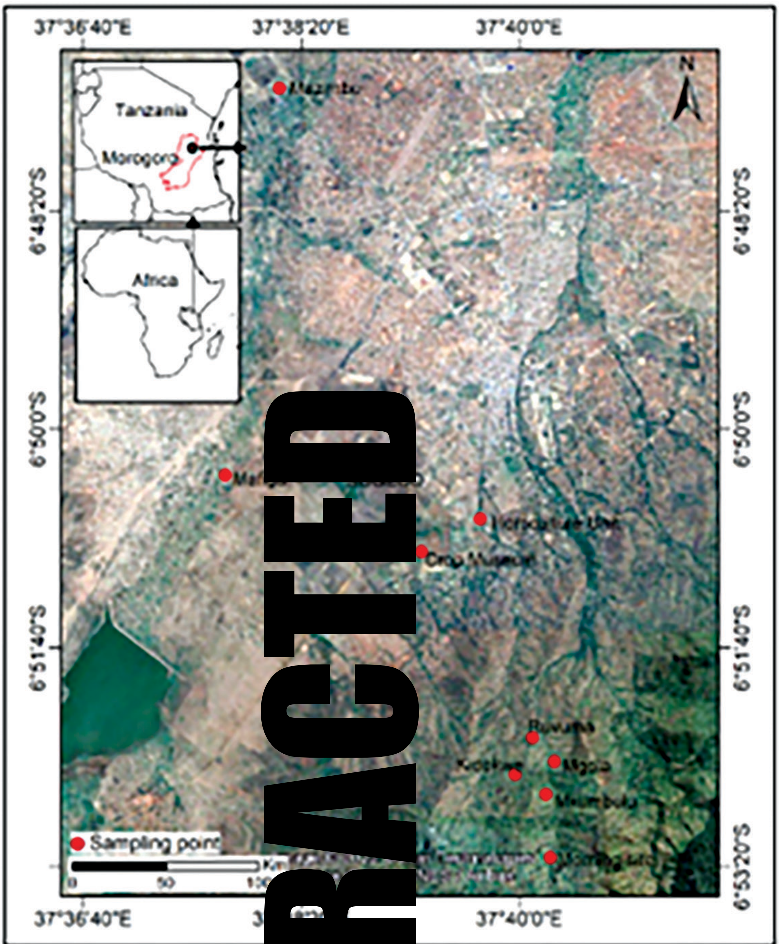


Figure 1: Map showing ten study sites in the plateau and the mountainous zones marked with a red dot followed by [illegible] the site in the Morogoro region, Tanzania

Table 1: Shows the zones Weather conditions, location, site Abbreviation, and coordinates

Zone	Locality	abbre[illegible]	[illegible]e	Longitude	Mean rainfall (mm)	Mean temperature (˚C)	Altitude (m)
Mountainous	Kidokwe	KD	[illegible]8”	E37°39’58”	1200	22-25	1007
	Morning site	MS	S6°53’16”	E37°40’14”	1200	22-25	1258
	Mgola	MG	S6°52’32”	E37°40’16”	1200	22-25	1015
	Mkumbulu	MK	S6°52’47”	E37°40’12”	1200	22-25	1057
	Ruvuma	RV	S6°52’21”	E37°40’06”	1200	22-25	952
Plateau	Crop museum	CM	S6°50’56”	E37°39’15”	750	27-32	524
	Horticulture unit	HU	S6°50’41”	E37°39’42”	750	27-32	517
	Mafiga	MF	S6°50’21”	E37°37’45”	750	27-32	497
	Mazimbu	MZ	S6°47’24”	E37°38’10”	750	27-32	485
	Sugeco	SG	S6°50’20”	E37°38’37”	750	27-32	505

three replications. Four pitfalls of 500ml size and 9cm diameter were randomly dug in each crop species, making a total of 36 per location. Sampling was done weekly for six consecutive weeks. Sampling started right after the flower emergence concerning crop phenology for two seasons. The number of identified families of insects captured per trap in a particular cucurbit crop was counted, sorted, identified, recorded, and kept in vials with 100% alcohol for preservation.

Specimen identification

The specimen identification was car[illegible] out at the Sokoine University of Agricult[illegible] entomology laboratory. Morpholog[illegible] identification was based on various docume[illegible] including the identification of insect pathogens by Poinar (2012); Delvare and Aberlenc (19[illegible]) insect families, and the identification of A[illegible] topical wasp, keys developed by Virgilio *et al.* (2014)

Data analysis

Due to the non-normality of the data[illegible] nonparametric test (Kruskal–Wallis) perform[illegible] in Origin pro version 9.1 was used to test the differences in species richness and abunda[illegible] between taxonomical groups and sites. Vari[illegible] statistical tools were used to assess spe[illegible] diversity, richness, and evenness. Sample-si[illegible] based rarefaction and extrapolation sampl[illegible] curve using Chao estimator (Chao *et al.,* 201[illegible]) was used to estimate species richness. Accord[illegible] to Mokam *et al.* (2014), species abundance [illegible] extrapolation curves are recommended when comparing species diversity from differ[illegible] landscapes and assessing the sampling effo[illegible] Three abundance-based estimators (ABE), i.e., Chao 1, abundance-based coverage estimator ACE, and Jackknife 1. And three incidence-based estimators (IBE), i.e., incidence-based coverage estimators (ICE, Chao 2, and Jackknife 2), were used to estimate the potential number of species per site. All these measures were computed using online PadeR software (Chao *et al.,* 2016b) and iNEXT online software available at https://chao.shinyapps.io/iNEXTOnline. The Shannon-Weiner (H') and Simpson reciprocal (D) diversity indices for equations one and two, respectively, were calculated for each site (pooled across 36 traps). The Pielou species evenness index (eq. 3) was used to assess the diversity of insects between and within locations, while the Margalef index (eq. 4) was used to pinpoint the most species-rich site.

$$Shannon = (H = -\Sigma_{i=1}^{S} \frac{nl}{N} x nl \frac{nl}{N} \quad (1)$$

$$Simpson = (D = \sum_{i=1}^{s} \frac{ni(ni-1)}{N(N-1)} \quad (2)$$

$$Pielo[illegible] = (J = \frac{H'}{lnS}) \quad (3)$$

$$Mar[illegible]lef = DMg \frac{S-1}{lnN}) \quad (4)$$

[illegible] *ni* = the number of individuals of each [illegible] in the collected sample; *N* is the total [illegible] of individuals in the sample, *S* is the number of species in the assemblage, and ln [illegible] [illegible]atural logarithm. All the used indices [illegible]dard in ecological studies and were [illegible]ted using excel software.

[illegible]

[illegible]e orders with 33 families were collected [illegible] pitfall traps in ten localities with 2133 [illegible]ividuals (S1). The average abundance of [illegible]ds was great in the Plateau (47.78±3.02) compared to the mountainous (14.84±6.0). [illegible]Wallis test (χ^2_18.11 df 9 p=0.03) revealed a significant difference among the sites [illegible] with a higher abundance and species [illegible] recorded at Sugeco (545) followed by Ma[illegible]ga (310), while the other sites ranged [illegible] 67 to 278 individuals (Fig. 2 and S1). [illegible]mon anthropods families found in both zones are *Formicidae, Lycosidae, Scarabidae, Agelenidae, Chrysomelidae,* and *Carabidae.* Formicidae were significantly higher (p=0.001) at Kidokwe (54%), followed by Ruvuma (36%) in the mountainous zone. Similarly, the same family was higher at Sugeco (47%), followed by Mafiga (42%) in the plateau zone (Fig. 3). The remaining sites had abundances from 0–41% (Fig. 3). A significantly higher abundance of *Araneae* was found in the mountainous (p<0.001) than in the Plateau. No significant difference (P=0.06) was revealed in the

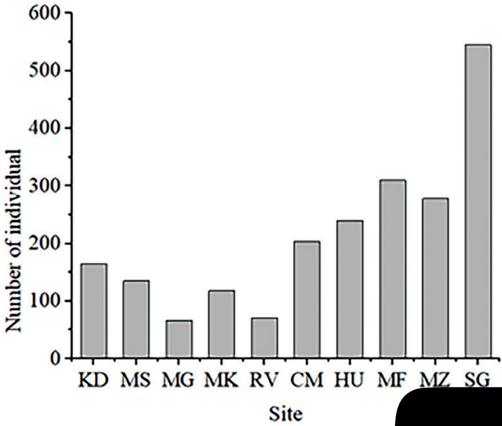


Figure 2: Number of insect individuals collected per site (Abbreviations refer to Table 1)

species-rich family with four species (Fig. 5).

Family Coleoptera: Five families of Coleoptera identified in the study sites were recorded in both mountainous and Plateau areas, while seven were exclusively found in the Plateau (Fig. 6). Scarabids were the most predominant (H'= 6.1; p=0.05) and species-rich family, with six species on the Plateau compared to three species in a mountainous area.

Family Hymenoptera: Two families of Hymenoptera were recorded in both landscapes; Formicids were found in both mountainous and Plateau zones, while Mutilids were exclusively found in the plateau sites (Fig. 7). Formicids were numerically predominant (H'= 4.0; p<0.01) and the most species-rich family, with four species,

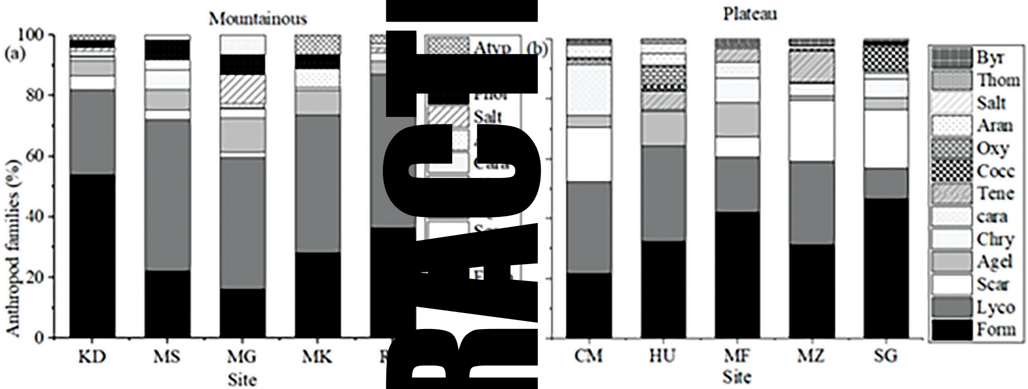


Figure 3: Percentage of anthropods [illegible] **different sites (a) Mountainous and (b) Plateau zone:** *Atyp = Atypidae, Thom = Thomisidae, Phol = Pholcidae, Salt = Salticidae, Aran = Araneidae, Cara = Cara*[illegible] *Cherysomelidae, Agel = Agelnidae, Scara = Scarabidae, Lyco = Lycosidae, Form = Formicidae, Byr = Byrrhidae, Oxy = Oxyopidae, Cocc= Coccinellidae, Tene = Tenebrionidae*

specie richness of Araneae between [illegible] Moreover, no significant difference i[illegible] species richness and abundance we[illegible] in Hymenoptera between the zones [illegible] the relative abundance of Coleoptera was significantly higher (P=0.05) in the mountainous zone compared to the Plateau and its species richness was higher (p<0.005) in plateau zone compared to mountainous (Fig. 4).

Araneae family: In total, 15 families of *Araneae* identified in the study sites were recorded in both zones; two families (Pholcids and Cosmetids) were exclusively found in the mountainous and Philodromids were solely found in the Plateau (Fig. 5). In all zones, Lycosids were numerically predominant (H'=3.5; p=0.001) and the most

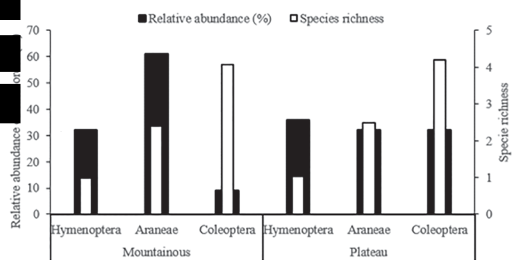


Figure 4: Relative abundance and species richness of insect orders collected in cultivated cucurbit species in the Plateau and mountainous zone of Morogoro, Tanzania, from March to November 2021

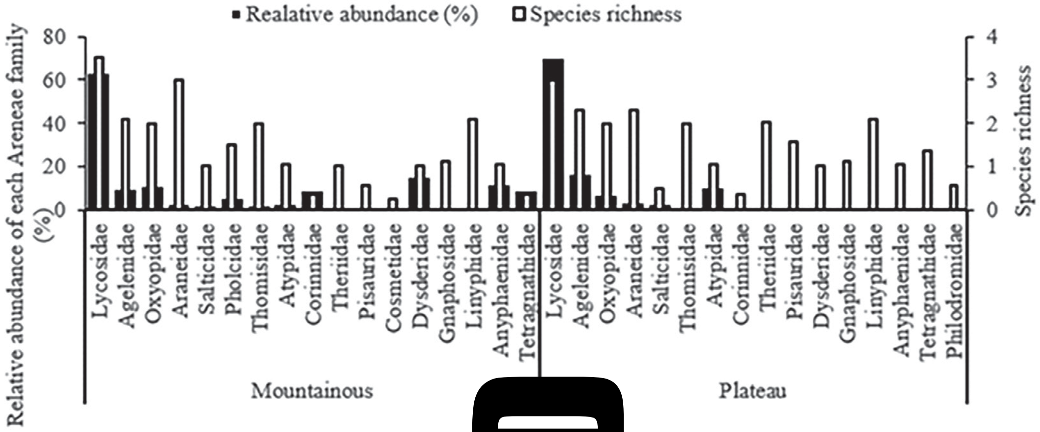


Figure 5: Relative abundance and species [illegible] raneae families collected in cultivated cucurbit species in the [illegible] lat[illegible]u a[illegible] mountainous zone of Morogoro, Tanzania, from March to Novem[illegible]

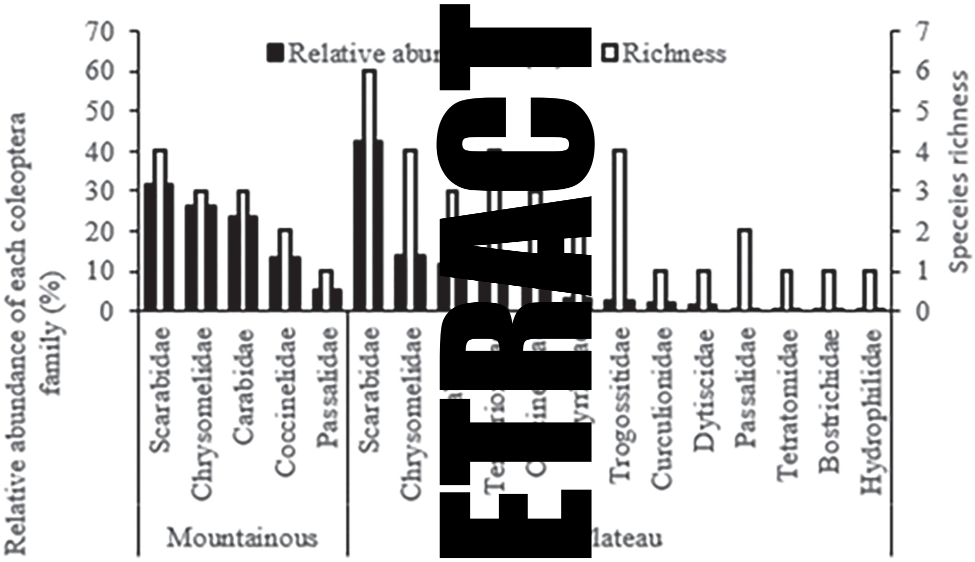


Figure 6: Relative abundance and species [illegible] leopteran families collected in cultivated cucurbit species in the [illegible] mountainous zone of Morogoro, Tanzania, from March to Novem[illegible]2021

e.g. Pheidole megacephala Fabricius), which is said to be a vital prey of fruit fly larvae (Mokam *et al.,* 2014).

Rarefaction curves for each site in both zones exhibited diverse species accumulation rates, with Sugeco having the highest species accumulation. At the same time, Ruvuma revealed the lowest rate (Fig. 8a and b). In the Plateau, the individual-based rarefaction curves, asymptotes were reached at 508, 310, 278, 240, and 204 for SG, MF, MZ, HU, and CM individuals, respectively Fig. 8a). In mountainous, Kidokwe reached the asymptote at 165, MS (135), MK (118), RV (71), and MG (61) (Fig. 8b).

The mean of the three abundance-based species richness estimators computed using online PadeR software (i.e., ACE, Chao1, and Jack 1) for Plateau zones were 30.3, 28, 26, 26, and 15 for MZ, HU, SG, CM, and MF respectively, (Table 2a). The estimated sampling efforts were 97.5%, 97.5%, 99.1%, and 99.7%,

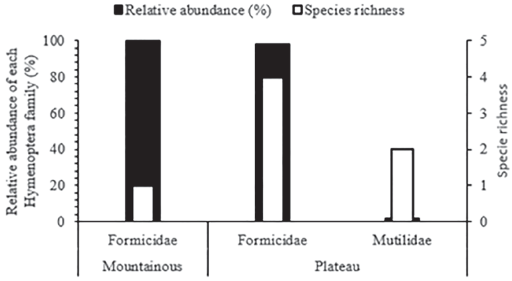
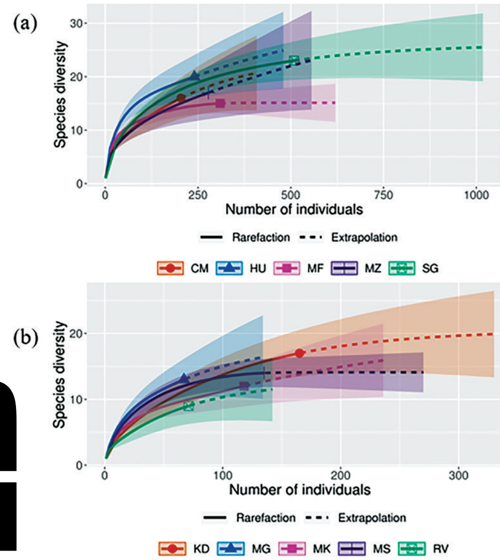


Figure 7: Relative abundance and species richness of Hymenopteran families collected in cultivated cucurbit species in the Pl[illegible] mountainous zone of [illegible] Tanzania, from March to [illegible] 2021

respectively. For the mountainous [illegible] species richness estimators were 2[illegible] 18, 18, 14, and 12.3 for KD, MG, MK, MS[illegible] with their estimated sampling efforts [illegible] 96.4%, 92.6%, 95.8%, 99.3%, and 94.4% res[illegible]ve[illegible] (Table 2b). This result reveals that th[illegible]ampling effort was adequate, and few species [illegible] unrecorded.

The species richness value was [illegible] the Plateau compared to the mountai[illegible] with SG having the highest value of 22, followed by HU (20), and MF in the mountai[illegible] having the lowest species richness o[illegible] 2a & b). The Shannon and Simpso[illegible] indexes ranked all sites as the most diverse e[illegible] in the Plateau and RV in the mountai[illegible]



[illegible]igure 8: Species accumulation curve based on the number of insect individuals (a) Plateau zone and (b) Mountainous zone collected in ten sites of Morogoro, Tanzania

[illegible]he Margalef index values showed significant [illegible]ifferences across the sites (p=0.05), with RV [illegible]evealing lower values than the rest (Table 3). [illegible]ielou's index values showed no significant [illegible]ifference in abundance distribution among the [illegible]ites studies except CM in Plateau and RV in [illegible]e mountainous zone, which showed the lowest values compared to other sites (Table 3).

Table 2a: Species richness estimato[illegible] ba[illegible]d o[illegible]he abundance of insects in cultivated cucurbit species in the pl[illegible] Morogoro, Tanzania

Plat[illegible] zone					
Species richness estimator	**Sp[illegible]ess generated (Mean ± SE)**				
	SG	[illegible]	MF	CM	MZ
Sob	22	20	15	16	17
Chao1 mean	26.15 ± 4.87	34.94 ± 13.5	15.12 ± 0.43	24.13 ± 8.24	41.42 ± 30.99
ACE means	26.33 ± 3.86	25.22 ± 4.64	15.44 ± 0.83	32.53 ± 13.57	27.06 ± 8.85
Jack 1 mean	26.26±1.58	25.97 ± 2.3	15.99 ± 1.41	22.96 ± 3.72	23.07 ±3.73
Mean of the three ABE	26	28	15	26	30.3
Chao 2 mean	27.17 ± 3.62	30.69 ± 6.2	14.16 ± 0.52	25.13 ± 4.24	42.56 ± 32.96
ICE means	26.17 ± 2.6	24.71 ± 3.45	16.23 ± 0.79	30.43 ± 6.1	26.67 ± 7.69
Jack 2 mean	28.68 ± 0.35	22.81 ± 4.62	15.43 ± 0.62	20.14 ± 6.93	24.76 ± 4.69
Mean of the three ICE	27	25	15	25	30.67

Sob, Species richness observed generated by SpedR online software (Chao et al., 2016b)

Table 2b: Species richness estimators based on the abundance of insects in cultivated cucurbit species in the mountainous zone of Morogoro, Tanzania

Mountainous zone					
Species richness estimator	**Species richness generated (Mean ± SE)**				
	KD	RV	MG	MS	MK
Sob	17	9	13	14	12
Chao1 mean	20.57 ± 3.8	12.96 ± 5.22	19.15 ± 0.28	14.99 ± 0.39	21.91 ± 10.12
ACE means	24.19 ± 5.81	13.69 ± 3.98	18.54 ± 5.19	14.49 ± 0.91	17.22 ± 5.43
Jack 1 mean	22.96 ± 3.44	12.94 ± 2.79	17.31 ± 3.12	14.00 ± 0.91	16.95 ± 3.14
Mean of the three ABE	22	12.33	18	14	18
Chao 2 mean	19.69 ± 2.9	14.96 [illegible]	[illegible]16 ± 0.37	15.06 ± 0.21	20.16 ± 9.26
ICE means	22.69 ± 3.69	12.06 [illegible]	[illegible]6 ± 0.69	14.07 ± 039	20.69 ± 3.46
Jack 2 mean	21.96 ± 4.6	11.07 [illegible]	[illegible]9 ± 0.71	14.09 ± 0.34	15.16 ± 4.67
Mean of the three ICE	20.67	12.3	1[illegible]	14.3	18.3

Sob, Species richness observed generated by Sp[illegible]are (Chao et al., 2016b) For sites abbreviation, please see (Table 1)

Table 3: Species richness and diversity in[illegible]s associated with cucurbit in plateau and mountainous sites in the Mo[illegible]goro, Tanzania

	Plateau					**Mountainous**				
	CM	HU	MF	MZ	SG	KD	MS	MG	MK	RV
Shannon-wiener index (H)	0.026a	2.17b	1.98c	[illegible]	[illegible]c	1.58c	1.84c	1.96c	1.69c	0.06a
Simpson's diversity index (D)	2.083c	5.7a	4.84a	[illegible]	[illegible]	2.97c	3.87b	4.68a	3.78b	2.69c
Margalef species richness index (SR)	2.82a	3.46b	2.44a	[illegible]	[illegible]	3.13b	2.65a	2.85a	2.3a	1.87c
Pielou's index (J)	0.01a	0.72b	0.77b	[illegible]	[illegible]	0.56b	0.70b	0.76b	0.68b	0.03a

On a given column, values followed by the same [illegible]perscript lower-case letters are not significantly different among sites at p<0.05. (For Abbreviati[illegible] ple[illegible]e se[illegible]able 1).

Discussion

Thirty-three families of insect pests w[illegible] collected, with a total of 2133 individuals fr[illegible] 360 pitfall traps in ten localities cultiva[illegible] with cucurbit species. High relative abundance was recorded in the plateau zone (47.78±3.02) compared to the mountainous area (14.84±6.0). The Kruskal-Wallis test (χ^2_18.11 df 9 p=0.03) revealed a significant difference among the sites studied, with a higher abundance and species richness insect associated with cucurbit recorded at Sugeco (545) followed by Mafiga (310). All of the sites with the higher number of individuals are located in the plateau areas, supporting the paradigm that altitudes significantly influence insect pests' distribution, [illegible]ce, and richness. Increased relative [illegible]ce in the Plateau could be attributed [illegible] favourable temperatures for breeding and [illegible]tion of invasive insect species in the area. The results concur with the report by Mwatawala *et al.* (2006) reported increased diversity of fruit flies in lowlands compared to highland areas in Tanzania. Similarly, Mokam *et al.* (2014) in Cameron and Kumar *et al.* (2019) in India reported higher relative abundance and richness of insect pests in plateau areas compared to highland regions.

The results revealed three insect feeding habits in the experimental sites, i.e., phytophagous saprophagous and parasitoids. The phytophagous insects were numerous compared to other feeding habits, which concur with results from Mokam *et al.* (2014) and Moran (1983) that this group accounts for more than 25% of all insects on earth. Many reports (Mokam *et al.,* 2014) have highlighted their economic importance as a pest of fruit and vegetables, causing 20-80% fruit loss (Helvaci *et al.,* 2018). The analysis by taxon revealed that Hymenoptera and Araneae were preeminent and agronomically most important in the mountainous zone, while *Hymenoptera* and *Coleoptera* were dominant in the plateau zone. The results showed that regardl[illegible] differences in altitudes, the *Hymenopt*[illegible]*ans* were found in all agroecological zones, rein[illegible] paradigm that Hymenopterans are eco[illegible]mically significant in crop production and [illegible] balance. (Kumar *et al.,* 2019) conclude[illegible] observation that Hymenopterans are [illegible]und in a wide range of altitudes. Among Hy[illegible] the families Formicidae (ants) were common in both zones, while Mutillidae (parasi[illegible]as[illegible] was exclusively found in the plateau [illegible] Formicids in cucurbit farms preyed o[illegible] larvae and Mutillids parasitizing moth[illegible] eggs on the larvae of other insects, p[illegible] role as a natural control of other insects.

On the other hand, Araneae was [illegible] widespread in the study sites, c[illegible]ng 15 families. Among the Araneae, t[illegible] Lycosidae featured in all zone [illegible]h high abundance and richness compared [illegible] families, which is contrary to Warg[illegible]t et al. (2011), who reported Araneidae and T[illegible]mi[illegible]ae were dominant in the selected agricu[illegible] in India. The mismatch could be du[illegible] the influence of habitation and weather c[illegible] According to Mashavakure *et al.* (2[illegible] Araneae are generalist predators of phytophagous insects, providing natural protection to field crops (Warghat *et al.,* 2011). The richness of the spider diversity in the study areas is a valuable indicator of healthier crops. Coleopteran order comprises 13 families. The *Scarabidae* were the most common, followed by *Chrysomelidae, Carabidae,* and *Coccinellidae* from the selected agricultural area. The *Tenebrionidae, Bostrichidae, Hydrophilidae, Tetratomidae, Dystscide, Trogossitidae, Byrrhidae* and *Curculionidae* were exclusively found in the plateau zone, indicating the stenotopic nature of the species. Furthermore, some species from the plateau zone were recorded in the mountainous zone. Indicating that diversity at the plateau zone denotes a subgroup of mountainous diversity, e.g., *Scarabidae Chrysomelidae Carabidae, Coccinellidae* and *Possalidae* were found in both zones indicating the eurytopic nature of the insects. The present results concur with reports by Salomão *et al.* (2021) and Şenyüz *et al.* (2019) in Mexico and the Mediterranean, who assess the stenotopic and eurytopic nature of *scarabidae*.

In the present study, six nonparametric estimators of species richness were arrayed. The ratio of observed species richness to the average of abundance-based and sample-based species richness estimators showed a stronger sampling effort higher than 93% in both zones, indicating few species were unrecorded. Furthermore, the specie accumulation curve in all sites reached the asymptote, meaning that the sampling strategies were exhaustive such that few species were unrecorded. According to Magurran (2004) and Chao *et al.* (2005), the asymptote in the species accumulation curve provides a reasonable estimate of the number of species existing in each locality. All the sites are shown to be species-rich in terms of insects associated with cucurbit fruits. Margalef's species richness index was significantly higher in Plateau compared to the mountainous one. In the case of the individual site high indices was recorded at the Horticulture unit (HU), Mazimbu (MZ), and Sugeco (SG in Plateau, while Kidokwe had a high index compared to other sites in the mountainous zone. This finding shows that the elevation may have a significant impact on species abundance and richness. Phophi *et al.* (2020) mentioned temperature as a driving force for insect distribution. Several researchers (Şenyüz *et al.,* 2019; Salomão *et al.,* 2021) reported that most insects decreased with elevation. Moreover, the values of Simpson and Shannon indices were low at the Crop Museum(CM) site in the Plateau and Ruvuma in the mountainous zone, which the Pielous index of evenness has also confirmed. This concurs with the report from Magurran (1988) that an ecosystem revealing a low evenness is one in which few species dominate.

Concluding remarks

This study aimed to depict the structure of Hymenoptera, Coleoptera, and Araneae communities associated with cucurbit fruits in ten sites situated in the plateau and mountainous zone in Morogoro, Tanzania. Based on the species accumulation curve, the sampling effort was efficient, and all sites reached asymptotes. The insect groups studied were species-rich, except at Ruvuma and crop museum. The relative abundance decreased with increasi[illegible] elevation, which could be attributed to weat[illegible] conditions.

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Conflict of interest

On behalf of all authors, the correspond[illegible] author states that there is no conflict of inter[illegible]

Authors contributions

Conceptualization; (Liberatus Lyi[illegible], Jackline Bakengesa), Methodology (Libera[illegible] Lyimo, Jacline Bakengesa, Sija Kab[illegible] and Patroba Bwire); formal analysis and investigation (Liberatus Lyimo, Jac[illegible] Bakengesa, Sija Kabota and Patroba Bwi[illegible] Writing-original draft preparation (Liberatus Lyimo);Writing- review and editing (Liberatus Lyimo, Jacline Bakengesa, Sija Kabota and Patroba Bwire).

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