

Effect of alley intercropping agroforests on insect pollinator's abundance and diversity in semi-arid Dodoma, Central Tanzania

Abstract

Little is known on the influence of crop farmlands on the status of insect pollinators in the tropics including semi-arid areas of central Tanzania. An on-farm completely randomized block design (CRBD) experiment was carried out among grapes (*Vitis vinifera* L.), (VV); maize (*Zea mays* L.), (ZM); sunflower (*Helianthus annuus* L.), (HA); and groundnut (*Arachis hypogaea* L.), (AH) mixed cropping systems in semi-arid Central Tanzania based on specific objectives: (1) to determine insect pollinators abundance and diversity, and (2) to determine pollinators' distribution across the VV, ZM, HA, and HA farmlands. Bated trap nets were used to collect bees, wasps, butterflies and moths, and manually for beetles along two diagonals and a bisector temporal plot (20 m x 20 m) in each of the four farmlands. Trapped pollinators were identified into their zoological nomenclature, and computed for tally, and analyzed for Analysis of Variance (ANOVA) using SAS Statistical Software. Results revealed variability in pollinators abundances ($P < 0.05$) and diversity ($P < 0.05$) across the four farmlands. A total of 21 insect pollinator species were recorded with high variability between farmlands ($P < 0.05$). Grapes (VV) and sunflower (HA) had higher diversity (0.828–0.888), ($P < 0.05$) than Maize (0.664). A total of six insect pollinator species: honeybees (*Psychomorpha epimenis* (15 %), *Xylocopa californica* (10 %)), *Belanogaster* sp. (8.0 %), *Leptosia nina* (5.0 %), *Colotis evagore* (5.0 %) and *Xylocopa flavoviridis* (4 %) were much more abundant to grapes, compared to *Andreana helianthi* (14 %) and *Apis mellifera* (4 %) that were mostly confined to sunflower. Results demonstrate the positive role of grapes and sunflower for enhanced abundance and diversity of the insect pollinators, possibly due to forage availability. Ensuring crop diversity both at spatial and temporal scales would enhance both insect pollinators' diversity and pollination services in semi-arid central Tanzania and elsewhere in the tropics.

Keywords: insect pollinators, diptera, hymenoptera, lepidoptera, coleoptera, mixed cropping, semi-arid, central Tanzania

Volume 9 Issue 3 - 2025

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Received: August 6, 2025 | **Published:** September 05, 2025

Abbreviations: CRBD, completely randomized design; VV, *Vitis vinifera*; ZM, *Zea mays*; HA, *Helianthus annuus*; AH, *Arachis hypogaea*

Introduction

Enhanced pollination of pollinator dependent crops in many parts of the world including Sub-Saharan Africa (SSA) is crucial for improved crop productivity¹ although pollination sustainability is threatened by the ongoing loss of pollinators habitat.² Less is known on the influence of agroforestry- based farming systems including mixed cropping systems of the woody grapes (*Vitis vinifera* L.), cereal- based Maize (*Zea mays* L.) intercrops and the oil seed crops (Sunflower (*Helianthus annuus* L.) and groundnuts (*Arachis hypogaea* L.), on the status of insect pollinators and their associated enhanced crop productivity from the pollination ecosystem services. Insect pollinators including beetles, honey bees (*Apis mellifera*),^{3,4} wasps, butterflies and moths⁵ represent potential pollinators integrals to the general ecological and agrobiodiversity sustainability⁶ for the enhanced global food security due to their influence on productivity of flowering plants including food crops of many farming systems. However, little is known on the status of pollinators in the farmlands including agroforestry- based mixed cropping systems. Agroforestry, a deliberate establishment of woody perennial crops comprising trees and animals or pasture on a piece of land at both spatial and temporal arrangement⁷ has the potential for integrated enhanced soil fertility, pollinators diversity and their

associated pollination services and crop productivity in many farming systems and agro ecologies including semi-arid areas of the globe including Central Tanzania. Agroforestry-based farming systems such as mixed cropping represent sustainable intensification systems (SI) for enhanced efficiency and sustainability of resources mainly soil nutrients and moisture of fragile ecosystems such as the semi-arid areas due to the inherent limited precipitation. Synchronization of the crop phenology (e.g., initiation and development of floral buds) with the available soil moisture reserve especially at the flowering stage of many crops including cereals (Maize, sorghum, millet, cow pea). Legumes (beans, cow pea, pigeon pea) and oil seed crops (sunflower, sesame, groundnuts, Bambara nuts, etc.) and the associated farming systems offer the potential for enhanced crop productivity. Pollination plays a crucial role in productivity⁸ of cereal crops (maize (*Zea mays* L.), oil seed crops (Sunflower (*Helianthus annuus* L.) Sesame (*Sesamum indicum* L.), groundnuts (*Arachis hypogaea* L.), pigeon pea (*Cajanus cajan*), widely cultivated in many agricultural ecologies including the semi-arid ecosystems such as semi-arid Dodoma of Central Tanzania. Pollinators play essential role on enhancing productivity of legumes such as beans (*Phaseolus vulgaris* L.), cow pea (*Cajanus cajan*) and pigeon pea (*Vigna unguiculata*); horticultural crops such as tomatoes (*Solanum incanum* L.), Avocado (*Persea americana* Mill.).⁹ However, information is lacking on the status of the insect pollinators in relation to pollination in many farming systems including agroforestry- based farming systems in East Africa, Tanzania and semi-arid Dodoma of Central Tanzania in particular

as key habitats. Loss of habitat and forage including flowers that provide pollen, nectar and sugars for the adult pollinators and for nurturing their juveniles due to pesticide exposure and the general lack of appropriate integrated pest management (IPM) strategies have been associated to declining trend of insect pollinators.² negatively impacting pollinators' (butterflies, moths, wasps) diversity and their associated pollination services in north east Tanzania.¹⁰ Pollinator diversity is essential on enhanced crop productivity in terms of both quantity and quality of crop produce.¹ However, negative ecological interactions for instance habitat fragmentation and habitat change for instance urbanization of many peri-urban areas have been associated with loss of pollinators.² A study was therefore conducted between March and May 2024 to assess status of insect pollinators in selected cereal- legume based mixed cropping farmlands of peri-urban areas of Dodoma City, Central Tanzania based on specific objectives: (1) to determine insect pollinators species diversity, and (2) to determine relative abundance and distribution of insect pollinators.

Material and methods

Study area

An on-farm study was carried out among four mixed cropping farmlands composed of: Grapes (*Vitis vinifera* L. (VV), Sunflower (*Helianthus annuus* L.) (HA), groundnuts (*Arachis hypogaea* L.) (AH) and maize (*Zea mays* L) (ZM) all at their flowering stage between March and May 2024, in peri-urban areas of Dodoma City of Dodoma region of Central Tanzania. The experiment was conducted among farmers' farmlands of Msalato Administrative Ward located between 6°74" S; 35.7542.322° E, a peri-urban area of Dodoma City. The study area is represented by undulating hills and plains at an elevation of between 1000 - 1100 m.a.s.l with valley bottoms being suitable for arable farming. The area receives unimodal annual rainfall 600 – 700 mm between late November/ early December and late March/ early April. Temperature varies from 18 °C to 28 °C for the minimum and maximum, respectively. Dominant vegetation include scattered thorny bushes including *Acacia* spp., *Dichrostachys cinerea* and Baobab (*Andersonia digitata*). Main subsistence crops include cereals (maize, millet, sorghum), legumes (ground nuts, Bambara nuts, pigeon pea), and vegetables (tomatoes, eggplant, cabbage, pepper, Okra, leafy vegetables (amaranths, night shade) being both subsistence and cash crops. Grapes (*Vitis vinifera* L.) sunflower (*Helianthus annuus* L.) are the main cash crop.

Experimental design

A completely randomized block design (CRBD) on-farm experiment involving four farms (3.9 ha; 8 acres) each approximately 0.98 ha (2 acres) for Grapes (*Vitis vinifera* L. (VV), Sunflower

(*Helianthus annuus* L.) (HA), groundnuts (*Arachis hypogaea* L.) (AH) and maize (*Zea mays* L) (ZM) all at their flowering stage were evaluated for pollinators diversity. Bated trap nets were used to collect the pollinators both by intercepting flight of the flying pollinators (bees, wasps, butterflies and moths) and manually for the beetles along two diagonals and a bisector of a 20 m x 20 m plot in each of the four line transects laid out systematically along the four crop farmlands (VV, ZM, HA and AH. The temporal caught pollinators in each of the four alley agroforestry farmlands (*i.e.*, VV, ZM, HA and AH) were identified into their Zoological nomenclature, recorded and released back into their original habitats.

Data analysis

Data on the pollinator species tally were computed for Simpson's index of diversity (D);

$$D = \sum_{i=1}^R \frac{n_i(n_i - 1)}{N(N - 1)} \text{ where } n_i \text{ is the number of individuals of}$$

species *i*; N is the total number of individuals in the sample¹¹ and abundance. Indices of diversity, were analyzed for analysis of variance (ANOVA) for means, standard errors and probability differences ($P < 0.05$) using SAS (Statistical Analytical System version 9.4) based on the statistical model: $Y_{ij} = \mu_{ij} + T_i + e_{ij}$, whereby Y_{ij} the general response, μ_{ij} are the i^{th} and j^{th} peculiar effects common for each observation, T_i is the i^{th} treatments farmland treatment (VV, ZM, HA and AH) on the abundance and diversity of the pollinators, and e_{ij} are the i^{th} and j^{th} random error terms that had cancelled with each other in each i^{th} treatment effects.

Results

Effect of farmlands on insect pollinators abundance and diversity

Effect of farmlands on insect pollinators diversity in Peri-urban areas of Semi-arid Dodoma, central Tanzania is indicated in Table 1. Results revealed variability ($P < 0.05$) in abundance (55 – 362; mean = 187) and diversity (0.664 – 0.888; mean = 0.80) of pollinator species with vineyard (VV) demonstrating higher abundance ($P < 0.05$) than sunflower (HA), maize (ZM) and groundnut (AH). The farmlands were characterized by relatively high abundances and diversity with maize (ZM) having the least diversity (0.664) compared to the rest of the farmlands (0.828–0.888), ($P > 0.05$). A total of 13 pollinators including *Apis mellifera* (Table 2) demonstrated relatively low relative abundances (1–4 %) important in provision of the pollination services of the cereal, fruit and vegetable- based farming systems of semi-arid Dodoma, Central Tanzania for enhanced crop productivity.

Table 1 Influence of grapes and cereals alley intercropping agroforestry systems on insect pollinators abundance and diversity (mean ± SE) in Peri-urban areas of Semi-arid Dodoma, Central Tanzania

[§] Croplands	[±] Crop	Abundance	^β Diversity
Grape vineyard	<i>Vitis vinifera</i> (L.)	362 ^a	0.888±0.0003 ^a
Maize	<i>Zea mays</i> (L.)	55 ^b	0.664±0.006 ^b
Sunflower	<i>Helianthus annuus</i> (L.)	196 ^c	0.806±0.014 ^a
Groundnut	<i>Arachis hypogaea</i> L.	134 ^c	0.828±0.006 ^a
Mean		187	0.80
SEM		n.a	0.009
Effect of croplands		**	**

[§] Mixed cropping systems; [±] Crops description; ^β reciprocal inverse of dominance (1-D)

Table 2 Relative abundance of insect pollinators of insect pollinators across different farmlands in peri-urban areas of semi-arid Dodoma, Central Tanzania.

SN	Pollinator Species	<i>V. vinifera</i> (VV) vineyard	<i>Z. mays</i> (ZM)	<i>H. annuus</i> (HA)	<i>A. hypogaea</i> (AH)	Total	Dominance
1	<i>Leptosia nina</i>	36	6	0	0	42	6
2	<i>Episcapha quadrinacula</i>	8	0	0	0	8	1
3	<i>Notobitus meleagris</i>	15	0	0	0	15	2.0
4	<i>Colotis evagore</i>	30	7	0	0	37	5.0
5	<i>Belonogaster</i> spp.	12	16	0	30	58	8.0
6	<i>Eurema mandarina</i>	9	0	6	0	15	2.0
7	<i>Abaeis boisduvaliana</i>	15	0	0	0	15	2.0
8	<i>Hypolimnas misippus</i>	12	0	4	0	16	2.0
9	<i>Apis mellifera</i>	8	0	0	25	33	4.0
10	<i>Xylocopa californica</i>	60	15	0	0	75	10.0
11	<i>Psychomorpha epimenis</i>	80	0	4	25	109	15.0
12	<i>Utetheisa pulchella</i>	9	0	0	0	9	1.0
13	<i>Pinacopteryx eriphia</i>	13	0	8	0	21	3.0
14	<i>Heliopetes alana</i>	19	0	0	0	19	3.0
15	<i>Pterophorus pentadactyla</i>	36	0	5	0	41	5.0
16	<i>Xylocopa flavirufa</i>	0	5	0	25	30	4.0
17	<i>Andrena helianthi</i>	0	0	101	0	101	14.0
18	<i>Coccinellidae</i>	0	0	8	16	24	3.0
19	<i>Colotis euipe</i>	0	6	0	0	6	1.0
20	<i>Colotis danae</i>	0	0	10	13	23	3.0
21	<i>Eristalinus megacephalus</i>	0	0	50	0	50	7.0
	Total	362	55	196	134	747	100

Discussion

Influence of croplands on insect pollinator abundance and diversity

The noted variability in both abundance and diversity of the insect pollinator species between the four farmlands could be highly ascribed to the specific crop- pollinator dependent species highly demonstrated by grape, maize, sunflower and groundnut cropping systems. The recorded pollinators' diversity could be highly explained by the pollen and nectar availability Results demonstrate the positive role of grape (*V. vinifera* L.) and sunflower (*H. annuus* L.) cropping systems for enhanced diversity of the pollinators. Variability in both abundance and diversity of the pollinators' species is highly ascribed to the nature of the crops and stage of flowering due to the influence of flowering on the type of the pollinator forage material (*i.e.*, pollen, nectar, sugar).

High abundance and diversity of insect pollinators recorded in vineyards could be highly ascribed to pollen and nectar availability as well as the associated vegetation mosaics that form micro habitats for the pollinators.¹² Higher abundance and diversity of the insect pollinators recorded in Grapes (*Vitis vinifera* L.) and sunflower (*H. annuus*) farmlands than maize (*Z. mays*) and groundnut (*A. hypogaea*) (to a large extent could be highly associated to high pollen biomass and its influence on pollinators' suitability compared to groundnut (*A. hypogaea* L.) and maize (*Z. mays* L.) possibly due to their relatively less pollen biomass. The noted variability in both abundance and

diversity of insect pollinators across farmlands could similarly be associated to crops flowering calendar and persistence of flowering with notable variations for both grapes and sunflower compared to maize and groundnut as related to nectar availability, and thus continued supply of pollen grains for foraging insect pollinators of the specific crop pollinator dependent species. High abundance and diversity of the honeybees including *Xylocopa* spp. (*X. californica*, *X. flavirufa*), *Psychomorpha epimenis* recorded mostly in grapes (*V. vinifera* L.); and even *Andrena helianthi* recorded in Sunflower (*Helianthus annuus* L.) could be highly explained by their specific crop pollinator dependent species and stage of crop growth.⁹ Similarly, the noted abundance and distribution of other insect pollinator species such as Lepidoptera moths and butterflies for instance *Colotis* spp. (*C. avagore*, *C. etuipe* and *C. annae*) is equally ascribed to pollen and nectar availability for the foraging by the insect pollinators. In addition, the observed diversity of the Lepidoptera including *Colotis* spp. (*C. avagore*, *C. etuipe* and *C. annae*) could also be ascribed to their diurnal variability, as most Lepidoptera are nocturnal pollinators.¹³

Comparable results on the influence of vegetation and crops on abundance and distribution of insect pollinators have been recorded elsewhere¹⁴ for Diptera (*Eristalinus* spp. (*E. aeryorum*, *E. aeneus*); Hymenoptera including *Apis* spp. (*A. mellifera*, *A. dorsala*, *A. florea*) and *Xylocopa* spp. in Sunflower (*Helianthus annuus* L.). The revealed Influence *V. vinifera* on the insect pollinator abundance and diversity concur to variability in diversity and abundance of pollinator groups: Hawkmoths (Lepidoptera; Sphingidae across forest vegetation cover

and farmlands reported in Usambara mountains of north eastern Tanzania.¹⁰ High abundance and diversity of pollinators species in the current study would be translated through enhanced pollination services. Contribution of the insect pollinator abundance and diversity on the enhanced pollination services and crop productivity¹⁴ has been reported globally for Hymenoptera,⁸ Diptera,⁴ Lepidoptera,⁵ and are thus regarded of uppermost importance in the ecosystem in relation to production of the important pollination services.^{3,6,9,13,15} Most of reported insect pollinator species are of high pollination potential for instance the Carpenter bee (*Xylocopa* spp.) mainly attributed to their morphological adaptation as related to their strong mandibles for extraction and large body size¹⁶ for pollen transportation and the subsequent plant/ crop pollination efficiency.

Conclusion

It could be concluded that, grapes (*V. vinifera*), cereal (*Z. mays* L.) and oil crops (sunflower (*H. annuus* L.) and groundnut (*A. hypogaea* L.)) diversification have the potential for enhanced diversity and abundance of the insect pollinators and crop productivity. A total of 21 insect pollinator species (*Apis mellifera*, (*Psychomorpha epimenis* (15 %), *Andrena helianthi* ((14 %) *Xylocopa californica* (10%)), comprising mostly three orders (Diptera, Lepidoptera and Hymenoptera) that demonstrated high diversity (0.0664 – 0.888) of the cereal (maize, sorghum/ millet / sunflower- based) and grapes farming systems of semi- arid Dodoma of central Tanzania. Insect pollinator species that demonstrated intermediate to moderate relative abundance were mostly Lepidoptera including mostly Lepidoptera (*Eristalis megacephalus* (7 %), *Belonogaster* (8 %), *Leptosia nina* (6 %), *Colotis evagore* (5 %) , and *Pterophophorus pentadactyla* (5 %) compared to the rest of 12 pollinators (*i.e.*, 62 %) that had relatively low relative abundances of 1–4 % though of importance in provision of the pollination services to the cereal, fruit and vegetable- based farming systems of semi-arid areas of Dodoma, Central Tanzania for enhanced crop productivity, provision of other ecosystem goods and services and environmental sustainability. Ensuring crop agro diversity at spatial and temporal scales would sustain the insect pollinators' diversity by ensuring sustainable pollen and nectar availability for the foraging insect pollinators in semi-arid agro-ecologies of Dodoma, central Tanzania and elsewhere in the tropics.

Acknowledgments

None

Conflicts of interest

There is no conflict of interest.

References

1. Kumsa T, Balliantyne G. Review – insect pollination and sustainable agriculture in sub-saharan Africa. *J Pollinat Ecol.* 2021;27(2):36–46.
2. Schwarz J, Habel JC, Eberte J. Effects of habitat biotic features on hymenopteran diversity in East Africa. *J Insect Conserv.* 2024; 28:821–830.
3. Malik S, Kaushish S, Kaur R, et al. Comprehensive review on bee w.s.r to honey bee. *Int J Ayu Pharm Chem.* 2020;13(3):350 –359.
4. Ssymank A, Kearns CA, Pape T, et al. Pollinating flies (Diptera): a major contribution to plant diversity and agricultural production. *Tropical Conservancy Biodivers.* 2008;9(1&2):86–89.
5. Ghazanfar M, Malik MF, Hussain M, et al. Butterfly and their contribution in ecosystem: a review. *J Entomol Zool Stud.* 2016;4(2):15–18.
6. Thapa RB. Honeybees and other insect pollinators of cultivated plants: a review. *J Inst Agric Anim Sci.* 2006;27:1–23.
7. Nair PKR. *An Introduction to Agroforestry.* The Netherlands: Kluwer Academic Publishers, ICRAF; 1993.
8. Khalifa SAM, Elishafey EH, Shetaia AA, et al. Overview of bee pollination and its economic value for crop production. *Insects.* 2021;12(5):1–23.
9. Martins DK. *Our friends the pollinators: a handbook of pollinator diversity and conservation in East Africa.* Nairobi, Kenya: Nature Kenya–The East Africa Natural History Society; 2014:102.
10. Sallem AE, Selemanni SS. Diversity and abundance of a pollinator group: hawkmoths (Lepidoptera: Sphingidae) in forests and surrounding farmlands, East Usambara Mountains, Tanzania. *Int J Environ Sci Nat Resour.* 2022;31(1):1–9.
11. Marcon E, Hérault B. Decomposing phylodiversity. *Methods Ecol Evol.* 2015;6(3):333–339.
12. Macgregor CJ, Pocock MJO, Fox R, et al. Pollination by nocturnal Lepidoptera and the effects of light pollution: a review. *Ecol Entomol.* 2014;39(6):1–9.
13. Muhammad W, Saeed S, Ahmad A, et al. Pollinator community of sunflower (*Helianthus annuus* L.) and its role in crop reproductive success. *Asian J Agric Biol.* 2021;1(2):1–6.
14. Choi W, Jung C. Diversity of insect pollinators in different agricultural crops and wild flowering plants in Korea: literature review. *J Apicult.* 2015;30(3):191–201.
15. Sadeh A, Shmida A, Keasar T. The carpenter bee *Xylocopa pubescens* as an agricultural pollinator in greenhouses. *Apidologie.* 2007;38:508–517.
16. Skandalis DA, Tattersall GJ, Prager S, et al. Body size and shape of the large carpenter bee, *Xylocopa virginica* (L.) (Hymenoptera: Apidae). *J Kans Entomol Soc.* 2009;82(1):30–42.