EJED 2023 5(1):17–28
Ethiopian Journal of Environment and Development
http://www.du.edu.et/duj

Plant-pollinator interactions of three selected plant species in Gullele Botanic Garden, Addis Ababa, Ethiopia

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Received: 02nd August 2023 *Accepted: 04th September 2023*

DOI: **10.20372/ejed.v05i1.02**

Abstract

Assessment of plant-pollinator interaction in three selected naturally grown plant species (Rosa abyssinica, Hypericum revolutum, and Vernonia leopoldi) was conducted using pollination observation method in the Gullele Botanic Garden, Addis Ababa, Ethiopia. Critical observation of pollinators was conducted while visiting the floral parts of each species, capturing a photo of each pollinator on the floral part, and at the same time recording the time and giving the general name of pollinators. This observation activity was conducted by walking along the garden, choosing any flowering individual for about 30 min observations for five flowers. Data was collected in five weeks between November and December 2021 about the plant-pollinator visits, pollinators' diversity, number of visits to each species, and pollinators' preferred time in a day were analyzed using descriptive analysis. A total of six functional groups (bees-Hymnoptera, beetles-Coleoptera, flies-Diptera, moths and butterflies-Lepidoptera, and bird) were recorded from pollination observation. Bees were the most flower-visiting/pollinating insect group for the three species. Beetles were the second most visited insects on the flowers of the three species, followed by flies, moths, butterflies, and birds. Plants attracted a range of insects, with bees as the most abundant visitor/pollinator, accounting for 88% of the total visits. The rate of insect flower visits for the three species indicated a decrease from the first to the fifth week of floral blooming. For mutual benefit and sustainable conservation of selected flowering plants and pollinating insects, it would be important to promote the botanic garden by establishing a pollinator garden as part of the thematic garden.

Keywords/Phrases: Functional groups, Gullele Botanic Garden, Insect-flower visitation, Plant-pollinator interaction

1 Introduction

In the plant-pollinator interaction, the pollinators feed from the flower (nectar and pollen). In return, the plant benefits as the pollinator moves from one flower to another, transferring pollen as it forages for food rewards. Plants invest in the production of pollen and nectar for the benefit of pollinators. In the process of plant-pollination interaction, pollen allows the plant to reproduce and exchange genetic information with other plants (Nicolson & Wright, 2017). Plant-pollinator interactions can be assessed by methods such as pollination observations, bagging, and cage experiments to indicate the effectiveness of specific pollinators. Pollination observations, among others, have been the widely used method in pollination ecology (Yamaji & Ohsawa, 2016). Pollinators ensure seed production and provide for healthy plants grown in gardens and urban and rural areas. Pollinators are essential components of the habitats and ecosystems that many wild animals rely on for food and shelter. Moreover, it has been a natural extension of the work of botanic gardens, conservatories, and arboreta dedicated to plants. Worldwide, over 100,000 species of invertebrates and 1,000 species of vertebrates act as pollina-

tors (FAO, 2018). For reproduction, 75% to 95% of the world's flowering plants, including one-third of our food crops, depend on these animal pollinators (Ollerton *et al*., 2011).

Flowers of different plants are visited by animal pollinators to collect or consume rewards. However, animals do not visit them with the express purpose of pollination. Rewards obtained from flowers include nectar (consumed by insects, bats, birds, and non-flying mammals) as a source of sugar; pollen (used by most bees that collect it for provisioning their larval cells, and beetles, flies, birds, and some bats and non-flying mammals that feed on it) for protein, vitamins, fatty acids and minerals; oils (collected by certain bees for provisioning their larval cells), and resins collected by various bees for use in nest construction(Woodcock *et al*., 2014). The major animal pollinators important for plant reproduction are insects (e.g. bees, butterflies, moths, flies, and beetles), and nearly 290,000 flower-visiting insect species have been reported worldwide (Nabhan & Buchmann, 1997). Insect pollinators are very important in determining the mating opportunity of plants, and they are a keystone process in both human-managed and natural terrestrial ecosystems. The biggest groups of insects for pollination are solitary bees, bumblebees, and honeybees because of their sufficient body hair and behavior patterns (Du Toit, 1988). The main food resource of bees is nectar and pollen, which they get from flowers of different plant species. Both plants and pollinators could have co-evolved, such that flowers of different plants would require specific bee pollinator(s) for effective pollination to occur (Michener, 2000). Moreover, bats, birds, butterflies, beetles, flies, moths, wasps, small mammals, and most importantly, bees are pollinators. These insects visit flowers of flowering plants to drink nectar or feed off pollen and then transport pollen grains as they move from one flower to the other. As moisture, sunlight, and soil fertility, the availability of pollinators is essential to the reproductive success of nearly half the world's flowering plants (Nabhan & Buchmann, 1997).

With few exceptions, beetles and wasps have short tongues and cannot exploit nectar in deep tubular flowers. They are recorded most frequently as components of the visitor fauna of generalist flowers with a shallow perianth and exposed nectar. Moreover, many examples of nectar-producing flowers are specialized for pollination by beetles and wasps (Johnson, 2005; Shuttleworth and Johnson, 2006). Besides the food that we eat, pollinators are essential in supporting healthy ecosystems that clean the air, maintain soil ecosystems, protect from severe weather, and support other wildlife. Across the heterogeneous landscapes and ecosystems of Africa, the contribution of animal pollinators to biological diversity is inestimable.

Very recently, urban greenery, as part of the Green Legacy campaign launched by the Ethiopian government, is getting new attention. The green legacy, which includes plantation and reforestation, has been practiced to maximize biodiversity recovery, enhancing carbon sequestration, reducing air pollution, beautification, and climate change mitigation, and soil and water erosion control. In developed countries, greening urban and sub-urban areas has included the benefits of pollinators with the potential that urban areas and gardens could act as an extensive network of pollinator-friendly habitats (Baldock, 2020). There are a great many different plant species and cultivars available to the gardener, which plants are most attractive to flower-visiting insects in the developed world. This is not true in countries like Ethiopia and other similar countries. Studies conducted about which pollinators prefer which plants, insect-flower visitation rate, and plant pollinators' interactions are lacking in Ethiopia in general and in Gullele Botanic Garden in particular. Because of the gaps in the knowledge of pollinator diversity, plant-pollinator interactions, and pollinator gardens, there has been no information regarding the conservation of both plants and their pollinators in the Gullele Botanic Garden. Thus, the present study was conducted to identify the functional groups of pollinators/visitors and their visitation rate, timing preference for pollination, and interactions for the sustainable conservation and management of pollinators and flowering plants. The selected plant species for the present study are the naturally grown indigenous and endemic ones, such as *Hypericum revolutum*, *Rosa abyssinica*, and *Vernonia leopoldi*. These plant species have unknown visitation rates and plant-pollination interaction. The selection was made based on the plant availability for sampling,

flowering season, germination failure, proximity, and they are indigenous to the country.

2 Research Methods

2.1 Description of the Study Area

This study was conducted in Gullele Botanic Garden (Figure 1), which was established in 2010. The GBG was established with the objective of research-based conservation of plant species, particularly, endemic, endangered, and economically important (3E) ones, among others. The GBG is located on the outskirts of northwestern parts of Addis Ababa, Ethiopia. Geographically, it belongs to the central plateau of Ethiopia with coordinates extending between latitudes of 8^{o}55'N and 9^{o}05'N and longitudes of 38^{o}05'E and 39^{o}05'E. It is located in the northwestern direction of Addis Ababa city, 4km away from the center. The GBG was established in the slopped and semi-slopped topography of Addis Ababa. The average annual rainfall is between 1100-1300 mm and an annual temperature of about 15-18 C0. February is the hottest month (20.7 ^{o}C), and December (7.5 ^{o}C) is the coldest month regarding the weather in the area. GBG is part of the green lung of Addis Ababa city, where varieties of collections of plants from various parts of the country exist. The garden area is silicics in rock types and the nitosols, cambisols & vertisols in soil type. Historically, the GBG was dominantly covered by the *Eucalyptus globulus*, *Juniperus procera*, and a combination of many other species.

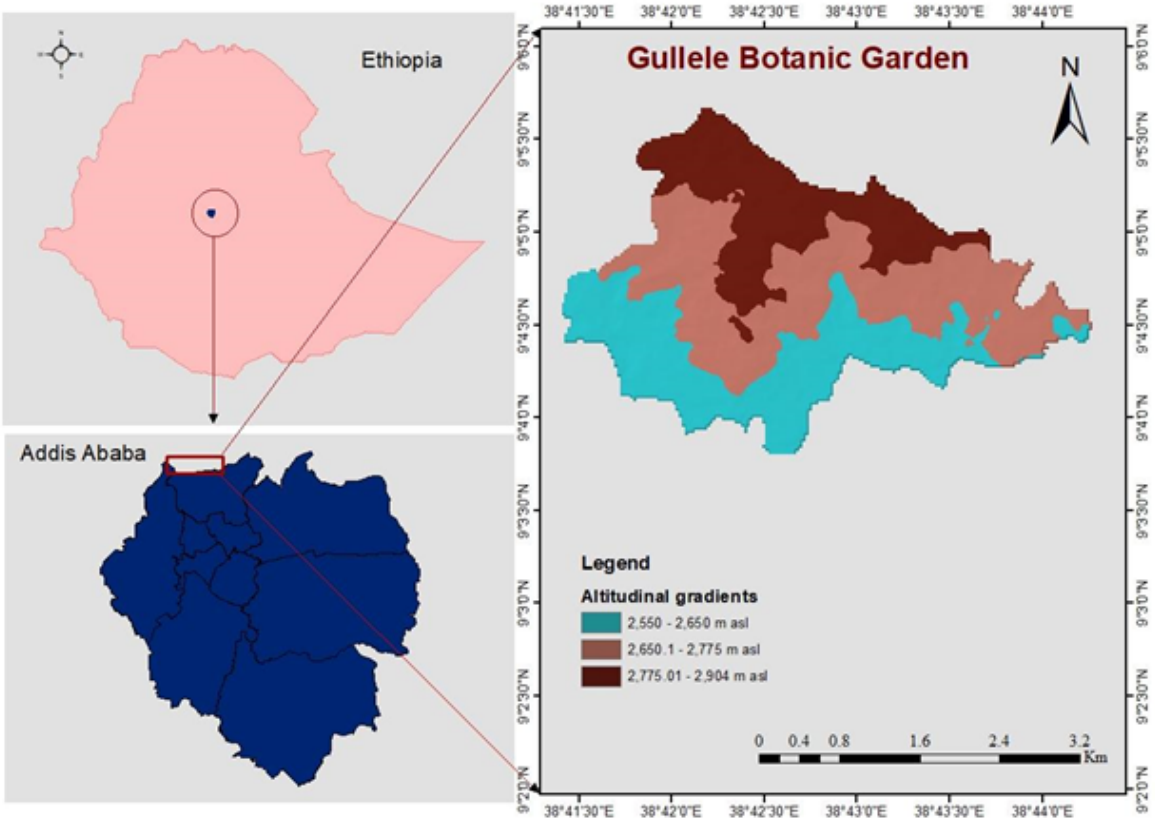

Figure 1. Map of Gullele Botanic Garden where the study was conducted

In terms of vegetation classification of Ethiopia, the study area belongs to the Dry Afromontane forest, and it has many naturally grown plant species (Table 1).

Table 1. Some of the plant species in the Gullele Botanic Garden

Scientific Name	Family Name	Scientific Name	Family Name
Juniperus procera	Cupressaceae	*Apodytes dimidiata*	Icacinaceae
Carissa spinarum	Apocynaceae	*Myrica salicifolia*	Myricaceae
Rhus glutinosa	Anacardiaceae	*Smilax aspera*	Smilacaceae
Olinia rochetiana	Oliniaceae	*Rosa abyssinica*	Rosaceae
Maesa lanceolata	Myrsinaceae	*Erica arborea*	Ericaceae
Hypericum revolutum	Hypericaceae	*Osyris quadripartita*	Santalaceae
Jassminium abyssinicum	Oleaceae	*Maytenus arbutifolia*	Celasteraceae
Rubus steudneri	Rosaceae	*Nuxia congesta*	Loganiaceae
Olea europaeae subsp. *Cuspidata*	Oleaceae	*Vernonia amygdalina*	Asteraceae
Dovyalis verrucosa	Flacourtaceae	*Vernonia leopoldi*	Asteraceae
Bersama abyssinica	Melianthaceae	*Buddleja polystachya*	Loganiaceae

2.2 Selection of plants for pollination study

Several naturally growing plants are found in the botanic garden, including climbers, lianas, and herbs to large trees. However, their flowering, fruiting season, and seed-forming time varies from species to species. For the present study, the three plant species: *Hypericum revolutum*, *Rosa abyssinica*, and *Vernonia leopoldi* were selected to identify their dominant pollinators and visitors. They were selected due to the same flowering seasons (October to December), fruiting seasons (January to March), and their floral structures, which are very attractive to pollinators and visitors. Besides, we have personal information that these species have a low level of propagation by seed. However, there has been evidence from our nursery that propagation by cutting is not as successful as was expected, particularly for *Hypericum revolutum*. For the sake of observation, five flowers/individuals were sampled for each species, totaling 15 observations for the three species.

2.3 Description and ecology of the selected plants

2.3.1 Ecology of *Rosa abyssinica* Lindley (Family: Rosaceae)

Rosa abyssinica is an endemic rose in Ethiopian highlands locally called '*Arbeq*', '*Qega*', '*Kega*', '*Engocha*', '*Qegga*' in Amharic and Abyssinian Rose in English (Figure 2).

Figure 2. *Rosa abyssinica* (Photo taken by Talemos Seta, Nov. 2021)

The plant is a creeping or climbing shrub forming a small tree up to 7 m, with prickly stems usually curved from a wide base and evergreen leaves. Leaflets of abyssinian rose are ovate to almost lanceolate with toothed margins. Flowers are sweet-smelling with white or pale yellow petals and numerous yellow stamens.

Flowers are sweet-smelling white-pale yellow and are usually 3 to 20 in dense heads, each stalked, the sepals long, narrow, and hairy, soon fall, and have five petals about 2cm long, tip rounded to square, with many stamens. The fruits are green at first but later ripen to orange-red. The fruits are edible and collected and eaten by children (Flora of Ethiopia, Vol.3). There is a report that indicates the fruits are being used against hookworms. The plant flowers throughout the year and honey bees visit the flowers for pollen. Habitat: rocky places, dry grassland, and riparian formations; also in different types of man-made habitats, sometimes standing alone as a small tree; 1900-3300 m altitudes (Fichtl & Adi, 1994).

2.3.2 *Vernonia leopoldi* (Sch. Bip. *ex* Walp.) Vatke (Family: Asteraceae)

An erect shrub or rarely woody herb, covered with soft hairs, growing to 2.5 m high (Figure 3).

Figure 3. The *Vernonia leopoldi* with its pollinators (Photo by Talemos Seta, Dec 2021)

Leaves grey-green with crenate margins, glabrescent, pilose or shortly strigose above with denser hair, especially on the veins beneath, base obtuse to decurrent, petiole (2-) 3-6(-8) mm long. Flower heads are purple and in large terminal corymbs. The leaves and flowers are used for dressing wounds. The roots are used against gastric disorders. Flowering from October to January, honeybees collect pollen and nectar from the flowers very frequently, and in dense stands, it can provide a good nectar flow. It grows in open forest margins such as Acacia wooded grassland with scrub of Maytenus, *Rosa abyssinica*, and Carissa on shallow soil, often in ravines, roadside thickets, and wasteland at altitudes between 1850 and 2850 m.

2.3.3 *Hypericum revolutum* Vahl. (Family Guttiferae)

A plant locally called '*Amija*' in Amharic and Curry bush in the English language. It is a shrub or tree up to 12 m tall, bushy or slender and glabrous (Figure 4). It is evergreen, with leaves opposite, closely spaced and crowded at the ends of branches, c. 20 × 5 mm, green to slightly glaucous, sessile, clasping at the base.

Figure 4. *Hypericum revolutum* (Photo by Talemos Seta; Dec.2021)

Flowers of this plant are terminal solitary, 35-80 mm in diameter, and showy, very attractive, bright yellow color. Its yellow, radially symmetric flower has five nectaries, and nectar is presented as a tiny drop at the base of each petal. Flowers usually last about 2 days with cumulative nectar production exceeding 19 μl per flower (Bartoš *et al*., 2012). According to studies conducted by Janeček *et al*. (2012), *H. revolutum* is frequently visited by sunbirds, which, however, contribute only negligibly to its pollination. It grows in open forest; forest margins montane savannas, and grassland, often with *Erica arborea* and/or *Hagenia abyssinica* at an altitude of 2250-3650 m a.s.l. The plant occurs nearly in all Ethiopian regions, south to Cape Province, and also in Nigeria, Cameroon, and S.W. Arabia. The roots of this plant are used for stomach and tooth problems.

2.4 Methods of Data Collection

In order to collect information on the three species related to pollination processes, the following activities were conducted. Data collectors were grouped into three by assigning one individual to each species. Three plants from each species and the same area were included in the data collection. The data collected from the present study include critical observation of pollinators while visiting the floral parts of each species, taking a photo of each pollinator/visitor on the floral part, and at the same time recording the time and naming the general name of pollinators (for example, bees, flies, birds, *etc*). During observation, flower visitors were sampled for a total 8-9 h period (from 7 a.m. to 6 p.m., with extra observation hours on major visitation periods by the researcher) for each tree species, with five flowers/individuals selected based on the exposure to pollinators. This observation activity was conducted by walking along planting lines and choosing any flowering individual for about 30 minutes of observation. The observation time was a day time and separated into four classes. These are 7 to 9 a.m., 10 to 12 a.m., 1 to 3 p.m., and 4 to 6 p.m. to identify the visitation frequency of pollinators. The observations in each time interval were recorded, and photos of the pollinator/visitor/robber on the flower were taken. This data collection was conducted for about five flowering periods from November to December 2021.

2.5 Identification and Data Analysis

From pollination observation, the observed insects pollinating/visiting flowers of the selected species were identified by entomologists into their functional

groups, such as bees, beetles, flies, moths, butterflies, and birds. Data collected from the field for three flowering plants in five weeks about the insect visitation, pollinators' diversity, number of visits to each species, and pollinators' preferred time in a day were analyzed using qualitative and quantitative analysis. In order to make this study complete, it requires further taxonomic research to identify the insects and determine insect diversity. Moreover, it is important to further extend studies toward pollen and nectar analysis to identify which insects, in deed, pollinate which specific plant species during interactions.

3 Results

3.1 Insect-flower pollination in three species

Though identification to the taxa level is not conducted, the total insect pollination observed during the flowering season of the three plant species was categorized into six functional groups, such as bees family, Apidae (Hymnoptera), beetles (Coleoptera), flies (Diptera), moths and butterflies (Lepidoptera), and birds. Wasps were rarely observed in the flowers of the selected three species. Types of bees encountered in the flower-visiting process of the three plant species were carpenter bees (*Xylocopa spp.*), honey bees (*Apis mellifera*), and solitary bees in Apidae. Generally, bees were the most flower-visiting insect group for the three species. For example, the *Vernonia leopoldii* flower was visited 24610 times, the *Hypericum revolutum* flower 25170 times, and the *Rosa abyssinica* flower 26240 times in the study period. The insect visitation rate by bees for the three species was 6-10 times/minute. Bees, particularly honey bees, visited more flowers per time at any time of the day for *Rosa abyssinica* and *Hypericum revolutum*. Beetles were the second most visited insects on the flowers of the three species, followed by flies, moths, butterflies, and birds (Figure 5). According to the present study, plants attracted a range of insects, with the honey bee as the most abundant visitor accounting 88% of the total visits for the three plant species. Of the six functional groups, five except birds were in abundance on all three plants in varying proportions.

During data collection, it was observed that more frequent flower visitation (*Rosa abyssinica* of beetles next to bees, particularly, happened in the morning session of the day. From the present study, the average visitation rate of beetles in the three species was 0.5-3/ minute. Moreover, flies visit the flower of all species at a rate of 2-2.6/minute followed by butterflies (1/minute), and moths (0.76/minute birds (0.6/minute).

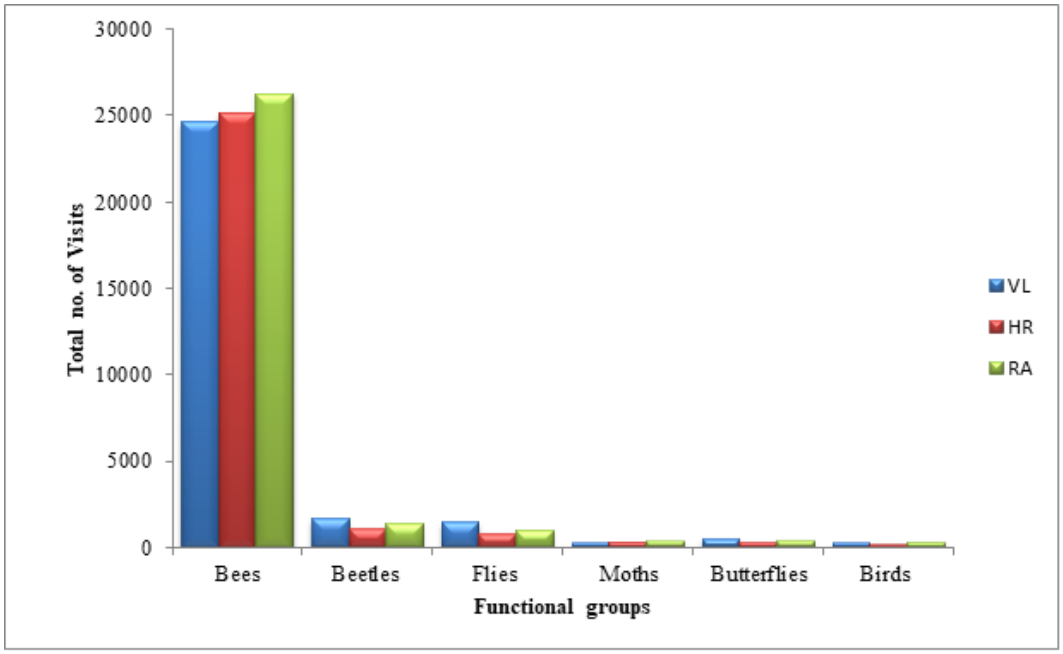

Figure 5. Visitation frequency by six functional groups

Generally, it was described that the flowers most visited by beetles have the following characteristics: bowl-shaped with sexual organs exposed, white to dull white or green, strongly fruity, open during the day, moderate nectar producers, may be large solitary flowers, and may be clusters of small flowers.

Among the functional groups, butterflies were least actively engaged in visiting flowers of the three species. More frequency of butterflies' visitation was observed in *Vernonia leopoldii* in the late morning and early afternoon session compared to the other two species in the garden.

3.2 Insect visitation to flowers in each observation time

As can be seen from figure 6, the visitation rate for bees is much higher than the other insects in four consecutive periods of a day. The flower visitation rate decreases from morning to late afternoon in each time interval, particularly for bees. However, the flower visitation rate by beetles was high in the late afternoon from 4 to 6 p.m. On top of this, total visits by birds were very low compared to other functional groups. In plant-pollinator interaction, the type of flower, shape, color, odor, nectar, and flower structure vary by the type of pollinators that visit them. It was observed during data collection that insects visited multiple flowers on the same plants, and sometimes insects visited multiple neighboring plants. In all three species, insect flower visitation in the morning session was comparatively higher. The rate of insect flower visitation for the three species indicated a decrease from the first week to the fifth week of floral blooming. In *Vernonia leopoldi*, there was a high number of floral visits by all the insect functional groups in the first and second week of the flowering period.

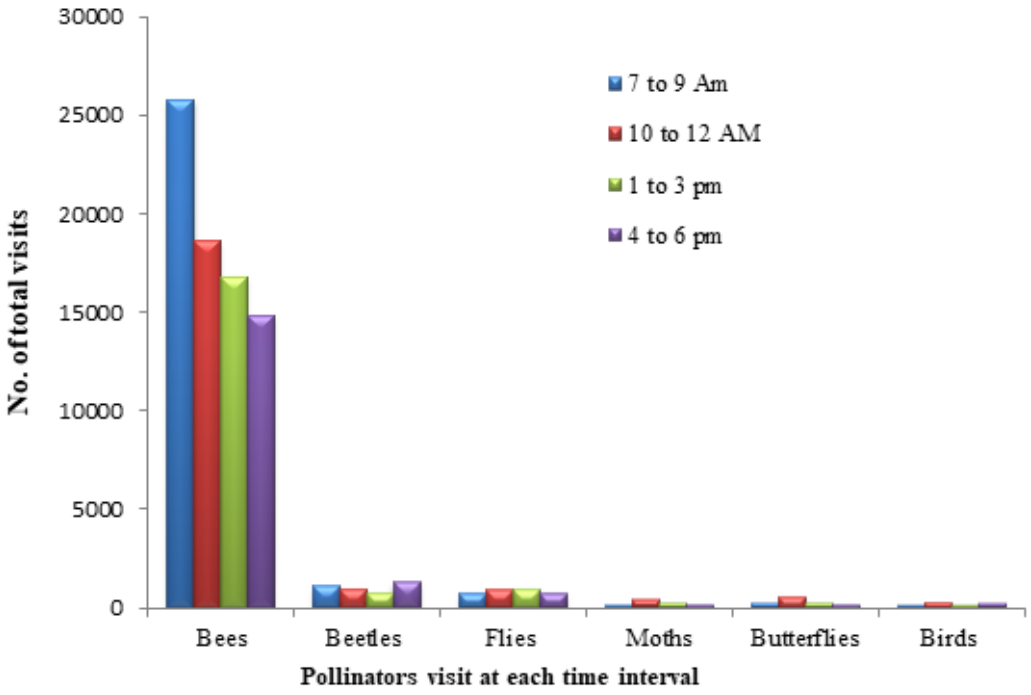

Figure 6. Pollinators visit at each time interval

3.3 Total insect-flower Visitation in the three species

It was observed from figure 7 that the total insect visitation to the floral parts of *Rosa abyssinica* (29722) is higher than the other two species, *Hypericum revolutum* and *Vernonia leopoldi*. Of all the six functional groups, only flower visitation by bees accounted for 88% of *Rosa abyssinica*, 90% of *Hypericum revolutum*, and 85.6% of *Vernonia leopoldi*. This result shows that most of the insect-flower visitation for the three species is taken role by bees. The remaining two species have a limited role either in pollination,

robbing, visiting, or stealing in the three species. The morning session of visitation hours (7 to 9 AM and 10 to 12 AM) were preferred by visiting insects for *Rosa Abyssinica*. The total visitation by bees is more active in the early morning and then eventually less active in the late afternoon for the three species. Later on after flowering season, it needs further studies a number of seeds have been set as indicated as was confirmed by researcher observation.

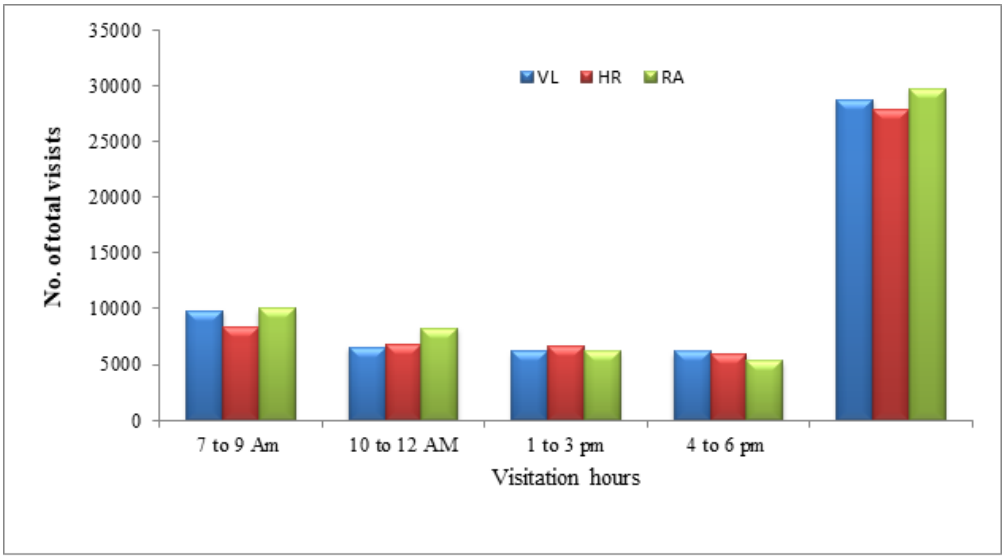

Figure 7. Total insect-visits in three species

4 Discussions

In this five-week observational study, six functional groups of insects either, visiting or pollinating flowers of *Rosa abyssinica*, *Vernonia leopoldi*, and *Hypericum revolutum* were identified. These plant species have brightly colored flowers (white, purple, and bright yellow) with nectars and pollen in them. Of the six functional groups, bees were the most common visitor/pollinators in the three species, which may be attributed to the flower structure, flower colour, odour, and availability of nectars. Insects are assumed to be responsible for 80-85% of all pollination, of which 75-80% was attributed to honeybees (Johannsmeier & Mostert, 2001)

Moreover, the development of the modern flower caused the evolution of some pollinating insects like moths and butterflies (Lepidoptera). Almost all species of Lepidoptera possess a tongue/proboscis adapted for sucking (https://www.britannica.com/science/pollination/Butterflies-and-moths).

According to an updated comprehensive overview of Lepidoptera in Ethiopia, Tujuba *et al* (2019) recorded and presented a total of 2,438 taxa in 48 families, of which 664 are endemic. For pollination, the biggest groups of insects are solitary bees, bumblebees, and honeybees because of their sufficient body hair and their behavior patterns even if this study did not identify this level of classification (Free, 1993; Du Toit, 1988), however, bees took the first place in the pollination. A high frequency of bees' visitation was recorded in three study species, indicating the high possibility for bees to be a major pollinating group for the three flowering plants in the Gullele Botanic Garden.

Of the total pollinators of major crops in Ethiopia, honeybees contribute 80% of the pollination service (Getachew Worku, 2018). Families of bees and butterflies are the most important pollinators in Ethiopia, and their diet (particularly for bees) is exclusively composed of pollen and nectar collected from flowers. For example, *Apis mellifera* and *Trigona spinipes* were the most generalist visitors, being the only insects that visited all olive tree species in the study reported by Kevan and Baker (1983). Bees are by no means the only insect pollinators worthy of mentioning. Butterflies (Lepidoptera), Flies (order Diptera), beetles (order Coleoptera), moths (order

Lepidoptera), and wasps (order Hymenoptera) are important pollinators as well, and some have developed specialized relationships with their preferred host plants. Moreover, these pollinators are essential in promoting the seed set of many flower and fruit crops, as well as the quality of seed /fruit, early flowering, oil content, pyrethrin content, rubber content, and the amount of lavender oil (Free, 1993).

Bees visited many flowers per minute for the three species compared to other insect groups. Bees, as the quickest visitors/pollinator visit, flowers in all three species over four to five times faster than beetles, flies, butterflies, and moths in this study. However, it was reported that families of bees and butterflies are well-known pollinators, once their diet (especially for bees) is more or less exclusively composed of pollen and nectar collected from flowers (Goulson, 2003). Even if butterflies are active during the day and visit a variety of wildflowers, they are less efficient than bees in transferring pollen from one to another flower because butterflies have highly perched long thin legs, which do not pick up much pollen on their bodies and lack specialized structures for collecting it. Butterflies probe for nectar, their flight fuel, and typically favor the flat, clustered flowers that provide a landing pad and abundant rewards. In addition, butterflies have good vision but a weak sense of smell. Unlike bees, butterflies can see red (Lewis, 1995).

The insect visitation in five weeks to the floral parts of *Rosa abyssinica* is higher than the other two species, which may be attributed to the floral structure, odour, and color. The floral structure of this species is very suitable for insects such as pollinators, visitors, robbers, and thieves. This species has floral parts that are open, fragrant, white-pale yellow, the sepals long, narrow, and hairy, soon fall and have five petals about 2 cm long, tip rounded to square, with many stamens (Fichtl & Adi, 1994).

The present study agrees with the finding of the previous work, which showed that hymenopterans were quicker than lepidopterans or dipterans in their visitation rates on lavender, in a study that described interspecific patterns of plant-pollinator interactions (Herrera, 1989; Garbuzov & Ratnieks, 2014). Moreover, bees in urban environments are keystone species for pollination purposes. Pollination services by bees help propagate both wild and ornamental plants that, in turn, support birds and other urban wildlife by providing fruit and seeds, as well as harboring insect prey (Biesmeijer *et al*., 2006; Ollerton *et al*., 2011). Bees directly benefit people by pollinating crops grown in residential and community gardens (Matteson & Langellotto, 2009) but they also present opportunities to interact with nature and engage in conservation (Colding *et al*., 2006).

Among other factors, flower shape, temperature, light, and season were the most important variables influencing insect visitation rates. In this study, the visitation frequency by bees and butterflies was higher in the early morning than afternoon and eventually became low in the late afternoon for the three species. This variation could be because of reduced secretion of sugar with increased sugar concentration due to the higher evaporation. Another reason could be the higher rate of nectar production in the morning than afternoon and lowest around the midday. This finding was supported by a similar study reported in Herrera (1990). Moreover, studies indicate that pollinator efficiency depends on visitation frequency and the total number of visits from a given functional group (Couvillon, 2015; Herrera, 1990; Garbuzov & Ratnieks, 2014). The present observational study demonstrates the density of insect functional groups and visitation rate varies across the visitation hours for the three species in the Gullele Botanic Garden, which would impact the process of pollination and production of seed set.

From an ecological point of view, studies showed the decline of pollinators, which affects ecosystem stability and loss of biodiversity and, in turn, the plants they pollinate (Biesmeijer *et al*., 2006; Taki & Kevan, 2007). This decline in pollinator populations is due to human practices that contributed to the loss of wild and flower-rich habitats. By changing some of our practices, such as how we manage flowering plants in our gardens and farms, we can help conserve these vital pollinator species. Unless the bee population and other pollinators in the botanic garden are not maintained, there will be a decrease in flowering plants and other plant biodiversity, including the species considered in this study. As a consequence, a decrease in the population size of bees and other pollinators will usually result in inad-

equate pollination of the three species, which in turn affects the reproductive capability of the sampled species and other flowering plants (Meixner *et al*., 2010; Winfree *et al*., 2009).

5 Conclusion and Recommendations

It is concluded from the present study that bees were the most frequent pollinators/visitors for the three selected flowering plants. The most active period for pollinators in a day was the early morning session compared to other periods for the three flowering plants. Of the five flowering weeks, the high frequency of visiting or pollinating by insects was recorded in the first flowering week, where all flowers were at the stage of blooming with plenty of nectar and pollen. The number of functional groups identified was fewer than in other similar studies, indicating that insect conservation should be integrated into the Gullele Botanic Garden. Bee-attractive native plants should be promoted in the Garden, particularly by establishing a pollinator garden as an additional theme for the sustainable conservation of other essential plant species, as well as its pollinators. Adding plants through tree planting and increasing plant diversity in the garden could enhance pollinators and their abundance. Finally, studies related to pollinator diversity, the taxonomy of pollinators, pollinators, and floral structures of animal-pollinated plants in the garden should be conducted as the second phase after this baseline study on three selected species.

Acknowledgments

I would like to thank research staff and gardeners of Gullele Botanic Garden for supporting me in data collection.

Conflict of Interest

The author declares that there is no conflict of interest.

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