

ADDIS ABABA UNIVERSITY
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**DIVERSITY and ECOLOGY of VASCULAR EPIPHYTES in HARENNA
AFROMONTANE FOREST,BALE, ETHIOPIA.**

By

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Abstract

*The Ecology and Diversity of vascular epiphytes were studied in Harena Afromontane Forest in southeastern Ethiopia at an altitude of 2000 -3000m. Fifty-five species of vascular epiphytes (i.e.22 holoeiphytes, 3 hemieiphytes and 30 opportunistic/humus/ epiphytes) were recorded. At all altitudinal levels, pteridophytes were the species rich group. The Shannon-Weiner index ($H' = 1.62$) of alpha diversity of the epiphyte community in the study area is low. The species diversity of vascular epiphyte is greatly influenced by the host tree biophysical factors, such as vertical gradient of host tree and size as well as the altitude. The regression correlation test showed that the number of species of vascular epiphytes and the size of host tree are positively correlated ($R^2 = 0.34$, $p = 0.0001$) but non-linear correlation exists between the species number and bark and humus pH. The altitudinal distribution of species of epiphytes was higher towards the lower altitudes (for holoeiphytes and hemieiphytes) but humus/edaphic epiphytes don't exhibit clear pattern of distribution. The altitudinal distribution of epiphytes may be influenced by altitudinal factors like temperature and moisture. The vertical distribution of vascular epiphytes (holoeiphytes and hemieiphytes) along the vertical gradient of the host trees indicated that most species were localized at the intermediate height, except humus epiphytes, which are mostly restricted to the base and below first branches of the host trees. The vertical ecological gradients (i.e. solar radiation and humidity differences from the forest floor to the canopy) may be relevant for the distribution of epiphyte floras. Majority of the species of epiphyte occurred in a wider range of both humus and bark pH (pH = 5.0 - 6.0 for bark and pH = 6.0 to 7.0 for humus) but few species were restricted to narrow range of pH. However, the pH values of humus and the barks utilized by specific species of vascular epiphytes were almost corresponds to each other. The host tree preference of vascular epiphytes was exhibited by few species such as *Aerangis brachycarpa*, hosted on *Vernonia amygdalina* and *Liparis deistelii*, on *Schefflera volkensii* and *Erythrina brucei*.*

Key words: Disturbance, Holoeiphyte, Hemieiphyte, Phorophyte, and Diversity, Bark pH, Humus pH.

1. INTRODUCTION

An epiphyte is a plant that grows on the surface of another plant without deriving food from its host (Heywood, 1993). It is derived from the Greek words (epi = upon; phyton = plants). The recent definitions of epiphyte indicate that epiphytes are not only growing on living plants, but also grow on non-living objects. Therefore, according to the current definition, an epiphyte is a plant that roots and perches on another plant or non-living objects (Fatland 1996).

Vascular epiphytes are the main component of forests in tropical regions. But the studies carried out in the past few decades have not concentrated on the epiphytes. Much of the studies have been concentrated on the tree components of vegetation. Schnitzer and Carson (2000) have published that in the past decades, most studies carried out on vascular plants were focused on the tree components, despite the fact that the non-tree vegetation is responsible for a high percentage of the total biodiversity in the tropical forests.

Various evidences have indicated that the epiphyte community was the long forgotten life form in any parts of the world. For example, no researcher has studied the ecology and diversity of vascular epiphytes of any forest existing in Ethiopia specifically. The main reason why the epiphytes are understudied compared to the other vegetation type is perhaps they do not provide immediate and direct benefit for the well-being of man (Schnitzer and Carson, 2000). The few studies made on vascular epiphytes showed that they are as important as other woody plants though most of them are not directly used as for example, for timber, fuel and construction.

They provide specialized services to the ecosystem functioning. The ecological services include: substrate and food for many canopy-dwelling animals, indicator for conservation initiatives and indicator of air quality (Hietz, 1999), nutrient and water cycling (Nadkarni, 1992) bioindicator to assess forest continuity (Rostalds *etal.* 2002), maintenance of the moisture of the environment (Benton and Werner, 1974), bioindicator of ecological damage (Barthlott *etal.* 2001), and contribute to plant species richness (biodiversity). Epiphytes have also been used extensively for medical, agricultural and horticultural purposes for human benefit (Bennett, 1992; Nadkarni, 1992; Raush, 1992; all cited in Barthlott *etal.* 2001). There could be other benefits that the vascular epiphyte may provide though not yet identified for they are not extensively studied.

Like other species of plants, vascular epiphytes are most commonly distributed in tropical rainforest. Different authors have published that vascular epiphytes constitute a large part of global biodiversity (10% of all vascular plants) and in tropical countries represent up to 25% of all vascular species (Neider *et al.*, 2001; Luttge, 1989). They are widely distributed throughout many plant divisions. Fattland (1996) has published that 84% of vascular plant families have at least one epiphyte in their group. The species diversity of epiphytes in tropical forest has been attributed to many factors: the evolutionary explosion of certain genera (Gentry, 1981; cited in Gentry and Dodson, 1987), co-evolution with pollinators (Gentry and Dodson, 1987), and an optimum level of disturbances (Benzing, 1981; cited in Hietz and Hietz-Seifert, 1995^b).

Even though the tropical forests consist of high diversity of vascular epiphytes, variation exists among the forests located in tropical regions. Johansson (1974) have published that the tropical forests of Africa are generally poorer in species composition compared to the other continents. According to the above author, the condition may be due to the high deforestation rates and various degrees of disturbances made by human activities in the African countries.

As the result of these disturbance activities, vascular epiphytes are more diversified in primary forests than in the secondary and disturbed forests (Barthlott *etal.*2001). The same author have published that the increase in species numbers, abundance, and species composition of primary forests are mainly due to highly diverse phorophyte structures and highly differentiated microclimates.

The fact that epiphytes are surviving on the substratum raised above the ground, the properties of the substrate influence their distribution. Epiphytes are mostly abundant on forks, horizontal branches and rough barks of the host trees, but least abundant on vertical and smooth branches (Hietz and Hietz-Seifert, 1995^a; Hietz, 1999). These sites are the place where soil is easily collected and anchored is easier for them .The ages, chemical composition of the barks, like bark pH, and size of the host trees are important for the abundance and diversity of the vascular epiphytes (Hietz, 1999).

As epiphytes are relying on other plants for support, they face several stressful conditions. In order to over come these unfavorable conditions, they evolved different adaptation mechanisms (physiological and morphological). Besides these structural and physiological modifications, the tropical areas provide suitable environment for the

survival of the epiphytes. The warm temperature, high precipitation, large tree size, and enough solar radiation are conditions best suitable for the survival of epiphytes (Johansson, 1974).

Therefore, Harennan Afromontane Forest is one of the tropical African forests harboring epiphyte community besides other species of woody plants. Though ecologists extensively studied the various aspects of the forest community such as syntaxonomy and phytogeography (Bussmann, 1997), its ecological survey (Lissanework and Mesfin, (1989), and partitioning an elevation of vegetation (Zerihun *et al.*) but no aspect of epiphyte community has been studied at all. Therefore, the current study describes for the first time the diversity and ecology of vascular epiphytes in Harennan Afromontane Forest.

2. LITERATURE REVIEW

2.1 What is an epiphyte?

There are several definitions of epiphytes, each with subtle differences. Heywood (1993) defined epiphyte as “a plant that grows on the surface of another, without deriving food from its host”. Raven *et al.* (1992) have defined epiphyte, as “a plant that grow on another plant, but is not parasitic on it”. Ewusie (1984) has defined “epiphyte as a plant that grows on another plant”. Luttge (1989) has defined “epiphytes as a plant that derives its physical support from another plant (host tree = phorophyte)”. The variation in growing sites and the numerous different types of inhabited vegetation clearly indicate that there is neither a simple definition of epiphytic habitat nor of environmental constraints imposed up on canopy dwelling (Hietz and Zotz, 2001). Therefore, epiphytes are currently defined as plants that root and perch on other plants or non-living objects. But the true vascular epiphytes, however, can live only in the canopy, falling to the ground results in death (Matelson, Nadkarni, and Longino, 1993; all cited in Reynolds, 2003).

The host plants (phorophytes) only provide support for epiphytes. Epiphytes obtain mineral nutrients and water from the air and some times know as air plants (Benton and Werner, 1974). The source of water is mainly precipitation but it can be from air moisture and water collected in the cracks of the bark surface of the host plants (Johansson 1974). The nutrient supply is from rainwater containing dissolved substances, decaying bark surfaces and accumulated wind born particles (Smith, 1992).

2.2 Holoepiphytes (True epiphytes)

Holoepiphytes (true epiphytes) are plants that never root in the soil. They complete their entire life cycle anchored to the host plants, and receives mineral nutrients and water from non-terrestrial resources. Neider *et al.* (2001) have defined holoepiphytes as non-parasitic plants that use other plants usually trees as a growing sites all through their life cycle. The true epiphytes, however, can live only in the canopy from the moment of seed dispersal typically by wind or birds (Benzing, 1995; cited in Reynolds, 2003).

2.3 Hemi epiphytes (Half epiphytes)

Hemiepiphytes (half epiphytes) are plants that are strictly epiphytic for one stage of their life cycle, but become rooted in the soil during other stages. Hemiepiphytic plants are characterized as structural parasites and rely on other plants (phorophytes) to grow vertically (Luttge, 1997). The same author has published that the hemiepiphytes have a soil connection for only a portion of their life cycle and represent a growth form between epiphytic and terrestrial plants. The hemiepiphytes are of two types: Primary and secondary hemiepiphytes. The primary hemiepiphytes are epiphytes, which begin life as an epiphyte and later become rooted in soil. The secondary hemiepiphytes begin life rooted in the soil and later assumes an epiphytes life. The secondary hemiepiphytes use other objects as a support in their quest for light and after establishing on the phorophyte, their old shoot and roots senesce and new aerial root grow towards the soil.

2.3 Humus epiphytes

Many humus epiphytes are opportunistic epiphytes. They may grow at ground level or on cliffs but will also grow in pocket of humus trapped in the boles and trunks of trees. They were also called as accidental or edaphic epiphytes. They are normal terrestrial plants but their diaspores accidentally land on the phorophytes by dispersal agents and the plants make establishment.

2.4 Distinguishing Features of Epiphytes

The distinguishing and remarkable feature of the epiphytic plant is their ability, in many cases their requirement, to grow in the canopy of the forest, rather than from the forest floor (Reynolds, 2003). Epiphytes have evolved to take advantage of resources not widely available to other plants (Fatland, 1996).

2.5 The Mode of Existence of Epiphytes

Epiphytes exist on their host plant by wrapping their root around the stem or branches (Kernan and Fower, 1995) and or by clustering with other epiphytes in mats (Matelson *et al.*1993); cited in Reynolds, 2003). Some epiphytes have adventitious roots, which enable them to cling or enter bark of the host plant or in the accumulated organic matter and litter at landing sites. This mode of existence is more challenging for these plants than for the forest floor would be. They face physical instability, reduced facilities for storage of nutrients

and water, high wind speed, and great fluctuation in temperature and moisture level (Reynolds, 2003). The absence of soil as anchoring substrate requires that the plant must obtain mineral nutrients and water from other sources (Fatland, 1996).

The sharp environmental gradients and periods of high stress existed in the habitat of the epiphyte have been important driving forces in evolutionary diversification (Gentry 1991; cited in Reynolds, 2003). The same author argued that epiphytic placement underneath a thick forest canopy creates a low light situation in which photosynthesis may be hindered so that they develop structural and physiological modification. Beside these competition for the above resources also provides a challenging for survival and successful reproduction of epiphytic flora.

In order to avoid the stressful habitat condition and to survive under these situations, epiphytes have evolved physical and structural adaptations. Structural and physiological adaptations found in epiphytes generally facilitate water retention, efficient gas exchange, efficient photosynthesis and acquiring mineral nutrients and reproduction (Fatland, 1996).

2.5.1 Structural Adaptations

Many epiphytes occupy microhabitats that dry rapidly and there has been strong selection for resisting drought. Generally epiphytes only have access to water after exposure to rain or dew (Fattland, 1996). With high environmental humidity in the rainforest, one would think water loss through transpiration would be a minimum (Johansson, 1974). High in the canopy, however, air circulation and turnover is greater than at the forest floor, so conditions are drier. With no direct water sources, adaptations are needed to conserve water (Vickery, 1984).

Many epiphytes have a waxy layer over their leaves to protect against water loss during dry periods and have roots that absorb water from the humid atmosphere (Reynolds, 2003). Many epiphytes also show zeromorphy, including thickened cuticle, sunken stomata and succulence (Vickery,1984). The same author published many tropical epiphytes belonging to the *Orchidaceae* family extend outward their roots into the air appearing as thick, un branched whitish organ. Covering the surfaces of the roots are a special layers of cells, which can take up water rapidly from the briefs of shower.

Shoot less ness or drought deciduousness (Benzing *et al.*1983; cited in Ng and Hew, 2000; Benzing,1990) are other alternative adaptation among epiphyte experiencing intermittent water supply. Humus epiphytes have a basket shaped leaf arrangement, which promotes the collection of plant material that can absorb and store water (Breedon, 1971; cited in Fatland, 1996). Nutrient scavenging in epiphyte is assisted by unusual morphological structures, but many of these (phytotel trichomes, Orchids velamen, radicum) may primary promote water up take (Heitz and Zotz, 2001). CAM epiphytes tend to be with thick leaves or succulent green stem (Ng and Hew, 2000). Some epiphytes spread their roots over the pant surface in such away that they are able to absorb the maximum available water, which look like a bird nest. Epiphytes thriving on small and exposed twigs are provided with water storing tanks (e.g. some orchids) and desiccation tolerant (*Polypodium* species) (Stuart, 1969; cited in Hietz and Hietz- Seifert, 1995^a).

2.5.2 Physiological Adaptation

In terms of plant water relation, there is an inevitable disadvantage of smaller plants because of less favored surface area to volume ratio (Schmidt *et al.* 2001; Schmidt and Zotz, 2001; Zotz and Thomas, 1999; all cited in Heitz and Zotz, 2001). According to these authors, larger plants do better in bridging rainless periods via a more efficient tank, and avoid large tissue water deficit by fast stomatal closure after tank water depletion.

2.6 Diversity and Distribution of Vascular epiphytes

In tropical rainforests epiphyte represents up to 25% of all vascular plants and over one third of all epiphytes are hemi-epiphytes (Nieder *et al.* 2001). The same author also estimated that vascular epiphytes constitute a large part of the global plant biodiversity (10% of all vascular plant species). Epiphytes are widely distributed throughout many plant divisions. Eighty-four vascular plant families have at least one epiphyte in the group (Fatland, 1996). Fatland (1996) has reported that about one third of ferns and monocot species are epiphytes. A great number epiphyte species are found in dicot than monocot species (Benzing, 1990; cited in Reynolds, 2003). Several plant families have large percentage of epiphytic species. According to Fatland (1996), in the class Liliopsida epiphytes are prevalent in the *Orchidaceae* (70% of the species are epiphytes) family. The same author also published that the class Magnoliopsida has several successful epiphytes containing families such *Piperaceae*. Eighty- nine percent of epiphytic vascular plants is angiosperms (Luttge, 1989).

Table 1. Taxonomic distribution of epiphytes among division of vascular plant, (source from Luttge, 1989)

	Epiphytic species	Total No of species.	%
All vascular plants	23466	231638	10
Division Pteridophytes (ferns)	2599	9000	20
Division Cycaophyta - Gnetophyta- Gymnosperms	4	770	0.5
Division Magnolophyta (Angiosperms)	20863	221868	9
Class Magnoliopsida (Dicotyledons)	4253	167893	3
Class Liliopsida (Monocotyledons)	16610	53975	31

2.7 Altitudinal Distribution of Epiphytes

Along altitudinal gradient, there is a drastic change of species number and striking differences in the percentage of different epiphytic families and genera (Bussmann *et al.* 2000). Johansson (1974) have published that the large altitudinal differences that exist in an area will naturally give different climatic conditions. The same author have published that several species of Pteridophytes and Orchids are more or less restricted to higher altitude on the Nimba mountain (in Liberia) and the proportion between the numbers of species of them altered with altitude.

According to Johansson (1974) in the high east African mountain, similar changes in the composition of epiphytic flora along the altitudinal gradients was observed. For example, on mountain Kenya, the trees near the forest boundary (at approximately 3200 m) were devoid of Orchids but exhibited a few pteridophytes, e.g. *Asplenium species* and *Pleopeltis excavata* (Bory.) Sledge. At 2600 m several species of Orchids were present. The same author also reported the altitudinal distribution of epiphyte on the eastern slope of mount Meru in Tanzania and between 2600-2700 m altitudes, only one orchid species was observed.

However, several species of Pteridophytes, e.g. *Asplenium aethiopicum* (Burm.F.) Becherer, and *A. Friesiorum* C. Chr. were abundant. At 2500 m the pteridophytes were very abundant e.g. *Asplenium aethiopicum* (Burm.F.) Becherer., *Pleopeltis macrocarp* (Willd.) Kaulf. and *Elaphoglossum* species. Only two orchid species were observed at this altitude. At 2250 m altitude in the Kiwira forest, at mount Rungwe in southern Tanzania, the ratio between the species of orchid and Pteridophyte was roughly 1:5 (Johansson, 1974). Epiphytes disappear according to (Tixier, 1966: 21; cited in Johansson, 1974) in tropical humid mountain forests, at an altitude of 3500 m in the Himalayas and Africa. Bussmann *et al.* (2000) has found that at an altitude of 2050 m in Estacion Cientifica San Francisco (ECSF), Ecuador, and the over all number of epiphyte species almost doubles compared with the diversity at altitudes existing above and below it.

2.8 Vertical distribution on phorophytes

The highest epiphyte diversity is always encountered in the upper most part of the trunk and the crown of the tree (Bussmann, *et al.* 2000) and this phenomenon doesn't change with altitude. The same author has reported that *Orchidaceae* and Pteridophyte mainly colonize the highest parts of the crowns. On the stem, the percentage of other families of the dicotyledonous is higher, and the number of hemiepiphytes increases.

Johansson (1974) has published that as it is possible to recognize the distribution pattern on the phorophyte according to the occurrence of a particular species of epiphyte, one also distinguishes a pattern for whole groups of epiphyte when the general distribution of epiphytes are considered. In the Johansson zone (the basal parts, main trunk, middle and upper crown), orchids, pteridophytes plus other vascular epiphytes, climbers and filmy ferns make a descending pattern on the host tree. These changes in epiphyte community composition is due to climatic and substrate factors. Most epiphyte species are able to grow in several zones except those adapted to the stem base (Hietz and Hietz Seifert, 1995^b).

Most epiphytes are able to cope with temporal drought, which is not too severe in a humid cloud forest, but a highly specialized group is restricted to the stem base by their high atmospheric humidity requirement. Such kinds of epiphytes, for example, Hymenophyllaceae, are practically incapable of regulating water loss by stomatal control and their root system may be too inefficient to substitute water loss in atmosphere not

permanently close to saturation with water vapour. A higher abundance of epiphytes occurred at intermediate height on the phorophytes probably because of an intermediate light incidence at these positions (Werneck *et al.* 2002).

Hietz and Hietz-Seifert (1995^a) published that, all species found with some frequency showed a clear vertical zonation, except for the more drought sensitive ferns (e.g. Hymenophyllaceae), which is restricted to the stem base, all others are found in several zones. Therefore, there is a clear gradient from the more shade loving to the sun loving and drought tolerant.

According to Johansson (1974), the distribution of vascular epiphytes is more or less restricted to one of two particular sections of phorophyte while a few occur more evenly in a number of sections. A large number of branches from several phorophytes were examined according to transect technique showed a rather clear distribution pattern for most species of epiphytes.

2.9 Epiphytes and the Host Traits

Epiphytes are found growing on trees, shrubs, lianas, leaves and submerged plants. They inhabit niches on trunks, limbs, branches and leaves of their host plant (phorophytes). The specificity of the host plants for epiphytes may be related to the traits of the host. Callaway *et al.* (2002) investigated that species-specific host relationships were highly correlated with water holding capacity of the tree bark. The same author published that the growth of epiphytes was significantly higher on host tree species that naturally bore high epiphyte loads than on host species with few or no epiphytes.

Epiphytes are specifically abundant on the forks of trees and horizontal branches, where anchor is easier and soil can collect. They are less abundant on the vertical and smooth surfaces (Johansson, 1974; Hietz and Hietz-Seifert, 1995; Annaselvam and Parthasarathy, 2001). According to Annaselvam and Parthasarathy (2001), positive relationship occurs between the trunk size and epiphytic association. Thick branches offer a different substrate, and are more densely covered and have been available for colonization for long time (Hietz & Hietz-

Seifert, 1995). These authors have published that the large numbers of species on bigger trees can be explained by large area offered, a greater variety of diameter, crotches, and knotholes available and high number of different microhabitat present for epiphytes. Especially thick branches are often densely covered with mosses and vascular epiphytes, accumulating substantial amount of humus, nutrients, and moisture.

Old trees carry the bulk of epiphyte biomass and diversity in forest by offering a larger surface and more diverse substrates. Host tree species had a strong effect on composition of the epiphyte community a fact related to differences in bark chemistry of the host. The suitability of a host tree for a vascular epiphyte appears to be related to the size, bark roughness and branching pattern. The stronger competition on thick branches might cause a different community structure.

2.10 The Bark of the Phorophytes

Johansson (1974) has published that the properties of the bark affect the epiphytes in several ways: the relief, growth habit, and its chemical composition affects the vascular epiphyte.

2.10.1 The Relief of the Bark

The importance of the bark's relief has been connected with the establishment of the seedling. A deep-fissured bark could provide both suitable microclimate for the germination of seeds and spores, and also easily prevent the young seedling from being washed away (Johansson, 1974). Went, (1940; cited in Johansson, 1974) observed the richness of rough bark in epiphyte floras. The same author has reported that phorophytes with a poor epiphyte flora frequently were found among species with smooth or hard bark. Furthermore the same author has reported that trees with defoliating barks seem to be very difficult for the epiphyte to colonize. However, several species of epiphytes seem to have a marked preference for smooth bark surfaces.

2.10.2 Bark pH

The pH value exhibits a more or less significant pattern within the phorophyte. The lowest value was obtained from the upper part of the main trunk and the outer branches (Johansson, 1974). Many authors using various

methods have studied the pH of the bark. It has been observed that the pH value decreases from the bases of the trees and upwards, probably due to decreasing dust content (Du Rietz, 1945; cited in Johansson, 1974).

According to Johansson (1974), when trying to evaluate the influence of pH value of the bark on the epiphytic flora, one should remember that the pH value might have changed since the time when the seedlings were established. The epiphytes themselves influence in a complex and imperfectly known way, the acidity in their environment. This can be done by collecting dust and forming humus, though photosynthesis, by release of lichen acids and exchange of ions (Kolkwitz, 1932; Skye, 1968; both cited in Johansson, 1974). Du Rietz (1945; cited in Johansson, 1974) distinguished 3 groups of barks based on their pH values. This author classified the barks by correlating the bark pH and the number of species it hosts. Accordingly, a bark with pH = 5 to 7 is rich bark, pH = 4 to 5, intermediate bark, pH < 4 is extremely poor bark.

2.11 Humus Deposit

2.11.1 Origin and Composition

The accumulation of humus starts with decomposition of the outer layers of barks by fungi, which in many cases are connected to the roots of epiphytes. The external materials like dead leaves, twigs, small branches etc from the phorophytes itself can be assumed to form the bulk of the deposit. The root systems of the epiphytes also help to catch debris. The deposition of humus can also take place through the accumulation of organic materials by wind, animals, and water running along branches and stems, help in the deposition of humus. Ants and termites carry material of inorganic and organic origin up in to the trees.

2.11.2 pH of Humus Deposit

Johansson (1974) has published that the pH of humus showed a rather high value, considerably higher than those of the bark. The same author has also reported that the pH value of humus deposit increases downward along the vertical gradient of the host trees. Each species of epiphyte utilize a wide range of humus pH (Boyer, 1964 and Schnell, 1952; both cited in Johansson, 1974)

2.1.2. Climatic Factors

2.12.1. Rainfall

Generally epiphytes only have access to water after exposure to rain or dew. Mature epiphyte success is more likely a factor of rainfall distribution during the year rather than total annual rainfall (Benzing, 1995; cited in Reynolds, 2003). The rainfall may not only be of importance for the water economy of the epiphyte but also serve as a source of nutrients. The high diversity of vascular epiphytes in the tropical forest may be the result of high rainfall distribution.

With high environmental humidity in the rain forest, one would think water loss through transpiration would be minimum. High in the canopy, however, air circulation and turnover is greater than at the forest floor, so condition is drier. In dry climates, epiphytes are restricted to non-vascular epiphytes but in warm, wet climates ferns and flowering plants are abundant (Vickery, 1984). Therefore, according to Vickery (1984), of all classes of vegetation, epiphytes are the most dependent on humidity.

2.1.2.2 Solar Radiation

Epiphyte growing on the top of trees includes cacti and bromeliads are specially adapted with an intense radiation and drought (Vickery 1984). Shade tolerant species are more often found close to the forest floor than requiring sun radiation (Reynolds, 2003). A higher abundance of epiphytes occurred at intermediate height of the phorophytes probably because of an intermediate light incidence at these position (Werneck *et al.* 2003).

2.12.4 Temperature

The temperature showed a smaller range of variation in the undergrowth than the upper level of the forest (Evan, 1939; cited in Johansson, 1974). According to the above author, in dry season the maximum temperature is about the same but in wet season the differences are much accentuated and the minimum temperatures in the undergrowths are in every case from one to two degrees higher than in the trees top (Johansson, 1974). The vertical temperature gradient shows, in the middle of the day, a fairly steady decrease from the canopy down to the undergrowth. At nighttime, the undergrowth is warmer than the air in the canopy.

3. Objectives of the study

3.1 General objective

- ❖ To document the species composition and to study the ecology of vascular epiphytes in Hareenna forest

3.2 Specific objectives

- ◆ To examine species diversity and ecology of vascular epiphytes in Hareenna forest.
- ◆ To study the vertical distribution of epiphytes on phorophytes and its distribution along an altitudinal gradient.
- ◆ To correlate the size, bark and humus pH as well as the bark textures of the host trees to species diversity and figure out what concerted role these parameters in either limiting or enhancing species diversity.

Research questions

- ❖ What are the species diversity, distribution, and abundance of vascular epiphytes in Hareenna forest?
- ❖ What is the host tree factors affecting the species diversity of vascular epiphytes? (size, pH, and bark textures, vertical gradient)
- ❖ What are the bark characteristics (bark pH and bark textures) that may affect species diversity of vascular epiphytes?
- ❖ Is the humus and bark pH affects the species diversity of vascular epiphytes?

4. MATERIALS AND METHODS

4.1 Description of the Area

4.1.1 Location

Haremma Forest is a moist Afromontane Forest, located in South Eastern part of Oromia regional state. It is a state forest found in Bale Mountain National Park. It is situated on the southern slopes of the Bale Mountain, and is about 480 km from Addis Ababa. It is located approximately between latitude 6° 20' and 6° 50' N and longitudes 39° and 40° E (Bussmann, 1997). The forest cover is estimated to be 3500-7000 km² and is the largest remaining in Ethiopia (Bussmann, 1997) and lies between an altitude of 3300 m- 1150 m asl. (Zerihun *et al.*1988).

4.1.2 Vegetation

The species composition of the Haremma Forest has been described by various authors including Friis (1986); Lissanework and Mesfin (1989); Bussmann (1997). These authors have identified almost similar vegetation zones along the altitudinal gradient of the forest. They have identified *Erica arborea* forest at an altitude of 3200-3500 m, *Hagenaea -Hypericum* forest at an altitude of 2800-3250 m, *Schefflera-Syzygium* forest at 2300-2800 m, *Aningeria-Olea-octea* forest at 1900-2300 m and *Podocarpus -Filicium* forest at 1450-1900 m asl.

Haremma Forest is a primary forest type showing an increased sign of disturbances (Zerihun *et al.*, 1988). The forest has been affected in one or other way by human activities. For example, the indigenous people living in the forest area were cutting down the forest trees for various purposes (for timber, fuel, etc). Their livestock were also causing heavy damage through grazing the under story herbs and shrubs. The damage caused by the local people was especially intensified in the northern part of the forest, where settlements are concentrated.

Haremma forest is characterized by its poorly developed shrub layers, which carry few numbers of species of vascular epiphytes. Epiphytes are mostly occurred on the big sized host trees that are also covered with dense mats of mosses. The vascular epiphytes are more abundant on the mosses covered portion of the stem especially for the flaky and smooth barked ones. The trees are bigger and diffusely branched at the higher and middle altitudes than the lower altitudes, though not denser. The less dense the forest tree means, the forest is open and light radiation penetrates down to the forest floor.

4.1.3 Climate

4.1.3.1 Temperature

The temperature of Hareenna Forest shows large variation between day and night. At night temperature was very cold. The mean monthly temperature of 10 years (1993-2003 EC) from the nearest weather station at Dollo-Menna is given in Fig.2. The mean monthly temperature was 22.48 °c (absolute minimum 15.51 °c, and absolute maximum 29.45 °c). During rainy seasons light cloud cover and fog occur normally on daily basis.

4.1.3.2 Rain fall

The mean annual rainfall recorded near weather station at Dollo-Menna showed that the rainfall is bimodal: March to May and September to November. The mean monthly rainfall data of 10 years (1993-2003 EC) from the near weather station at Dollo Menna was 85.78 mm and is given in Fig.2. The lowest monthly rainfall was 11.37 mm in June and the highest value was 219 mm in October.

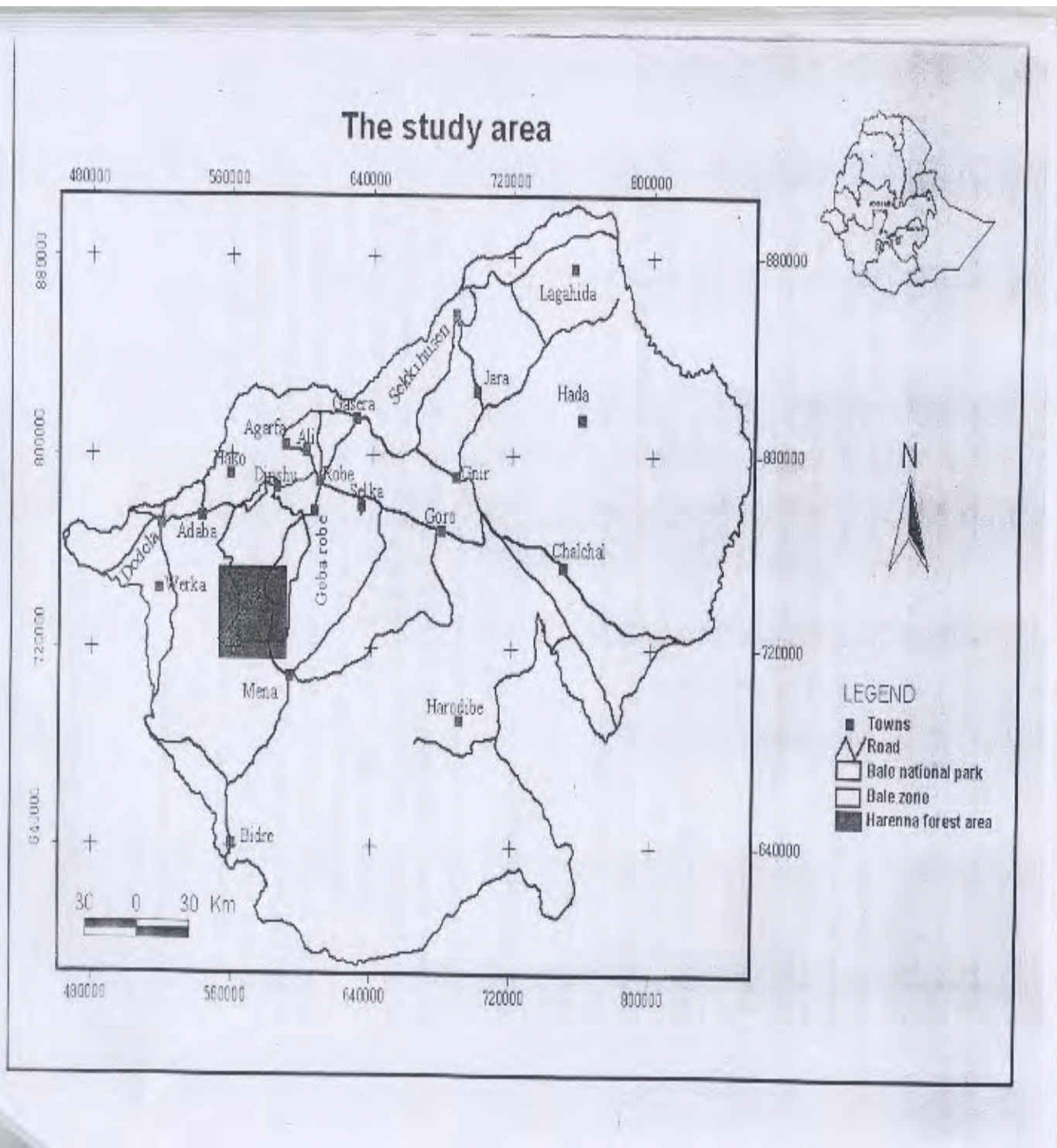


Figure 1. Map of the study area.

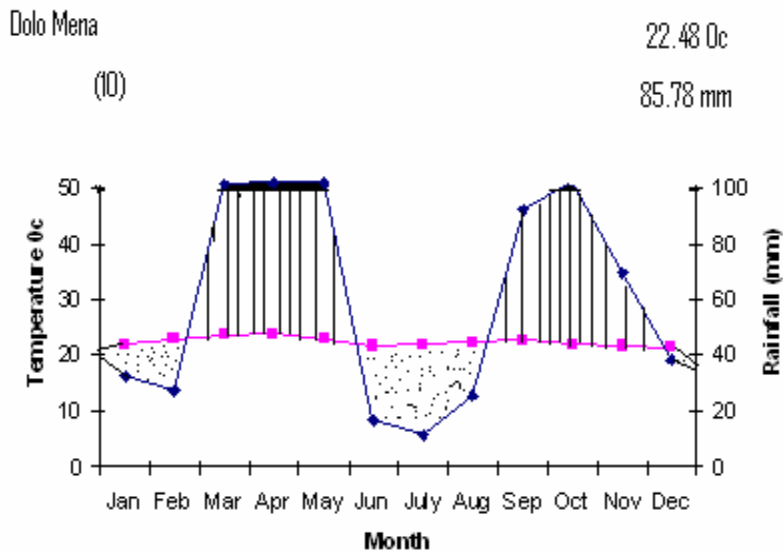


Figure 2. Clima diagram for Harena forest

4.1.3.3. Vegetation sampling

A reconnaissance survey of the study area was made on December 11/2004. The actual collection of the sample was carried out from 13 December 2004 to 12 January 2005. Sampling method employed was systematic sampling method. A line transect was laid along an altitudinal gradient between 3000-2000 m asl. Relevés were laid at every 25m-drop in altitude. The size of each releve was 25 m x 25 m (625m²) following the method used by Hietz and Hietz –Seifert (1995). In each releve, counting the number of individuals of species of epiphytes occurring on the phorophytes, measurement of DBH (diameter at breast height) and bark pH of phorophyte individuals, humus pH, sampling and recording of epiphyte and host tree species, and determination of the exact location of the epiphytes on the phorophytes were carried out. The area around the plot and along the transect line was searched systematically for additional epiphyte species in order to complete inventory. A total of 41 relevés were analyzed.

During sampling, all vascular epiphytes occurring on host trees rooted inside the plots were recorded. Sample collection of vascular epiphytes was performed with the help of indigenous climbers. Epiphyte individuals

occurring high up in the crown were counted and identified with the help of binocular. The number of vascular epiphytes on each phorophyte was counted. Those epiphytes occurring in dense stands such as *Peperomia abyssinica* and *Drynaria volkensii* were counted as one individual following Barthlott *etal.* (2001) and Johansson (1974), where one stand is counted as one individual.

To study the altitudinal distribution of vascular epiphytes, the altitudes were systematically classified in to higher (2700-3000 m), middle (2300-2675 m), and lower (2000-2275 m) altitudes. The vertical distribution of vascular epiphytes on the phorophytes was studied following Johansson zonation (Johansson, 1974). Accordingly, host trees were partitioned into 4 sections: (1) 0-2m above ground level, (2) stem from 2m to below first branch, (3) intermediate height (from first branch to below third branches), (4) upper crown (from third branch and above).

For the host trees (phorophytes), DBH (diameter at breast height) was measured. The bark textures (smooth, rough, or flaky), and inclination were recorded. The abundance, exact location on the phorophytes, and the life forms of epiphyte species were determined.

Sampling and determination methods of the bark and humus pH were done following the methods used by Johansson (1974). The procedures to determine the bark pH were the following: The outer most section of the bark pieces were removed and pulverized in a crucible in its fresh state. The crashed bark pieces were dried in a sun for 24 hours. Distilled water twice the dry weight of the sample was added. The pH measurement was performed 24 hours later by *IQ* pH meter.

To determine the pH of the bark and humus deposit in which the epiphytes are rooted, the sample of bark pieces and humus were collected from the point of attachment of the epiphytes to the phorophyte. The bark pH along the vertical gradient of the host trees was determined by sampling the bark pieces from three sections of the phorophytes (basal area, middle crown, and upper crown).

To measure the pH of humus deposit, the procedures used were the same to the one used for bark pH. The humus deposit was sieved using a mesh to remove some undecomposed materials added from the environment. Adding distilled water twice the dry weight of the humus in 100ml beakers formed the humus solution. The pH measurement was performed after 24 hours later using pH meter.

Dispersal syndrome of the epiphytes was determined by referring to different books, literature reviews, and published floras of Ethiopia and Eritrea (Hedberg and Edwards 1989; Edwards *et al.* 1995,1997, 2000; Mesfin, 2004). The life forms of epiphytes were recorded following Hosokawa (1943;cited in Freiberg, 1996).

Plant specimen identification to the family and species level took place at the National Herbarium of Addis Ababa University by means of taxonomic keys, comparison with Herbarium collection, with reference to the published volumes of Floras of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edward *et al.*1995, 1997,and 2000; Mesfin, 2004) and consultation of specialists.

Data Analysis

The relationship between the size of host trees and the numbers of epiphyte species it hosts, the relationship between number species of epiphytes and the hums pH, and as well as the relationship between the bark pH and

the number of epiphyte species per host trees were analyzed using regression correlation by statistical package SPSS version 10.0.5.

The diversity of vascular epiphytes in Hareenna Forest was analyzed using Shannon - Weiner diversity index (Shannon and Weiner, 1949). Shannon - Weiner diversity index is calculated by the following formula.

$$\text{Shannon -Weiner index } (H') = -\sum P_i \ln P_i$$

Where P_i is the proportion of a species compared to the total abundance.

The influence of bark textures of the phorophyte on the diversity of epiphytes species per tree was compared by calculating the mean number of species it hosts

5. RESULTS

5.1 Species diversity of vascular epiphytes

Fifty-five species of vascular epiphytes belonging to 35 families were recorded in the current study (Table 2). Of these, holoepiphytes have constituted only 40%, hemiepiphytes about 5% and edaphic (humus) epiphytes about 55% (Fig.3). In holoepiphytes, the most species rich family is *Aspleniaceae* and is followed by *Orchidiaceae* and *Polypodiaceae*. The least species rich family was found to be *Campanulaceae*, *Piperaceae*, and *Urticaceae* (Fig.4). The species diversity of the vascular epiphyte for the study area is calculated using Shannon-Weiner index and it shows low value ($H' = 1.62$)

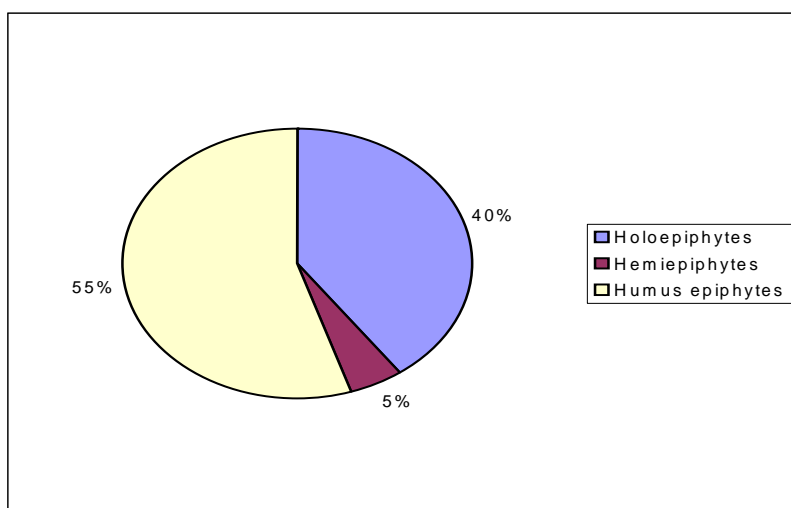


Figure 3. Percentage of species of the three types of vascular epiphytes in Harena Afromontane Forest

Holoepiphytes are with less family and species rich than the edaphic ones but more family and species than hemiepiphytes (Fig.5). In terms of life cycle, most of the species of edaphic epiphytes are perennial. It is to be noted that the edaphic epiphytes could be loosely categorized into two, i.e., those which thrive to maturity (e.g. *Impatiens aethiopica*, *Kalanchoe petitiiana*) and those which fail to grow to maturity because their nutrient demand is more than provided by a substratum. Examples of the latter are seedlings of tree species such as *Allophylus rubifolius* and *Bersama abyssinica*.

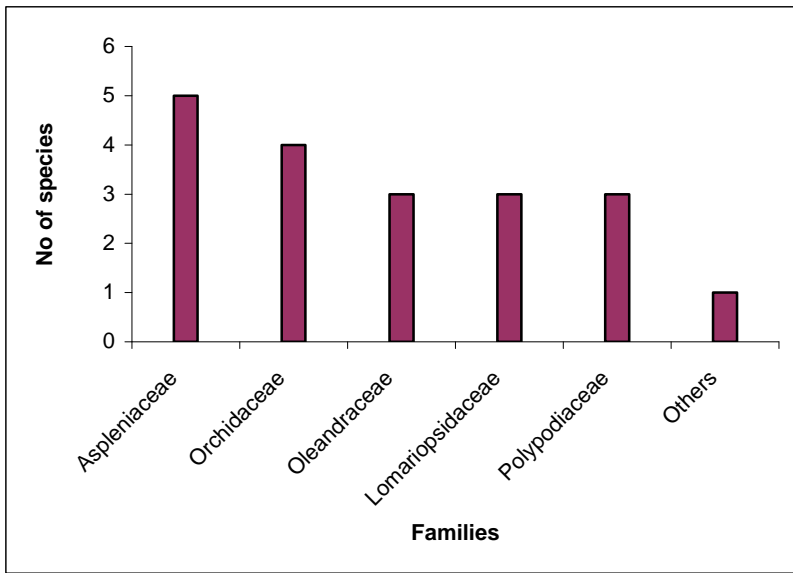


Figure 4. The species richness of the families of holoepiphytes.

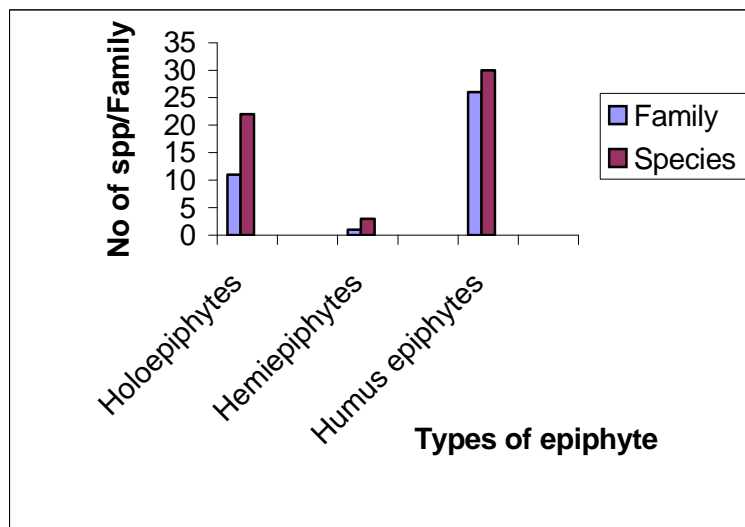


Figure 5. Types and number of species and families vascular epiphytes in Harena Afromontane Forest

5.2 Basic dispersal syndromes of vascular epiphytes

In the study area 21 wind dispersed (anemochory), 7 animals dispersed, and 2 self- dispersed humus epiphytes were recorded (Fig.6). The proportion of wind-dispersed taxa is the highest, which is in turn followed by

epizoochory (e.g. *Achyranthes aspera*) and orinthochory (e.g. *Memordica* species) or dispersed by birds. The fleshy propagules are of two types in the current study, i.e., relatively small, indehiscent and large and berry. The former is exemplified by *Kniphofia foliosa* and the latter by *Memordica* species. It is also to be noted that some of the species recorded as edaphic epiphytes occur in both ericaceous and afroalpine belts sensu Hedberg (1951). Examples are *Kniphofia foliosa* and *Cerastium octandrum*. Mechanical dispersal syndrome via ejaculating seeds forcefully was recorded in edaphic epiphytes such as *Impatiens* species.

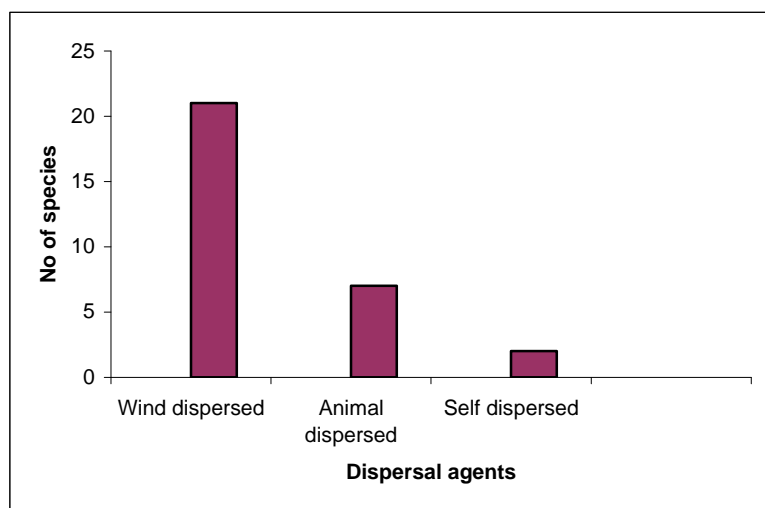


Figure 6. Major dispersal mechanisms of edaphic vascular epiphytes in Harena Afro alpine forest.

In Harena Forest 19 wind dispersed, 3 animal dispersed vascular holoepiphytes were recorded (Fig.7). No self-dispersed species of holoepiphytes was recorded in the current study. Further diasporas dispersal syndrome, i.e., exozoochory (dispersal via sticky diasporas as in *Peperomia abyssinica* was recorded in the current study. From the standpoint of dispersal, the currently recorded holoepiphytes of Bale Mountains are grouped in to two, i.e. minute spores (pteridophytes), minute seeds (orchids) and fruit of small berry (*Peperomia*). The first two are adapted for wind carriage and the last one for bird dispersal. Dispersal from tree to tree is obviously mediated by these dispersal mechanisms.

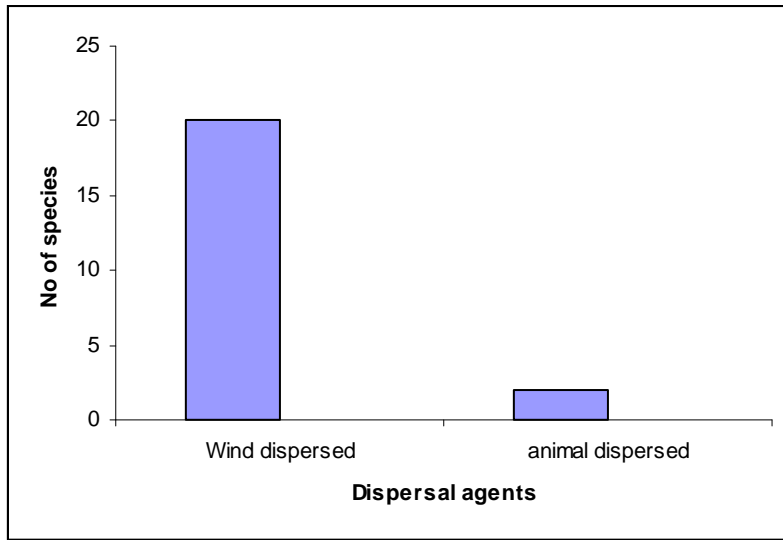


Figure 7. General dispersal mechanisms of Holoepiphytes in Harena Forest

5.3 Host specificity of vascular holoepiphytes epiphytes

In the study area, most vascular holoepiphyte species (90.9%) were not host specific. They were recorded from more than 3 and above species of phorophytes. Only 2 species of vascular epiphytes (9.1%) were recorded from specific host trees species from the current study. The orchid species, *Aerangis brachycarpa* was recorded from one phorophyte, *Vernonia amygdalina* and *Liparis diestelii* was recorded from two different species of phorophyte: *Schefflera volkensii* and *Erythrina brucei*. On the other hand almost all phorophytes (92%) carry 3 and more than 3 species of vascular epiphytes. Only two species phorophytes, *Lepidotrichlia volkensii* and *Canthium oligocarpum* hosts 2 species of epiphytes

Table 2 Lists of vascular holoepiphytes, hemi-epiphytes, and edaphic epiphytes recorded from Harena Afromontane forest.

Holoepiphytes

Species

Adiantum incisum Forssk.
Asplenium gemmiferum Dominii
Asplenium theciferum (Kunth.) Mett.
Asplenium aethiopicum (Burm. F.) Becherer
Asplenium anisophyllum O. Kuntze
Asplenium protensum Schard.
Canarina eminii Ascherers ex A. Weinnif
Elaphoglossum lastii (Baker.) C.Chr.
Elaphoglossum deckenii (Khun.) C.Chr.
Huperizia ophioglossoides Lam.Rothm.
Olendra distenta Kunze
Arthropteris monocarpa (Cordon) C.Chr.
Diaphananthe schimperiana (A. Rich) Sumerh.
Liparis deistelii Schtr.
Aerangis brachycarpa (A. Rich) Rchb. F.)
Diaphananthe tenuicalar (A. Rich) Sumerh
Peperomia abyssinica Miq.
Pleopeltis excavata (Bory ex Wild.) Slodge
Pleopeltis macrocarpa (Bory ex Wild) Slodge
Drynaria volkensis Hieron
Elastostema orientale Engl.
Vittaria guineesii Desv.

Family

Adiantaceae
Aspleniaceae
Aspleniaceae
Aspleniaceae
Aspleniaceae
Aspleniaceae
Campanulaceae
Lomariopsidaceae
Lomariopsidaceae
Lycopodiaceae
Olendraceae
Olendraceae
Orchidiaceae
Orchidiaceae
Orchidiaceae
Orchidiaceae
Piperaceae
Polypodiaceae
Polypodiaceae
Polypodiaceae
Urticaceae
Vittariaceae

Hemi-epiphytes

Schefflera volkensis (Engl.) Harms
S. abyssinica (Hochst ex Rich.) Harms
S. myriantha (Bak.) Drake

Araliaceae
Araliaceae
Araliaceae

Continued

Edaphic (humus) epiphytes**Species**

Acanthus emenii C.B. Clarke
Achyranthus aspera L.

Families

Acanthaceae
Amaranthaceae

<i>Arisaema addis abebensis</i> Chiov	Araceae
<i>Kniphofia foliosa</i> Hochst	Asphodelaceae
<i>Sonchus melanolepis</i> Fresen	Asteraceae
<i>Senecio myrinocephalum</i> Sch.B.P. ex A. Rich.	Asteraceae
<i>Vernonia auriculifera</i> Hiern	Asteraceae
<i>Helichrysum schimperi</i> Sch.B.P.Moesner	Asteraceae
<i>Impatiens aethiopica</i> Grey-Wilson	Balsaminaceae
<i>Cerastium octandrum</i> Hochst.ex A. Rich	Caryophyllaceae
<i>Convolvulus kilimandschari</i> Engl.	Convolvulaceae
<i>Memordica friesirum</i> (Harm.) Jeffery	Cucurbitaceae
<i>Polystichum piceopalenceum</i> Dominii	Aspidiaceae
<i>P. ammifolium</i> (Poir.) C.Chr.	Aspidiaceae
<i>Asplenium. protensum</i> Schard	Aspleniaceae
<i>Carex johnstoni</i> Boeck.	Cyperaceae
<i>Carex beguaertii</i> De.Willd	Cyperaceae
<i>Asplenium bugoinse</i> Hieron	Aspleniaceae
<i>Medicago polymorpha</i> L.	Fabaceae
<i>Lepidotrichilia volkensis</i> Fresen	Meliaceae
<i>Bersama abyssinica</i> Fresen	Melanthaceae
<i>Botrychium virginicum</i> S.W.	Ophioglossaceae
<i>Holthriix unifolia</i> Rcbb.F.	Orchidiaceae
<i>Sporobulus piliferus</i> (Trin) Kunth	Poaceae
<i>Pavetta abyssinica</i> Fresn	Rubiaceae
<i>Allophylus rubifolus</i> (Hochst ex A.Rich.) Engl.	Sapindiaceae
<i>Drougutia ineris</i> (Forrsk) Scheinf	Urticaceae
<i>Urera hypselodendron</i> Desv	Urticaceae
<i>Lobelia giberroa</i> Hemsl	Lobeliaceae
<i>Kalanchoe petitiانا</i> A. Rich.	Crassulaceae

5.4 Life-form systems of holoepiphytes

The most common life-form system of epiphytes was a creeping with buds close to a substrate (Mobiligemmi), namely, a tufted and upright form where the buds are close to one another. A densely tufted and hanging life form is the second most common one within the Mobiligemmi. Rosette forms (Fasicularis) and creeping forms with buds far away from the substrate (Scandens vel Volubilis) is the relatively infrequent. A creeping life-form with buds far apart is the rare one recorded in the current study. The life forms recorded for each species of holoepiphyte is given (Table 3)

5.5 Altitudinal Distribution of Vascular epiphytes

The distribution pattern of each epiphyte species along the altitudinal gradient is different (Table 4). Some species, for example, *Asplenium aethiopicum*, *Peperomia abyssinica*, and *Asplenium gemmiferum* occur through out the altitudinal gradient. Other groups vascular epiphyte species such as *Pleopeltis excavata*, *Asplenium protensum*, and *Elaphoglossum deckenii* were restricted to the higher altitudes. The third group were restricted to middle altitudes were *Liparis deistelii*, and *Asplenium theciferum*. Lastly, there are species such as *Diaphananthe tenuicalar* and *Aerangis brachycarpa*, which are restricted to the lower altitudes. From this pattern of distribution one can recognize the increment of the number of species to wards the lower altitudes.

Table 3. Holoepiphytic species and life-form systems in Hareenna Afromontane forest.

Taxon	Life-form systems
<i>Adiantum incisum</i>	Reptata densa upright

<i>Asplenium gemmiferum</i>	Reptata densa upright
<i>Asplenium theciferum</i>	Reptata densa upright
<i>Asplenium aethiopicum</i>	Reptata densa upright
<i>Asplenium anisophyllum</i>	Reptata densa upright
<i>Asplenium trichomones</i>	Reptata densa upright
<i>Canarina eminii</i>	Reptata densa pendulus
<i>Elaphoglossum lastii</i>	Reptata densa pendulus
<i>Elaphoglossum deckenii</i>	Reptata densa upright
<i>Huperizia ophioglossoides</i>	Reptata densa pendulus
<i>Olendra distenta</i>	Reptata densa pendulus
<i>Arthropteris monocarpa</i>	Reptata densa upright
<i>Diaphananthe schimperiana</i>	Reptata densa pendulus
<i>Liparis deisteli</i>	Fasiculari
<i>Aerangis brachycarpa</i>	Fasicularis
<i>Diaphananthe tenuicalar</i>	Reptata densa pendulus
<i>Peperomia abyssinica</i>	Reptata remota
<i>Pleopeltis excavata</i>	Reptata dense upright
<i>Pleopeltis macrocarpa</i>	Reptata dense upright
<i>Drynaria volkensis</i>	Fasicularis
<i>Elastostema orientale</i>	Reptata dense upright
<i>Vittaria guineese</i>	Reptata densa pendulus

Table 4. Patterns of altitudinal distribution of vascular **holoepiphytes** and **Hemi-epiphytes**

A= 3000-2900m, B=2875-2800m, C= 2775-2700m, D= 2675-2600m, E= 2575-2500m F=2475-2400m, G=2375-2300m, H=2275-2200m, I =2175-2100m, J= 2075-2000m

Holoepiphytes

Species	Altitudinal ranges
---------	--------------------

	A	B	C	E	F	G	H	I	J	K
<i>Asplenium gemmiferum</i>	+	+	+	+	+	+	+	+	-	+
<i>Asplenium aethiopicum</i>	+	+	+	+	+	+	+	+	+	+
<i>Asplenium anisophyllum</i>	+	+	+	+	+	+	+	+	+	+
<i>Pleopeltis macrocarpa</i>	+	+	+	+	+	+	+	+	+	+
<i>Drynaria volkensii</i>	-	+	+	+	+	+	+	+	+	+
<i>Elastostema orientale</i>	+	+	+	+	+	+	+	+	+	+
<i>Peperomia abyssinica</i>	+	+	+	+	+	+	+	+	+	+
<i>Diaphananthe schimperiana</i>	+	+	+	+	+	+	+	+	+	+
<i>Asplenium protensum</i>	+	-	-	-	-	-	-	-	-	-
<i>Pleopeltis excavata</i>	+	-	-	-	-	-	-	-	-	-
<i>Elaphoglossum lastii</i>	+	+	-	-	-	-	-	-	-	-
<i>Elaphoglossum deckenii</i>	+	+	-	-	-	-	-	-	-	-
<i>Adiantum incisum</i>	+	+	-	-	-	-	-	-	-	-
<i>Canarina eminii</i>	+	+	+	+	+	-	+	+	-	-
<i>Huperizia ophioglossoides</i>	-	+	+	+	+	+	+	+	-	-
<i>Asplenium theciferum.</i>	-	-	-	+	+	-	+	-	-	-
<i>Liparis deistelii</i>	-	-	-	-	+	-	-	-	-	-
<i>Vittaria guineesii</i>	-	-	-	-	-	+	+	+	+	+
<i>Olendra distenta</i>	-	-	-	-	-	-	+	+	+	-
<i>Arthropteris monocarpa</i>	-	-	-	-	+	+	+	+	+	+
<i>Diaphananthe tenuicalar</i>	-	-	-	-	-	-	-	+	+	-
<i>Aerangis brachycarpa</i>	-	-	-	-	-	-	-	-	+	-

Hemi epiphytes

<i>Schefflera volkensii</i>	+	+	+	+	+	+	+	+	+	+
<i>S. abyssinica</i>	+	+	+	+	+	+	+	-	-	-
<i>S. myriantha</i>	-	-	-	-	-	+	+	+	+	-

5.6. Vertical distribution of epiphytes on phorophytes

Distribution of species of vascular epiphytes on the phorophytes is not the same from basal parts to the top most branches. The lists of the species of vascular epiphytes recorded from different section of the phorophyte are given in Table 5., and the tree sections are represented in Fig.8. This distributional pattern is not influenced by altitudinal changes. Depending on this, the species of vascular epiphytes such as *Asplenium aethiopicum*,

Peperomia abyssinica, and *Asplenium anisophyllum* were found distributed in all sections of phorophytes. On the other hand, species such as *Adiantum incisium* is restricted to the basal region of the phorophytes (Class A). Although they lack wide amplitude of climate gradient, some species, e.g. *Pleopeltis macrocarpa* and *Elaphoglossum deckenii*, *Drynaria volkensii* are well represented in a most portion of the phorophytes (class B-D). In the present study, strict xeric and light demanding epiphytes are characterized by *Canarina emenii*, *Diaphananthe* species and *Huperzia ophioglossoides*. Noteworthy is also that the edaphic epiphytes are restricted to classes A & B while the hemiepiphytes extend only to Class C.

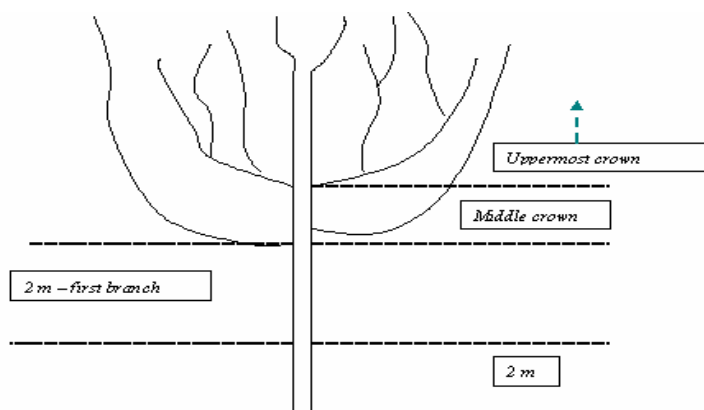


Figure 8. Schematic representation of vertical microclimate gradient of phorophytes.

Table 5. Lists of species of vascular epiphytes distributed in different zones of the phorophytes.

Class A = base area (0 - 2m above ground), Class B = 2m - first branches, Class C = middle crown (first branches to below third branches), Class D = upper crown (above third branches)

Species	Class of phorophytes			
	Class A	Class B	Class C	Class D

<i>Asplenium. theciferum</i>	+	+	+	+
<i>Asplenium aethiopicum</i>	+	+	+	+
<i>Asplenium anisophyllum</i>	+	+	+	+
<i>Elaphoglossum lastii</i>	+	+	+	+
<i>Elaphoglossum deckenii</i>	+	+	+	+
<i>Arthropteris monocarpa</i>	+	+	+	+
<i>Schefflera volkensii</i>	+	+	+	+
<i>Schefflera abyssinica</i>	+	+	+	+
<i>Peperomia abyssinica</i>	+	+	+	+
<i>Drynaria volkensii</i>	-	+	+	+
<i>Pleopeltis macrocarpa</i>	-	+	+	+
<i>Asplenium. protensum</i>	-	+	+	+
<i>Elastostema orientale</i>	+	+	-	-
<i>Liparis deistelii</i>	+	+	-	-
<i>Adiantum incisum</i>	+	-	-	-
<i>Asplenium gemmiferum</i>	+	-	-	-
<i>Pleopeltis excavata</i>	+	-	-	-
<i>Aerangis brachycarpa</i>	-	+	-	-
<i>Schfflera myriantha</i>	-	+	+	+
<i>Canarina eminii</i>	-	-	+	+
<i>Olendra distenta</i>	-	-	+	+
<i>Huperizia ophioglossoides</i>	-	-	+	+
<i>Vittaria guineese</i>	-	-	+	+
<i>Diaphananthe schimperiana</i>	-	-	+	+
<i>Diaphananthe tenuicalar</i>	-	-	+	+

Continued

Species	Class of phorophytes			
	Class A	Class B	Class C	Class D
<i>Acanthus eminii</i>	-	+	-	-
<i>Achyranthus aspera</i>	+	-	-	-
<i>Arisaema addis abebensis</i>	+	-	-	-
<i>Kniphofia foliosa</i>	+	-	-	-
<i>Sonchus melanolepis</i>	+	-	-	-

<i>Senecio myrinocephalum</i>	+	-	-	-
<i>Vernonia auriculifera</i>	+	-	-	-
<i>Helichyrisum schimperi</i>	+	-	-	-
<i>Impatiens aethiopicum</i>	+	-	-	-
<i>Cerastium octandrum</i>	+	-	-	-
<i>Convolvulus klimandascharii</i>	+	-	-	-
<i>Momordica friesirum</i>	+	-	-	-
<i>Polystichum piceopalenceum</i>	+	-	-	-
<i>P. amnifolium</i>	+	-	-	-
<i>Asplenium trichomonas</i>	+	+	-	-
<i>Carex johnstonii</i>	+	-	-	-
<i>Asplenium bugoinse</i>	+	+	-	-
<i>Carex beguaertii</i>	-	+	-	-
<i>Medicago polymorpha</i>	+	-	-	-
<i>Lepidotrichilia volkensis</i>	+	-	-	-
<i>Bersama abyssinica</i>	+	-	-	-
<i>Botrychium viginicum</i>	-	+	-	-
<i>Holothix unifolia</i>	-	+	-	-
<i>Sporobulus piliferus</i>	-	+	-	-
<i>Pavetta abyssinica</i>	-	+	-	-
<i>Kalanchoe petitiana</i>	+	+	-	-
<i>Allophyllus rubifolius</i>	+	-	-	-
<i>Droglitia ineris</i>	+	-	-	-
<i>Urera hypselodendron</i>	+	-	-	-
<i>Lobelia giberroa</i>	-	+	-	-

5.7 Epiphytes and characteristics of Phorophytes

The present study has identified 24 species of phorophytes distributed into 18 families of vascular plants (Table 6).

Table 6. Lists of species of **phorophytes** in Harena Forests of Bale Mountains.

Species	Families
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<i>Allophylus abyssinicus</i> (Hochst.) Radlkofer	Sapindaceae
<i>Bersama abyssinica</i> Fresen.	Meliaceae
<i>Buddleja polystachya</i> Fresen.	Loganiaceae
<i>Diospyros mespiliformis</i> Hochst. ex. A.DC.	Ebenaceae
<i>Dombeya torrida</i> . L.	Sterculiaceae
<i>Canthium oligocarpum</i> Hieron	Rubiaceae
<i>Croton macrostachyus</i> Hochst ex A. Rich.	Euphorbiaceae
<i>Ficus sur</i> Forssk.	Moraceae
<i>Galiniera saxifraga</i> (Hochst.) Bridson	Rubiaceae
<i>Celtis africana</i> Burm.F.	Ulmaceae
<i>Hagenia abyssinica</i> J.F. Geml	Rosaceae
<i>Hypericum revolutum</i> (Forssk.) Vahl	Hypericaceae
<i>Lepidotrichlia volkensii</i> (Gurke) Leroy	Araliaceae
<i>Maytenus addat</i> (Loes.) Sebsebe	Celastraceae
<i>Prunus africana</i> (Hook. F.) Kalkam.	Rosaceae
<i>Polycias fulva</i> (Hiern) Harms.	Araliaceae
<i>Myrsine melanophlooes</i> (Hochst.ex A.)Dc. Mez.	Euphorbiaceae
<i>Schefflera abyssinica</i> (Hochst. ex A.Rich.)Harms.	Araliaceae
<i>Schefflera volkensii</i> (Engl.) Harms.	Araliaceae
<i>Syzygium guineense</i> (Willd.) D.C..	Myrtaceae
<i>Erythrina brucei</i> Schweinf.	Fabaceae
<i>Rydingynia neglecta</i> (Hiern.) Robiins	Rubiaceae
<i>Vepris dainellii</i> (Pichi-Serm.) Kokuaro	Rutaceae
<i>Vernonia amygdalina</i> Del.	Compositae

A regression analysis of the DBH of phorophyte and number of vascular epiphytic species has found to be significantly related in almost a linear fashion ($R^2 = 0.34$, $p = 0.0001$; Fig. 9). An increase in a DBH entailed an increase in the number of species of vascular epiphytes. It is evident that the size of the host trees and the number of species it hosts are positively correlated (Fig.8).

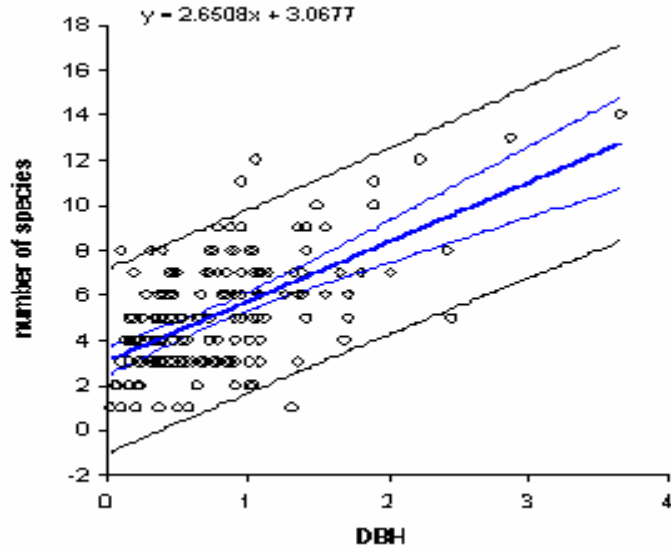


Figure 9. Relationship between DBH of phorophytes and number of species vascular epiphytes.

Nature of bark determines the number of epiphytes, which settle on a tree. In the present study, the bark of phorophytes was classified into three, i.e., rough, smooth, and flaky. Most phorophytes (92%) were rough barked. The rest (8%) were smooth and flaky barked. The average number of epiphyte species on flaky bark and rough barked phorophytes were the same, but the smooth barks hosted little number of species.

Although *Hagenia abyssinica* has flaky bark, the older trees hosted a high number of species of vascular epiphytes mainly at their middle and uppermost crown. Similarly, the bark of *Polyscias fulva* is more or less smooth and the epiphytes were found confined to the forks of branches of middle and uppermost crown (Class C & D, see above).

5.8 Biochemical features of phorophytes as a function of diversity of vascular epiphytes

The basic chemistry of bark and deposited humus will be presented in this section.

5.8.1 Bark pH

A regression analysis of bark pH and species diversity of vascular epiphytes is given in Fig. 10. and the correlation is nonlinear ($R^2 = 0.01$, $P = 0.001$). Unlike humus pH, bark pH ranges from acidic to neutral pH (Table 7). In the case of holoeiphytes, some species occur in all pH ranges in line with the above limit for bark and others have a restricted pH range. All of the hemieiphytes occur in two or all of the pH ranges for bark. The pH range is very restricted for accidental/opportunistic vascular epiphytes (Table 8)

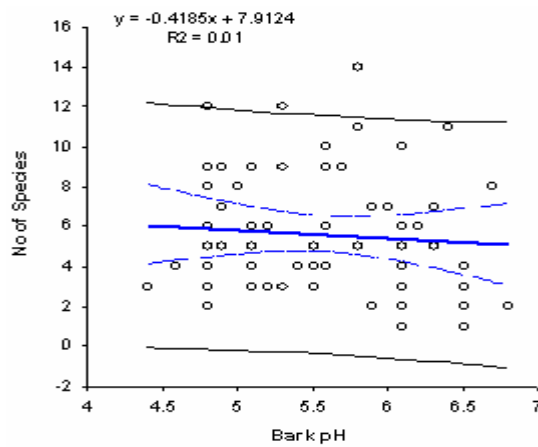


Figure 10. Relationships between bark pH and number of vascular epiphytes.

Table 7. Lists of species of vascular **holoeiphytes** and **hemieiphytes** existing in different ranges of bark pH.

holoeiphytes

Species	Bark pH			Humus pH			
	4.0-5.0	5.1-6.0	6.1-7.0	4.0-5.0	5.1-6.0	6.1-7.0	7.1-8.0
<i>Asplenium gemmiferum</i>	+	+	+	+	+	+	+
<i>Asplenium aethiopicum</i>	+	+	+	+	+	+	+

<i>Asplenium anisophyllum</i>	+	+	+	+	+	+	+
<i>Pleopeltis macrocarpa</i>	+	+	+	+	+	+	+
<i>Drynaria volkensis</i>	+	+	+	+	+	+	+
<i>Elastostema orientale</i>	+	+	+	+	+	+	+
<i>Elaphoglossum deckenii</i>	+	+	+	-	-	+	+
<i>Peperomia abyssinica</i>	+	+	+	-	+	+	+
<i>Pleopeltis excavata</i>	+	+	+	-	+	+	+
<i>Arthropteris monocarpa</i>	+	+	-	+	+	+	+
<i>Canarina eminii</i>	-	+	+	+	+	+	+
<i>Diaphananthe scheimperiana</i>	-	+	+	-	+	-	-
<i>Diaphananthe tenuicalar</i>	-	+	+	-	+	-	-
<i>Huperizia ophioglossoides</i>	-	+	+	-	+	+	-
<i>Asplenium theciferum</i>	-	+	+	-	+	+	+
<i>Adiantum incisum</i>	-	-	+	-	-	-	+
<i>Vittaria guineese</i>	+	-	-	+	-	-	-
<i>Aerangis brachycarpa</i>	+	-	-	-	+	-	-
<i>Elaphoglossum lastii</i>	+	-	-	-	-	+	-
<i>Asplenium protensum</i>	-	+	-	-	+	-	-
<i>Liparis deisteli</i>	-	+	-	-	+	+	-
<i>Oleandra distenta</i>	+	+	-	-	+	-	-

Hemiepiphytes

<i>Schefflera volkensis</i>	+	+	+	+	-	+	-
<i>S. abyssinica</i>	+	+	-	-	-	-	
<i>S. myriantha</i>	+	+	-	-	-	-	-

continued

Table 8. Species lists of **humus epiphytes** occurred in different ranges of humus and bark pH

Species	Bark pH			Humus pH			
	4.0-5.0	5.1-6.0	6.1-7.0	4.0-5.0	5.1-6.0	6.1-7.0	7.0-8.0
<i>Achyranthus aspera</i>	+	-	-	-	-	-	+
<i>Sonchus melanolepis</i>	+	-	-	-	+	-	+
<i>Convolvulus klemandaschrii</i>	+	-	-	+	-	-	-

<i>Asplenium. thrichomanes</i>	+	-	-	+	-	-	-
<i>Carex beguaertii</i>	+	-	-	+	-	-	-
<i>Lepidotrichilia volkensii</i>	+	-	-	+	-	-	-
<i>Holthriix unifolia</i>	+	-	-	+	-	-	+
<i>Allophylus rubifolus</i>	+	-	-	+	-	-	-
<i>Drougutia ineris</i>	+	-	-	+	-	-	-
<i>Urera hypselodendron</i>	+	-	-	-	-	+	-
<i>Acanthus eminens</i>	-	+	-	-	-	-	+
<i>Arisaema addis abebensis</i>	-	+	-	-	-	+	-
<i>Knifofia foliosa</i>	-	+	-	-	--	+	+
<i>Senecio myrinocephalum</i>	-	+	-	+	-	-	-
<i>Vernonia auriculifera</i>	-	+	-	-	-	-	+
<i>Helichrysum scheimperi</i>	-	+	-	-	-	-	+
<i>Impatiens aethiopica</i>	-	+	-	-	-	+	-
<i>Cerastium octandrum</i>	-	+	-	-	-	+	-
<i>Momordica friesirum</i>	-	+	-	+	-	+	+
<i>Carex johnstoni</i>	-	+		+	-	-	-
<i>Asplenium bugoinse</i>	-	+	-	-	-	+	-
<i>Medicago polymorpha</i>	-	+	-	-	-	-	+
<i>Bersama abyssinica</i>	-	++	-	-	-	+	-
<i>Botrychium virginicum</i>	-	+	-	-	-	-	+
<i>Pavetta abyssinica</i>	-	+	-	-	-	+	-
<i>Kalanchoe petitiana</i>	-	+	-	-	-	-	+
<i>Lobelia gibberoa</i>	-	+	-	-	-	+	+
<i>Sporobulus piliferus</i>	-	+	-	-	-	+	-
<i>Polystichum piceopalenceumi</i>	-	-	+	-	-	-	+
<i>P. ammifolium</i>	-	-	+	-	-	-	+

5.8.2 Humus pH

The pH of humus deposit on the phorophytes (host trees) was measured and the average values on each species of phorophyte are given (Appendix 1). The range of humus pH values from which the whole epiphytes were collected is in between 4.0 to 8.0 (Table 7 and 8). Most vascular epiphytes occurred in a wider range of humus pH, for example, *Asplenium aethiopicum*, *Elastostema orientale*, and *Drynaria volkensii*. Other species exist in

very narrow humus pH for example, *Elaphoglossum lastii*, *Adiantum incisum*, and *Asplenium protensum*. Hemiepiphytes don't utilize humus materials after they have attached to the host trees. Their seed can germinate in the absence of humus in the cracks of the bark. Almost all humus epiphytes occurred in very narrow range of humus pH. Linear regression ($R^2 = 0.01$; $P = 0.001$) was calculated to test the relationship between the number of species of epiphytes and the pH of humus deposit from which they were collected and it shows nonlinear relationship. The pH values of humus exhibited more or less higher than the bark pH (Appendix 1).

There is no linear relationship exist between humus pH and number of taxa of vascular epiphytes (Fig.11). The general trend is, however, that there are relatively high taxa at and almost near neutral pH. There are very few species, which were recorded at acidic pH (Table 7 and 8). It is also to be noted that some species have wide amplitude of pH, i.e., occurring from acidic to alkaline pH (e.g. *Asplenium aethiopicum*) and others have a given sets of restricted or specific pH ranges e.g. *Adiantum incisum* or *Elaphoglossum lastii* (Table 7 and 8).

On the other hand, humus pH is a major limiting factor for germination and ephemeral establishment of accidental/opportunistic vascular epiphytes. For example, *Achyranthes aspera* can only be established at acidic pH while *Lobelia giberroa* establishes a neutral to alkaline pH. There are also species, which grow from a less acidic to neutral pH, e.g. *Sporobolus piliferus* and *Cerastium octandrum*. One hemi-epiphyte, *Schfflera volkensii* falls in the latter category.

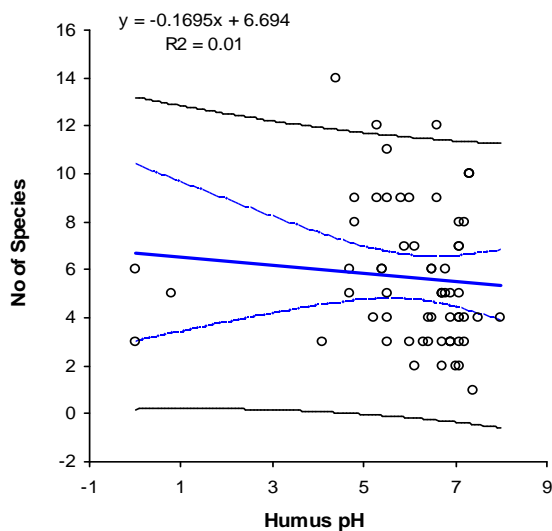


Figure11. Relationship between humus pH and number of species of vascular epiphytes.

Interrelationship of bark and humus pH used by vascular epiphytes species was explored to record their interactions, i.e., whether they show linear relations or not. Variations in the pH of humus deposits cannot be entirely the function of a bark pH ($R^2 = 0.04$ $P = 0.001$) given a poor fit of the regression line (Fig. 12). It is also to be noted that there is no linear relationship of these two parameters.

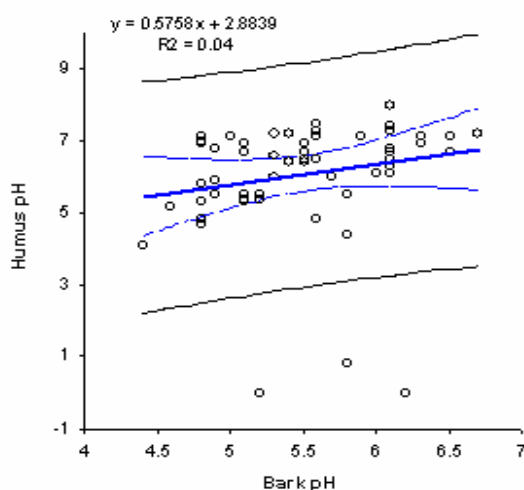


Figure12. Relation ship between bark pH and humus pH

6 DICUSSION

6.1 Diversity and Distribution

A total of 55 species of vascular epiphytes were recorded from the study area, and it is very low number of species when compared to the numbers reported from different tropical forests. Different authors have reported a very high number of vascular epiphytes species from various montane forests. Benavides, *et al.* (2003) reported 213 species from Colombian, Amazonian forest; Barthlott *et al.* (2001); reported 178 and 81 species from primary and secondary rainforests respectively in the Venezuelan Andes); Bussmann (2000) reported 223 species from Estacion Cientifica San Francisco, Ecuador; Hietz and Hietz- Seifert (1995^b) reported 135 species from central Vera Cruz.

The low diversity of vascular epiphytes in Haremma forest can be related to the forest disturbances caused by human activities and their domestic stocks. The existence of intensified disturbances has been reported (Lissanework and Mesfin, 1989; Zerihun *et al.* 1988). The deforestation activities performed by local people (for agriculture, fuel, and timber) and logging activities were some of the disturbances observed in the forest areas. All these disturbance activities resulted in the removal of forest trees on which the epiphytes were hosted, thus resulting in decrease of species diversity of the epiphytes.

Furthermore, different authors have also reported that disturbance factors are the main cause for the decrease in species diversity. Barthlott *et al.* (2001) has reported the decrease in species diversity of epiphytes with increasing gradient of forest disturbances by comparing the species number of epiphytes in disturbed and secondary forest and primary forest of Venezuelan Andes. The change in local climatic factors of the forest and loss of habitat of the epiphyte due to disturbances such as deforestation has also been reported (Hietz, 1999). The dryness and more sun exposed characteristic of disturbed habitat has also been reported (Berthlott *et al.* 2001) that resulted in to water stress which has negative effect on the abundance of epiphytes.

The alpha diversity ($H' = 1.62$) of the epiphyte community of the study area shows low diversity due to the above-mentioned factors. This value more or less corresponds to the value calculated for the disturbed forest ($H' = 1.62$) of Venezuelan Andes (Barthlott, *etal.* 2001).

In Haremma Forest area, the families of Pteridophyte species of vascular epiphytes exist in higher diversity than any other families of epiphytes in the forest. The high species diversity of ferns doesn't correspond to the diversity reported by the following authors (Bussmann, 2000; Hietz, 1999; Benavides *et al.* 2003; Barthlott *et al.* 2001). These authors have reported the highest diversity in the families of Orchidaceae from their study sites. The high diversity of Pteridophytes in Haremma forest may be related to the high moisture content of the forest area as a result of high annual rainfall distribution. A high diversity of epiphytes belonging to the families of ferns in the wet and warm climates has been reported by Vickery (1984). Furthermore, Andrades and Nobel (1977) have reported the high humidity requirement of ferns.

The low diversity of epiphytic Orchids in Haremma forest may be related to the preference of dry air condition but Haremma forest is wet and humid forest. Fattland (1996) has reported the preference of Orchids for dry forest.

Orchids survive in dry habitats due to the presence of xeromorphic structures. The preference of host trees to Orchids may be limiting their distribution, for example the epiphytic orchid, *Aerangis brachycarpa* was recorded from single species of host tree, *Vernonia amygdalina*. The preference to the host trees for some epiphytes may be related to bark chemistry. Heitz (1999) has reported that the bark chemistry of host trees can inhibit successful germination of the seeds some epiphytes.

The number of the species of vascular epiphytes exhibited an increasing pattern along the altitudinal gradient (lower in the upper, higher towards the intermediate and lower altitudes). The main reason for the decrease in number of epiphytes towards higher altitudes could be attributed to the low density of the forest trees, which resulted in the unavailability of suitable host trees (phorophyte) on which the epiphytes grew. As a result of this condition of the forest at higher altitudes, the species richness and abundance of associated epiphytes was limited. Furthermore, at higher altitudes of the study area, forest openness is high and light radiation reaches the forest floor so that the location closer to the forest floor will become sunnier and drier thus threatening the growth of epiphytes due to water stress. The decrease in temperature at higher altitudes (Johansson, 1974) may also have a detrimental role in limiting the distribution of epiphyte flora. According to Johansson (1974), low temperature will naturally influence evapotranspiration and favored less drought sensitive species. At higher altitudes of Harena forest epiphytes were restricted to the basal parts of the phorophytes, which may indicate forest openness and availability of moisture near the base.

Various authors have reported the high distribution of vascular holoepiphytes and hemi epiphytes towards the middle altitudes (Bussmann, 2000; Hietz, 1999; Hietz and Hietz-Seifert, 1995^b) from their study sites. This corresponds to the distribution of epiphytes at the lower altitudes of Harena forest. The discrepancy can be attributed to the difference in altitudinal ranges of the study areas where the study was conducted.

The current study showed that fern species were distributed in high number at all altitudinal levels. The above authors have reported that the epiphyte species belonging to *Orchidaceae* is highly distributed at all altitudinal levels. But the proportion and distribution of Pteridophytes and Orchids along the altitudinal gradient of Harena Forest is very similar to those reported from east African forests (Kenya and Tanzania) by Johansson (1974).

The vertical distribution of epiphytes on the phorophytes is a function of microclimatic conditions. Mesophytes (moisture-loving) epiphytes are confined to the lower portion (class A and B). The main reason for this apparent situation in the current study is, the lack of structures, such as waxy layer over their leaves and sunken stomata, leaf and stem succulence which reduce evapotranspiration.

On the other hand xeromorphic epiphytes such as *Peperomia abyssinica*, and *Diaphananthe* species, have leaf succulence, which is used to store water. Other species at intermediate height like *Huperizia ophioglossoides* and *Canarina eminii* may have structures, which either absorb water or reduce evapotranspiration. *Aerangis brachycarpa* has whitish root spreading over the phorophyte and succulent leaves, which may be used to absorb moisture or store water.

Although, the current study didn't attempt to relate anatomical features of these categories of epiphytes, this approach may prove useful in providing empirical data on the adaptation of vascular epiphytes in association to microclimatic conditions. The high preference of vascular epiphytes for the basal parts is related to its high moisture content and low insolation requirement (Johansson,1974). It has been variously reported that the vascular epiphytes occurring at intermediate height of the host tree are perhaps due to intermediate nature of moisture and light incidence (Werneck *et al.* 2002) or low moisture and intermediate insolation requirement (Johansson, 1974).

The upper most crowns is characterized by free air circulation (Veckery, 1984) and the condition is drier than the forest floor, so that the crown species such as *Diaphananthe Schimperiana* and *Diaphananthe tenuicalar* with succulent leaves are found in abundance. Furthermore, the upper most crown epiphytes were characterized by their low moisture requirement and apparent demand for high light intensities (Bussmann, 2000).

However, some species of vascular epiphytes such as *Peperomia abyssinica*, *Asplenium aethiopicum*, and *Asplenium anisophyllum* were found in all vertical microclimatic gradient classes of phorophytes owing to their wider ecological requirements and tolerance Johansson (1974) and Annaselvam and Paratharathy (2000) noted that some species are generalist with regard to their ecological requirements.

6.2 Dispersal biology and establishment of vascular epiphytes.

Most of the salient features that may be critical to success as an epiphyte are shared by a species richness of vascular epiphytes of Afromontane forest of Hareenna. Furthermore, the success of some of the taxa is mainly due to the nature of their propagules (Madison, 1977). Fern families and Orchidaceae, for example, have small, numerous dust-like propagules, which are mainly wind-dispersed (Fig.6). This particular attribute of their propagules has perhaps accounted for their successful dispersal resulting in highest species diversity. Fattland (1996) has reported that 84% of epiphyte species use wind dispersal. Oliver (1930) and Curtis (1933); both cited in Johansson, (1974) have reported that the types of diaspores enable us to assume most epiphytes are dispersed by wind. It is to be noted that such propagules of these two families represent an extreme in re-selection strategy and a high-risk gamble on establishment. The highest diversity of edaphic epiphytes (Fig.5.) could be explained through the same argument.

Although rare among holoepiphytes, another relatively prevalent mode of dispersal, i.e., birds, could account for the establishment of propagules of species such as *Kniphofia foliosa* and *Momordica* species. Noteworthy is the occurrence of some of these edaphic epiphytes such as *Impatiens* species is mainly due to the dispersal syndrome of its diaspores i.e. it has an explosive capsule which could place seeds at a distance sufficient enough to avoid competition with parent plants.

Although this type of dispersal syndrome may play little role for the overall dispersal and guidance to evolutionary trends, it chiefly prevents accumulation of large number of seeds within the shadow and circumference of the adult plant (Stebbins, 1971). The same author has also noted that the greatest distance to which seeds are ejaculated are only few meters e.g. 15 m in *Bauhinia purpurea* and 14 m in *Hura crepitans*. In the current study, such a distance is sufficient enough to accumulate seeds of *Impatiens* on surrounding phorophytes and the establishment of the seeds could be due to the suitable microclimate

6.3 Biophysical characteristics of phorophytes as a function of diversity of epiphyte flora.

As the size of phorophytes increases, the potential habitats and microhabitats of the epiphytes increase. The bark relief of the phorophytes gets rougher when the tree age increases as well (Campbell and Coxson, 2001). The observed high number of epiphytes on phorophytes having rough textured bark could be attributed to their high

holding capacity for epiphytes since it provides suitable microclimate for germination of seeds and spores as well as protecting the young seedling from being washed away.

A positive relationship between phorophyte size and number of epiphyte species has been reported elsewhere (see Johansson, 1974; Hietz, 1999; Hietz and Hietz-Seifert, 1995^a; Anaselvam and Parasarathy, 2001). These authors argued that big host trees offer larger surface areas and more diverse habitats for survival of epiphytes. Similarly Hietz and Hietz-Seifert (1995^b) have also reported that big host trees have great varieties of branch diameter, crotches and knotholes that are potential habitats for epiphytes. Furthermore, Johansson (1974) has also reported that thick branches of phorophytes are often covered with mosses and epiphytes accumulating substantial amount of humus, nutrients and moisture for establishment of vascular epiphytes. Note worthily is also that many epiphytes prefer rough bark to flaky or smooth (Johansson 1974).

Vascular epiphytes were found to be more abundant in bark pH range from 5.0 - 6.0 than above or below bark pH ranges but there are some species, which occur in a wide range of bark pH (Table 6). Besides, Johansson (1974) has been reported that most epiphytes usually utilize a wide range of pH. The same author has been reported that decreasing trends of bark pH from basal parts upward in to the crown of phorophytes probably due to decreasing dust content. Furthermore, this decreasing trend may be related to the accumulation of heavy deposit of humus materials in the lower portion of the phorophytes compared to the upper crown, which helps in the increase of pH in the basal parts. Wind is the most potential factor, which may be responsible for the decrease in bark pH through its effect of enhancing draining up water brought up by fog and rain. These may have a remarkable effect on the water contents of the bark and habit of vascular epiphytes. The current study asserts that mesophytic epiphytes are more or less basophilic (or less acidophilic) while xeromorphic ones are acidophilic in terms of bark chemistry. Although this denotation was explicitly mentioned, a bark pH range of 5.0-6.0 was reported to be suitable for vascular epiphytes (Du Rietz, 1945; cited in Johansson, 1974).

In current study, big sized trees, such as *Schefflera abyssinica*, and *Hagenea abyssinica* accumulate large humus deposit than small sized trees and its accumulation was high at the base of the tree. Larger trees have high surface area to hold and catch the source materials used for the formation of humus deposit. The various sources of humus deposit are decaying parts of phorophytes, decaying tissues of epiphytes, invertebrates, vertebrates and dust particles carried by wind. The humus deposit exhibits a high pH value than the bark pH. As the relationship

of bark and humus pH are non-linear with the species number of epiphytes as to which one of them plays more influential role to govern the distribution vascular epiphytes on the phorophytes is open to question.

Furthermore, humus pH is not only the factor, which influence the establishment of vascular epiphytes species for there are other non-vascular epiphytes such as bryophytes, and lichens, which may have crucial role in determining the establishment of vascular epiphytes. Although the current study did not study the epiphytic bryophytes, they are pioneers and create favorable microclimate for the establishment of the vascular epiphytes on the phorophytes (Campbell and Coxson 2001). It has been reported that different epiphytes (non-vascular and vascular) could play crucial role with regard to accumulation of humus (Bartlott *et al.*2001).

7. CONCLUSIONS AND RECOMMENDATION

The species diversity of vascular holoepiphytes in Harena forest is comparatively low, which may be attributed to the forest disturbance. The distribution of the epiphyte species has shown a decreasing pattern from lower to

higher altitudes but an increasing trend from the stem base to the upper crown on individual phorophyte. Host tree size has an effect on the number of species of vascular epiphytes in that the larger the size, the more number of epiphyte floras it supports.

Majority of the species of vascular epiphytes utilized a bark pH ranged from 5.0 to 6.0 and a humus pH from 6.0 to 7.0. The pH of the bark showed a decreasing pattern from basal parts upward into the crown of trees and the humus pH is more or less higher than the values recorded for bark pH.

Vascular epiphytes are the main components of the forest ecosystem, but are understudied. They provide substrate and food for canopy dwelling animals, indicator for conservation initials, nutrient and water cycle, and maintenance of moisture of the environment. They are also very sensitive to disturbances compared to other vegetation communities. Though this vegetation community plays an important role in many aspects of forest ecology, few studies were carried out on them in the past decades. The lack of attention may be related to the lack of immediate and tangible products compared to woody trees. Therefore I recommended that:

- ❖ The diversity of the epiphyte community in any forest is strongly tied to species composition of the forest trees. Disturbance factors especially anthropogenic disturbances are the main threat to forest biodiversity. The local people who are living in Harena forest are one of the agent of disturbance though the have indigenous knowledge of conservation of the forest. These people should continue to use the traditional conservation knowledge though the increase in population pressure enhances forest disturbance. Therefore, their indigenous knowledge of conservation will result in effective conservation of the forest in general and the epiphytes community in particular.
- ❖ Logging of the forest for timber by any institution including the government should be stopped as soon as possible since massif logging was observed in the area. Deforestation resulted in to loss of the habitat of the epiphyte and change in macroclimate and microclimate to which the epiphytes are very sensitive.
- ❖ Any conservation measure to conserve the forest community should primarily consider the epiphyte community, as they are very sensitive to disturbances.

- ❖ Unlike other plant community, the study of the diversity and ecology of vascular epiphytes in Ethiopia is not available. The current study is the first attempt to study vascular epiphyte in Harena forest. Therefore, ecologists, biologists, agriculturists, and research centers existing in the country should pay attention to study the epiphyte community, which are one of the component of the forest.

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Appendix 1. Average values of bark and humus pH of the species of phorophytes. I = basalparts, II = intermediate height, III = upper crown

Species	Section of the tree			Humus pH
	Bark pH			
	I	II	III	
<i>Hypericum revolutum</i>	5.5	4.8	4.5	6.7
<i>Schefflera volkensii</i>	5.9	5.7	5.2	7.3
<i>Rapanea melanophloes</i>	5.2	5	4.9	7
<i>Hagenea abyssinica</i>	5.1	4.6	4.2	6.5
<i>Maytenus addat</i>	5.6	4.7	4.7	6.7
<i>Galiniera saxifraga</i>	5.4	5.4	5.3	6.8
<i>Vernonia amygdalina</i>	5.1	5	4.5	6.1
<i>Bersaema abyssinica</i>	5.6	5.3	5.1	6.2
<i>Dombeya torrida</i>	5.7	5.3	4.9	6.7
<i>Buddleja polystachya</i>	6.1	5.4	5.2	6.5
<i>Diospiros mespiliformis</i>	6.1	5.9	5.7	-
<i>Allophylus abyssinicus</i>	6.1	5.9	5.6	8
<i>Schefflera abyssinica</i>	5.5	5.1	5.1 5	5.5
<i>Erythrina brucei</i>	6.5	6.1	6	7.1
<i>Teclea noblis</i>	4.9	4.8	4.8	5.3
<i>Rydingyria neglecta</i>	5.2	5.1	4.9	5.3
<i>Prunus africana</i>	5.1	5.1	5.1	6
<i>Polyscias fulva</i>	6.3	6.1	5.9	7.1
<i>Croton macrostachyus</i>	6.5	6.5	6.4	6.7
<i>Ficus sur</i>	5.8	5.5	5.1	6.8
<i>Ekebergia capensis</i>	4.8	4.5	4.4	4.7
<i>Syzygium guineense</i>	5.2	5.1	5.0	5.4
<i>Veparis dainellii</i>	6.1	6	5.9	6.3
<i>Lepidotrichilia volkensii</i>	4.9	4.8	4.5	5.5
<i>Canthium oligocarpum</i>	5.1	5	4.8	5.
<i>Celtis africana</i>	4.8	4.9	4.8	5.5

Appendix II. The altitudinal range of specific **holoepiphyte** and **hemiepiphyte** species

Distributed

Taxa	Altitudinal range
<i>Adiantum incisum</i>	2900-2975
<i>Asplenium gemmiferum</i>	2175-3000
<i>Asplenium. theciferum.</i>	2225-2600
<i>Asplenium aethiopicum</i>	2175-3000
<i>Asplenium anisophyllum</i>	2025-3000
<i>Asplenium. protensum</i>	2925
<i>Canarina eminii</i>	2400-2875
<i>Elaphoglossum lasti</i>	2825-2900
<i>Elaphoglossum deckenii</i>	2875-2900
<i>Huperizia ophioglossoides</i>	2000-2850
<i>Olendra distenta</i>	2095-2425
<i>Arthropteris monocarpa</i>	2000-2975
<i>Diaphananthescheimperiana</i>	2000-2900
<i>Liparis deisteli</i>	2425-2500
<i>Aerangis branchycarpa</i>	2025
<i>Diaphananthe tenuicala</i>	2000-2200
<i>Peperomia abyssinica</i>	2000-2975
<i>Pleopeltis excavata</i>	2925-3000
<i>Pleopeltis macrocarpa</i>	2025-2975
<i>Drynaria volkensii</i>	2000-2850
<i>Elastostema orientale</i>	2175-3000
<i>Vittaria guineesii</i>	2100-2425
<i>Schefflera volkensii</i>	2375-3000

S. abyssinica

2350-2875

S. myriantha

2450-2100