Diversity and Ecological Analysis of Vascular Epiphytes in Gera Wild Coffee Forest, Jimma Zone of Oromia Regional State, Ethiopia

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ABSTRACT

The diversity and ecological analysis of vascular epiphytes was studied in Gera Forest in southwestern Ethiopia at altitudes between 1600 and 2400 m a.s.l. A total area of 4.5 ha was surveyed in coffee and non-coffee forest vegetation. Fifty sampling plots, each 30 m x 30 m (900 m^2), were used for the purpose of data collection. A total of 59 species of vascular epiphytes were recorded and of which 34(59%) were holo epiphytes, two (4%) were hemi epiphytes and 22 (37%) species were accidental vascular epiphytes. To study the altitudinal distribution of vascular epiphytes, altitudes were classified into higher >2000, middle 1800–2000 and lower 1600–1800 m a.s.l. according to Shannon-Wiener Index (H/ = 3.411) of alpha diversity the epiphyte community in the study area is medium. There was a statistically significant diference between host bark type and epiphyte richness as determined by one–way ANOVA ($F(3, 91) = 21.833$, $p = 0.001$). The post–hoc test shows that there is significant difference of vascular epiphytes richness between Smooth bark with rough, flack and corky bark ($P = 0.001 < 0.05$), as well as rough and cork bark ($p = 0.43 < 0.05$). However, between rough and flack bark ($p = 0.753 > 0.05$) and between flack and corky bark ($p = 0.854 > 0.05$) no significant difference of epiphyte abundance was observed. Rough bark had 38%, corky, 26%, flack, 25%, and only 11% vascular epiphytes abundance occurred on smooth bark. The regression correlation test, ($R^2 = 0.773$, $p = 0.0001 < 0.05$), showed that the number of species of vascular epiphytes and host DBH size are positively correlated. The regression correlation test ($R^2 = 0.28$, $p = 0.0001 < 0.05$), showed that the number of species and host tree height positively correlated. The host tree preference of vascular epiphytes was recorded for only Vittaria volkensii species hosted on Syzygium guineense trees. The result of similarity analysis indicated that Gera Forest showed the highest vascular epiphytic similarity (0.35) with Yayu Forest and shared the least vascular epiphytic similarity (0.295) with Harenna Forest. It was concluded that horizontal stems and branches, large and rough, flack and corky bark type trees are more suitable for vascular epiphytes seedling attachments and growth. Conservation and protection of these phorophytes are important for the surivival of vascular epiphytes and increase their ecological importance.

***Key words**: Accidental epiphytes, Bark texture, Diversity, Hemi epiphyte, Holo epiphyte, Phorophyte.*

Contents

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDCE

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LIST OF ACRONYMS

AAU	Addis Ababa University
ANOVA	Analysis of variance
DBH	Diameter at Breast Height
ENMSA	Ethiopian National Meteorological Station Agency
ETH	National Herbarium
GDARDO	Gera District Agriculture and Rural Development Office
GPS	Geographical Position System
IBC	Institute of Biodiversity Conservation
M a.s.l	Meters above sea level

CHAPTER ONE

1.1. INTRODUCTION

Epiphytes, commonly referred to as air plants, are specialist plants that grow on other plants (usually trees and shrubs). They derive their nourishment from atmospheric sources. In forest ecosystem, epiphytes play useful roles in nutrient cycles, provide shelter and nesting materials for some insects and bird species, and are important sources of food for some foraging animals (Coxson and Nadkarni, 1995; Stuntz *et al.*, 2002). Epiphytes constitute an important bio indicator group of species that can be monitored to provide useful information on overall ecosystem health and productivity, because of their arboreal lifestyle and sensitivity to environmental stress (Fatland, 1996; McCune, 2000; Jovan and McCune, 2006). Epiphytes are extremely important elements of the flora (they represent about 10% of all plant species globally (Neider and Barthlott, 2001).

Epiphytes are responsible for much of the biotic diversity that makes humid tropical forests the most complex of all the world's terrestrial ecosystems (Gentry and Dodson, 1987). Epiphytes may live high in the tree branches (in the canopy) and may also be attached anywhere along the trunk of a suitable tree. Most are found in the lower branches, where they are shaded. Most epiphytes can grow on more than one species of tree and even on rocks. They produce many seeds, because most will fall to the ground and die without lodging within the tree canopy. Growing on a tree, above the ground, allows these plants to escape animals grazing on the ground. It also reduces other risks faced by plants growing on the ground, such as flooding on the forest floor and ground fires. This growth habit also presents several problems. If the branch on which an epiphyte is growing is broken from the tree by the wind, the epiphyte then falls to the ground with the branch. A larger problem is getting water and nutrients. An epiphyte's roots serves to anchor it to its host tree, and not to absorb water and food. Some epiphytes receive the water they need from rain, others from dew and mist. Many epiphytes provide food and living accommodations for specific insects, birds, bats or other mammals. Epiphytes, both vascular and nonvascular, play crucial roles in the water cycle of the forests. They capture moisture as rain or fog and then release it, along with vital nutrients, during dry periods, thus maintaining the higher humidity levels of this environment (Benzing, 1990). Pollination of epiphytes is usually conducted by insects, birds, and bats (Benzing, 1995).

Epiphyte distribution and occurrence are impacted by the existence of a vertical gradient of light within the canopy; leaf arrangement (alternate, opposite, or whorl) may also affect the passage of light from the upper canopy to epiphytes photosynthesizing below, oppositely-spaced leaves providing maximum light penetration to the tree's lower branches. Water availability for the epiphyte at any stage of development not only depends on local rainfall and humidity, but also upon the bark type of the host tree. Seedlings growing on rough, porous, and/or water-retaining bark have greater drought resistance than seedlings growing on smooth bark unable to retain adequate surface moisture, and water scarcity continues as a threat for the mature epiphyte (Benzing, 1990).

In addition to its role as a water sink for epiphytes, tree bark also provides the essential substrate to which epiphyte roots anchor the plant far above the forest floor. Many studies showed that epiphytes in general are vulnerable to human disturbances (Hietz-Seifert *et al.* 1996; Barthlott *et* *al.* 2001). Epiphytes can be used as indicators of forest disturbance but they also provide resources and niche possibilities for canopy-dependent fauna (Benzing, 1990). Since they are useful climatic indicators they can be used as a warning system for changing conditions in microclimate and even as indicators of global climatic change (Benzing, 1998).

The diversity and ecological analysis of vascular epiphytes was not studied in most of the Ethiopian forests. Most of the research carried out on Ethiopian forests dealt with identifying the species diversity and analysis of vegetation structure. A study on epiphytes diversity is scanty in many Africans countries. This could be possibly due, in part, to the limitation of experts in the field. The Gera Forest was highly dominated by wild coffea arabica and currently local farmers and investors are highly involved in coffee cultivation in the study area. Coffee shrubs are highly important for the attachment of vascular epiphytes, especially for, *Polystachya cultriformis* and *Diaphanante adoxa* epiphyte species. The coffee itself benefited from the vascular epiphytes in many ways. Epiphytes are highly important for ecological service such as water and nutrient cycling, slowdown of high rainfall to the ground and regulating the humidity of the forest. However, the local communities have no idea on the ecological importance of the vascular epiphytes. They think, they are parasites or missiletos, harm the coffee plant, and decrease the productivity of the coffee. Similarly the study of Matthias 2011; Hylander and Nemomissa, 2008 found that farmers are concerned about epiphytes for a possible yield decline.Due to this misconception, they remove the vascular epiphytes from the coffee plant and other shrubs at the coffee cultivation area. This will be a challenge on future diversity and richness of the vascular epiphytes in the study area. The challenge is more sever for Orcidaceae family.

Another problem in the Gera Forest was farmers remove most of the shrub plants for coffee cultivation and canopy opening. Inappropriate coffee plantation management highly affect the epiphytic diversity. Coffee cultivators and investors use a limited number of plant species for coffee shade purpose such as *Albizia gummifera* and they remove under growth shrubs for reduction of competition to coffee plants. They remove tree species such as *Syzygium guineense* from coffee cultivated areas. However, these plant species are highly important for vascular epiphyte attachment due to bark texture, DBH size, canopy architecture, and high moisture retention capacities. Due to this reason, the species harbored a high number of species of vascular epiphytes. Human interference has highly affected the diversity and abundance of vascular epiphytes in Gera Forest.

This sudy therfore aimed at finding the diversity, ecology and the current situation of vascular epiphytes in Gera Forest.

1.2. Objectives of the Study

1.2.1 General objective

- To study the species diversity, ecology and threats to the vascular epiphytes in Gera Forest.

1.2.2 Specific objectives

- To identify and document the vascular epiphyte species diversity
- To study the vertical distribution of epiphytes on phorophytes and theirs distribution along an altitudinal gradient.
- To correlate the size of host tree (DBH, height), and the bark textures of the host trees to epiphytic species diversity.
- To study the life form and attachment direction of vascular epiphytes in Gera Forest.
- To identify the threats to vascular epiphytes in the study area and recommend would be solution for management of the species.

1.3 Research Questions

- What are the species diversity, distribution, and abundance of vascular epiphytes in Gera Forest?
- What factors are influencing the diversity and distribution of epiphytes?
- What is the host tree factors affecting the species diversity of vascular epiphytes? Is it the size of the host tree, dbh of phorophyte, bark textures of the phorophytes, vertical gradient, humus deposition affect the richness and abundance of vascular epiphytes?

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Definitions of Epiphytes

Many definitions of epiphytes have been formulated. Madison (1977) defined epiphytes as species, which normally germinate on the surface of another living plant and pass the entire life cycle without becoming connected to the ground. Ewusie, (1980) defined epiphytes as plants which grow attached to the trunks, branches and even leaves of the trees, shrubs and lianas. Furthermore, Benzing, (1987) defined epiphytes as plants that spend much or all of their lives attached to other plants. Epiphytes are plants that live on other plants but do not take any food from them (they are not parasitic). Many kinds of bromeliads, orchids and ferns are found as epiphytes are very common in tropical rain forests. Epiphytes do not depend on their support plant for their nutritional requirement, and are distinguished from parasites. Similarly, Kress (1989) defined epiphytes as those plants that normally spend their entire life cycle perched on another plant and receive all mineral nutrients from non-terrestrial sources.

The effect that they exert on their support is the weight that they add to its branches. Epiphytes, however, provide the principal habitat for animals in the ecosystem. For example, the roots of epiphytes, flowering plants and ferns often provide the nesting place for arboreal ants (Ewusie, 1980). One of the ways in which tropical epiphytic communities differ from temperate ones is that while temperate epiphytes consist almost entirely of cryptogamic groups (algae, fungi and bryopites) tropical epiphytes also include vascular epiphytes largely pteridopytes and flowering plants. According to the study of Kress, (1986), over 200 genera of 33 families of flowering plants and about 20 genera of pteridophytes which are estimated as epiphytes and 24, 000 or more vascular plant species are epiphytes, which constitute a major part (perhaps as much as 10%) of the global plant diversity.

The host plants (phorophytes) only provide support for epiphytes. Epiphytes obtain mineral nutrients, water from the air, and thus are sometimes known 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 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.

2.2 The Mode of Existence and life forms 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). Some epiphytes have adventitious roots, which enable them 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 epiphytic 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). According to Johansson (1974), epiphytes occurring on the lower parts of the trees are living under constant conditions of humidity and would need little for adaptation against desiccation. The filmy ferns, *Trichomanes* and *Hymenophyllum* that are common on the lowest parts of trunks, represent the most drought-sensitive epiphytes. Higher up on the trees the epiphytes with some what fleshy leaves establish themselves. In more exposed habitats, the size and total number of leaves are reduced. The number of stomata and their distribution on the leaves may also be of adaptive importance.

Based on drought resistance, epiphytes are divided into two major groups, the drought tolerant and the drought avoidant. The shape and texture of the leaves often indicate to which group a certain species belongs. The leaves of the drought avoidant epiphytes, being deciduous, are not adapted to survive the dry season; the drought tolerant epiphytes often have a reduced number of leaves (Johansson, 1974). Based on growth forms, epiphytes are classified into two major groups symposia and monopodia growth forms. Symposia growth means the plants develop a shoot which is limited in apical growth. Thus the development of pseudo bulbs and leaves takes place during the wet season, each shoot terminating in an inflorescence. The following wet season a new shoot will appear. This growth form is generally considered to be favorable for epiphytes (Holtum, 1960) apart from giving them an indefinite length of life. According to Johansson (1974), orchids with sympodial growth life form would be no need of advanced adaptations towards desiccation however, Monopodia growth life form, where each stem has an indefinite apical growth, is subject to a more serious threat to desiccation, since they keep their leaves during the dry season. Holtum (1960) states that orchid species having monopodia growth life form are found mainly in areas, which have no long dry season.

2.3 Factors of the Habitat on epiphytic Environment

The factors of the habitat of epiphyte are not quite the same as those of plants living on the ground. The fact that the substratum is raised above the ground level often means higher illumination and lower relative humidity. The host or the part of it to which the epiphytes is attached may be inclined at any angle ranging from a horizontal to a strictly vertical position; these create the problem of seed dispersal and successfuly attachment and maintenance at that angle. The bark of the host tree may be rather smooth, as is typical of tropical rain forest trees, and when this is the case, the problem of anchoring becomes acute. Where the host tree trunk has burrows and fissures or is covered with large and persistente leaf bases as in the case of oil palm tree, then anchorage presents no problem and the growth of epiphytes become luxuriant.The shortage of soil in the habitat means that epiphytes must necessarily depend on the small quantities of debris in cracks and hollows on the supporting trees, or on what debris they can collect among their own roots and leaves. In addition, the ants, which inhabit the root system of most epiphytes, gather dead leaves, seeds, and debris that are broken down in to humus. The humus improves the water-holding capacities of the soil and also provides the epiphytes with nutrients. Water shortage can become severe for epiphytes owing to the high rates of evaporation that are attendant up on low relative humidity. In order to overcome this, epiphytes are either drought resistant or conserve water supply (Ewusie, 1980)

2.4 Illumination factors on Epiphytic Environment

According to Ewusie (1980), the types of epiphytes found are related to three levels of illumination: bright light; dense shade; and a wide range of conditions. These levels affect the distribution of epiphytes at different heights on the trees, and are classified as follows:

i. Extreme Xerophilous epiphytes: These are the types of epiphytes, which live on the top most branches and twigs of the taller trees. Examples of which are some bromeliads and surprisingly some cacti.

ii. Sun epiphytes: These are usually xeromorphic and occur mainly within the crown and on the larger branches of the upper tree storeys and which as a group form the richest of epiphytic synusiae in terms of individual and of species.

iii. Shade Epiphytes: These occur mainly on the trunks and lower branches of and may occur on the stems of the larger lianes. Shade epiphytes often show typical mesophtic and not zerophytic features.

2.5 Inclination factors on Epiphytic Environment

Difference in inclination and aspect between different parts of the same tree may affect the epiphytic vegetation not only by influencing the colonization of seeds and spores but also by modifying illumination and evaporation. Epiphytic vegetation on the vertical trunk will be different from that on the horizontal branches. For example, it is noted that large epiphytic ferns like *Asplenium nidus* and *Asplenium africanum* tend to prefer the trunks to the branches (Ewusie, 1980). As the inclination of the surface also affects the rate of accumulation of humus, certain humus epiphytes occur only where relatively large amounts of humus can collect, as in the forks of branches. Inclination of trunk and branches indirectly affects the vertical distribution of epiphytes, the interception of light and water increase as inclination decreases. Decreasing inclination also enhances the successful settling of seeds and spores and the accumulation of organic material (Ter Steege and Cornelissen, 1989).

2.6 Age factors of host tree on Epiphytic Environment.

The epiphytic vegetation on tree may also depend on the ages of host tree (Ewusie, 1980). For example, the epiphytic vegetation of *Altingia excels* when it is young tree and smooth–barked is different from that on the same plant when it becomes old and scaly barked.

2.7 Adaptation of Epiphyte Community to Nutrition

According to Benzing, (1990) epiphyte growth is often limited by inadequate nutrient supply. Nutrient leached from the upper canopy are trapped by epiphytic plant (Tukey, 1970; Benzing, 1990). The mineral composition of rain through fall available to epiphytes is variable. Variability is depending on seasonal differences in the airborne deposition and on the type /density of the upper canopy. According to Nadkarni and Matelson, (1991), the estimated nutrient input from litter fall retained within the canopy was shown to be small relative to epiphytic productivity. They conclude that the nutrient source contributing to epiphytic nutrition, atmospheric deposition and foliar leachate were likely to be important.

According to Ewusie, (1980) epiphytes differ in their adaptation to the collection of water and the accumulation of soil. Based on their adaptation he classified them in to four forms of adaptation, as follows:

i. Proto epiphytes: these are rather simple forms with no special structures for the collection of water or soil. The roots or rhizomes creep on the support plant in order to exploit a large area of substratum. They have xeromorphic structures with various types of organs for water storage. A characteristic anatomical structure is the special non-living tissue at the outside of the aerial roots, the velamen tissues become full of water. When this water dries up in dry weather, the velamen then serves as a layer against further loss of water and excessive heating. Examples of such proto epiphytes include the epiphytic orchids, ferns, and species of *peperomia* and *vaccinium* (Ewusie, 1980).

ii. Nest and bract Epiphytes**:** these types of epiphytes accumulate humus and debris from which the roots obtain water and mineral substances. The roots of nest epiphytes form dense interwoven mass, which looks like a bird's nest, ants nest in these roots and helps to make humus available. Ferns, aroids, and orchids are among the nest epiphytes. Bracked epiphytes have bracket like leaves.

iii. Tank Epiphytes have long broad stiff leaves which form a rosette with their sheathing bases which holds water.

iv. Hemi epiphytes develop long aerial root, which eventually reach the ground from where they are able to obtain water and nutrient like normal land plants (Ewusie, 1980).

2.8 Dispersal Mechanisms of Epiphytes

Nearly all epiphytes have fruits, seeds, or spores with special mechanism for dispersal. This may be suited for dispersal by animals or by wind. Often the fruits are fleshy with sticky pulp. Thus the seed easily sticks to the bark of the tree where they may germinate. The very small seeds of orchids and the spores of ferns are very light indeed and are easily carried by the wind. Where the seeds are heavier, they often have parachute appendages. Epiphytes produce far more seeds than their grounded counter parts because so many of their seeds fail to reach suitable places to grow. Many epiphytes have wind-dispersed, microscopic seeds equipped with wings, gliding apparatuses, or parachutes. Even epiphytes that offer fleshy fruits may have several thousand seeds in a single berry. In addition, the seeds have a sticky coat, so they can easily stick to the tail and feathers of birds. Hence, when the bird rubs the seeds on canopy branches, complete with natural fertilizer, the seeds end up in just the right place for growth (Chansa *et. al* 2012).The largest number of epiphytes occurs among the orchids and the pteridophytes, which both have very minute diaspores. These are so small that they can easily be carried by the wind. According to Holtum (1960), insects disperse epiphytes. Ants may have an important function in several ways. They may carry seeds, especially small seeds which contain food useful to them. Some of the seeds, including seeds of orchids, are sought chiefly for oil drops in the outer tissues and ants may not destroy the embryos. The seeds grow in ants' nests, which provide shelter and minerals for the seedlings. Numerous birds, bats, monkeys, and squirrels living in the trees may also contribute to the dispersal of the epiphytes.

2.9 Holo-Epiphyte, Hemi-epiphyte and Accidental Epiphytes

2.9.1 Holo epiphytes

Also termed "true epiphytes" are plants that never root in soil; this type completes its entire life cycle anchored to a host plant, and receives mineral nutrients only from non-terrestrial sources. Holo-epiphytes grow slowly and tend to have a long life span (Nadkarni, 1992). For that reason, it is likely that substrate instability, due to tree or branch fall or detaching bark, is a major factor of mortality among holo epiphytes (Laube and Zotz, 2006a).

2.9.2 Hemi epiphyte

It is strictly epiphytic for one stage of the life cycle but becomes rooted in the soil during another stage. Hemi epiphytes maintain soil contact for at least part of their life by means of aerial roots. Primary hemi epiphytes start their life as epiphytes, germinating on a host tree and sending down aerial roots to the ground to take up nutrients (Benzing, 1990). Some primary hemi epiphytes may strangle or kill their host (e.g., *Clusia* spp., *Ficus* spp.); others never do so (*Philodendron* spp.). Secondary hemi epiphytes germinate on the forest floor before climbing a host tree, keeping their roots connected to the soil during their entire life cycle (Kress, 1986).

2.9.3 Accidental epiphytes

Are predominantly terrestrial plants that accidentally germinate in the tree trunk crevices without special adaptations to epiphytic life that can occasionally be found growing in soil pockets on trees or on rotting stumps (Fernanda and Talita, 2000).

2.10 Host Preferences and Host Traits of Epiphytes

Difference in abundance and floristic composition of epiphytes may depend on the support tree (Ewusie, 1980). The abundance of epiphytes on *Samanea saman*, for example as compared with that on other tree species commonly planted in tropical towns, is often very marked. It has been shown that the specialization of epiphytes on some species of trees is due not to physical factors but rather to the chemical composition of the barks (Ewusie, 1980). Under suitable conditions of humidity, irradiation, and nutrients, almost all trees could support epiphytic plants. In less suitable sites, however, only trees with rough and weathered bark have epiphytes due to an enhanced capacity for water and nutrient retention by these substrates (Ter Steege and Cornelissen, 1989). Vascular epiphytes are common in subtropical, tropical, and temperate rainforests, making up about 10% of the world's total flora (Kress 1986). Epiphytes benefit substantially from their host trees, and so the overall relationship, at least in one direction, is facultative. According to the study of Ragan *et al.* (2002) the salient role of the host appears to be simply to provide substrate above the forest floor. Studies of vascular epiphyte-host associations have identified a complex array of potential interactive mechanisms that could lead to species-specific interactions. These include variation in canopy effects on light, allelopathic and/or fertilization effects through fall, substrate moisture conditions, bark stability, and factors such as bark surface rugosity that might affect epiphyte colonization (Ragan *et al.*, 2002). All of these factors are likely to vary among hosts. Tree bark is a common substrate for many epiphyte species, a number of which grow almost exclusively on this surface (Sarah, and Bruce, 2011). Observations of the distribution of bark epiphytes on trees of different species suggest host-specific differences in composition and abundance. With the bark characteristics of the host tree affecting the ability of different epiphytes to establish, remain attached, and grow on the bark surface (Wyse, and Burns, 2011). Individual host trees can contain a diverse community of epiphytes that may, or may not, be similar to those found on other host trees belonging to even the same species, emphasizing host specific differences in epiphyte community assemblages (Laube and Zotz, 2006a). Microhabitat resource availability, particularly water supply and, to a lesser extent, nutrient supply has perhaps the strongest influence on epiphyte diversity, and a key factor in determining a good host (Sots, and Hietz, 2001). Many epiphytes show preference for specific host traits such as tree age, size, branch size, bark quality, and microclimatic conditions associated with the host (Zotz and Schulitz, 2003).

2.11 Structural Adaptations of Epiphytes

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 xeromorphism, including thickened cuticle, sunken stomata and succulence (Vickery, 1984). The same author indicated that many tropical epiphytes belonging to the Orchidaceae family extend their roots outward into the air appearing as thick, unbranched whitish organ. Covering the surfaces of the roots are special layers of cells, which can take up water rapidly from the brief showers.

2.12 Water Economy of Epiphytes

Most of the substrates used by epiphytes have a limited storage capacity for water. This means that the epiphytes themselves must be able to affect a rapid water uptake during the limited period when the substrate is wet, or collect the water in small pools between the leaves (tank or cistern epiphytes among many bromeliads of the Americas). Water absorbed in humus may also serve as a water supply. The roots of epiphytic orchids exhibit several specialized features in their morphology and anatomy. The aerial roots are surrounded with a white, papery, or spongy layer of dead cells called the velamen (Johansson, 1974). Different parts of the epiphytic parts are appropriate for water storage. Some epiphytes with a large root system compared to the stem and leaves naturally hold a major part of the water in the roots. As a rule the stem and rhizomes of most epiphytic orchids are woody and hold only minor amounts of water supply.

2.13 Distribution of Vascular Epiphytes on Phorophytes

The distributions of epiphytes depend on the phorophyte species, age and characteristics such as shape, bark texture, branching patterns and height (Freiberg, 1996). Also crown shape, size of leaves and canopy density, affect the total rain retention and rearrangement, which also influences the distribution of epiphytes (Patrick, 2007). In addition to environmental characteristics, intra and interspecific interactions can also control the distribution patterns of some species (Hietz and Hietz-Seifert, 1995). Distribution of epiphytes among different host species is related to factors such as moisture retention, chemical composition and bark morphology, which can be decisive on the establishment and development of some species (Benzing, 1990). The vertical distribution of epiphytes is mostly determined by patterns in photon flux density (PFD) and humidity in subsequent forest strata (Ter Steege and Cornelissen, 1989).

2. 14 Host tree characteristics

Johansson (1974) has published that the physical, properties, and chemical composition of the bark affect the vascular epiphytes in several ways. Sanford (1968), Ter Steege and Cornelissen (1989) and Johansson (1970) found that in relatively dry areas, smooth barked trees carried fewer epiphytes than rough barked trees. The importance of the bark 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). 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 base of the trees and upwards, probably due to decreasing dust content.

2.14.1 Humus Deposit

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. The formation of the humus was slow on the phorophytes. It was estimated that it takes 10 years to form a layer of 10 cm thickness The external contribution to the assemblage of humus may be small in volume but important in its nutritional effect on the epiphytic flora (Johansson, 1974).

2.15 Slow Growth Rate and Establishment Limitation of epiphytes

Epiphytes are inherently slow growing organisms and usually take a long period of time to fully reach maturity and colonize their hosts (Zotz, 1998). The slow growth of epiphytes is assumed to be a result of the intermittent supply of water and nutrients in the habitats they occupy (Benzing, 1990). Growth rates and habitat suitability determine epiphyte establishment process. The inability of epiphytes to colonize or establish in a new stand can be referred to as establishment limitation. Establishment limitation in epiphytes could be related to biotic factors like competition and host specificity (Sillett *et al.*, 2000). Substrate availability is a critical factor in epiphyte species diversity because dispersed seeds or spores require suitable substrates to germinate, grow, and colonize. Epiphytes usually establish on the tree bark and branches, and trapped soil or organic matter in crevices on bark surfaces and branches. Their preference for these substrates is related to the roughness, water-holding capacity, bark pH, branch age and branch size (Callaway *et al.*, 2002)

2.16. Climatic Factors

2.16.1 The effects of rainfall and seasonality on epiphyte community composition

Epiphytes can 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; Reynolds, 2003). In a study of vascular epiphytes in Western Amazonia, Kreft *et al*. (2004) found that climatic patterns of high annual rainfall and low seasonality were strongly correlated with high species richness. Benzing (1998) suggests that areas that receive heavy but unevenly distributed rainfall are more likely to have smaller and less diverse epiphyte communities than areas with less total but more evenly distributed rainfall. 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 (Johansson, 1974). With high environmental humidity in the rain forest, one would think water loss through transpiration would be minimal. 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. The greatest abundance of epiphytes is found where there is a yearly rainfall of 100 inches (≈ 2500 mm) or more and where no month has an average of less than 2 or 3 inches (Holtum, 1960; cited in Johansson, 1974).

2.16.2 Light and epiphytes

Epiphytes may experience photo system damage in high light or may experience light limitation in deep shade (Ragan, *et. al* 2002).A higher abundance of epiphytes occurred at intermediate heights on the phorophytes, probably because of an intermediate light incidence at these positions. Shade tolerant species are more often found close to the forest floor than that requiring sun radiation (Reynolds, 2003).

2.17 Severity of Disturbances for Epiphytic Diversity

Disturbance that causes the loss of a preferred host species or suitable habitat can consequently result in the loss of dependent epiphyte species (Hietz, 1998). In addition, a disturbance event disrupts the prevailing microclimatic conditions in the habitat, and the resulting changes in microclimate are key determinants of epiphyte assemblages (Samuel and Han, 2012). Both stand-replacing disturbance and intermediate or non-stand-replacing types of disturbance might affect epiphyte species diversity in several ways. Stand-replacing disturbances have both short and long term effects on epiphyte diversity (Samuel and Han, 2012). Stand replacing disturbance such as wild fire potentially consumes all host trees including old, large trees and branches, together with available *in situ* dispersed propagules, resulting in loss of epiphytes in the stand or landscape. Because all trees present are physically consumed including old trees, specialized epiphyte species that require or establish solely on old and large trees and branches are particularly vulnerable. In the event that stand replacing disturbance initiates a new stand or creates a mosaic of young and old-growth stands at the landscape, epiphyte propagules for colonizing the new, young stands would have to come from a nearby source community, usually an adjacent old-growth stand (Samuel and Han, 2012). Intermediate or non-stand replacing disturbances such as tree fall, blow down, disease, and insect outbreak cause partial tree mortality, resulting in the loss of habitat or establishment substrates for epiphytes because of their less severe nature, many preferred hosts and habitats are retained, together with *in situ* propagules, and therefore less diversity loss. Such small-scale disturbances typically create space in the canopy with the concomitant release of hitherto scarce resources such as light and moisture. This may enhance epiphyte species diversity since the niche requirements of the different resident epiphytes can be met (Samuel and Han, 2012).There is however, the potential of high insolation and desiccation in the new open environment in the disturbed habitat to which some epiphyte species that are not well adapted to it may be affected (Laube and Zotz, 2003).

2.18 Global Climate Change and Epiphyte Diversity

Climate change is widely considered one of the greatest threats to biodiversity (Samuel and Han, 2012). Epiphytes occupy narrow ecological niches because of their existence at the interface of vegetation and atmosphere. Therefore, changes in atmospheric climate can potentially alter their diversity. Many studies have demonstrated that temporal and spatial variation in climatic conditions including moisture, humidity, temperature, and rainfall patterns influence epiphyte diversity (Hietz and Briones, 1998; Zotz and Hietz, 2001). Epiphyte diversity is not only directly affected by changing climates. Drought and global warming affect epiphytic diversity indirectly increase tree mortality, fire activity, and insects and pathogens associated with climate change (Logan *et al.*, 2003; Flannigan *et al.*, 2009).

CHAPTER THREE

3. Material and Methods

3.1 Study Area

3.1.1 Location

The study was conducted in Gera District, Jimma Zone of Oromia National Regional State, Southwest Ethiopia (Figure 1). The study Forest is located at about 380 km from Addis Ababa and has a total area of 80,830.4 ha. The altitudinal range of the study Forest varies from 1650 to 2320 m a.s.l. Gera District has an area of 1,330.1 km^2 and one urban center, Chira town. It is bordered on the south by Gojeb River which separates it from the Southern Nations, Nationalities and Peoples Region, on the northwest by Sigmo, on the north by Setema, on the northeast by Gomma, and on the east by Seka Chekorsa districts (Figure 1).

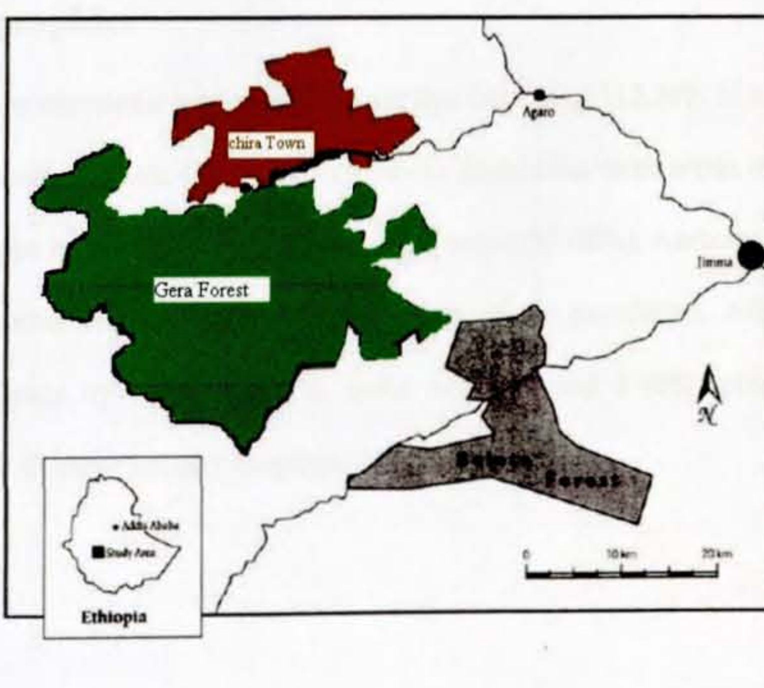


Figure 1Maps of Ethiopia and Jimma Zone showing the Study Area

3.1.2 Topography

Gera District is characterized by mountains (Waka, Kimbibit and Timba), plateaus (Chewra and Kella), plains (Walla, Kecho, Tuta and Tuam Mayi.) and valleys (Naso and Gojeb). The District extends between 1390 and 2980 m a.s.l. Gera Forest, however, is situated in the intermediate altitudinal range between 1600 and 2400 m a.s.l. (GPS reading during field work).

3.1.3 Soil

The study area has a dystric nitisol soil type, which is deep, clay red soil. The soil is porous and has good potential for agriculture, good physical properties, stable structure, deep rooting volume, and high moisture storage volume. Orthic acrisol and dystric nitosol are the major soil types found in Gera District (GDARDO., 2012).

3.1.4 Demographics

The 2007 national census reported a total population for this District of 112,395, of which 56,488 were men and 55,907 were females; 4,746 or 4.22% of the population were urban dwellers. The three largest ethnic groups reported in Gera District were Oromo (86.08%), Amhara (8.27%), and Kafficho (4.16%); all other ethnic groups made up 1.49% of the population. Afan Oromo is spoken as a first language by 86.02%, 9.71% spoke Amharic, and 3.48% spoke Kafa; the remaining 1.52% spoke all other primary languages (Wikipedia, 2012).

3.1.5 Climate and agroclimatic zones

The rainfall and temperature data for the study area was collected from National Meteorological Service Agency (NMSA, 2013). The mean annual temperature is about $18.4C^0$ and the mean minimum and maximum temperatures are $11.7\ C^0$ and $26.5C^0$ respectively. The mean annual rainfall of the study area is 1805 mm (Figure 2). Gera is classified into dega (5%), woinadega (75%) and kolla (20%) agroclimatic zones (G.D.A.R.D.O, 2012).

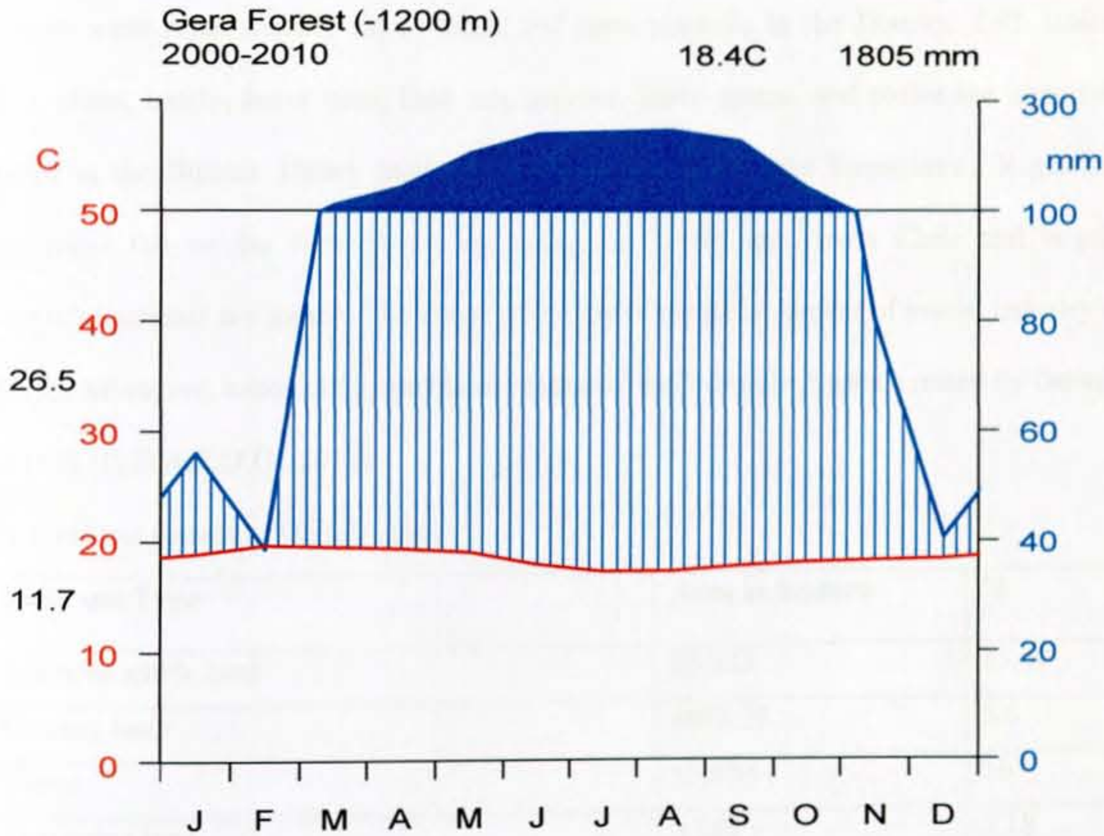


Figure 2 Climadiagram of the study area showing rainfall distribution and temperature variation from 2000 to 2010. Data source: National Meteorological Service Agency (NMSA, 2013).

3.1.6 Land use, agriculture, trade and tourism

The proportion of arable, grazing and forest lands in Gera District is 15.47%, 5.6% and 56% respectively (GDARDO., 2012). The remaining land area is either degraded, built-up or serves for other purpose (Table 1). High forest, woodland and plantation forests are available in the District. The majority of the natural forests are under the government protection. Gera District has 226,754 cattle, 54,801 sheep, 14,473 goats, 7,041 mules, 30,532 horses, 1934 donkeys and 21, 205 poultry (GDARDO., 2012).

There were some retail traders, small shops, and open markets, in the District. Teff, maize, wheat, sorghum, barely, horse bean, field pea, peppers, fruits, spices, and coffee are important cash crops in the District. Honey production is also practiced in the forest area. Regarding tourism, water fall on the Naso River, hot springs at Walla and Timba Chele and largely available wild animals are some of the major potentials of the development of tourist industry in the District. Moreover, historically, the District is one of the five Gibe States, created by Guunji, around 1835 (G.D.A.R.D.O., 2012).

Table 1 Land use pattern of Gera District

No.	Land use Type	Area in hectare	%
1	Potential arable land	22,323	15.47
2	Grazing land	8089.22	5.6
3	Forest	80,830.4	56
4	Cultivable land	3,148	2.18
5	Uncultivable land	5,901.76	4.09
6	Construction	9002.62	6.24
7	Others	15,045	10.42
	Total	**144,340**	**100**

Source: G.D.A.R.D.O. (2012)

3.1.7 Wildlife

The Forest vegetation of Gera District hosts various species of wild animals including mammals, birds, reptiles and amphibians. Some of the common mammals like buffalo, lion, Colobus monkey, Gelada baboon, vervet monkey, leopard, warthog, pig, civet cat and antelope are found in the Forest. However, the wildlife populations of these animals are under severe threat due to deforestation and habitat fragmentation mainly because of human encroachment. There is no wildlife conservation area in the District.

3.1.8 Drainage

Gera District, with an altitudinal range between 1390 and 2980 m a.s.l. and with various topographic land forms, is endowed with numerous streams and rivers. Several perennial rivers such as Naso and Gojeb, and intermittent streams (Atta, Naniya, Sisay, Koka, Dacho.) are flowing through the District. Locally protected springs, rivers, developed springs and wells are the major sources of drinking water in Gera (Wikipedia, 2012).

3.1.9 Vegetation

The vegetation type of the study area is broad-leaved and moist montane forest with important species in the forest including *Olea capensis, Schefflera abyssinica, Prunus africana, Elaeodendoron, buchannanii, Diospyros abyssinica, Albizia gummifera, Syzygium guineense, Bersama abyssinica, Pouteria adolfi friedericii, Apodytes dimidiata, Cassipourea malosana, Celtis africana, Croton macrostachyus, Ekebergia capensis* and *Ficus sur* (IBC 2005.)

The high forest area of Gera Forest has been cleared for *Coffea* plantation, road construction, timber harvesting, and agricultural intensification which resulted in bushland and farmland formation.

Plate 1 Photo showing parts of Gera Forest (Photo by Bedilu Tafesse)

3.2. Marerials

The materials that were used during the actual plant data collection in the field were plant press, Pole cutter, Secateurs, Plastic bags, Diameter tape, Binocular, GPS, Digital camera and Tree climbing rope.

3.3 METHODS

3.3.1 Reconnaissance survey

A Reconnaissance survey of the study area was done on November 15, 2012. The actual collection of the samples was carried out from November 16/2012 to 13 December 2012.

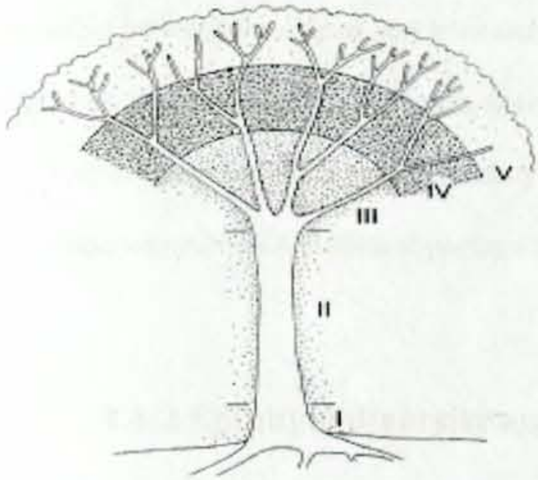
3.3.2 Sampling design

Sampling method employed was systematic sampling method. A line transect was laid along an altitudinal gradient between 1600 to 2400 m a.s.l. Sampling sites were arranged along transects in three directions. The first transect was laid from Chira town to Anfallo. The second transect was laid from Chira town to non- Coffea Forest of Gera. The third transect was laid from Chira town to Beshasha town, on the way to Agaro. The size of each releve was 30 m x30 m (900 m^2). The plots were arranged at a distance of 100 m from each other depending on the length of the transect. In each releve, the number of individual species of epiphytes occurring on the phorophytes were counted. The DBH (diameter at breast height) and bark texture of the phorophytes, attachment direction of epiphytes, height of the phorophytes, 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 fifty (50) quadrants were analyzed.

3.3.3 Epiphytes and Host sampling

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. The number of vascular epiphytes on each phorophyte was counted. Those epiphytes occurring in dense stands such as *Peperomia abyssinica* and *Drynaria volkensii, Peperomia tetraphylla, Peperoma molleri, Polystachya bennettiana* were counted as one individual following Barthlott *et al.* (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 into lower 1600 – 1800 m), middle (1800 - 2000 m), and higher (2000 – 2400 m) altitudes. The vertical distribution of vascular epiphytes on the phorophytes was studied following Johansson zonation (Johansson, 1974). Accordingly, host trees were partitioned into four sections as depicted in Figure 2: (i) 0-2 m above ground level, (ii) stem from 2 m to below first branch, (iii) intermediate height (from first branch to below third branches), (iv) upper crown (from third branch and above). Trees, which are dangerous to climb, were not selected.



Legends:

I =0 to 2m above ground level.

II= stem from 2m to below first branch.

III = intermediate height (from first branch to below third branches.

IV= upper crown (from third branch and above.

Figure 3 Modified from Johansson Zones (Johansson, 1974).

To investigate the relationship of host tree characters with epiphytes abundance and diversity, the bark was classified into rough, corcky, flacky and smooth texture. The abundance and exact location of vascular epiphytes on the phorophytes, and the life forms of epiphyte species were determined.

Dbh and Height of host tree (phorophytes) was also measured to correlate epiphytes abundance. Host size was classified as follows: small phorophytes with diameter at breast height (dbh) 2.5 to 20 cm; medium phorophytes dbh 21 to 50 cm and larger phorophytes dbh > 51 cm.

Plant specimen identification took place at the National Herbarium (ETH) of Addis Ababa University by means of taxonomic keys, comparison with authenticated Herbarium collections, and with reference to the published Flora of Ethiopia and Eritrea. The life forms of epiphytes were recorded following Hosokawa (1943; cited in Freiberg, 1996).

3.4 Data Analysis

3.4.1 Epiphytes and host relation analysis

The relationship between the size of host trees and the numbers of epiphyte species per host trees was analyzed by using regression correlation statistical package SPSS version 20. The influence of bark texture of the phorophyte on the diversity and richness of epiphyte species per tree was analyzed by one way ANOVA statistical package SPSS version 20.

3.4.2 Epiphyte diversity analysis

The diversity of vascular epiphytes in Gera Forest was analyzed by using Shannon - Weiner diversity index.

Shannon - Weiner diversity index was calculated by the following formula.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where; H: Shannon-Wiener Index

Pi: is the proportion (n/N) of individual epiphyte species

Ln: is the natural log

Σ: is the sum of the calculations, and

S: is the number of species.

3.4.3 Similarity coefficient analysis of Gera, Harenna and Yayu forest epiphytes

Sorensen's similarity index was used to determine the pattern of species turnover between the epiphytic community of Gera, Harenna, and Yayu forests. The epiphytic data for Harenna and Yayu was obtained from the study of Tesfa Alemayehu (2006) and Abuna Tfa (2010) respectively.

Calculated as follows

Where; **Ss**= Sorensen's similarity coefficient;

Sorenson's Coefficient (Ss) $= \frac{2a}{2a + b + c}$

a = common epiphytic species between Gera and the forest in comparison

b = number of epiphytic species found only in Gera Forest

c = number of epiphytic species found in forest of other sites in comparison with Gera Forest

CHAPTER FOUR

4. RESULTS

4.1 Vascular Epiphyte Composition of the Study Area

A total of 59 vsacular epiphyte species belonging to 37 genera and 26 families were recorded, identified and presented from Gera Forest (Appendix 1). Of these, holo epiphytes constituted 59 %, hemi epiphytes 4% and accidental epiphytes about 37% (Figure 4). Orchidaceae was the most dominant family with twelve species (20%) belonging to six genera, Aspleniaceae was the second dominant family with eight species (13.33%) representing one genera. The third species rich family was Polypodiaceae with seven species (11.66) belonging to four genera. The fourth species rich family were Piperaceae and Asteraceae with four species (6.66%) each (Table 2). The families, which contributed two species each, were Acanthaeae, Balsaminaceae and Lamiaceae. The rest 18 families contained only one species each (Table 2). The species diversity of the vascular epiphytes for the study area is calculated using Shannon –Weiner index of $H' =$ 3.537.

Sebsebe Demissew *et al.*, (2004) suggested that among three orchid genera that are represented by more than ten species in Ethiopia, *Polystachya* is predominantly an epiphytic genus with 12 species. Out of the 12 species of *Polystachya*, Gera Forest hosted 5 species.

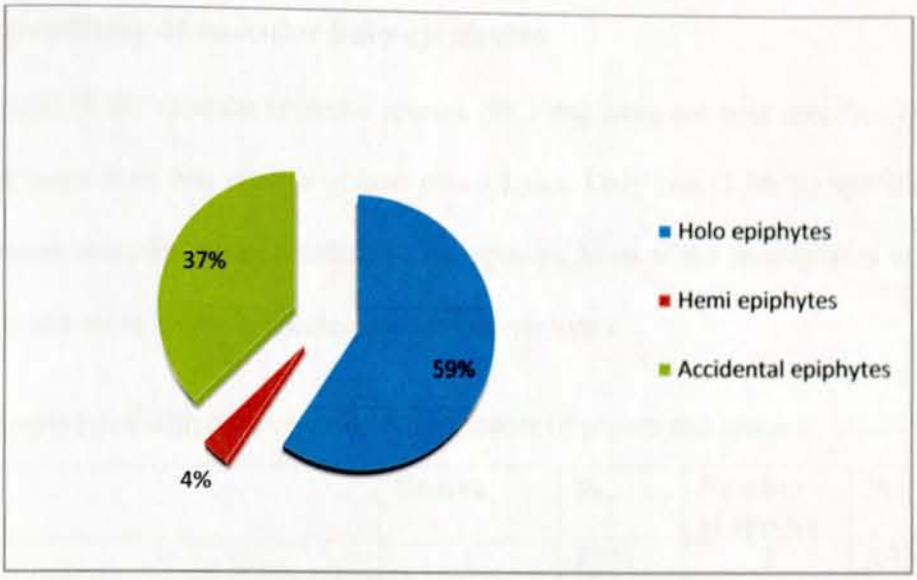


Figure 4 Percentage distribution of the, holo, hemi and accidental epiphytes in Gera forest.

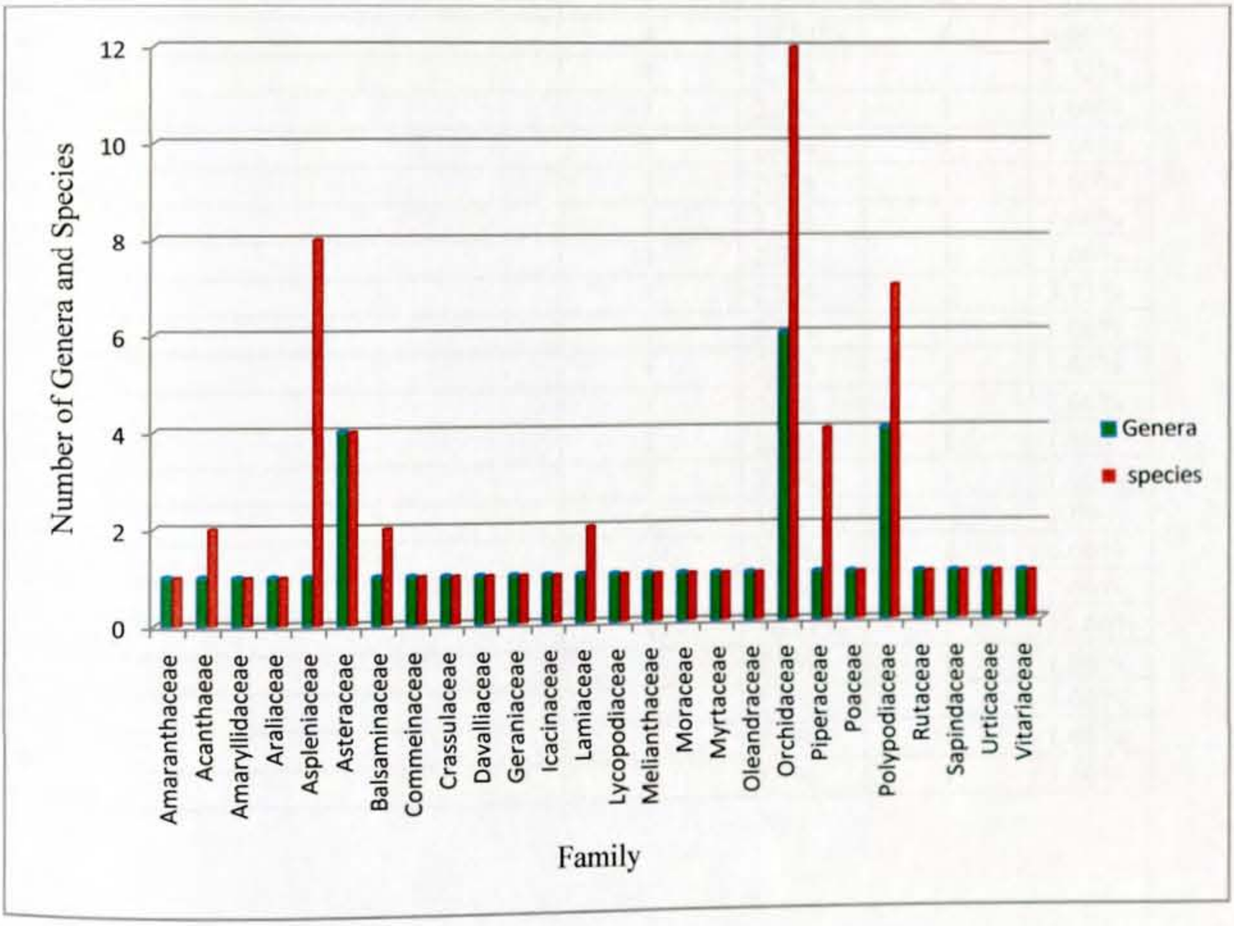


Figure 5 The species richness of the families of holo epiphytes

4.2 Host specificity of vascular holo epiphytes

In the study area, most of the vascular epiphyte species (98.33%) were not host specific. They were recorded from more than two species of host phorophytes. Only one (1.66 %) species of vascular epiphytes were recorded from specific host tree species. Most of the phorophytes in the study area carry two and more than two species of vascular epiphytes.

Table 2 Families of epiphytes with their corresponding number of genera and species.

Family	Genera	%	Number of species	%
Acanthaeae	1	2.7%	2	3.33%
Amaryllidaceae	1	2.7%	1	1.66%
Araliaceae	1	2.7%	1	1.66%
Aspleniaceae	1	2.7%	8	13.33%
Asteraceae	4	10.81%	4	6.66%
Balsaminaceae	1	2.7%	2	3.33%
Commelinaceae	1	2.7%	1	1.66%
Crassulaceae	1	2.7%	1	1.66%
Davalliaceae	1	2.7%	1	1.66%
Geraniaceae	1	2.7%	1	1.66%
Icacinaceae	1	2.7%	1	1.66%
Lamiaceae	1	2.7%	2	3.33%
Lycopodiaceae	1	2.7%	1	1.66%
Melianthaceae	1	2.7%	1	1.66%
Moraceae	1	2.7%	1	1.66%
Myrtaceae	1	2.7%	1	1.665
Oleandraceae	1	2.7%	1	1.66%
Orchidaceae	6	16.21%	12	20%
Piperaceae	1	2.7%	4	6.66%
Poaceae	1	2.7%	1	1.66%
Polypodiaceae	4	10.81%	7	11.66%
Rutaceae	1	2.7%	1	1.66%
Sapindaceae	1	2.7%	1	1.66%
Urticaceae	1	2.7%	1	1.66%
Vittariaceae	1	2.7%	1	1.66%

4.3 Life Forms of Holo epiphytes in Gera forest

The most life form of epiphytes species in Gera forest was buds close to one another (Reptata densa upright). Buds close to one another, densely tufted, pendulus life form was the second common life form of epiphytic species. Buds far apart, shoots or leaves scattered (Reptata remota) and Rosette forms (Fasicularis) life form was relatively low. Buds on basal portion of plant, upright shoots tufted (Caespitosa) life form is rare in epiphytic species recorded from Gera Forest. The life forms recorded for each species of holo epiphyte is given (Table 3).

Table 3 Life-forms of holo epiphytes in Gera Forest

Species	**Life form**
Asplenium abyssinicum	Reptata densa upright
Aerangis thomsonii	Fasicularis
Aerangis brachycarpa	Reptata densa upright
Asplenium smedsii	Reptata densa upright
Asplenium erectum	Reptata densa upright
Asplenium protensum	Reptata densa upright
Asplenium sandersonii	Reptata densa upright
Asplenium aethiopcum	Reptata densa upright
Asplenium theciferum	Reptata densa upright
Arthropteris orientalis	Reptata densa upright
Cyrtorchis arcuata	Fasicularis
Diaphananthe adoxa	Reptata densa pendulus
Diaphananthe tenuicalcar	Reptata densa pendulus
Drynaria volkensii	Fasicularis.
Huperzia ophioglossoides	Reptata densa pendulus

Lepisorus excavatus	Reptata dense upright
Lepisorus schraderi	Reptata dense upright
Loxogramme abyssinica	Reptata dense upright
Microcoelia globulsa	Reptata densa pendulus
Peperoma molleri	Reptata remota
Peperomia abyssinica	Reptata remota
Peperomia tetraphylla	Reptata densa upright
Phymatosorus scolopendria	Reptata densa upright
Pleopeltis excavata	Reptata dense upright
Pleopeltis macrocarpa	Reptata dense upright
Polystachya rivae	Reptata densa upright
Polystachya bennettiana	Reptata dense upright
Polystachya cultriformis	Caespitosa
Polystachya tessellata	Reptata denseupright
Polystachya lindblomii	Reptata denseupright
Diaphanante adoxa	Reptata densa pendulus
Scadoxus nutans	Fasicularis
Vittaria volkensii	Reptata densa pendulus
Asplenium linkii	Reptata densa pendulus
Indet. fern sp.	Fasicularis

For description of life forms see glossary in Appendix 7

4.4 Altitudinal Distribution of Vascular Epiphytes

The altitudinal distribution of holo and hemi vascular epiphyte species in Gera forest shows different pattern (Table 4). At altitude between 1600 m to 2400 m 30% of holo and hemi vascular epiphytes were recorded in the study area (Figure 6). Most of the holo and hemi vascular epiphytic species (52%) were recorded from the middle altitudinal range between 1800 m to 2000 m. within the upper(> 2000 m) and lower altitudinal range (1600 m to 1800 m) 13% and 5% of holo and hemi vascular epiphytic species were recorded respectively (Figure 6).

Table 4 Patterns of altitudinal distribution of Holo and Hemi – vascular epiphytes in Gera Forest

Legend: A = 2400 -2300, B= 2300 -2200, C = 2200 – 2100, D= 2100 -2000, E =2000 -1900, F=1900 -1800, G=1800 -1700, H=1700 -1600

Species	Altitudinal Range							
	A	B	C	D	E	F	G	H
Aerangii thomsonii	+	+	+	+	+	+	+	+
Aerangis brachycarpa	+	+	+	+	+	+	+	+
Allophylus macrobotrys	+	+	+	–	–	–	–	–
Apodytes dimidiata	–	+	+	–	–	–	–	–
Arthropteris monocarpa	+	+	+	+	+	+	+	+
Arthropteris orientalis	–	–	–	+	+	+	+	
Asplenium anisophyllum	–	–	–	–	+	+	+	–
Asplenium erectum	+	+	+	+	+	+	+	+
Asplenium protensum	+	+	+	+	+	+	+	+
Asplenium sandersonii	–	–	–	–	+	+	+	–

Asplenium abyssinicum	–	–	–	+	+	+	+	+
Asplenium aethiopcum	+	+	+	+	+	+	+	+
Asplenium linkii	-	-	-	-	+	+	+	+
Asplenium theciferum	–	–	+	+	+	+	+	–
Cyrtorchis arcuata	–	–	–	–	+	+	+	+
Diaphananthe adoxa	+	+	+	+	+	+	+	+
Diaphananthe tenuicalcar.	+	+	+	+	+	+	+	+
Drynaria volkensii	+	+	+	+	+	+	+	+
Ficus thonningii	–	–	–	+	+	+	–	–
Huperzia ophioglossoides	+	+	+	+	–	–	–	–
Lepisorus excavatus	+	+	+	+	+	+	+	+
Lepisorus schraderi	+	+	+	+	+	+	+	+
Loxogramme abyssinica	+	+	+	+	+	+	+	+
Microcoelia globulosa	–	–	–	+	+	+	+	+
Peperomia molleri	-	-	-	-	-	+	+	+
Peperomia abyssinica	+	+	+	+	+	+	+	+
Peperomia tetraphylla	+	+	+	+	+	+	+	+
Phymatosorus scolopendria	-	-	-	-	-	-	-	+
Pleopeltis excavata	+	+	+	+	+	+	+	-
Pleopeltis macrocarpa	+	+	+	+	+	+	+	+
Polystachya rivae	+	+	+	+	+	+	+	+
Polystachya bennettiana	–	–	–	–	+	+	+	+
Polystachya cultriformis	–	–	–	–	–	+	+	+
Polystachya tessellata	–	–	–	+	+	+	+	+
Polystachya lindblomii	-	-	-	-	+	+	+	+
Scadoxus nutans	–	+	+	–	–	–	–	–
Schefflera abyssinica	–	–	+	+	+	+	–	–
Vittaria volkensii	–	+	–	–	–	–	–	–
Indet. fern sp.	-	-	-	-	+	+	-	-

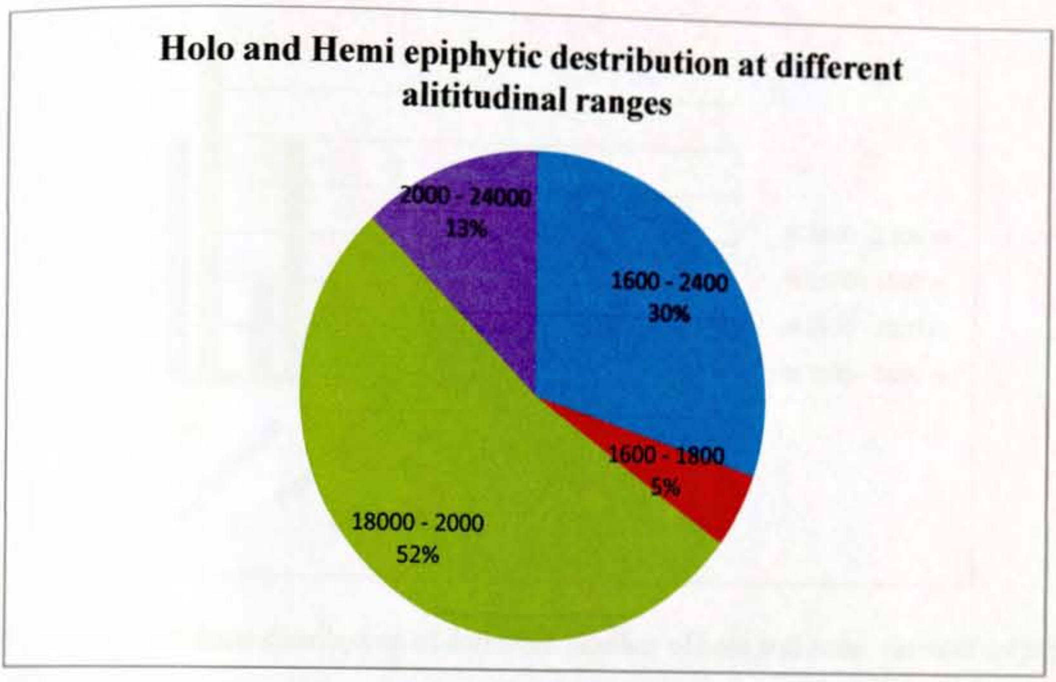


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Figure 6 Altitudinal distribution of Holo and Hemi epiphytic vascular epiphytes species in Gera Forest.

4.5. Altitudinal distribution of dominant vascular epiphhyte Family

In Gera forest the dominant families of holo and hemi vascular epiphytes show different distributional pattern along altitudinal gradient from 1600 m to 2400 m a.s.l. (Figure 7). Orchidaceae, Aspleniaceae, polipodiaceae and Lycopodiaceae are dominant families of vascular epiphytes in the study area.

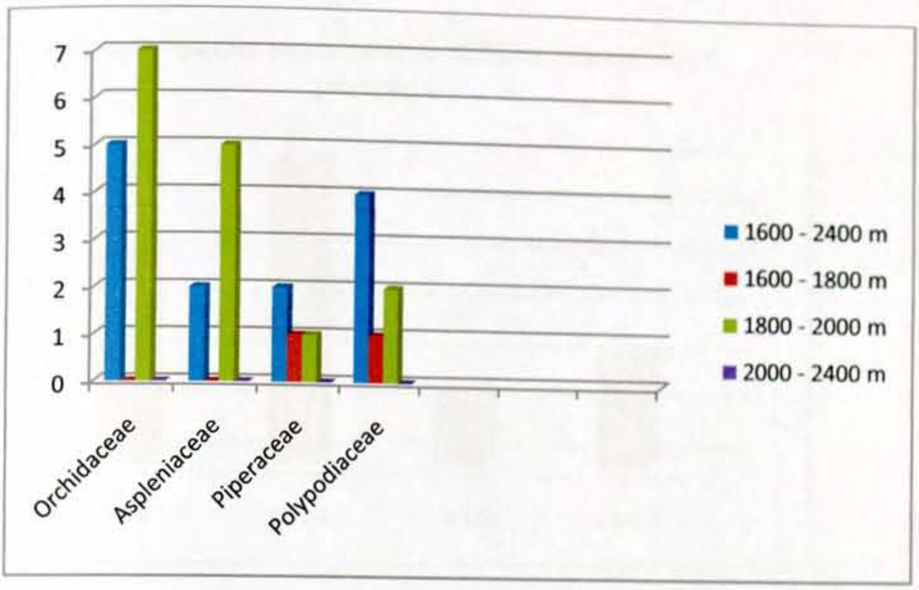


Figure 7 Altitudinal distribution of dominant families of holo and hemi vascular epiphytes in Gera forest.

The figure (7) shows that most of the orchidaceae and Aspleniaceae family distribution was restricted at the middle(1800 m – 2000 m) altitudinal ranges followed by declining at lower and upper altitudinal ranges. The species of these families are also distributed throughout the altitudinal ranges in the forest. Piperaceae also distributed at all altitudinal range however some of the species are restricted to the lower (1600 m – 1800 m) and middle (1800 m – 2000 m) altitudinal ranges.

4.6 Attachment direction of epiphytes on phorophytes

The attachment direction of vascular epiphyte species in Gera forest shows different patterns (Table 5). Most of the species were recorded from west and east direction of the phorophytes. Species such as: *Drynaria volkensii, Asplenium anisophyllum, Asplenium theciferum, Microcoelia globulosa* and *Peperomia tetraphylla* were collected from north and south face of the phorophytes (Table 5). However, richness of species was observed on the east and west face of the phorophytes. Attachment direction recorded for each species of epiphyte is given (Table5).

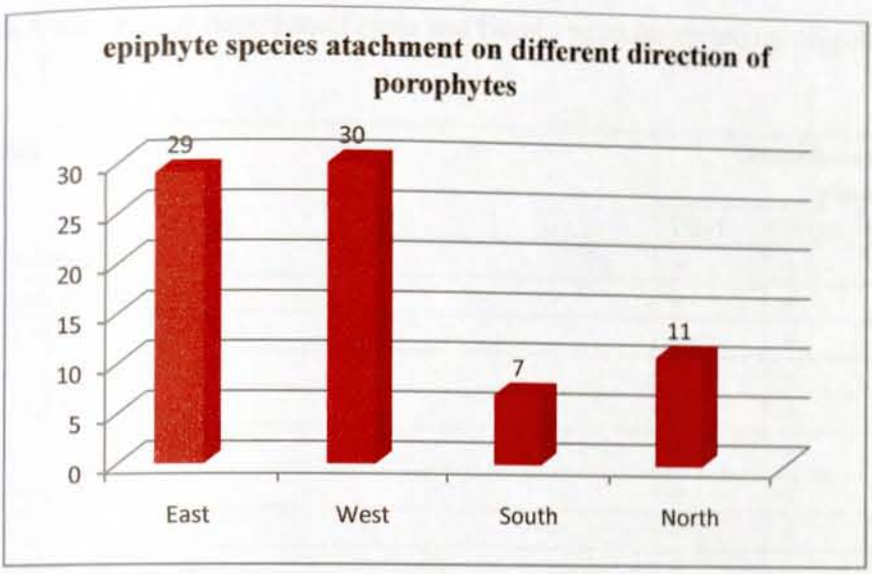


Figure 8 Number of species attached at different directional phase of phorophytes.

Table 5 Attachment direction of Holo and Hemi - vascular epiphytes on phorophyts in Gera Forest

Species	**Attachment direction on phorophytes**			
	East	**West**	**North**	**south**
Asplenium abyssinicum	+	+	-	-
Aerangis brachycarpa	+	+	-	-
Arthropteris monocarpa	-	+	-	-
Arthropteris orientalis	+	+	-	-
Aerangii thomsonii	+	+	-	-
Asplenium aethiopcum	+	+	-	-
Asplenium linkii	+	+	-	-
Asplenium smedsii	+	+	-	+
Asplenium protensum	+	+	-	+
Asplenium sandersonii	-	+	-	-
Asplenium theciferum	+	+	+	-
Cyrtorchis arcuata	+	-	+	-
Diaphanantheadoxa	+	+	-	-
Diaphananthe tenuicallcar	+	+	-	+
Drynaria volkensii	+	+	+	+
Huperzia ophioglossoides	+	+	-	-
Lepisorus excavatus	+	+	-	-
Aspillinium erectum	+	+	+	-
Lepisorus schraderi	-	+	-	-
Loxogramme abyssinica	+	+	-	+
Microcoelia globulosa	+	+	+	+
Peperomia abyssinica	+	+	-	-
Peperomia fernandopoiana	+	-	-	-
Peperomia molleri	+	+	-	-
Peperomia tetraphylla	+	+	+	+
Phymatosorus scolopendria	+	+	-	-
Pleopeltis excavate	-	+	-	-
Pleopeltis macrocarpa	-	+	-	-
Polystachya bennettiana	+	+	+	-
Polystachya cultriformis	+	+	-	-
Polystachya rivae	+	+	+	-
Polystachya lindblomii	+	-	-	-
Rhipidoglossum adoxum	+	+	+	-
Scadoxus nutans	+	-	-	-
Vittaria volkensii	-	+	-	-
Indet. fern sp.	+	-	-	-
Ficus thonningii	-	-	+	-
Schefflera abyssinica	-	+	-	-


A
B
C
D


E
F
G
H

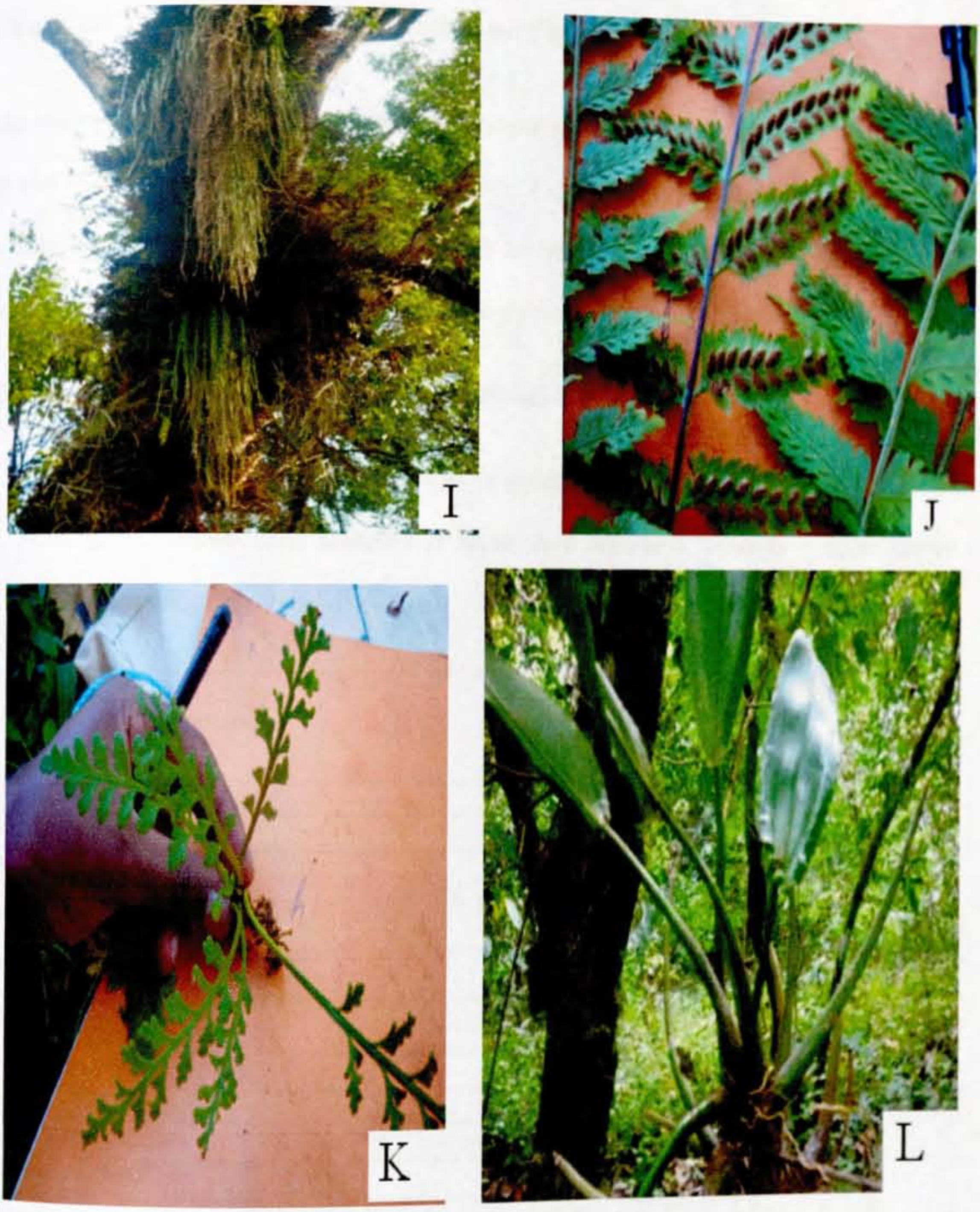


Plate 2 Pictures of some vascular epiphyte species of the Gera Forest. **(A)** *Aerangis brachycarpa,* **(B)** *Asplenium sandersonii,* **(C)** *Peperomia tetraphylla,* **(D)** *Polystachya bennettiana,* **(E)** *Peperomia abyssinica*, **(F)** *Ficus thonningii,* **(G)** *Huperzia ophioglossoides,* **(H)** *Drynaria volkensii,* **(I)** *Vittaria volkensii,* **(J)** *Asplenium smedsii,* **(K)** *Asplenium theciferum,* **(L)** *Polystachya cultriformis*. (Photo by Bedilu Tafesse, 20012).

4.7 Vertical Distribution of Epiphytes on Phorophytes

In the study area the distributional patterns of vascular epiphytes on phorophytes vary from the basal part to the top of most crowns. The numbers of epiphytic species increase from the tree base to middle branches followed by a decline in the top branch region. The lists of epiphytes recorded from different part of the phorophytes are given in Table 6.

Table 6 Lists of species of vascular epiphytes distributed in different zones of the host tree

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

Species	Class of phorophytes /host tree.			
	A	**B**	**C**	**D**
Achyranthes aspera	+	-	-	-
Adenostema mauritianum	+	-	-	-
Aerangis thomsonii	+	+	+	-
Aerangis brachycarpa	-	+	-	-
Allophylus macrobotrys	+	+	-	-
Apodytes dimidiata	+	+	+	-
Arthropteris monocarpa	+	+	-	-
Asplenium abyssinicum	+	+	-	-
Asplenium aethiopcum	+	+	+	+
Asplenium smedsii	+	+	+	-
Asplenium erectum	+	+	+	+
Asplenium linkii	-_	+	+	
Asplenium protensum	+	+	+	-
Asplenium sandersonii	+	+	+	+
Asplenium theciferum	+	+	-	-
Bersama abyssinica	+	-	-	-
Bidens pilosa	+	-	-	-

Clausena anisata	+	-	-	-
Commelina diffusa	+	-	-	-
Crassocephalum crepidioides	+	+	+	-
Cyrtorchis arcuata	-	+	-	-
Diaphananthe adoxa	-	-	+	+
Diaphananthe tenuicalcar	-	+	-	-
Drynaria volkensii	-	+	+	+
Ficus thonningii	-	+	+	
Geranium arabicum	+	-	-	-
Huperzia ophioglossoides	-	+	+	+
Hypoestes forskaolii	+	-	-	-
Hypoestes triflora	+	-	-	-
Impatiens hochstetteri	+	+	-	-
Impatiens rothii	+	-	-	-
Kalanchoe petitiana	+	+	-	-
Lepisorus excavatus	+	+	-	-
Lepisorus schraderi	+	+	+	-
Loxogramme abyssinica	+	+	+	-
Microcoelia globulosa	-	+	-	-
Oplismenus hirtellus	+	-	-	-
Peperomia abyssinica	+	+	+	+
Peperomia molleri	+	+	+	+
Peperomia tetraphylla	+	+	+	+
Phymatosorus scolopendria	+	+	-	-
Pilea rivuaris	+	+	-	-
Pleopeltis excavata	-	+	+	+
Pleopeltis macrocarpa	+	+	+	-
Polystachya rivae	-	+	+	+
Polystachya bennettiana	-	+	+	+
Polystachya cultriformis	-	+	-	-
Polystachya lindblomii	-	-	+	+
Polystachya tessellata	-	+		
Pycnostachys abyssinica	+	-	-	-
Pycnostachys eminii	+	-	-	-
Diaphanante adoxa	-	+	-	-
Scadoxus nutans	+	-	-	-
Schefflera abyssinica	-	+	+	-
Syzygium guineense	+	-	-	-
Urera hypselodendron.	+	+	-	-

Vernonia auriculifera	+	-	-	-
Vittaria volkensii	-	-	+	-
Indet. fern sp.	-	+	+	-

Accidental epiphytes were highly distributed in the lower class of the host plant (Class A). Rarely some species such as *Impatiens hochstetteri* and *Kalanchoe petitiana* reached up to clases B and C respectively. *Polystachya cultriformis* species were restricted to clases A and B of the phorophytes. And *Scadoxus nutans* was restricted to the lower class A of phorophytes that usually grow between branches. However, hemi epiphytes such as *Ficus thonningii*, and *Schefflera abyssinica* extend only up to Class C (Table 6). The leafless orchid *Microcoelia globulosa* mostly grows on the top most outer branches and twigs of trees. The *Drynaria volkensii* is the most common species of epiphyte in the study area. It is found in all clases of the phorophytes and abundant in upper canopy.

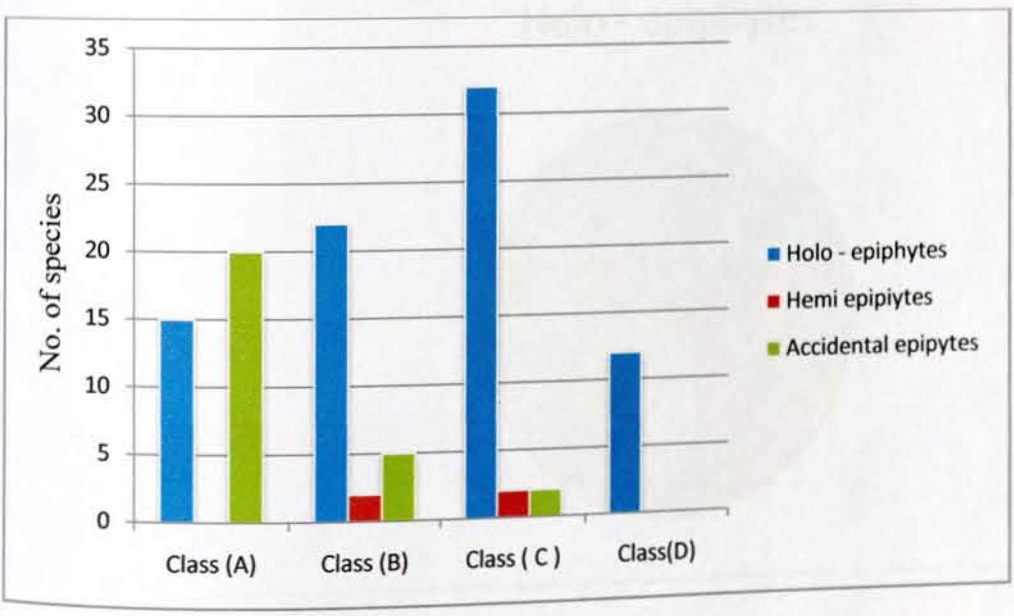
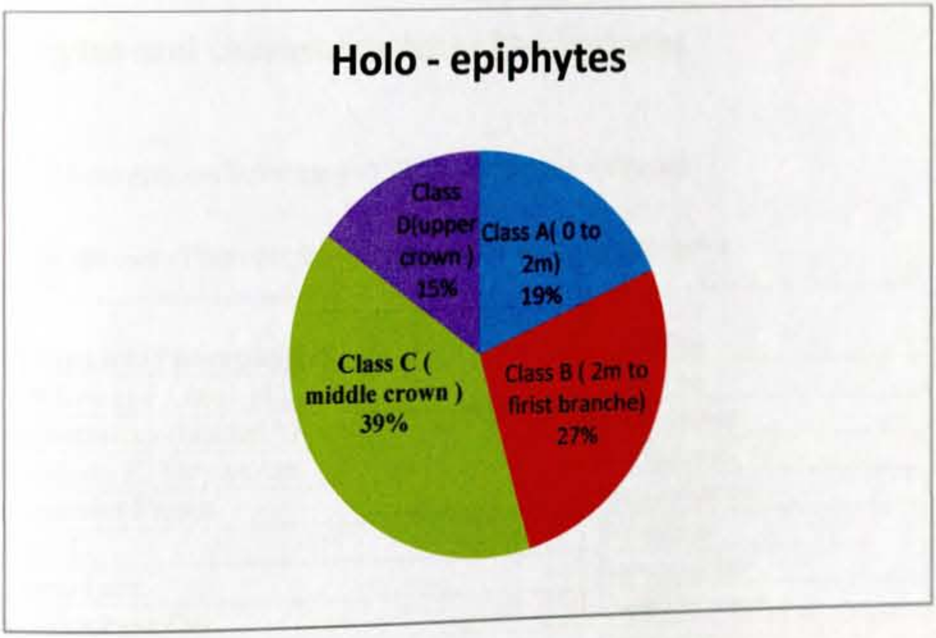


Figure 9 Types of vascular epiphytes distributed on different class of host tree

The holo epiphytes are gradually increased from Class A to Class C, followed by decline in Class D (Figure 9). Highes holo epiphytes (39%) occurred on the middle class of the phorophytes from below the first branch to the third branches, most of these epiphytes are orchid species, followed by class B (27%) occurred from 2 meter to below third branches. The least holo vascular epiphytes were recorded from class D (15%) and class A (19%) of phorophyte (Figure 10A). However, Accidental epiphytes gradually decreased from class A to Class C, and totally absent on upper crown (Class D) (Figure 9). In Gera Forest high accidental vascular epiphytes were recorded at class A (75%) followed by class B (21%). Only 4% of accidental vascular epiphytes reached up to class C of phorophytes (Figure 10B). Hemi epiphytes were totally absent on the lower class (A) and upper crown (Class D), they are only restricted on class B and C (Figure 9).



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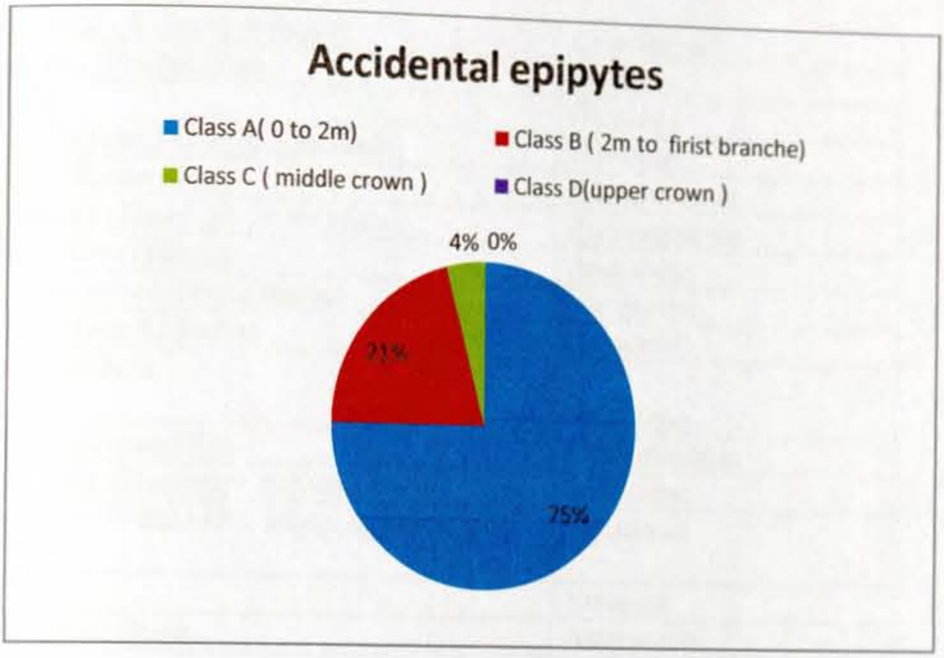


B

Figure 10 Species Percentage of Holo epiphytes **(A)** and Accidental epiphytes **(B)** at vertical class of phorophytes

4.8 Epiphytes and characteristics of Phorophytes

In the study area, 29 host species belonging to 23 families were recorded.

Table 7 List of Host species (Phorophytes) harboring the vascular epiphytes

List of Host Species (Phorophytes)	Families
Albizia gummifera (J.F.Gmel.) C.A.Sim.	Fabaceae
Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae
Apodytes dimidiata E. Mey.exAm.	Icacinaceae
Bersama abyssinica Fresen.	Melianthaceae
Coffea arabica L.	Rubiaceae
Cordia africana Lam.	Boraginaceae
Croton macrostachyus Del.	Euphorbiaceae
Dracaena steudneri Scw.ex Engl.	Dracaenaceae
Ficus sur Forssk.	Moraceae
Flacourtia indica Burm.f.Merr.	Flacourtaceae
Grewia ferruginea Hochst. ex A.Rich	Tiliaceae
Macaranga capensis (Bail.) Sim.	Euphorbiaceae
Maesa lanceolata Forssk.	Myrsinaceae

Maytenus arbutifolia (A .Rich) Wilczek	Celastraceae
Millettia ferruginea (Hochst.)Bak.	Fabaceae
Olea capensis L.	Oleaceae
Olea welwitschii (Knobl.) Gilg & Schellenb	Oleaceae
Pittosporum viridiflorum Sims.	Pittosporaceae
Podocarpus falcatus (Thunb.)R. B. ex Mirb.	Podocarpaceae
Polyscias fulva (Hiern) Harms	Araliaceae
Pouteria adolfi-friederici (Engl.) Baehni	Sapotaceae
Prunus africana (Hook.f.) Kalkm	Rosaceae
Psychotria orophila Petit	Rubiaceae
Sapium ellipticum (Krauss) Pax	Euphorbiaceae
Schefflera abyssinica (Hochst.ex A.Rich.) Harms	Araliaceae
Syzygium guineense (Willd.) DC. subsp. *afromontanum* F.White	Myrtaceae
Teclea nobilis Del.	Rutaceae
Vernonia auriculifera Hiern.	Asteraceae

In Gera Forest host species such as *Croton macrostachys, Millettia ferruginea* and *Polyscias fulva* harbored low epihyte species richness. Only a small number of *Polystachya bennettiana* epiphyte species occurred on the branches of these host species. Host species such as *Albizia gummifera* and *Pouteria adolfi-friederici* have large dbh size and heights. However, they harbored low number of epiphytic species in the study area. Host species *such as Flacourtia indica, Grewia ferruginea, Macaranga capensis, Maesa lanceolata, Maytenus arbutifolia, Vernonia auriculifera* and *Coffea arabica* are suitable for epiphytes like *Polystachya cultriformis, Diaphanante adoxa, Microcoelia globulosa* and *Aerangis brachycarpa*.

In the study area host tree species such as: *Cordia africana, Syzygium guineense, Sapium ellipticum and Olea capensis* harbored high epiphyte species richness.

4.9 Relation of types Host Barks, DBH, Height, and Canopy Architecture with Epiphytic Richness and Diversity

4.9.1 Host bark types and epiphyte richness

In Gera Forest, epiphytic species diversity and richness show significant diference between host bark types (Appendix 5) and positive correlation with host tree size (Figures 11 and 12). Epiphytic species were recorded from smooth, rough, flacky and corky host barky textures. There were significant interactions between host bark texture and epiphyte species richness in the study area. The mean value for species recoreded from smooth bark tecture is 3.50, rough 13.4, flacky, 11.66 and corky, 10.26(Annex 5). The minimun and maximum species recorded per tree was significantly differente between smooth and other host bark texture. Minimum and maxmum speies recorded from smooth bark is (1 and 10), rough bark (5, 10) flacky bark (3 and 21) and corky (12 and 28) species respectively (Annax 5). There was a ststistically significant diference between bark type and epiphyte abundance as determined by one – way ANOVA ($F(3, 91) = 21.833$, $p = 0.001$), with rough host bark hosting the greatest abundance of epiphytes. The post – hoc test shows that there is significant difference of vascular epiphyte richness between the host bark types between Smooth bark and Rough, flack and Corky bark (P =0.001*),* as well as Rough bark and cork bark (p =0.043 < 0.05). However between Rough and Flack bark (p = 0.753 > 0.05) and between Flack and Corky bark (p = 0.854 > 0.05) no significant difference of epiphyte abundance was observed (Annex 5). Species richness shows that 38 % was from rough bark 26 %, 25 % and 11 % were from flack, corky and smooth bark textures, respectively (Figure 10). This result shows that smooth bark textures are less suitable for seedling establishment and anchoring of epiphytes. In other hand Rough bark types are more sutable for epiphyte attachment.

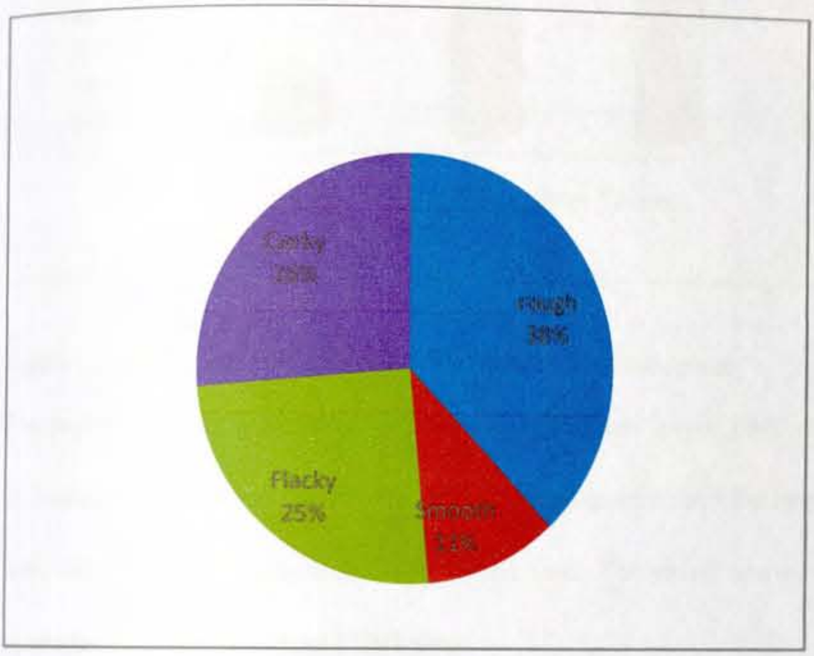


Figure 11 Host bark textures and epiphytes species richness

4.9.2 Host DBH size and epiphytes species richiness.

In the study area DBH had positive effect on epiphyte richness (Figure 12). The results show that host tree species having large DBH anchored high amounts of vascular epiphyte species.

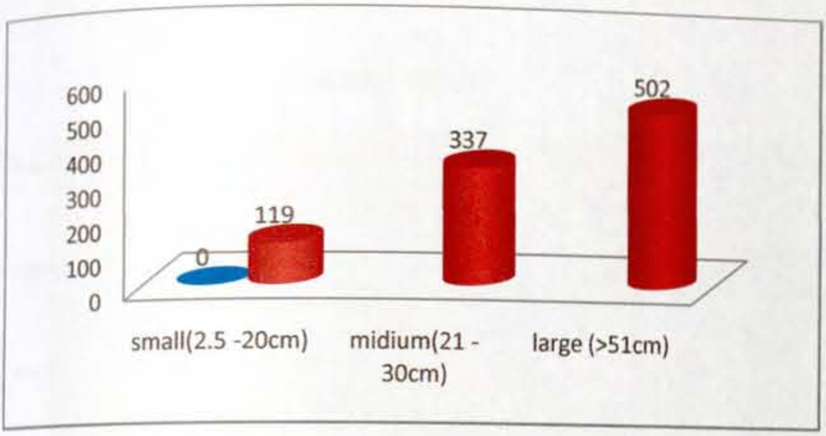
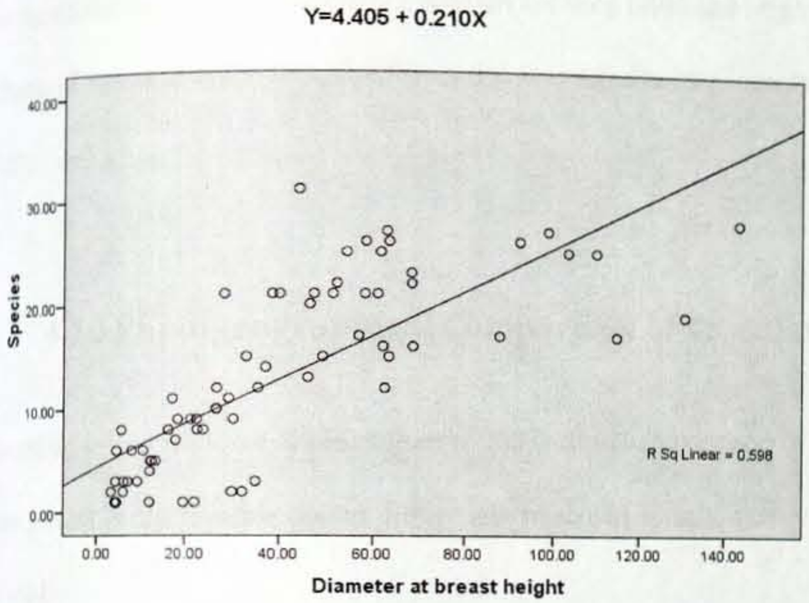


Figure 12 Host DBH classification and epiphytic abundance

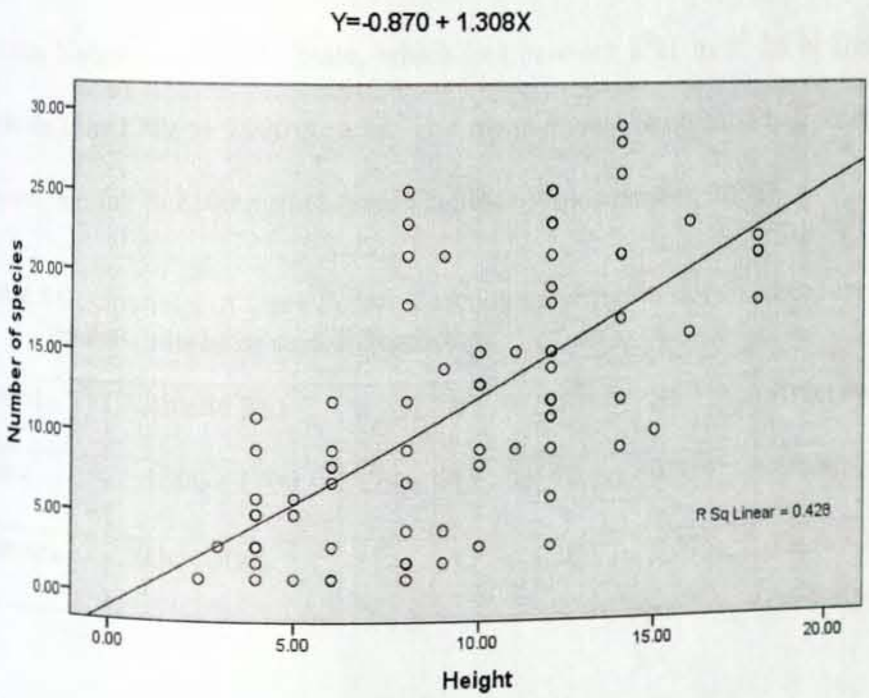
The highest epiphyte abundance was recorded from larger DBH class >51 cm (52%), followed by medium class size 21 to 30 cm (35%) were recorded and the least epiphytes abundance (13%) were recorded from the small host class size. The result shows that strong relation between epiphytes richness and host DBH size.

The regression correlation test showed that the number of species of vascular epiphytes and the size of host tree are positively correlated (R^2 = 0.773, p = 0.0001< 0.05). This may be due to large host size having different microclimate, which is suitable for different species of vascular epiphytes. In current study host tree DBH size and epiphyte species richnes shows strong positive correlation. Larger sized host tree species harbored high epiphyte species richness (Figure 13A).

The regression correlation test (R^2 = 0.28, p = 0.0001 < 0.05), showed that the epiphyte species richness increased with host tree height increase (Figure 13B).



A



B

Figure 13 Corelation of Host species DBH (**A**), Heights (**B**) and epiphyte richness

The figure shows positive correlation relation between DBH and height of host tree species and richness of vascular epiphytes. Epiphytes richness significantly increased with increasing host height.

4.10 Phytogeographical Comparison of Vascular Epiphytes

According to the Tadesse Woldemariam(2003) direct comparison of the species diversity with other forests is not feasible due to differences in size of forests, survey methods, and objective of the study.

Accordingly, Gera Forest was compared with 2 forests in the country to know the similarity of vascular epiphyte species in the forests and indicate to which forest type it is related (Table 8) Yayu forest is located in southwestern part of northwestern higlands, in illu – Ababora Zone of oromia National Regional State, which lies between $8^{0}21$ to 8^{0} 26 N and $35^{0}45$ to $35^{0}03$ E. It extends from1200 to 2000 m a.s.l. The mean annual temperature is about 20^{0} C and the mean annual rain fall is 2100 mm to /year (Tadesse Woldemariam, 2003).

Table 8 Comparison of Gera Forest Vascular epiphytes with two other forests in Ethiopia based on their similarity and difference.

Forest	Altitude (m)	a	b	c	Ss	References
Yayu	1300 - 1700	17	43	19	0.354	Abuna Tafa, 2010
Harenna	2000 - 3000	17	43	38	0.295	Tesfa Alemayehu, 2006

Result of similarity analysis (Table 9) of Gera Forest showed the highest vascular epiphytic similarity (0.354) with Yayu Forest and shared the least vascular epiphytic similarity (0.295) with Harenna Forest. Common vascular epiphytic species between the three forests is listed in Table 10. The result shows that Gera Forest had more holo vascular epiphytic similarity with Yayu Forest than Harenna Forest. The most common epiphytic species between Gera and Harenna forests are Accidental vascular epiphytes. The high similarty observed Gera and Yayu forests could be due to similarity in altitudinal range, climatic condition and proximity.

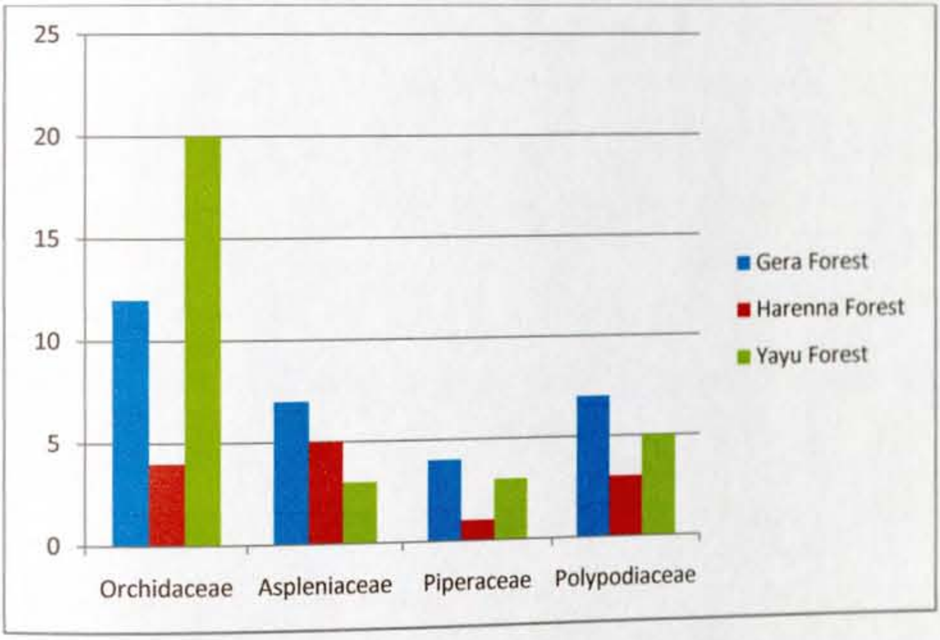


Figure 14 Comparison of epiphytic species abundance of the common Families within Gera, Harenna, and Yayu forests

The above figure shows that comparsion of epiphyte species abundance between common epiphyte families in Gera, Harenna and Yayu forests. The result shows that Orichidaceae are more abundant in Yayu Forest, folowed by Gera Forest. However Aspleniaceae, Piperaceae and Polypodiaceae are more abundant in Gera Forest than the two forests (Figure 14).

The common vascular epiphye species recorded from the three forests are *Asplenium theciferum, Arthropteris monocarpa, Aerangis brachycarpa, Drynaria volkensii and Peperomia abyssinica* (Appendce 4).

CHAPTER FIVE

5. Discussion, Conclusion and Recommendations

5.1 Discussion

5.1.1 Epiphytic Species Composition of Gera Forest

A total of 59 vascular epiphytes species recorded from Gera Forest is very low number compared to the number reported for different tropical forest. Barthlott *et al.* (200) reported 178 and 81 epiphytic species from primary and secondary rainforests respectively in the Venezuelan; Bussmann (2000) reported 223 species from Estacion Cientifica San Francisco. This could be related to the forest disturbances caused by human activities. The deforestation activities performed by local people (for agriculture, fuel, and timber) and logging activities were some of the disturbances observed in the study area. Coffee cultivator farmers and investors remove shrub plants and only leave selective tree species for coffee shade purpose. Most of the coffee shade plants have smooth bark textures which are not suitable for seedling establishment of vascular epiphytes. This could be due to low accumulation of litter and low water retaining capacity. The disturbance activities mentioned above resulted in the removal of forest trees on which the epiphytes could have been hosted, thus resulting in the decrease of epiphytic species diversity.

The diversity of Aspleniaceae and Orchidaceae families was higher than other families of vascular epiphytes. *Drynaria volkensii, Peperomia tetraphylla, and Polystachya bennettiana* were the most abundant epiphytic species in the study area.

5.1.2 Altitudinal Distribution of Vascular Epiphytes

The altitudinal distribution of vascular epiphytes in the study area showed that most species were found in the middle elevation (Figure 7). At altitudes between 1600 and 2400 m the following epiphytic species were recorded: *Drynaria volkensii, Asplenium aethiopcum, Peperomia abyssinica, Peperomia tetraphylla, Aerangis thomsonii, Aerangis brachycarpa, Arthropteris monocarpa, Asplenium erectum, Asplenium protensum, Diaphananthe adoxa, Diaphananthe tenuicalcar* and *Lepisorus schraderi* all occuring throughout the altitudinal gradient (Table 4). Of the total vascular epiphytic species 30% were recorded from this altitudinal range. Similarly, Abuna Tafa (2010) recorded the following species: *Drynaria volkensii* and *Arthropteris monocarpa* throughout the altitudinal gradient (1300 m to 1700 m) of Yayu Forest.

In Gera Forest, the distribution of *Phymatosorus scolopendria* was restricted below 1800 m. *Huperzia ophioglossoides, Scadoxus nutans* and *Vittaria volkensii* were only recorded from the altitudinal range between 2000 and 2350 m.

The highest species richness was found at mid – elevation between 1800 and 2000 m (Figure 7). Similar to this study Wolf and Alejandro (2003), recorded the highest species richness in Chiapas study area at mid – elevation between 500 and 2000 m. A mid-elevation species richness bulge has been suggested for vascular epiphytes in general (Schimper 1888; Madison 1977; Nieder *et al*., 2001.). From dominant families of holo and hemi vascular epiphytes in the study area, Orchidaceae and Aspleniaceae were highly distributed at middle elevation between 1750 and 2000 m (Figure 8). Similarly Cardelus *et al*. (2006), recorded orchid richness at elevations between 1600 and 2000 m. Kessler (2001), in his study stated that in Bolivia a mid-elevation belt of high epiphyte pteridophyte diversity was correlated with high amounts of precipitation in that zone. However, in Gera Forest, Piperaceae and Polypodiaceae were distributed at all altitudinal ranges and few of them were restricted to middle and lower elevations (Figure 7).

Gera Forest is relatively more diverse compared to other moist montane forests in Ethiopia. In Harenna Forest, southeastern Ethiopia, 55 vascular epiphytes were recorded between an altitude of 2000 m and 3000 m (Tesfa Alemayehu, 2006). Thirty – six vascular epiphytes were recorded at altitudes between 1300 and 1700 m in Yayu Forest, southwestern Ethiopia (Abuna Tafa, 2010)

5.1.3 Vertical Distribution of Epiphytes on Phorophytes

Vertical stratification of epiphytes on forest trees in relation to changes in microclimatic conditions along the tree has often been described (Johansson 1974, Ter Steege and Cornelissen, 1989). The distribution of vascular epiphytes amongst trees (horizontal) and within trees (vertical) depends on niche differentiation (competition) and dispersal (Wolf and Alejandro, 2003). The vertical distribution of vascular epiphytes in the study area depicted differences in epiphytic species diversity and abundance from the base of the host tree up to its crown. This may be due to the difference of microclimate in different zones of the host plants. Vertical distribution of epiphytes is mostly determined by light, moisture, water and substrate availability (Ter Steege and Cornelissen, 1989).

In this study, high abundance (39%) of the holo – epiphytic species was recorded from the middle of the host crown; 27% epiphytic species abundance was recorded from 2 m to first branches (Class B) followed by 19% and 15% from basal to 2 meter of the main trunk(class A) and from upper crown Class (D) respectively (Figure 10A). This finding is in agreement with other studies on vascular epiphytes (Freiberg, 1996; Arevalo and Betancur, 2006) who recorded high epiphytic abundance in the centre of host crown.

In Gera Forest accidental epiphytes were highly distributed in the lower class of the host plant (Class A); they were dominant in the forks of the big branches, mainly in the base branch region. This could be due to their humus-adaptation. Similar to this study Patrick (2007) recorded dominance of *Ficus* species and herbaceous epiphytes from the forks of big branches. Rarely, some species such as *Impatiens hochstetteri* and *Kalanchoe petitiana* reached up to class (B and C) respectively (Table 6). However, hemi epiphytes such as *Ficus thonningii and Schefflera abyssinica* extend only up to Class (C). The existence of forks of the big branches where there is humus and moisture accumulation and the bryophyte mats on branches for moisture and mechanical support provision to the epiphytes are other factors favoring the diversity of the hemi-epiphytes and facultative epiphytes (Patrick, 2007). The leafless orchid *Microcoelia globulosa* mostly grew on the top most outer branches and twigs of trees in the study area.

In Gera Forest, epiphytic species such as *Drynaria volkensii, Peperomia tetraphylla, Peperomia abyssinica, Asplenium aethiopicum, Asplenium sandersonii* and *Peperomia molleri* were distributed in all sections of the phorophytes. *Drynaria volkensii* is probably the most common species of epiphyte in the study area. It was found in sunny habitats, mostly in the crowns.

In the study area, vascular epiphytic species such as *Polystachya bennettiana, Huperzia ophioglossoides, Pleopeltis excavata* and *Pleopeltis macrocarpa* were widely distributed in middle strata of the phorophytes, from below first branches to 3rd branches (class C). Three vascular epiphytic species, *Microcolia globulosa, Aerangis brachycarpa, Diaphananthe tenuicalcar* and *Diaphanante adoxa,* occurred restricted to 2 meter to 3rd branches of the phorophytes. Twenty five vascular epiphytic species were found mostly in two or three classes of phorophytes (Table 6). Similarly, different studies showed different epiphytic distribution pattern along vertical gradient in the forest, explained by variation of moisture, luminosity, substrate availability and substrate characteristics (Tersteege and Cornelissen, 1989, Kernan and Fowler 1995).

Other studies showed that certain epiphyte species were more abundant at specific site inside the forest (Sanford, 1968). Niche segregation in epiphytes appeared related to species-specific adaptations to the environmental and structural conditions along a tree (Wolf and Sots, 2009). In the study area, the species *Drynaria volkensii* was highly dominant on the upper crown of host trees both on the vertical trunk and horizontal branches. On the other hand species such as *Diaphananthe tenuicalcar* occured on the branches and twigs of the host trees. According to the study of Bussmann (2000), the upper most crown epiphytes were characterized by their low moisture requirement and apparent demand for high light intensities.

According to Patrick (2007), the species rich community in the canopy zone may reflect an optimum balance between light and moisture requirements. The other factor is that of niche diversification and the large surface area available for attachment of epiphytes on the large branches. The result obtained from Gera Forest demonstrated the different vertical distribution of vascular epiphytes along host trees from base to upper crown. This could be due to difference in microclimate and substrate availability on the different strata of phorophytes.

5.1.4 Attachment Direction of Epiphytes on Phorophytes

In the current study, 30 species (39%) were recorded from the west face of the phorophytes and 29 species (38%) from east face of the phorophytes. The least epiphyte species were recorded from south and north direction of phorophytes seven (9%) and 11(14%) respectively (Figure 8). This may be related to the entrance of flux of light to the forest during sun rise in the east, and sun set in the west. While the nest forming *Drynaria volkensii* epiphytic species occurred in all face of the phorophytes, however the species abundance was observed in east and west face of the vertical trunk. According to the study of Hietz and Briones (1998), epiphytes can grow under different light conditions ranging from the nearly full sun, which is out in the open branches to the deep shade on base of the stem. Epiphytes depend on their host tree mainly for support. Successful establishment of epiphytes on their host depends on several host tree traits such as size, age, branch quality and bark texture (Callaway *et al.*, 2002). Not only requirement of light determines the attachment of epiphytes direction on the phorophytes, but the deposition of humus, host tree architectures and wind direction affect the attachment of epiphytes in the studied forest. Other epiphytic species, especially members of the Orchidaceae family were attached on the phorophytes on the west or east direction depending on the openings of the canopy.

5.1.5 Effect of Host Tree size, Bark Texture, and Canopy Architecture on Vascular Epiphyte Richiness and Abundance

Host tree size showed a strong positive effect on epiphyte species diversity and abundance in the study area. Phorophyte characteristics such as tree size bark texture, age and crown architecture contributed to habitat heterogeneity and created vertical stratification, which promoted epiphyte diversity (Bennet, 1986). Several Studies undertaken in different areas have demonstrated the effects of bark traits in shaping epiphyte communities (Bates, 1992; Talley *et al.*, 1996; Callaway et al., 2002).

5.1.5.1 Effect of Bark texture on vascular epiphyte richness

The different bark types of the host plants showed different epiphytic diversity and abundance in the Gera Forest. This may be due to the water holding capacity, humus deposition and bark chemical differences of the host plant.

There was a statistically significant difference between bark type and epiphyte richiness as determined by one – way ANOVA (F (3, 91) = 21.833, p = 0.001), with rough host bark hosting the greatest richness and abundance of epiphytes. The post – hoc test shows that there is significant difference of vascular epiphytes richness between the smooth host bark type and rough, flack and corky bark (P =0.001< 0.05*)*, as well as rough bark and cork bark (p =0.43 < 0.05). However between rough and flack bark (P = 0.753 > 0.05) and between flack and corky bark (p = 0.854 > 0.05) no significant difference of epiphyte richness was observed (Appendix 5).

In the current study 38% of vascular epiphytic species were recorded from rough bark texture and 26%, 25% and 11% of them were recorded from flack, corky and smooth bark textures respectively (Figure11). Smooth bark texture, on the other hand, harbored lower number of epiphyte richness. This could be related to the low water holding capacities, humus deposition and inappropriateness of the bark for seedling establishments. However, rough bark had space for holding water, humus and seeds. This creates a suitable environment for epiphytic establishment and colonization. This could be the main reason for high epiphytic abundance recorded from rough bark types. Similar to this study, Chansa *et al.* (2011) stated that rough barks provided better surface for anchorage of epiphytes. Khullar (1981) also suggested that the bark of trees is a factor meriting considerable importance for the prevalence of epiphytic ferns.

5.1.5.2 Host tree size and vascular epiphyte richness

In Gera Forest, host species having large DBH harbored high numbers of vascular epiphytic species, especially epiphyte richness of Aspleniaceae and Piperaceae families recorded from large sized host trees. This may be due to large sized trees have different microclimate suitable for different epiphytic species colonization. The regression correlation test showed that the number of species of vascular epiphytes and the DBH size of host tree are positively correlated ($R2 = 0.773$, $p = 0.0001 < 0.05$) (Fig15A). Similar to this study Laube and Zotz (2006), found positive correlation between host tree size and epiphyte richness. They also detected higher colonization rates of epiphytes per surface area on larger trees.

Not only host DBH, but also host tree height has its own relation with epiphyte richness. The regression correlation test for epiphytes richness and host tree height ($R2 = 0.28$, $p = 0.0001 < 0.05$) showed that the number of species richness and host tree height are positively correlated in the study area (Figure 13B). According to the study of Annaselvam and Parthasarathy (2001), bigger trees offering a larger area and more microhabitats are expected to have larger numbers of epiphytes. Arévalo and Betancur (2006) also found high number of epiphyte richness on larger host tree size in their study area.

In the study area epiphytic diversity and abundance also showed different pattern on vertical and horizontal branches of host trees. The difference in epiphytic richness on vertical trunk and horizontal branches of host tree has been reported (e.g. Benzing, 1981, 1990; Barkman, 1995; Chansa *et al.,* 2011,). According to Benzing (1981, 1990), the presence of humus on horizontal branches improves water retention capacity that provides a more continuous moisture supply for epiphytes than the atmosphere of a vertical or bare bark. A significant difference of epiphytic richness in vertical and horizontal branches of host tree occurred in Gera Forest. Especially Orchidaceae, Lycopodiaceae and Piperaceae families were abundant on vertical branches than trunks. This may be due to the dead organic matter that more easily accumulated on the horizontal branches than vertical trunks. This accumulation of dead organic mater was important for the seedling establishment, colonization and survival of vascular epiphytes. Chansa *et al.* (2011) reported a more inclined or vertical branch receives less wet season rainfall and experiences more rapid run off than a less inclined or horizontal branch. Propagules and canopy litter are less likely to settle on a vertical branch and rapid runoff of moisture could accelerate leaching compared to conditions on horizontal surfaces (Chansa *et al.,* 2011).

The humus collecting on horizontal surfaces may also accelerate bark decay (Barkman, 1995) and improve physical anchorage of seeds, spores, and propagules. Likewise, interception of light and water increases as inclination decreases. Decreasing inclination enhances successful settling of seeds and spores and the accumulation of organic matter (Chansa *et al.*, 2011). All these conditions provided a suitable medium for epiphyte establishment. These properties favor horizontal branches to have more epiphytes than inclined or vertical branches. It is for this reason that, in the Gera Forest, more epiphytic abundance was recorded from the upper layer of horizontal branches than vertical trunk. The other reason for abundance of epiphytes in the branches is that epiphytes are light demanding species, and therefore, light availability becomes higher in the crown than in the vertical trunks.

Height of host tree was another factor for epiphyte diversity and abundance. This may be due to increasing of light availability as the tree trunk height increases. This condition is more suitable for the colonization of sun epiphytes such us Orchidaceae family than shade epiphytes. However, as the host tree grows above the forest canopy, it becomes a big challenge for the survival of shade epiphytes such as Aspleniaceae and Piperaceae families. This could be the reason why shade epiphytes are abundant in the basal area of the host trees. In Gera Forest some host tree species (e.g., *Pouteria adolfi-friederici* and *Polyscias fulva*) having large height harbored less number of epiphytic richness. This could be due to smooth bark types which are not suitable for epiphytes seedling attachment and humus deposition and low number of branches.

5.1.6 Host Tree Preference

In Gera Forest, no host specificity was observed except in a single species (*Vittaria volkensii*), which was recorded from *Syzygium guineense* host tree. However, the result may not necessarily indicate the host preference of the species because the species was not recorded repeatedly from other individual trees of *Syzygium guineense*. Similar to this study Maaike (1999) didn't record host specificity in his study of the distribution of vascular epiphytes in secondary cloud forest of central Cordillera. In the current study, most of the epiphytic species were recorded from more than two host tree species. According to the study of Chansa *et al*. (2011), host preference of epiphytes depends on humidity, bark texture of host trees, trunk physiognomy and availability of minerals in the canopy of host trees. Variations in the distribution of epiphytes on host tree species may also have reflected differences in establishment requirements, host tree microhabitats and dispersal agents (Johanson, 1974).

5.1.7 Epiphytes and Characteristics of Phorophytes

In Gera Forest, some host tree species have higher number of epiphytic species than others. In the current study, the host species such as *Cordia africana, Sapium ellipticum, Olea welwitschii, Prunus africana* and *Schefflera abyssinica* harbored large number of vascular epiphytes. This may be due to their large crown, rough and corky bark texture. In agreement to the present study Matthias (2011) reported *Sapium ellipticum* as the most species rich host tree. In the study area host tree species harbored different number of epiphytic species richness and abundance which could be due to bark characteristics, canopy architecture, number of branches, DBH and heights of host trees. The physical attributes of a host tree such as huge trunk size, rough bark, horizontal branching and numerous invaginations on the stem facilitate epiphyte establishment (Mucunguzi, 2007). *Schefflera abyssinica* host tree harbored high number of accidental epiphytes in Gera Forest. This could be due to the high accumulation of humus and large trunk size. Matthias, (2011) reported that depending on the species, host plants can have certain characteristics that improve the establishment and growth of vascular epiphytes.

In Gera Forest, *Croton macrostachys* has the most abundant individuals; however, it harbored a low number of epiphyte species. This could be due to it is open crown and a smooth bark nature of the tree. *Millettia ferruginea* and *Polyscias fulva* harbored the least vascular epiphytic species richness in the study area. This may be due to their smooth bark textures, which are not suitable for seedling establishment of vascular epiphytes. *Syzygium guineense,* which is a medium sized tree with dense crown and a flacky bark texture harbored large number of epiphytic species of *Huperzia ophioglossoides*. A variety of spatial, temporal and many other abiotic factors influence epiphyte diversity and abundance. Host tree characteristics such as taxonomic identity or size have an important effect on species richness and composition of epiphytes (Zotz and Schultz 2008).

5.1. 8 Phytogeographical Comparison of Vascular Epiphytes

The result of similarity analysis indicates that Gera Forest showed the highest vascular epiphytic similarity (0.35) with Yayu Forest. Range of altitude and climatic condition of Yayu Forest are very similar to that of Gera Forest. The two forests are among the moist montane forests in southwest Ethiopia. This common characteristic of the two forests contributed to the vascular epiphytic similarity. Gera Forest shared least vascular epiphytic similarity with Harenna Forst (0.29). The altitudinal range of Harenna Forest is very different from that of Gera Forest; moreover, the geographical location and climatic condition of the two forests are also different. These may be the reasons for the low epiphytic species similarity of the two forests.

In comparison of common vascular epiphytic families between the three forests (Figure 14), the result indicated that Yayu Forest had more species diversity in Orchidaceae family than the two forests. Gera Forest is more diverse than Harenna in Orchidaceae family. For comparison of Aspleniaceae family, Gera Forest has more species diversity than the two forests.

Yayu Forest has less number of species than the two forests for Aspleniaceae family. Piperaceae family species diversity is more abundant in Gera Forest than in the two forests; however Yayu Forest has more species diversity for Piperaceae family than Harenna Forest. For Polypodiaceae family, species diversity is higher in Gera Forest than in the two forests followed by Yayu Forest. Generally, in comparison of common epiphytic family of the three forests, Gera Forest was found to be more diverse than the two forests followed by Yayu except for the Orchidaceae family. Harenna forest has the least species diversity than the two forests in all of comparable families.

5.2 Conclusion and Recommendations

5.2.1. Conclusion

Based on the results of this study, the following conclusion and recommendations may be drawn. Size, bark types, canopy architectures, and species of host plants were the factors influencing diversity and abundance of vascular epiphytes. Large DBH and heights of trunk and branches of host trees have different microclimate and high amounts of humus deposition. These could be the reasons for high epiphytic abundance on the larger poropohytes. Older and rough hosts accumulate high humus and have high water holding capacity than smooth bark textures. Due to these reasons older trees, larger trunks and rough bark types were found to be better substrates for epiphyt colonizers.

Vascular epiphytes are one of the most important components of forest ecosystem they are the home of many arthropods and birds, thus reduction of epiphytes species due to human activity may have indirect effect in agro ecosystem related to pollination and other ecosystem service.

In the study area, forest disturbance due to logging of trees for timber and removal of regenerated shrubs and selective growing of trees for coffee shade system have been found to be big challenges for future epiphyte diversity and distribution.

Another problem in the study area is that the coffee cultivator's thinking of vascular epiphytes as parasites that reduce the quality and yields of their coffee. They remove epiphytes from coffee host trees and small shrubs around the coffee trees/shrubs. Most of the orchid species are highly affected by this factor.

Generally, the study of vascular epiphytes is full of challenges in our country, starting from data collection to herbarium specimen identification. Due to insufficient field materials and experts. For this study, epiphyte species sampling from upper crown, were done by the help of indigenous tree climbers by using single rope technique.

5.2.2 Recommendations

From the results of this study, the following recommendations can be forwarded:

- Since epiphytes are affected by forest disturbance, which are highly important as climate change indicators, any forest management activity should be considering the conservation of vascular epiphytes.
- Agricultural institutions, research centers, biodiversity institutions, biologists, ecologists, environmentalists and other stakeholders should work on the study on their diversity, ecologyl, physiological aspects and conservation of vascular epiphytes in different parts of the remaining Ethiopian forests.
- Awareness raising to coffee cultivator farmers and investors' on the ecological importance of vascular epiphytes should be critically important for future sustainability of vascular epiphytes in coffee cultivated areas.

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APPENDICES

Appendixe 1 List of epiphyte species collected from Gera Forest

Key: **HO**: Holo epiphytes, **HE**: Hemi epiphytes, **AC** : Accidental epiphytes, BT: Bedilu Tafesse.
T: Tree, **EP**: Epiphyte.

Species	**Family**	**Local Name**	**Hab it**	**Coll. No.**
Achyranthus aspera L.	Amaranthaceae		AC	BT4T2EP6
Adenostema mauritianum DC.	Asteraceae	maxxane	AC	BT41T1EP1
Aerangis brachycarpa (A.Rich.)Th.Dur.& Schinz	Orchidaceae		HO	BT8T2EP2
Aerangis thomsonii (Rolfe) Schltr	Orchidaceae		HO	BT14T2EP2
Allophylus macrobotrys Gilg	Sapindaceae		AC	BT3T1EP2
Apodytes dimidiata E. Mey.ex Arn.	Icacinaceae	wendaboo	AC	BT21T1EP1
Arthropteris monocarpa (Cordem.) C.Chr.	Oleandraceae		HO	BT4T2EP5
Arthropteris orientalis (Gmel.)Posth.	Davalliaceae		HO	BT5T1EP1
Asplenium abyssinicum Fee	Aspleniaceae		HO	BT25T1Ep1
Asplenium aethiopicum (Burm.f.)Bech.	Aspleniaceae		HO	BT1T6EP1
Asplenium erectum Bory ex Willd.	Aspleniaceae		HO	BT1T3EP3
Asplenium linkii Kuhn.	Aspleniaceae		HO	BT5T2EP2
Asplenium protensum Schrad.	Aspleniaceae		HO	BT21T3EP3
Asplenium sandersonii Hook.	Aspleniaceae		HO	BT14T1EP3
Asplenium smedsii Pic.Serm.	Aspleniaceae		HO	BT22T2EP2
Asplenium theciferum (HBK.) Mett.	Aspleniaceae		HO	BT6T1EP1
Bersama abyssinica Fresen.	Melianthaceae		AC	BT3T3EP1
Bidens pilosa L.	Asteraceae		AC	BT18T3EP2
Clausena anisata (Willd.) Benth.	Rutaceae		AC	BT31T2EP2

Commelina diffusa Burm .f	Commeinaceae		AC	BT39T1EP1
Crassocephalum crepidioides (Benth.) S.Moore.	Asteraceae		AC	BT35T1EP1
Cyrtorchis arcuata (Lindl.) Schltr.	Orchidaceae		HO	BT1T1EP1
Diaphanante adoxa Rasm.	Orchidaceae		HO	BT18T2EP2
Diaphananthe tenuicalcar Summerh.	Orchidaceae		HO	BT24T3EP2
Drynaria volkensii Hieron.	Polypodiaceae		HO	BT5T3EP3
Ficus thonningii Blume	Moraceae		HE	BT31T2EP2
Geranium arabicum Forssk.	Geraniaceae		AC	BT35T2EP2
Huperzia ophioglossoides (Lam.) Rothm.	Lycopodiaceae	Qorchaa bofa	HO	BT5T1EP1
Hypoestes forskaolii (Vahl)Rom. & Schultes	Acanthaeae		AC	BT27T1EP1
Hypoestes triflora (Forssk.) Roem & Schultes	Acanthaeae		AC	BT25T1EP1
Impatiens hochstetteri Warb.	Balsaminaceae		AC	BT2T3EP2
Impatiens rothii Hook.f.	Balsaminaceae		AC	BT31T1EP1
Kalanchoe petitiana A.Rich.	Crassulaceae		AC	BT22T1EP2
Lepisorus excavatus (Wi1ld.) Ching	Polypodiaceae		HO	BT17T2EP2
Lepisorus schraderi (Mett.) Ching	Polypodiaceae		HO	BT4T1EP2
Loxogramme abyssinica (Baker) M.G.Price	Polypodiaceae		HO	BT9T2EP2
Microcoelia globulosa (Hochst.) L. Jonsson	Orchidaceae		HO	BT18T2EP2
Oplismenus hirtellus (L.) P. Beauv	Poaceae		AC	BT39T3EP3
Peperoma molleri C.DC.	Piperaceae		HO	BT1T1EP1
Peperomia abyssinica Miq.	Piperaceae		HO	BT5T2EP2
Peperomia tetraphylla (Forster) Hook. & Arn.	Piperaceae		HO	BT11T4EP4
Phymatosorus scolopendria (Burm.f.) Ching	Polypodiaceae		HO	BT13T2EP3
Pilea rivuaris Wedd.	Urticaceae		AC	BT4T2EP4

Pleopeltis excavata (Willd.) Sledge	Polypodiaceae		HO	BT25T2EP2
Pleopeltis macrocarpa (Willd.) Kaulf	Polypodiaceae		HO	BT18T1EP1
Polystachya rivae Schweinf.	Orchidaceae		HO	BT3T1EP1
Polystachya bennettiana Rchb.f.	Orchidaceae		HO	BT1T5EP1
Polystachya cultriformis (Thouars) Spreng.	Orchidaceae		HO	BT2T3EP3
Polystachya lindblomii Schltr.	Orchidaceae		HO	BT15T3EP2
Polystachya tessellata Lindl.	Orchidaceae		HO	BT8T3EP2
*Pycnostachys abyssinica*Fresn.	Lamiaceae		AC	BT8T3EP3
Pycnostachys eminii Gürke.	Lamiaceae		AC	BT37T1EP1
Scadoxus nutans (Friis & I.Bjørnstad) Friis & Nordal	Amaryllidaceae		HO	BT17T3EP3
Schefflera abyssinica (Hochst ex A. Rich.) Harms	Araliaceae		HE	BT3T3EP2
*Syzygium guineense (*Willd.) DC.	Myrtaceae		AC	BT35T2EP2
Indet. fern sp.			HO	BT36T3EP2
Urera hypselodendron (A.Rich.)Wedd.	Urticaceae		AC	BT26T1EP2
Vernonia auriculifera Hiern	Asteraceae		AC	BT11T1EP1
Vittaria volkensii Hieron.	Vittariaceae		HO	BT27T1EP2

Appendix 2 Shanon-winner diversity index value of Gera epiphytes

Species	number of individuals (n)	n/N	pi	pi^2	ln pi	$-(P_i * \ln P_i)$
Achyranthes aspera L.	5	5/902	O.OO5	2.5	-5.298	-0.026
Adenostema mauritianum DC.	4	4/902	0.004	1.6	-5.521	-0.022
Adiantum incisum Forssk.	14		0.015		-4.199	-0.062
Aerangis thomsonii (Rolfe) Schltr.	19		0.021		-3.863	-0.081
Aerangis brachycarpa (A.Rich.)Th.Dur.& Schinz	33		0.036		-3.324	-0.119
Allophylus macrobotrys Gilg	3		0.003		-5.809	-0.017
Apodytes dimidiata E. Mey.ex Arn.	3		0.003		-5.809	-0.017
Arthropteris monocarpa (Cordem.) C.Chr.	23		0.025		-3.6888	-0.092
Asplenium aethiopicum (Burm.f.) Bech.	54		0.05		-2.995	-0.149
Asplenium smedsii Pic.Serm.	25		0.027		-3.611	-0.097
Asplenium erectum Bory ex Willd.	23		0.025		-3.688	-0.092
Asplenium protensum Schrad.	32		0.035		-3.352	-0.117
Asplenium sandersonii Hook.	26		0.028		-3.575	-0.100
Asplenium theciferum (HBK.) Mett.	5		0.005		-5.298	-0.026
Bersama abyssinica Fresen.	2		0.002		-6.214	-0.012
Bidens pilosa L.	4		0.004		-5.521	-0.022
Clausena anisata (Willd.) Benth.	4		0.004		-5.521	-0.022
Commelina diffusa Burm.f.	4		0.004		-5.521	-0.022
Crassocephalum crepidioides (Benth.) S.Moore.	6		0.006		-5.115	-0.030
Cyrtorchis arcuata (Lindl.) Schltr.	8		0.008		-4.828	-0.038
Diaphananthe tenuicalcar Summerh.	13		0.014		-4.268	-0.059
Drynaria volkensii Hieron.	55		0.060		-2.81	-0.168
Ficus thonningii Blume	4		0.004		-5.521	-0.022
Geranium arabicum Forssk.	3		0.003		-5.809	-0.017
Huperzia ophioglossoides (Lam.) Rothm.	34		0.037		-3.506	-0.129
Hypoestes forskaolii (Vahl) R. Br.	2		0.002		-6.214	-0.012
Hypoestes triflora (Forssk.) Roem & Schult.	3		0.003		-5.809	-0.017
Impatiens hochstetteri Warb.	4		0.004		-5.521	-0.022

Impatiens rothii Hook.f.	4		0.004		-5.521	-0.022
Kalanchoe petitiana A.Rich.	2		0.002		-6.214	-0.012
Lepisorus excavatus (Willd.) Ching	20		0.022		-3.816	-0.083
*Lepisorus*schraderi (Mett.) Ching	19		0.021		-3.863	-0.081
Loxogramme abyssinica (Baker) M.G.Price	21		0.023		-3.772	-0.085
Microcoelia globulosa (Hochst) L.Jonsson	23		0.025		-3.688	-0.092
Oplismenus hirtellus (L.)P. Beauv.	3		0.003		-5.809	-0.017
Peperoma molleri (C.DC) .	32		0.035		-3.352	-0.117
Peperomia abyssinica Miq.	46		0.050		-2.995	-0.149
Peperomia tetraphylla (Forster) Hook.& Arn.	66		0.073		-2.617	-0.191
Phymatosorus colopendria (Burm.f.) Pic.Serm.	4		0.004		-5.521	-0.022
Pilea rivularis Wedd.	4		0.004		-5.521	-0.121
Pleopeltis excavata (Willd) Sledge	25		0.027		-3.611	-0.097
Pleopeltis macrocarpa (Willd.) Kaulf	32		0.035		-3.352	-0.117
Polystachya rivae Schweinf	21		0.023		-3.772	-0.086
Polystachya bennettiana Rchb.f.	45		0.049		-3.015	-0.147
Polystachya cultriformis (Thouars) Spreng.	34		0.037		-3.296	-0.121
Pycnostachys abyssinica Fresen.	3		0.003		-5.809	-0.017
Pycnostachys eminii Gürke.	4		0.004		-5.521	-0.022
Diaphanante adoxa Rasm.	23		0.025		-3.688	-0.092
Scadoxus nutans (Friis & I.Bjørnstad) Friis & Nordal	3		0.003		-5.809	-0.017
Schefflera abyssinica (Hochst ex A. Rich.) Harms	3		0.003		-5.809	-0.017
*Syzygium guineense (*Willd). DC.	3		0.003		-5.809	-0.017
Urera hypselodendron (A.Rich.)Wedd.	3		0.003		-5.809	-0.017
Vernonia auriculifera Hiern	5		0.005		-5.298	-0.026
Vittaria volkensii Hieron.	3		0.003		-5.809	-0.017
N	902					H = -3.411

Appendix 3 Alititudnal range of holoepiphyic species

Species	Altitudinal range
Aerangis thomsonii (Rolfe) Schltr	1650 -2350
Aerangis brachycarpa (A.Rich.)Th.Dur.& Schinz	1650 -2350
Allophylus macrobotrys Gilg	2125 -2350
Apodytes dimidiata E. Mey.exAm.	2125 - 2275
Arthropteris monocarpa (Cordem.) C.Chr.	1650 -2350
Arthropteris orientalis (Gmel.) Posth.	
*Asplenium anisophyllum*O. Kuntze	1875 - 1950
Asplenium erectum Bory ex Wil1d.	1650 -2350
Asplenium protensum Schrad.	1650 -2350
Aspillinium sandersonii Hook.	1800 - 2125
Asplenium abyssinicum Fee	
Asplenium aethiopcum (Burm.f.)Bech.	1650 -2350
Asplenium linkii Kuhn.	
Asplenium theciferum (HBK.)Mett.	1875 - 2200
Cyrtorchis arcuata (Lindl.) Schltr.	1650 - 2025
Diaphananthe adoxa Rasm.	1650 -2350
Diaphananthe tenuicalcar Summerh.	1650 -2350
Drynaria volkensii Hieron.	1650 -2350
Ficus thonningii Blume	1875 -2125
Huperizia ophioglossoides Lam.Rothm.	2125 - 2350
Lepisorus excavatus (Wil1d.) Ching	1650 -2350
Lepisorus schraderi (Mett.) Ching	1650 -2350
Loxogramme abyssinica (Baker) M.G.Price	1650 -2350
Microcoelia globulosa (Hochst.) L.Jonsson	1650 - 2125
Peperomia molleri C. DC.	1650 - 1950
Peperomia abyssinica Miq.	1650 -2350
Peperomia tetraphylla (Forster) Hook.& Arn.	1650 -2350
Phymatosorus scolopendria (Burm.f.) Ching	1650
Pleopeltis excavata (Willd.) Sledge	1800 - 2350
Pleopeltis macrocarpa (Willd.) Kaulf	1725 -2350
Po1ystachya rivae Schweinf.	1725 - 2350 -
Polystachya bennettiana Rchb.f.	1650 - 2025
Polystachya cultriformis (Thouars) Spreng.	1725 – 1950
Polystachya tessellata Lindl.	
Polystachya lindblomii Schltr.	1650 – 1875
Scadoxus nutans (Friis & I.Bjørnstad) Friis &Nordal	2125 – 2275
Schefflera abyssinica (Hochst. ex A. Rich.) Harms	1875 – 2200
Vittaria volkensii Hieron.	2275

Appendix 4 List of Common epiphytic species between Gera, Harenna and Yayu Forest

Gera Vs. Harenna Forest	**Gera Vs. Yayu forest**	**Common species within the three forests**
Asplenium smedsii	*Asplenium sandersonii*	*Asplenium theciferum*
Pleopeltis macrocarpa	*Polystachya bennettiana*	*Aerangis brachycarpa*
Achyranthes aspera	*Aerangis brachycarpa*	*Arthropteris monocarpa*
Aerangis brachycarpa	*Asplenium theciferum*	*Drynaria volkensii*
Arthropteris monocarpa	*Peperomia tetraphylla*	*Peperomia abyssinica*
Asplenium aethiopicum	*Cyrtorchis arcuata*	
Asplenium theciferum	*Peperoma molleri*	
Asplenium protensum	*Loxogramme abyssinica*	
Bersama abyssinica	*Drynaria volkensii*	
Diaphananthe tenuicalar	*Lepisorus excavatus*	
Drynaria volkensii	*Vittaria volkensii*	
Huperzia ophioglossoides	*Peperomia abyssinica*	
Kalanchoe petitiana	*.Arthropteris monocarpa*	
Peperomia abyssinica	*Pleopeltis macrocarpa*	
Pleopeltis excavata	*Polystachya cultriformis*	
Schefflera abyssinica	*Polystachya tessellata*	
Urera hypselodendron	*Diaphananthe tenuicalcar*	
Vernonia auriculifera		

Appendix 5 ONEWAY ANNOVA

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species BY bark
/STATISTICS DESCRIPTIVES OMOGENEITY WELCH
/PLOT MEANS
/MISSING ANALYSIS
/POSTHOC = TUKEY BONFERRONI GH ALPHA(.05).
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Oneway

Descriptives

Species

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
smooth	24	3.5000	2.88926	.58977	2.2800	4.7200	1.00	10.00
Rough	30	13.4000	6.58420	1.20211	10.9414	15.8586	5.00	29.00
Flack	9	11.6667	5.78792	1.92931	7.2177	16.1157	3.00	21.00
Corky	32	10.2813	2.53026	.44729	9.3690	11.1935	6.00	15.00
Total	95	9.6842	5.92015	.60739	8.4782	10.8902	1.00	29.00

Test of Homogeneity of Variances

Species

Levene Statistic	df1	df2	Sig.
12.277	3	91	.000

ANOVA

Species

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1378.858	3	459.619	21.833	.000
Within Groups	1915.669	91	21.051		
Total	3294.526	94			

Robust Tests of Equality of Means

Species

	Statistic(a)	df1	df2	Sig.
Welch	34.056	3	28.957	.000

a Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: species

	(I) bark	(J) bark	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Tukey HSD	smooth	Rough	-9.90000(*)	1.25652	.000	-13.1885	-6.6115
		Flack	-8.16667(*)	1.79337	.000	-12.8602	-3.4732
		Corky	-6.78125(*)	1.23895	.000	-10.0238	-3.5387
	Rough	smooth	9.90000(*)	1.25652	.000	6.6115	13.1885
		Flack	1.73333	1.74377	.753	-2.8304	6.2970
		Corky	3.11875(*)	1.16600	.043	.0672	6.1703
	Flack	smooth	8.16667(*)	1.79337	.000	3.4732	12.8602
		Rough	-1.73333	1.74377	.753	-6.2970	2.8304
		Corky	1.38542	1.73115	.854	-3.1453	5.9161
	Corky	smooth	6.78125(*)	1.23895	.000	3.5387	10.0238
		Rough	-3.11875(*)	1.16600	.043	-6.1703	-.0672
		Flack	-1.38542	1.73115	.854	-5.9161	3.1453
Bonferroni	smooth	Rough	-9.90000(*)	1.25652	.000	-13.2890	-6.5110
		Flack	-8.16667(*)	1.79337	.000	-13.0037	-3.3297
		Corky	-6.78125(*)	1.23895	.000	-10.1229	-3.4396
	Rough	smooth	9.90000(*)	1.25652	.000	6.5110	13.2890
		Flack	1.73333	1.74377	1.000	-2.9699	6.4366
		Corky	3.11875	1.16600	.053	-.0261	6.2636
	Flack	smooth	8.16667(*)	1.79337	.000	3.3297	13.0037
		Rough	-1.73333	1.74377	1.000	-6.4366	2.9699
		Corky	1.38542	1.73115	1.000	-3.2838	6.0546
	Corky	smooth	6.78125(*)	1.23895	.000	3.4396	10.1229
		Rough	-3.11875	1.16600	.053	-6.2636	.0261
		Flack	-1.38542	1.73115	1.000	-6.0546	3.2838
Games-Howell	smooth	Rough	-9.90000(*)	1.33899	.000	-13.4831	-6.3169
		Flack	-8.16667(*)	2.01744	.011	-14.3935	-1.9399
		Corky	-6.78125(*)	.74020	.000	-8.7545	-4.8080
	Rough	smooth	9.90000(*)	1.33899	.000	6.3169	13.4831
		Flack	1.73333	2.27317	.870	-4.8286	8.2953
		Corky	3.11875	1.28262	.089	-.3315	6.5690
	Flack	smooth	8.16667(*)	2.01744	.011	1.9399	14.3935
		Rough	-1.73333	2.27317	.870	-8.2953	4.8286
		Corky	1.38542	1.98048	.895	-4.8147	7.5856
	Corky	smooth	6.78125(*)	.74020	.000	4.8080	8.7545
		Rough	-3.11875	1.28262	.089	-6.5690	.3315
		Flack	-1.38542	1.98048	.895	-7.5856	4.8147

* The mean difference is significant at the .05 level

Appendix 6 Correlation test between host size and vascular epiphytes richness

Correlations

		Diameter at breast height	Species
Diameter at breast height	Pearson Correlation	1	.773**
	Sig. (2-tailed)		.000
	N	71	71
Species	Pearson Correlation	.773**	1
	Sig. (2-tailed)	.000	
	N	71	71

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 7 **Glossary**

Reptata remota: buds far apart, shoots or leaves scattered

Reptata densa: buds close to one another

Reptata densa upright: buds close to one another, densely tufted, upright

Reptata densa pendulus :buds close to one another, densely tufted, pendulus

Fascicularis : rosette leaves

Caespitosa : buds on basal portion of plant, upright shoots tufted