

# THE GERMINATION OF *LEEA GUINEENSIS* (LEEACEAE) AND ITS ROLE IN ARTHROPOD COMMUNITIES

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## HERRMANN JD. 2012. The germination of *Leea guineensis* (Leeaceae) and its role in arthropod communities.

Despite the evolutionary affinity of *Leea* spp. with grapes and their potential use as medicinal herb, the ecology of *Leea guineensis* is poorly known. Information on its ecology is important if *L. guineensis* is to be included in high diversity forest farming systems. Therefore, the aim of this study was to investigate the general germination requirements of *L. guineensis* and its importance to arthropod communities. *Leea guineensis* had low germination rate under laboratory conditions. The best germination rate was 27 °C with exposure to light, a characteristic of pioneer plants. The study highlighted the role of *L. guineensis* as food source for a variety of arthropod species. It is classified as myrmecophyte, showing mutualistic relationship with ants from the genus *Crematogaster*. The study suggests the use of this plant as a pioneer species in high diversity forest farming systems.

Keywords: Vitaceae, inflorescence, pollination, ant plant, myrmecophyte, domatia, mutualism, bees, *Crematogaster*

## HERRMANN JD. 2012. Percambahan *Leea guineensis* (Leeaceae) dan peranannya dalam komuniti artropod.

Ekologi *Leea guineensis* kurang diketahui walaupun genus *Leea* mempunyai kesamaan evolusi dengan pokok anggur dan ia berpotensi digunakan sebagai herba perubatan. Maklumat tentang ekologiinya penting jika *L. guineensis* dimasukkan sebagai spesies dalam sistem pertanian hutan berkepelbagaian tinggi. Kajian ini bertujuan untuk menyelidiki percambahan *L. guineensis* dan kepentingannya dalam komuniti artropod. *Leea guineensis* mempunyai kadar percambahan yang rendah di dalam makmal. Kadar percambahannya adalah terbaik pada suhu 27 °C dan dalam cahaya. Ini merupakan ciri tumbuhan perintis. *Leea guineensis* memainkan peranan sebagai sumber makanan kepada pelbagai spesies artropod. Ia dikelaskan sebagai mirmekofit iaitu menjalinkan perhubungan saling dengan semut daripada genus *Crematogaster*. Kajian ini mencadangkan penggunaan tumbuhan ini sebagai spesies perintis dalam sistem pertanian hutan kepelbagaian tinggi.

## INTRODUCTION

The use of plants or plant parts as a source of medicine to treat different ailment and disease symptoms is common to all cultures in the world. Extracts of *Leea guineensis* are used to treat muscular pain, arthritis, rheumatism, vertigo, oedema, abscess and furuncle, and are applied on wounds to promote healing. Published work supports the positive effects of this herbal medicine scientifically (Falodun et al. 2007).

The genus *Leea* has been neglected by researchers for a long time. The genus was either summarised together with the economically important grape family Vitaceae (Dahlgren 1983, Thorne 1992) or classified within its own family Leeaceae (Cronquist 1988). Unlike Vitaceae, *Leea* species are erect shrubs or trees lacking tendrils. The most recent revision

(Watson & Dallwitz 2010) reported 70 species distributed in the tropics.

Despite the evolutionary affinity of *Leea* spp. with grapes and their potential use as medicinal herb, the ecology of *L. guineensis* is poorly known. So far, only one study has dealt with its germination requirements (HsiangHua et al. 1997). Furthermore, the cymose inflorescence is reported to flower all year long (Ridsdale 1976), which suggests a high diversity of flower visitors (Molina 2009). Detailed information of *L. guineensis* becomes important if it is included in high diversity forest farming system (Göltenboth 1999). Therefore, the aim of this study was to investigate the general germination requirements of *L. guineensis* and its importance to arthropod communities.

## MATERIALS AND METHODS

### Plant

*Leea* is a fast-growing, evergreen large shrub and a widespread component of secondary regrowth vegetation in the Philippines, Taiwan and Micronesia. It is also found in primary forests (Ridsdale 1976, Rojo 1999). It has large, pinnate leaves with elliptic leaflets and terminal inflorescences which seem to flourish all year long. The largest inflorescence in the present study had diameter of up to 40 cm, whereas the majority of observed inflorescences reached a diameter of about 25 cm. The inflorescence is trichotomous, leaf-opposed cyme and consists of up to several hundred flowers. The highest number of flowers counted on the plants is 1800 single flowers. The flowers are actinomorphic and bisexual. The calyx is campanulate and about  $2.25 \times 2$  mm in size. The shape of the five sepals is triangular and red to reddish orange in colour. The five-merous petals are ivory-white to citrus-white on the inside and red to reddish orange on the outside.

### Site

The study site was located in mid-eastern Philippines on the island Leyte ( $10^{\circ}44' 18''$  N,  $124^{\circ} 49' 05''$  E) with mean temperature of  $27.4^{\circ}\text{C}$  and mean precipitation of 2603 mm per year (Müller-Edzards 1996). The site was located uphill of Cienda village at an altitude of 160 m asl, at the foothill of Mt Pangasugan along the Tubod River. The site belongs to the Sitios (territorial enclave that forms a part of a small administrative division), Cienda and San Vicente (Mueller et al. 2002) and located in part of the 447 ha large 'Multiple Use Area' which includes a mixture of abaca and coconut plantations, and secondary forest. The vegetation in the secondary forest was dominated by herbaceous chamaephytes (Bulayog et al. 2002). In the study area, no pesticides or herbicides were used.

### Germination

Ripe berries were collected from 10 available, fructiferous individuals over three months. All individuals were located on a strip of land ( $500 \times 10$  m) along the Tubod River. A total of 1830 seeds were extracted from 598 berries and stored at room temperature in a closed glass bottle.

Prior to the germination trial, a tetrazolium test was conducted to assess the viability of seeds. Ten seeds were selected randomly and cut so that the embryo was bisected. The seeds were placed into a Petri dish with filter paper with the cut side facing the paper. Then 0.1% solution of 2,3,5-triphenyltetrazolium chloride (TTC) was added (Contrell 1947). The Petri dish was wrapped with photoresistant foil to avoid discoloration caused by light. It was placed in a climate chamber with temperature of  $30^{\circ}\text{C}$ . Viable embryos released hydrogen ions during respiration, causing the TTC to turn red or pink. After 48 hours, the seeds were taken out of the growth chamber and examined under microscope for discoloration.

For germination test, randomly selected seeds were disinfected with 1% NaOHCl solution for 5 min (Poulsen et al. 1998) and then rinsed with distilled water. In addition, ultrasonic bath was carried out to disinfect the surface of seeds. After disinfection, the seeds were macerated for 48 hours in tap water. The seeds were tested under six different conditions. The test was conducted in climate chambers with 15, 27 and  $40^{\circ}\text{C}$ , each temperature with and without light. Germination was observed for 30 days.

For each temperature, eight dishes were prepared: four dishes with 25 seeds and four with 50 seeds to study density-related germination effects (Baskin & Baskin 1998). This resulted in 24 Petri dishes and 900 tested seeds. For better water storage, Petri dishes were laid out with two filter papers and the dishes were sealed with parafilm to reduce evaporation. Half of the dishes with 25 and 50 seeds were wrapped with photo-resistant foil to test the light influence. The seeds were evenly distributed in Petri dishes because clumping of seeds might decrease germination (Bergelson & Perry 1989). As the orientation of seeds with regard to substrate could affect germination (Boxy & Aarssen 1995), all seeds were placed with one of the straight sides (cross-section is triangular-heart-shaped) facing the filter paper. To simulate natural light periodicity of the latitude of  $10^{\circ}\text{N}$  as much as possible, light interval of 12 hours a day was used. The water was refilled two times a week and dishes were checked daily for newly germinated seeds. Dead seeds covered with fungi were removed (Baskin & Baskin 1998). The criterion for germination was radical emergence of at least 1 mm long (Thomas et al. 2003).

## Flower visitors

Field observation was carried out from mid-September till mid-December. Only five of the 18 discovered *L. guineensis* plants in the study area were flourishing. Flower visitors were observed on these five different, equal-sized *L. guineensis* plants. All selected plants were located next to the Tubod River in similar habitat conditions. Therefore, the two most distant plants were approximately 100 m apart. Flower visitors were counted on these plants from earliest 8.30 a.m. till latest 2.30 p.m. throughout the study period according to a randomised sampling design. Thereby, flower stage and time of observation were kept as independent as possible (unpublished data;  $r = 0.23$ ,  $p = 0.16$ ). Observation period lasted from 30 till 210 min. Special attention was paid not to count the same visitors twice.

Three flowering stages were defined through preceding observations. Prior to every observation, the flower quantity was estimated. Flower visitors were observed during the three predefined stages of the floral lifecycle: (1) young inflorescences (< 50 open flowers) (2) mature inflorescences (80–120 open flowers) and (3) old inflorescences (< 50 open flowers). The visitors were identified to family or genus level (Naumann 1990, Michener 2000), divided into morphospecies (if individuals could be identified to genus level, it is mentioned in the results section) and counted. Unknown species were caught, labelled and stored in alcohol for identification later. Sampling was carried out using sweep net for larger insects and aspirator for smaller insects. Care was taken not to damage the flowers during the catch.

## Myrmecophyte

A total of 10 different *L. guineensis* individuals were observed in relation to ant mutualism. Peculiarities were noted and photographed.

## Analyses

The similarity of flower visitor communities between the different flower stages was compared using Morisita's overlap index (Morisita 1959). A Kruskal–Wallis test (Kruskal & Wallis 1952) with Bonferroni correction was used to analyse flower visitor frequency between different flowering stages.

Individual-based rarefaction curves scaled to number of individuals were calculated for

the three different flowering stages. Expected flower visitor species richness standardised to an appropriate number of individuals obtained from these curves was used to compare species richness in different flowering stages.

All statistical analyses were performed using the R software with the packages stats (R Development Core Team 2010) and vegan (Oksanen et al. 2010).

## RESULTS

### Germination

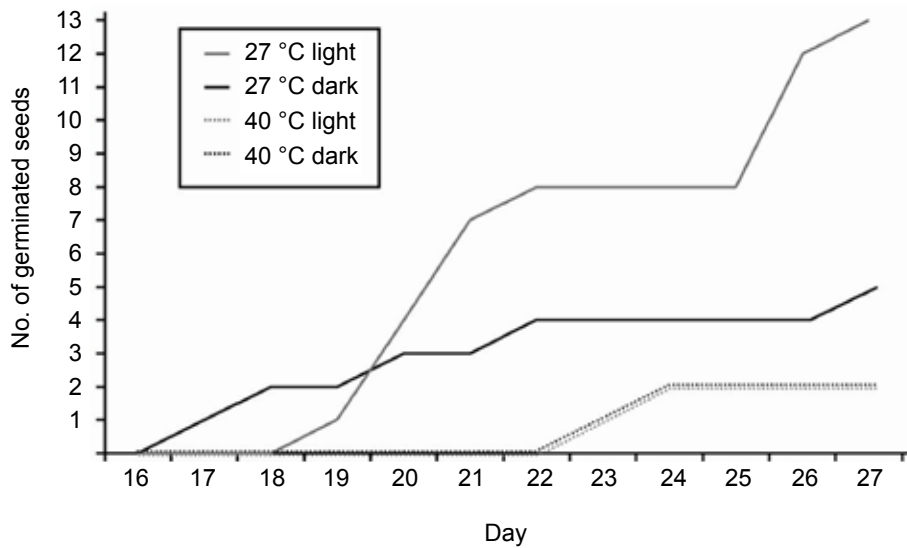
Nine out of ten seeds showed pink discoloration after exposure to TTC. The main discoloration was present around the embryo, indicating that 90% of the tested seeds were still able to germinate.

Within the 15 °C group, none of the seeds germinated, regardless of the light condition. At 27 °C, 8.7% of the 150 seeds germinated in the light exposure regime, while only 3.3% germinated in darkness (Figure 1). The 40 °C group showed no difference in the number of germinated seeds between light and darkness. In both cases, 1.3% of the seeds germinated.

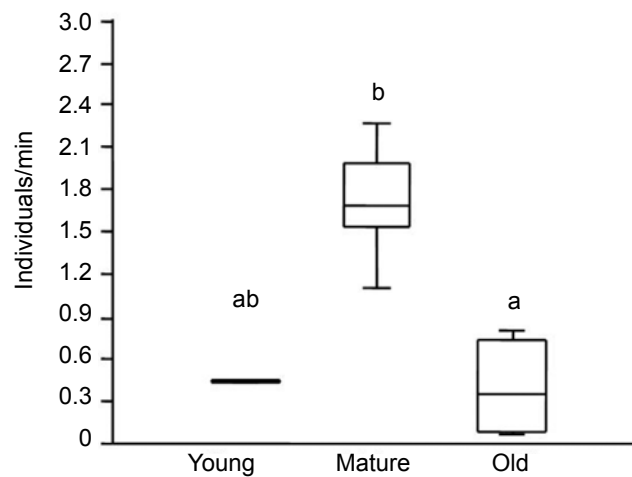
The first seed germinated after 17 days, the last seed after 26 days. No density-related germination effects between the 25 and 50 seed treatments were observed (results not shown).

### Flower visitors

During the 25 hours of observation, 1288 flower visitors from 32 morphospecies visited the flowers of *L. guineensis*. The flower visitation frequency on young inflorescences averaged 0.43 visitors per min, whereas the highest flower visitation frequency of 1.72 individuals per min was observed on mature inflorescences (Figure 2). The frequency on old inflorescences with 0.36 visitors per min was significantly lower ( $p < 0.01$ ) than that of mature inflorescences. The observed species richness ( $S_{\text{obs}}$ ) ranged from 10 morphospecies in young inflorescences to 29 morphospecies in mature inflorescences (Table 1). Truly comparable estimates of flower visitor species richness were obtained from the rarefaction curves of individual plants as the projected y-value corresponding to an abscissa of  $x = 45$  flower visitors ( $S_{\text{RAR45}}$ ; Figure 3 and Table 1).  $S_{\text{RAR45}}$  ranged from 9.9 on young inflorescences to 10.8 on mature inflorescences, indicating that



**Figure 1** Seed germination of *Leea guineensis* as a function of time; 15 °C line was excluded as none of the seeds germinated



**Figure 2** Flower visitor frequencies on young, mature and old inflorescences; different letters show significant difference at  $p < 0.05$

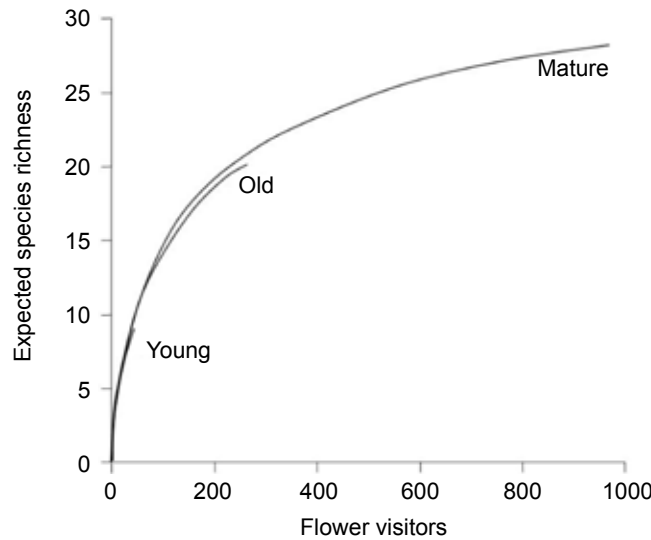
the expected number of flower-visiting species observed from 45 individuals varied only in approximately one species (Table 1). However, species overlap was higher between young and old inflorescences ( $C_D = 0.75$ ; with  $C_D = 1$  meaning complete overlap in species composition) than between young and mature ( $C_D = 0.58$ ) or old and mature ( $C_D = 0.51$ ) inflorescences. The bee composition changed from mainly solitary bee species (*Austronomia* sp.1, *Lipotriches* sp.1, *Amegilla* sp. 1, *Xylocopa* sp. 1, *Thyreus* sp. 1) in the early stage of the inflorescence to mainly social bees (*Apis cerana*, *Trigona* sp. 1) in full bloom and back to majority of solitary bees at the end of the inflorescence cycle (Figure 4). Furthermore,

flower visitors included wasps which were represented by the families Chrysididae (cuckoo wasps), Ichneumonidae (ichneumonid wasps), Pompilidae (spider wasps), Scolidae (scoliid wasps), Sphecidae (*Liris* sp. 1, digger wasps) and Vespidae (yellow jacket in this case), each with one morphospecies, and the Eumeninae (potter wasps), which were represented by two morphospecies (*Delta* sp. 1 and Morphospec. 1). *Liris* sp. 1 was the most dominant wasp species during the three flowering stages. The Lepidoptera (butterflies) were represented by the families Nymphalidae (brush-footed butterflies) and Papilionidae (swallowtail butterflies), each with three morphospecies, the Pieridae, with two

**Table 1** Sampling effort with resulting individual numbers and species richness for the three investigated inflorescence stages on the five plants studied

Flower stage	Sampling effort (min)	Individual	S <sub>obs</sub>	S <sub>RAR45</sub>	± SE
Young	105	46	10	9.91	0.28
Mature	590	977	29	10.83	1.62
Old	805	265	21	10.53	1.81

S<sub>obs</sub> = observed species richness, the cumulative number of flower visitor species recorded during the whole sampling effort for each flower stage; S<sub>RAR45</sub> = rarefaction-estimated species richness, obtained from the individual-based rarefaction curve for each flower stage; SE = standard error



**Figure 3** Individual-based flower visitor rarefaction curves depicting the expected accumulation of species richness with increasing number of individuals obtained separately for the three inflorescence stages; the confidence intervals around each rarefaction curve have been omitted from the graph to avoid cluttering, but confidence belts of the three flowering stages were largely overlapping

morphospecies, and the Glyphipterigidae (sedge moths), Hesperidae (skipper butterflies), Pterophoridae (plume moths) and Lycaenidae (gossamer-winged butterflies) with one morphospecies respectively. The order Diptera (flies) was represented by Calliphoridae (blow flies), Drosophilidae, Lonchaeidae (lance flies), Muscidae and Syrphidae (hoverflies), each with one morphospecies.

**Myrmecophyte**

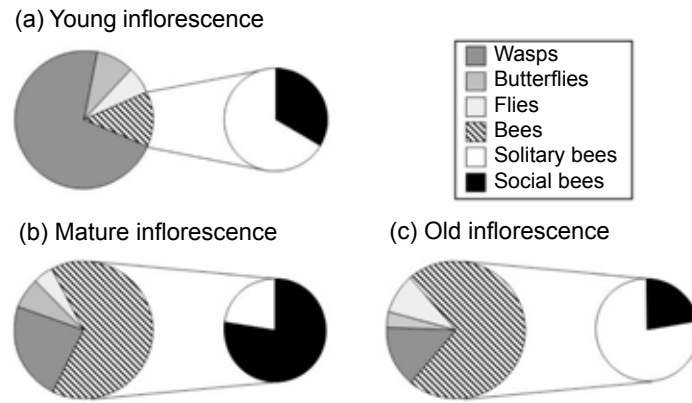
A total of 40% (four out of ten) of *L. guineensis* individuals maintained close relationship with ants. Ant domatia were found within the stem which were inhabited by ants of the genus *Crematogaster* (Figure 5a). Individuals of the nests could be observed gathering around newly

evolved stipules (Figure 5b). The holes on stem only occurred if ants were present.

**DISCUSSION**

**Germination**

In spite of the tetrazolium test, which indicated germination ability of 90%, only 2.4% of the tested seeds germinated. Such low germination ratios could be caused by the artificial set up of germination trials. In natural habitats, seeds are exposed to alternating, not constant temperatures. Some species only germinate at alternating temperature regimes (Pons & Schroder 1986, Pegtel 1988). Furthermore, studies with crop species have indicated that seeds must attain certain minimum species specific moisture content before they will germinate (Hunter & Erickson 1952). Thus, germination



**Figure 4** Large circles depict the general species composition of flower visitors for the three investigated inflorescence stages; small circles depict the segmentation of bees in solitary and social species



**Figure 5** Pictures showing (a) ant holes in the stem of *Leea guineensis* and (b) individuals of the genus *Crematogaster* gathering along newly evolved stipules

may be inhibited if the amount of water is too low (Williams & Shaykewich 1971, Edgar 1977). Even though the Petri dishes were tightly sealed with parafilm to stop evaporation, it could not be ruled out that moisture occasionally dropped below the seed specific critical value.

Another problem could have been the choice of filter paper as substrate. Even though filter paper exhibited more standardised conditions, soil could have been the better choice. Seeds of *Trientalis borealis*, for example, germinate to higher percentages on sand than on filter paper (Anderson & Loucks 1973) and seeds of *Gilia capitata*, *Oenothera micrantha* and *Mimulus bolanderi* (Sweeney 1956) germinated better on soil than on filter paper.

Beside the low germination rate, the germination success was related to tested temperatures. As seen in Figure 1, none of the seeds germinated at 15 °C, only 1.3% of the seeds germinated at 40 °C and the highest germination was achieved at 27 °C. These results reflected the

climatic properties of distribution in tropical and subtropical habitats (Ridsdale 1976).

More seeds germinated in light than in darkness. These results corresponded with the results of HsiangHua et al. (1997), where seeds of *L. guineensis* were planted in trays of forest soils. *Leea guineensis* did not germinate when placed in the forest understorey but began rapid germination when moved to the nursery opening. This observed germination pattern suggested a canopy-induced facultative dormancy as dormant seeds germinated to higher percentages in light than in darkness (Grime et al. 1981, Baskin & Baskin 1988). In addition, seeds were still able to germinate even after six months of storage, which might be useful to outlast in soil until a gap within the forest canopy emerged to induce germination. These findings and the small size and smooth seed coat of the seeds (Ridsdale 1976) make it very likely that *L. guineensis* is part of the persistent seed bank waiting for a gap in the canopy to start germination.

## Flower visitors

This paper highlights the role of *L. guineensis* as a food source for a variety of arthropod species. Thereby, the composition of flower visitors changed during the ageing process of the inflorescence. While the young and old inflorescences were visited by similar species, the mature inflorescence showed a different species composition. This change could be mainly attributed to the change in bee species. Solitary bees preferred the young and old inflorescences, whereas the number of social bees was higher on mature inflorescences with many open flowers. As shown in other studies, social bees are known to prefer mass-flowering plants (Sudgen et al. 1996). However, Klein et al. (2002) observed a decline of social bees and an increase of solitary bees when only single flowers were blooming. This could be due to the interspecific competition of social and solitary bees (Dewenter & Tschardt 2000). Social bees are able to recruit nest mates, which make them able to harvest food that would not be as readily available to an individual foraging alone. Such food sources are large and temporal limited and thus more effectively harvested by a group of individuals (Resh & Cardé 2003). Therefore, social bees are able to dominate the mature inflorescences through intraspecific communication. When the number of open flowers drops under a critical value, it is no longer lucrative for a bee colony to visit this inflorescence. Then, the ratio of solitary bees and other repressed species is able to increase. However, the lower quantity of open flowers led to a lower visitation rate on young and old inflorescences.

## Myrmecophyte

The present study describes for the first time domatia in the genus *Leea* which were used by ants from the genus *Crematogaster*. In such relationships, ants usually benefit from food (in the form of food bodies) and also from nesting sites supplied by the host, and the plants benefit from protection against herbivores and vines (Davidson & McKey 1993). When domatia for ants appear in hollow stems, the plants often evolve modifications in order to facilitate the ants' access (Federle et al. 2001). Some myrmecophytes have developed self-opening slits or holes, which give easy access to many non-specific stem-nesting

ant species (Fiala et al. 1996, Maschwitz et al. 1996). Other myrmecophytes keep their hollow stems completely closed (Davidson et al. 1991, Maschwitz & Fiala 1995). These plants can only be colonised by specialised ant species. The queens of these ant species must be capable of locating the host species and biting holes into live plant tissue. When such ant partners are present, however, ant-plant can facilitate hole-boring by providing especially prostoma (thin zones) in the domatium wall (von Ihering 1907). This type of stem modification is more selective since it does not give free access to non-specific interlopers. In *L. guineensis*, holes were only observed in already colonised individuals. This is why we assume that the stem (at least a part of it) is already hollowed and the domatia are covered with prostomata.

Furthermore, observations showed an affinity of ants to stipules (Figure 5b). This could indicate the presence of ant food-bodies on the stipules. Pearl glands have been reported in Leeaceae (Watson & Dallwitz 2010) and food-bodies have been reported from other species of the closely related family Vitaceae (Paiva et al. 2009). A reason for food-bodies on the stipule surfaces could be the protection of the buds. The buds contain meristematic cells which are known to be the most sensitive part of the whole sprout (Raunkjær 1934).

## Value for high diversity forest farming systems

Goals of high diversity forest farming systems are the restoration of biodiversity found in the native rainforests together with the utilisation of plant species with economical value (Göltenboth 1999). Most forest farming systems are initiated with the cultivation of sun-requiring pioneer plants on degraded land. They close the canopy fast and in later years shade-loving trees are cultivated under the established pioneers. The results of the conducted germination experiments could characterise *L. guineensis* as a pioneer plant. This feature and its medium size (height of 3–8 m), and broad, shade-creating pinnate leaves (Rojo 1999) show the potential of this plant to be used as first stage pioneer plants in forest farming system. Furthermore, the inflorescences of *L. guineensis* provide nutrition to flower visitors and thus help maintain a high biodiversity. The mainly hemitrop and eutrop flower visitors could contribute to higher yield of

the forest farming system through pollination of other agricultural plants. Predators such as *Liris* sp. and *Delta* sp. could contribute to the control of pest species.

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