*Quest Journals*
*Journal of Research in Agriculture and Animal Science*
*Volume 13 ~ Issue 5 (May, 2026) pp: 31-38*
*ISSN(Online): 2321-9459*
www.questjournals.org

**Research Paper**

# The Population of Vegetable Fern (*Diplaziumesculentum*) Under Forest Garden Stands

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***ABSTRACT:*** *Vegetable fern (Diplaziumesculentum) is a fern widely used as a food source and plays an ecological role in maintaining soil moisture and preventing soil erosion. This research aims to analyze the population of vegetable ferns under forest garden stands. The research was conducted from September to October 2025 at forest farmer's cultivated area plot number 4, one of the plots cultivated by forest farmers members of the Harapan Baru Forest Farmers Group Alliances (FFGA) in the Wan Abdul Rachman Grand Forest Park. The data was collected through vegetation surveys using nested rectangular plots that arranged systematically with a sampling intensity of 2.8%. The data collected includes the species of trees as components of forest garden stands and the number of individuals for each species, the number of individual vegetable ferns, and the environmental conditions of the habitat (including solar radiation intensity, air temperature, air humidity, and altitude). Data were analyzed by calculating density (D) and Ochiai index (OI) at 5% significance level. The results showed that the composition of forest garden stands consisted of 14 tree and shrub species with a total density of 1,997.5 individuals/ha. The population density of vegetable fern varied between plots (0-20 individuals/plot) with an average of 9.6 individuals/plot or 2.4 individuals/$m^2$. Vegetable fern lived under the shade of avocado, durian, candlenut, and stink bean trees, with air temperature conditions of 27-33 oC, air humidity of 55-77%, solar radiation of 407-1,687 lux, and altitude of 360-508 m above sea level. The OI between vegetable fern and avocado trees was 0.73; with durian trees 0.73; with candlenut trees 0.67; and with stink bean trees 0.50. The association between vegetable fern and these shade trees was not statistically significant ($\chi^2_{corrected} < 3.84$).*

***KEYWORDS:*** *Association, Forest garden, Vegetablefern*

*Received 13 May., 2026; **R**evised 25 May., 2026; **A**ccepted 27 May., 2026 © The author(s) 2026.*
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## I. INTRODUCTION

Vegetable fern with the scientific name *Diplaziumesculentum* (Retz.) Swartz is a member of the Diplazium genera, Polypodiaceae family (Heyne, 1987) or Athyriaceae family (Semwal et al., 2021). The Diplazium genera was estimated to comprise 350 species (Semwal et al., 2021; Sharma & Kumar, 2021). Ferns have various species that spread across various habitats (Hasibuan et al., 2016). The number of fern species was estimated at 350 species (Semwal et al., 2021). Ferns are grouped into three based on their habitat, namely terrestrial ferns, epiphytic ferns, and aquatic ferns (Sahertian & Lady, 2022). According to Ramndana et al. (2023), the most commonly found ferns include various species of members of the Pteridium genera (*Pteridium spp.*), true ferns (*Matteucciastruthiopteris*), and various species of members of the Stenochlaena genera (*Stenochlaena spp*.), and various species of members of the Diplazium genera (Diplazium*spp*.).

Vegetable ferns are wild plants as one of the components of the forest ecosystem, as well as a biodiversity that is less noticed (Wulandari & Rahmawati, 2019). However, the vegetable fern can also be cultivated in places with moist soil conditions, as well as sunny and cool weather conditions (Thepsilvisut et al., 2023). Vegetable fern is a plant native to Asia, then spread throughout tropical, subtropical, and temperate regions, namely India, Japan, China, Cambodia, Laos, Thailand, Taiwan, Indonesia, South Asia, Southeast Asia, Oceania, Vietnam, Polynesia, and Malaysia Malaysia(Sharma & Kumar, 2021). Vegetable ferns live in the soil, so they are terrestrial ferns (Sakai et al., 2016). Vegetable ferns in tropical and subtropical forest areas are at an altitude of 100--1,200 m asl(Sharma & Kumar, 2021), whereas in temperate region at an altitude of 1,200--2,500

m asl(Negi&Kanwal, 2024). In general, ferns are cosmopolitan, meaning they have a very wide distribution area (Wulandari & Rahmawati, 2019). Furthermore, Wulandari & Rahmawati (2019) stated that ferns live in primary forests, secondary forests, and open areas, in lowland to highland areas, and likes humid/wet and shady places (Devi, 2020; Negi & Kanwal, 2024).

Vegetable ferns can be used by humans for food (vegetable ingredients), so they are included in non-timber forest product commodities (Sakai et al., 2016). Trail et al. (2003) stated that vegetable ferns are used by the community as vegetables in various traditional dishes and have good nutritional value. Vegetable fern is also useful as a raw material for traditional medicine (Negi & Kanwal, 2024). Vegetable fern was traditionally used for the prevention or treatment of several diseases such as diabetes, smallpox, asthma, diarrhea, rheumatism, dysentery, headache, fever, wounds, pain, measles, hypertension, constipation, oligospermia, bone fractures, and glandular swellings (Semwal et al., 2021). Vegetable fern leaf extract contains the hormone gibberellic acid (GA3) which can be used to accelerate the seed germination process, stimulate plant vegetative growth, and improve the quality of fruit growth (Astawa et al., 2023).

Vegetable ferns not only have economic benefits but also have ecological benefits (Ramndana et al., 2023). Vegetable ferns are included in the undergrowth group that complements the lower strata components in forest vegetation. The general benefit of undergrowth plants is as ground cover that plays a role in hydrological processes (Wulandari & Rahmawati, 2019). According to Sahertian & Lady (2022), vegetable ferns are useful as a source of humus formation, as ground cover that can maintain soil moisture, and prevent erosion. Thus, vegetable ferns are an important element in the hydro-orological processes in forests and support the achievement of forest ecosystem balance.

In the Wan Abdul Rachman Grand Forest Park, Indonesia, there are traditional blocks prepared to accommodate communities surrounding the forest who need cultivated land (UPTD Taaman Hutan Raya Wan Abdul Rachman, 2017). Farmers working on the forest land are required to plant MPTS (multipurpose tree species) in the MPTS agroforestry system, thus establishing a forest garden stand. Farmers can utilize non-timber forest products from the trees they plant without cutting them down, thus ensuring the sustainability of forest garden stands (Indriyanto, 2022). However, farmers are also permitted to harvest undergrowth planted or growing wild beneath the forest garden stands to meet their needs. Among the undergrowth plants with many benefits is the vegetable fern, scientifically known as Diplaziumesculentum( Devi, 2020; Sharma & Kumar, 2021).

Based on initial observations, it was discovered that vegetable ferns were growing under forest garden stands in areas cultivated by forest farmers. Currently, there is no information about the condition of the vegetable fern population under the forest plantation stands. Therefore, research was conducted on the presence of vegetable ferns under forest garden stands to analyze the species of trees and shrubs that make up the forest garden stands, the condition of the fern population, the environmental conditions in which they grow, and the possibility of associations of vegetable ferns with the trees they shade.

## II. Methods

**Research Site**

The research was conducted from September to October 2025. The research was conducted at forest farmer's cultivated area plot number 4, one of the plots cultivated by forest farmers members of the Harapan Baru Forest Farmers Group Alliances (FFGA). The forest farmers' cultivated area is located within the traditional block of the Wan Abdul Rachman Grand Forest Park in Lampung Province, Indonesia. Plot 4, the research site, covers 28 hectares. A map of the research location can be seen in Figure 1.

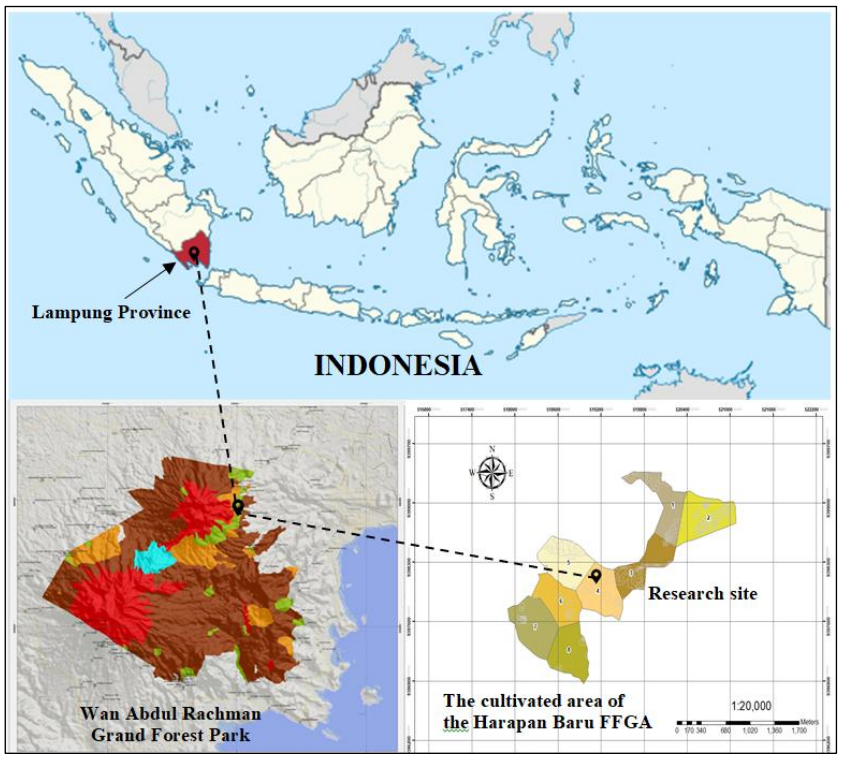


**Figure 1**. Map of the research site at Cultivated Plot number 4 of the farmers' cultivated area of the HarapanBaru Forest Farmer Group Alliances in Wan Abdul Rachman Grand Forest Park, Lampung Province, Indonesia (adapted from UPTD Taman Hutan Raya Wan Abdul Rachman, 2017).

## Equipment

The equipment used for this research consists of string of raffia,wooden stakes,measuring tapes, GPS (global positioning system), haga meter, thermohygrometer, lux meter, digital camera,a writing board, ballpoint pens, and tally sheets.

## Data Acquisition

Data were collected through a vegetation survey, using a systematic sampling method with a sampling intensity of 2.8% on an area of 28 hectares. Twenty sample plots were used, each in the form of a nested rectangular plots.The shape and size of the nested plots in the nested rectangular plots design can be seen in Figure 2.

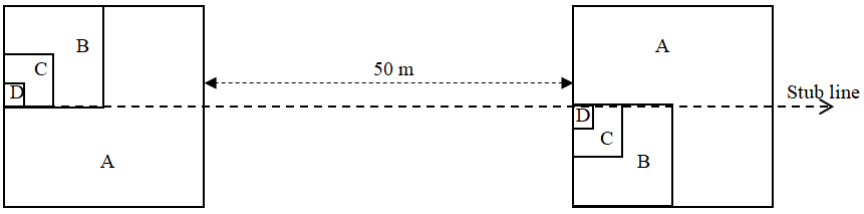


**Figure 2**. Shape and size of the nested plots in the nested rectangular plots design (Indriyanto, 2021).
Remark: A= plot measuring 20 m x 20 m for observation of mature trees phase
B= plot measuring 10 m x 10 m for observation of poles phase
C= plot measuring 5 m x 5 m for observation of saplings phase
D= plot measuring 2 m x 2 m for observation of seedlings phase and vegetable ferns

The stub lines were drawn parallel to the slope of the land and/or perpendicular to the baseline. The baseline was the line where the stub lines were placed. The baseline was drawn across the slope of the land and located on the lowest side of the area. A total of four stub lines were used, with the distance between each stub line being 100 m. Five nested sample plots were systematically arranged with a distance of 50 meters between each plot on each stub line. The distance between nested plots within each stub line was 50 m.

The collected data included the tree and shrub species comprising the forest garden stand, the number of individuals of each tree and shrub species, the tree stem diameter measured at a height of 1.30 m above ground level, and the tree and shrub height. The collected data on vegetable ferns included the number of individual vegetable ferns and the nearest tree or shrub species that shaded the vegetable ferns. The collected environmental data included altitude, solar radiation intensity, air temperature, and air humidity in each sample plot where the vegetable ferns were collected.

## Data Processing

The density of each tree and shrub species in the forest garden stand was analyzed to illustrate the population size of each tree and shrub species. Likewise, the density of vegetable ferns was analyzed to describe the size of the vegetable fern population. The density of each tree or shrub species, and the density of vegetable ferns was calculated using the following formula (Indriyanto, 2021). The density data was then presented in the form of a stem histogram.

$$\text{Density (D)} = \frac{\text{number of individuals of a plant species}}{\text{area of entire sample plot}} \quad (1)$$

The level of association between vegetable ferns and shade trees was analyzed using the Ochiai Index as follows (Ludwig dan Reynolds, 1988).

$$OI = \frac{a}{(\sqrt{a+b})\,(\sqrt{a+c})} \quad (2)$$

Remark:
OI= Ochiai Index
a= the number of sample plots containing a particular species of tree and vegetable fern
b= the number of sample plots containing only a particular species of tree
c= the number of sample plots containing only vegetable ferns

Whether the association between vegetable ferns and shade trees is real or not can be tested using the $\chi^2$ test as follows.

$$\chi^2_{count} = \frac{(ad-bc)^2 x\ n}{(a+b)(c+d)(a+c)(b+d)} \quad (3)$$

The $\chi^2_{count}$ is corrected with the YATES correction, so $\chi^2_{corrected}$ are as follows:

$$\chi^2_{corrected} = \frac{(|ad-bc|-\frac{n}{2})^2 x\ n}{(a+b)(c+d)(a+c)(b+d)} \quad (4)$$

$$\chi^2_{table} = \chi^2_{(df;p)} = \chi^2_{(k-1;0.05)} \quad (5)$$

If $\chi^2_{corrected} > \chi^2_{table}$, then there is an association and is stated as real at the 5% level of significance. Conversely, if $\chi^2_{corrected} < \chi^2_{table}$, then there is no association.

# III. RESULT AND DISCUSSION

## Species and Density of Trees that Make up Forest Garden Stands

The forest garden stands at the research location consist of approximately 13 tree species and 1 shrub species. The density of each tree and shrub species in the forest garden stands varies from 5 individuals/ha to 600 individuals/ha. The total density of forest garden stands was estimated at 1,997.5 individuals/ha. These tree and shrub species cover all growth phases: seedlings, saplimgs, poles, and mature trees.

Data on tree and shrub species, as well as the density of each species, are presented in the form of a histogram in Figure 3.

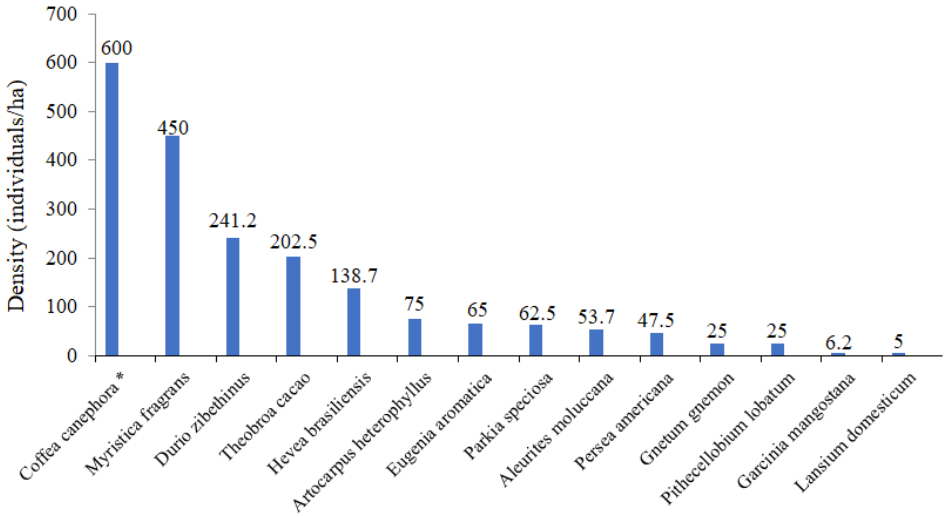


**Figure 3**. Density of population of tree and shrub species that make up forest garden stands at Cultivated Plot number 4 of the farmers' cultivated area of the HarapanBaru Forest Farmer Group Alliances in Wan Abdul Rachman Grand Forest Park, Lampung Province, Indonesia

Remark: *= species of shrub plants

Based on the composition of the species of forest garden stands in Figure 3, the forest garden is classified as a mixed forest garden. A criterion for a mixed forest or mixed forest garden is if more than 10% of the number of individual trees comprising it are of different tree species (Indriyanto, 2010).

Forest garden stands are the result of the technical application of MPTS (multipurpose tree species) agroforestry. The MPTS agroforestry technique is a cultivation method that combines various species of MPTS carried out on a single plot of land (Nair, 1993). Multipurpose tree species are species of trees that have various uses, namely uses in ecological aspects, economic aspects, and socio-cultural uses (Nair, 1993). Therefore, the application of MPTS agroforestry techniques can achieve multiple objectives, such as the diverse uses of tree species. MPTS agroforestry techniques are often required to achieve forest development by involving communities in the management of areas within protected and conservation forest areas (Indriyanto, 2022).

The application of MPTS agroforestry techniques offers the possibility of regulating tree species composition as a compromise to achieve many of the goals mentioned above (Nair, 1993). Communities that plant MPTS species in cultivated areas within the region can harvest non-timber commodities from the trees they plant without having to cut down the forest (Indriyanto, 2022). Thus, the forest garden stands are not disturbed by their closure, and the community can even utilize shade-tolerant understory plants that live naturally or are cultivated, such as cardamom, javanese turmeric, galangal, fragrant ginger, and so on (Indriyanto, 2025). Even under the forest stands, it is possible for vegetable ferns to live and grow well, which by their nature require shaded places (Thepsilvisut et al. 2023; Trail, 2003). Thus, within the forest garden stands, there is a rich potential for natural biological resources that can be utilized by the community carefully to meet many of their life needs.

## Density of Vegetable Ferns under Forest Garden Stands

The density of the vegetable fern population in each sample plot varied greatly. The density of the vegetable fern population varied between 0 individuals/plot and 20 individuals/plot, with each sample plot measuring 4 $m^2$. The data of the vegetable fern density in each sample plot are presented in Figure 4.

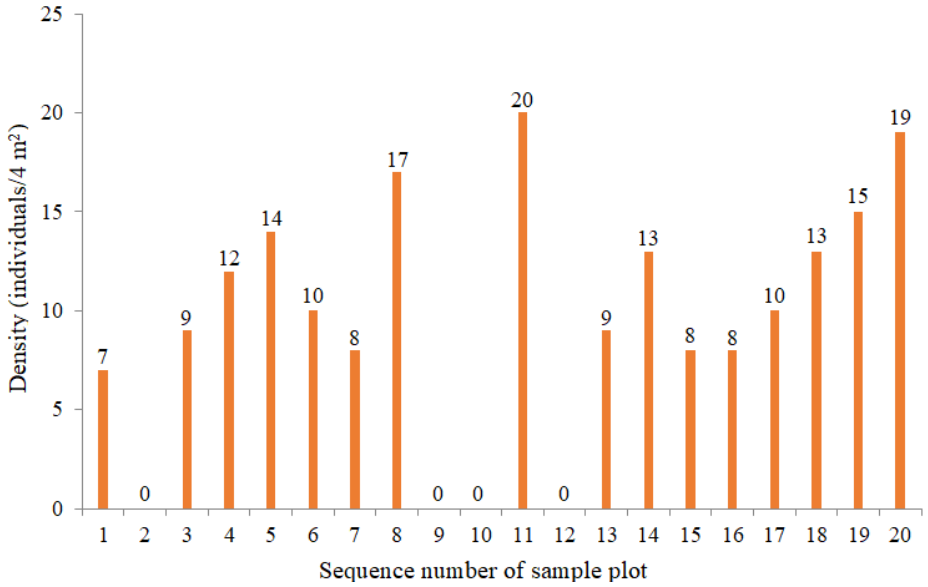


**Figure 4**. Density of the vegetable fern population in each sample plot under the forest plantation stand at Cultivated Plot number 4 of the farmers' cultivated area of the HarapanBaru Forest Farmer Group Alliances in Wan Abdul Rachman Grand Forest Park, Lampung Province, Indonesia

Based on the data in Figure 4, there are four sample plots with a density of 0 individuals per plot. This means that there are four sample plots where no vegetable ferns were found. Vegetable ferns grow in shaded areas or areas shaded by trees or other woody plants. It is evident that areas not shaded by tree canopies are devoid of vegetable ferns. Conversely, in areas shaded by tree canopies, vegetable ferns are found. Even in areas that receive denser shade from tree canopies, an increasing number of vegetable ferns were found. According to Pratiwi et al. (2024), forest stand density correlates with the presence of ferns, including vegetable ferns. De Pauw et al. (2022)suggest that ferns generally require shady and humid conditions. Vegetable ferns at the research location were found under the shade of tree canopies with solar radiation intensity conditions of 407–1,687 lux, air temperature of 27–33° C, air humidity of 59–77%, and at an altitude of 360–508 m asl (Table 1). The species of trees that are closest to the presence of vegetable ferns function as the main shade for vegetable ferns, namely durian (*Durio zibethinus*), avocado (*Persea americana*), stink bean (*Parkiaspeciosa*), and candlenut (*Aleurites moluccana*) trees.

**Table 1**. Environmental factors of vegetable ferns under forest plantation stands at Cultivated Plot number 4 of the farmers' cultivated area of the HarapanBaru Forest Farmer Group Alliances in Wan Abdul Rachman Grand Forest Park, Lampung Province, Indonesia

| Environmental factors | Based on the results of observations at the research site | Based on references |
|---|---|---|
| Intensity of solar radiation (Lux) | 407—1,687 | 117—1,603 (Hamidah et al., 2020) |
| Air temperature (° C) | 27—33 | 21—27 (Rizky et al., 2018) |
| Air humidity (%) | 59—77 | 60—80 (Imaniar& Murdiyah, 2017) |
| Altitude (m asl) | 360—508 | 100--1,200 (Sharma & Kumar, 2021), |

Forest stands or forest gardens stand with more complex structures tend to create local conditions that are more suitable for the growth of shade-requiring undergrowth such as vegetable ferns compared to sparse or homogeneous stands (De Pauw et al., 2022). Shady and humid areas can be created by the shade of trees, which reduce solar radiation, regulate air temperature and humidity, and produce litter as organic soil material. Tree litter can increase the amount of organic matter in the soil, which can support the growth of ferns (Salwanafi et al., 2023).

**Association of Vegetable Ferns with Shade Trees**

The tree species closest to the vegetable ferns provide the primary shade for the vegetable ferns. The canopy of various species of trees will reduce the intensity of solar radiation, then change the local climate conditions under the forest garden stands, so that they suit the conditions required by vegetable ferns.

Based on the research results, the tree species closest to the presence of vegetable ferns under the forest garden stand are durian, avocado, stink bean, and candlenut. The association between vegetable ferns and the four main shade tree species was analyzed. The results of the association analysis between vegetable ferns with durian, avocado, stink bean, and candlenut trees are presented in Table 2.

**Table 2**. Ochiai Index values and $\chi 2$ test results of the association between vegetable ferns and four main species of shade trees at Cultivated Plot number 4 of the farmers' cultivated area of the HarapanBaru Forest Farmer Group Alliances in Wan Abdul Rachman Grand Forest Park, Lampung Province, Indonesia

| Number | Species of shade trees | The association value of vegetable ferns with shade trees | | | |
|---|---|---|---|---|---|
| | | Ochiai Index | $\chi^2_{corrected}$ | $\chi^2_{table}$ | Significance |
| 1. | Durian (*Duriozibethinus*) | 0.73 | 0.13 | 3.84 | not significant |
| 2. | Avocado (*Perseaamericana*) | 0.73 | 0.01 | 3.84 | not significant |
| 3. | Stink bean (*Parkiaspeciosa*) | 0.50 | 0.23 | 3.84 | not significant |
| 4. | Candlenut (*Aleuritesmoluccana*) | 0.67 | 0.23 | 3.84 | not significant |

Based on the data in Table 2, the Ochiai Index (OI) values between vegetable ferns and the four species of shade trees varies from 0.50 to 0.73. An OI value greater than zero (> 0) indicates that there is an association between vegetable ferns and shade trees. If the OI value is greater or closer to 1, then the association that occurs is stronger (Ludwig dan Reynolds, 1988). This means that vegetable ferns require shade trees, as shade trees can alter and control environmental conditions to make them suitable for their survival.

Based on the results of the $\chi 2$ test, the association of vegetable ferns with all species of shade trees was not significant because $\chi^2_{corrected} < \chi^2_{table}$. This means that vegetable ferns require shade trees, but not specifically the species of tree. Vegetable ferns can grow anywhere that gets shade from trees, so that the environmental conditions are shady and humid (De Pauw et al., 2022). This is an example of an commensalism type of association.

The association between undergrowth (such as ferns) and the trees that shade them is a type of commensalism association (Indriyanto, 2024). Undergrowth are groups of herbs/herbs, grasses, lianas, and ferns that make up the lowest canopy layer of the forest canopy stratification. Amensalism association is a type of association between one species of biota with another species of biota, where one party benefits, while the other party does not benefit and does not suffer losses (Indriyanto, 2024). In the association between vegetable ferns and shade trees, the vegetable ferns benefit from the tree's shade, which reduces solar radiation intensity and climate control, as well as soil improvement due to the addition of organic matter from tree litter. Meanwhile, the shade trees themselves neither directly benefit nor suffer losses from their association with the vegetable ferns.

## IV. CONCLUDING REMARK

### Conclusion

Thirteen tree species and one shrub were found forming the forest garden stand. These thirteen tree species are classified as multipurpose tree species (MPTS), allowing farmers to utilize non-timber commodities from MPTS trees without felling them. Furthermore, farmers can utilize the vegetable ferns growing beneath the forest garden stand.

The density of vegetable ferns in each sample plot varied between 0 individuals/4 $m^2$ to 20 individuals/4 $m^2$. Four of the 20 sample plots contained no vegetable ferns. Vegetable ferns thrive in areas shaded by trees. Four species of trees were found to be the main shade for the vegetable ferns because they are located closest to where the vegetable fern plant lives, namely durian (*Duriozibethinus*), avocado (*Perseaamericana*), stink bean (*Parkiaspeciosa*), and candlenut (*Aleuritesmoluccana*).

The Ochiai Index (OI) values between vegetable ferns and the four species of shade trees varies from 0.50 to 0.73. The association of vegetable ferns with all species of shade trees was not significant, this means that vegetable ferns require tree shade, but not specific to species of trees.

### Recommendation

It is recommended to conduct research at other forest farmer's cultivated areas and analyze the relationship between the density of vegetable fern populations and various environmental factors (e.g. soil fertility, soil moisture, air humidity, and solar radiation intensity) under forest garden stands.

## ACKNOWLEDGEMENT

Acknowledgements are extended to the lecturers at the University of Lampung who have guided them in carrying out research and writing scientific articles. Thanks are also expressed to UPTD Taman Hutan Raya Wan Abdul Rachman which has permitted research in the forest area, and also the farmers who are members of the Harapan Baru FFG Alliances which accompanied me in data collection.

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