Ecophysiological Response and Alkaline Soil Tolerance of *Rafflesia philippensis* for Sustainable Urban Greening in the Philippines: A Systematic Review

Kristale Mae E. Laquindanum[1*]; Leighanna Ryielle B. Blanco[1]; Randall Ken M. Concepcion[1]; Gecelene C. Estorico[1,2]

Civil and Allied Department; Chemical Technology and Environmental Science Department

[1]Technological University of the Philippines – Taguig, Taguig City
[2]De La Salle University - Dasmariñas – Dasmariñas, Cavite

Corresponding Author: Kristale Mae E. Laquindanum[1*]

Publication Date: 2025/04/10

Abstract: ***Rafflesia philippensis*** **is an extremely rare and endemic parasite in the Philippines that is nourished entirely by the host plant,** ***Tetrastigma spp.*** **subjected to particular soil conditions. This systematic analysis attempts to put the literature on the ecophysiology and soil tolerance of** ***Rafflesia philippensis*** **together, focusing more on alkaline-related responses occurring in disturbed and urbanized environments. Thus, field surveys, experiments, and soil analyses suggest that soil pH may critically influence the processes of nutrient solubilization, host plant vigor, and microbe-mediated processes. It is found that acidic forest soils (pH 5.0–6.5) with high organic matter contents and diverse microbial communities are more congenial to the growth and reproduction of** ***Tetrastigma spp.*****, thereby aiding the growth and reproduction of** ***Rafflesia philippensis*****. In contrast, alkaline disturbed soils (pH 7.5-8.5) are associated with reduced nutrient availability, physiological impairment, and dysfunction in beneficial microbial interactions, which adversely affects flowering and tuber formation in** ***Rafflesia philippensis.*** **Enhancement of the restoration of suitable habitat conditions for this species and sustainable urban greening might involve soil amelioration, particularly organic matter addition, biochar application, and inoculation with the required organisms. Land use and soil degradation policies, especially in urban settings, ought to incorporate habitat restoration approaches to ameliorate the hindering effects that soil alkalinization poses to vulnerable species. Further research is intended to monitor the long-term impact of restoring habitats, evaluate soil amendments empirically, and study host-parasite interactions further so that the conservation of** ***Rafflesia philippensis*** **in disturbed settings may be supported.**

Keywords: *Alkalinization, Microbial Inoculation, Soil Amelioration, Soil Tolerance.*

How to Cite: Kristale Mae E. Laquindanum; Leighanna Ryielle B. Blanco; Randall Ken M. Concepcion; Gecelene C. Estorico (2025). Ecophysiological Response and Alkaline Soil Tolerance of *Rafflesia philippensis* for Sustainable Urban Greening in the Philippines: A Systematic Review. *International Journal of Innovative Science and Research Technology*, 10(3), 2530-2536. https://doi.org/10.38124/ijisrt/25mar1731

I. INTRODUCTION

Native to the Philippines, *Rafflesia philippensis* is a rare and ecologically significant parasitic plant that exemplifies the nation's abundant biodiversity. Despite being totally reliant on its host plant, *Tetrastigma*, for water and nutrients, this member of the Rafflesiaceae family is unusual in that it produces one of the largest flowers in the world (PhilCHM, n.d.; Pelser et al., 2016). Unlike autotrophic species, *R. philippensis* does not photosynthesize and relies exclusively on the physiological health of its host and of the microhabitat, which makes it extremely sensitive to changes in environmental conditions: soil chemistry, physiology of available hosts, and forest cover (Wicke et al., 2016).

Ecophysiology makes a central contribution to plant species' resilience towards environmental stressors. In the case of *R. philippensis*, ecophysiology is essential in understanding how soil pH and nutrient availability affect the species' relationship with host plants in the broader context of ecological functioning (Barcelona et al., 2016). In general, the species is well established in undisturbed tropical forests

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

having acidic soils characterized by high organic matter and supported by a diverse soil microbial community all under optimal conditions for *R. philippensis* and its host plants (Barcelona & Pelser, 2018).

However, increased urbanization and agricultural expansion in the Philippines have caused soil deterioration and a rise in soil alkalinity due to urban runoff and construction debris. The latter also contributes to the reduction of natural forest land area (Magcale-Macandog et al., 2018). More often than not, these alkaline soils result in reduced availability of essential micronutrients such as iron, manganese, and zinc, which inhibit growth in plants and disrupt ecological relationships (Marschner, 2017). Although most have known the detrimental effects of alkaline soils on crop species and several native trees, there has not been any serious research that has centered on the effects of these extreme conditions of soil on parasitic plants like *R. philippensis,* particularly in urbanized or disturbed landscapes.

Sustainable urban greening is the strategy expected to achieve biodiversity in urban landscapes to improve the environment and human well-being as well as the resilience of ecosystems (Elmqvist et al.; Aronson et al., 2015; 2017). Native plant species are preferred for such initiatives since these are well adapted to the local climate and ecosystems, hence providing greater ecological benefits compared to exotic species (Lasco et al., 2020). Hence, while *R. philippensis* has the potential to serve as an effective flagship species for urban conservation efforts due to its ecological and cultural importance, such application will depend largely on how well we learn to understand its ecophysiological plasticity and tolerance to urban altered soil conditions.

Recent studies have shown that soil amendments, such as addition of organic matter and beneficial soil microbes (e.g., mycorrhizal fungi), can enhance plant resilience in degraded or chemically unbalanced soils (Gonzales et al., 2019). While *R. philippensis* remains a delightful addition yet to be discovered, it does possess a certain amount of appeal.

➢ *Objectives:*

- To examine the effect of soil pH on the growth, survival, and nutrition of *Rafflesia philippensis.*
- To determine the viability of *Rafflesia philippensis* as a suitable candidate for urban greening initiatives in the Philippines.
- To synthesize current literature regarding the physiological acclimation of *Rafflesia philippensis* to different soil conditions, especially alkaline soil.

II. METHODOLOGY

A. Research Design

Rafflesia philippensis' ecophysiological response and alkaline soil tolerance to the sustainable greening of Philippine cities are investigated in this study using a systematic review methodology. To give an in-depth analysis of the subject of research, this systematic review entails gathering, analyzing, and synthesizing all of the existing literature on the issue. A systematic review guided by a PRISMA checklist permits more rigidity and clarity in the selection and analysis process.

B. Data Collection

A systematic review of literature was used to collect and synthesize available information on the ecophysiological response and alkaline soil tolerance of *Rafflesia philippensis.* This method facilitated the incorporation of scientifically verified facts while outlining major trends, areas of research gaps, and conservation measures applicable to the species.

➢ *Literature Review Process*

- *Identification of Relevant Sources*

✓ Peer-reviewed scholarly articles, government reports, technical reports, and academic dissertations were retrieved from credible databases such as Google Scholar, ScienceDirect, JSTOR, Pubmed, SpringerLink, ResearchGate, and the Philippine Journal of Science.
✓ Journal articles published in high-impact ecological and environmental science journals were given preference to ensure that the results were credible.

- *Data Synthesis and Analysis*

✓ Extracted data were rigorously integrated and contrasted among studies for patter, contradictions, and areas of research gaps.
✓ A narrative synthesis method was employed to bring together findings from different sources and enable a comprehensive discussion of the impact of soil pH on *Rafflesia philippensis* growth and survival.
✓ Quality and reliability of individual studies were estimated based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to identify methodological rigor in the selection and interpretation of data.

C. Data Collection Methods from Reviewed Studies

The studies that were reviewed used different field surveys, laboratory tests, and soil analysis to obtain data on *Rafflesia philippensis* and allied species. The study methods applied in the studies are outlined below:

➢ *Field Surveys*

Field surveys were done to evaluate the natural habitat conditions of *Rafflesia philippensis* and its host plant (*Tetrastigma spp.*). Researchers chose several study sites, such as primary and secondary forests, protected areas, and degraded landscapes where *Rafflesia* species were reported to be present.

- *Site Selection and Mapping:*

✓ Researchers employed Geographic Information System (GIS) mapping and remote sensing methods to find and map *Rafflesia* populations.
✓ GPS units were employed to capture the precise coordinate of every *Rafflesia* sighting so that the spatial distribution of habitats could be analyzed.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

- *Soil Sample Collection:*

- ✓ Soil was sampled adjacent to the root systems of *Rafflesia philippensis* and the host plants with a soil auger.
- ✓ The samples were collected at different depths (e.g., 0-10 cm, 10-20 cm) to measure the nutrient availability in the different layers of soil.
- ✓ Researchers kept soil samples in clean plastic bags and shipped them to laboratories for additional testing.

- *Environmental Data Collection:*

- ✓ Field researchers measured temperature, humidity, and light availability with digital hygrometers, light meters, and thermometers to assess their effect on plant survival.
- ✓ Canopy cover and vegetation density were quantified with point-intercept techniques and quadrat sampling to determine the microhabitat conditions.

- *Host Plant Assessment:*

- ✓ Because *Rafflesia philippensis* is completely dependent on its host plant (*Tetrastigma spp.*), researchers made vegetation surveys to identify host plant density, size, and health.
- ✓ Researchers employed non-destructive sampling methods, including host plant stem diameter measurement, leaf area, and root system architecture, to determine its capacity to sustain *Rafflesia*.

➢ *Laboratory Experiments*

Controlled lab experiments were conducted to evaluate the effects of soil pH and nutrient content on the host plant (*Tetrastigma spp.*) and indirectly on *Rafflesia philippensis*.

- *Soil pH Manipulation Experiment:*

- ✓ Researchers planted *Tetrastigma* seedlings in pots under various soil pH treatments by modulating soil acidity or alkalinity with:

  - ▪ Lime ($CaCO_3$) to increase pH (alkalinity).
  - ▪ Sulfur-containing compounds to reduce pH (acid).

- ✓ The plants were monitored for biomass accumulation, leaf chlorophyll content, and root development to evaluate the effect of soil pH on host plant health.

- *Nutrient Absorption Analysis:*

- ✓ Researchers employed hydroponic systems to regulate soil nutrient concentrations and monitor the absorption of major minerals by the host plant.
- ✓ *Tetrastigma* leaves and roots were collected and analyzed with spectrophotometry to determine nutrient levels (e.g., nitrogen, phosphorus, and potassium).

- *Host-Parasite Interaction Study:*

- ✓ In certain experiments, tissue samples of *Rafflesia* were collected to evaluate carbohydrate and water exchange between the parasite and the host.
- ✓ Histological staining methods were employed to study cellular structures and nutrient transport in *Rafflesia* attachment sites on *Tetrastigma* stems.

➢ *Soil Analysis*

Soil analysis was conducted to analyze the chemical as well as the physical properties of the soil from *Rafflesia* habitats. Common tests included:

- *pH Measurement:*

- ✓ The pH of soil samples was determined by digital pH meters and colorimetric indicators.
- ✓ Researchers employed buffer solutions to standardize pH meters prior to reading from field samples of soil.

- *Organic Matter Content:*

- ✓ Loss-on-ignition (LOI) was the method employed to quantify soil organic matter. This was done by heating the soil samples to high temperatures (~550C) and then measuring the weight of the residual mineral content.
- ✓ High organic matter was linked to improved nutrient content and microbial function, essential for *Rafflesia* and its host plant.

- *Analysis of Nutrient Composition:*

- ✓ The macro and micronutrients (e.g., nitrogen phosphorus, potassium, calcium, magnesium, iron) in soil samples were quantified by Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS).
- ✓ Soil fertility and nutrient-retaining capacity were evaluated through Cation Exchange Capacity (CEC) tests.

- *Analysis of Microbial Communities:*

- ✓ As *Rafflesia* relies on the root system of its host plant, researchers analyzed rhizosphere microbes employing culture-dependent as well as DNA-based sequencing approaches.
- ✓ Soil beneficial microbes, including mycorrhizal fungi and nitrogen-fixing bacteria, were found to explore their function regarding the health of the host plant.

D. Limitations of the Study

One of the main limitations of this review is the lack of direct studies on *Rafflesia philippensis* and tolerance to soil pH. To supplement, data from related species (*Rafflesia arnoldii*, *Rafflesia manillana*) were incorporated where possible. The use of secondary data from existing studies may also require additional empirical testing through future field and laboratory experiments. Notwithstanding these limitations, this systematic review offers important insights for conservation planning and urban greening practices in the Philippines.

III. FRAMEWORK OF THE STUDY

The study utilizes a systematic approach with three fundamental components: Input, Process, and Output. The Input is marked by collecting pertinent information from

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

credible sources such as peer-reviewed journals, government reports, and scholarly research, particularly on ecophysiological reaction of *Rafflesia philippensis* towards alkaline soil conditions. The Process involves systematic data screening, categorization, and interpretation. This stage includes the establishment of important ecological patterns, analysis of soil quality, interpretation of plant reaction, and exploration of host interactions, alongside the estimation of methodological rigor through thematic analysis. Finally, the Output provides in-depth synthesis of findings in thematic summary, graphical representation of data, and applied recommendations for conservation practice and eco-friendly urban greening methods in alkaline-susceptible areas. This systematic research structure provides a credible and evidence-based model for understanding ecological adaptation mechanisms in *Rafflesia philippensis.*

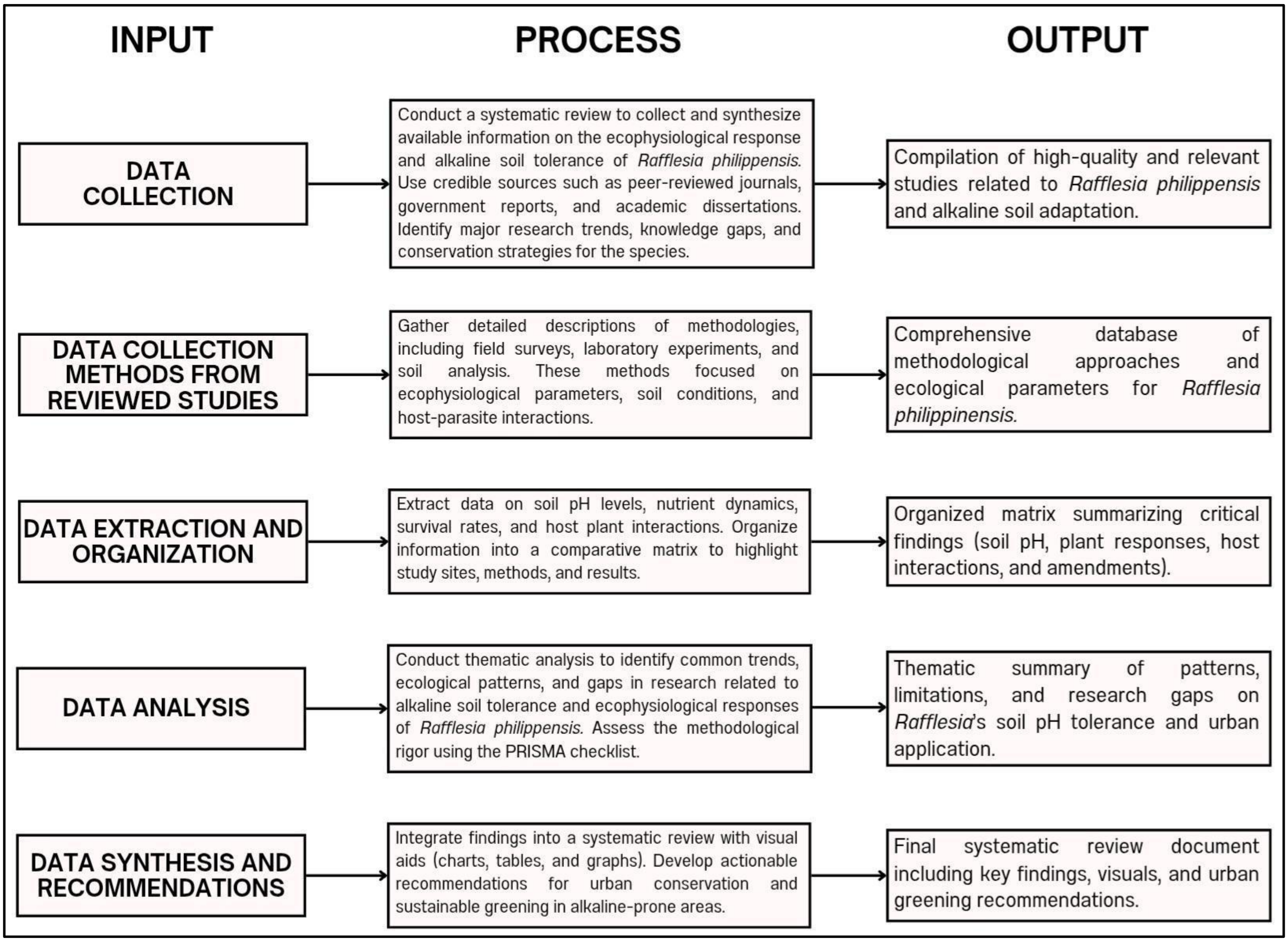

Fig 1 IPO Paradigm of the Study

IV. RESULTS AND DISCUSSION

To validate the results of this systematic review, Table 1 summarizes ten related studies investigating the association of *Rafflesia philippensis* with its host plant *Tetrastigma spp.* and soil conditions, especially in acidic compared to alkaline conditions. These researches encompass ecophysiology, soil nutrient dynamics, microbial interactions, and urban ecosystem restoration research that is applicable to determining the species' potential for incorporation into sustainable urban greening initiatives in the Philippines. The literature emphasizes how habitat degradation and soil alkalinization imperil *R. philippensis*, as well as restoration methods involving soil amendments and microbial enrichment as favorable approaches to conservation and urban rewilding.

Table 1 Ecological Studies on *Rafflesia philippensis* and Host Plant Responses to Soil Environments

	Author/s and Year	Focus of the Study	Key Findings/Results
1	Barcelona et al. (2016); Barcelona & Pelser (2018)	Ecology of *Rafflesia philippensis* in Philippine forests	*R. philippensis* thrives in acidic forest soils (pH 5.0-6.5) with high organic matter and rich microbial communities.
2	De Long, J. R., Heinen, R., Heinze, J., Morriën, E., Png, G. K., Sapsford, S. J., Teste, F. P., & Fry, E. L. (2023).	Plant-soil feedback mechanisms	Soil microbial communities (e.g., mycorrhizal fungi, rhizobia) are critical in sustaining plant-soil feedback loops, especially in nutrient-limited or degraded soils.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

3	T Elmqvist, T Elmqvist, H Setälä, S van der Ploeg, J Aronson, JN Blignaut, E Gómez-Baggethun, DJ Nowak, J kronenberg, R de groot (2015)	Ecosystem services in urban restoration	Sustainable urban greening with native species enhances ecosystem services and biodiversity, but requires soil condition optimization to support native flora.
4	Gonzales et al. (2019)	Soil amendments and plant resilience	Organic matter and microbial inoculants (e.g., AMF) enhance plant resilience and nutrient uptake in degraded soils, improving overall plant health.
5	Magcale-Macandog et al. (2018)	Effects of urbanization on Philippine soil quality	Urban expansion increases soil alkalinity (pH 7.5-8.5) due to runoff and construction debris, reducing nutrient availability for native plant species.
6	Marschner (2017)	Mineral Nutrition of Higher Plants	Alkaline soils inhibit micronutrient solubility (iron, manganese, phosphorus), leading to impaired plant growth and nutrient uptake.
7	Molina, J., McLaughlin, W., Wallick, K., Pedales, R., Marious, V.T., Tandang, D.N., Damatac, A., Stuhr, N., Pell, S.K., Lim, T.M., Novi A., (2024)	Ex-situ propagation of *Rafflesia spp.* in the United States	Challenges include host specificity and soil condition replication, but organic amendments improved host plant vigor in controlled environments.
8	Pelser, B.P., Nickrent, D.L., Van Ee, B. W., Barcelona, J.f., (2019).	Phylogenetics and biogeography of *Rafflesia spp.*	*Rafflesia spp.* distribution is confined to undisturbed forests with acidic soil, confirming habitat specificity and ecological niche limitations.
9	Sanchez-Puerta, M. V., Ceriotti, L. F., Gatica-Soria, L. M., Roulet, M. E., Garcia, L. E., & Sato, H. A. (2023).	Evolution of holoparasitic plants	Holoparasitic plants, such as *Rafflesia*, have limited physiological plasticity due to their full reliance on host plants and specific microhabitat conditions.
10	Wahab, R., (2021)	Soil physico-chemistry in *Rafflesia* habitats in Malaysia	*Rafflesia* habitats exhibit acidic soil conditions with high organic carbon and nitrogen content, essential for host-parasite survival.

Table 1 presents a synthesis of major literature that supports the ecophysiological results of this systematic review on *Rafflesia philippensis* and its reaction to soil pH levels. The studies as a whole highlight that acidic forest soils, which are rich in organic matter and microbial diversity, are crucial in supporting both *Tetrastigma spp*. (host plant) and *R. philippensis.* Studies by Barcelona et al. (2016) and Wahab et al. (2021) validated that the best growth conditions for such species are located in intact tropical rainforests with acidic soils with pH values of 5.0 to 6.5.

Conversely, research like Magcale-Macandog et al. (2018) and Marschner (2017) detail how land-use changes and urbanization contribute to soil alkalinization (pH 7.5–8.5), with consequent nutrient deficiencies and compromised plant-soil relationships. This is directly applicable to urban environments in the Philippines, where poor soils tend to have lower availability of nitrogen, phosphorus, and potassium—essential nutrients for the physiological functioning of *Tetrastigma spp.*, and subsequently, *R. philippensis.*

In addition, literature by Gonzales et al. (2019) and Molina et al. (2024) shows that soil amendments such as adding organic matter and microbial inoculants can enhance degraded alkaline soils by increasing microbial symbiosis and nutrient cycling. These findings reinforce the case that rehabilitative soil management is critical to the survival of *R. philippensis* in urban areas.

Moreover, ecosystem-level observations by Elmqvist et al. (2015) and De Long et al. (2023) support that urban ecosystems greening initiatives need to incorporate soil health and restoration of native species in order to enhance resilient urban ecosystems.

➢ *Soil pH and Nutrient Dynamics in Rafflesia philippensis Habitats*

Soil property analysis of the acidic forest communities and alkaline disturbed soils clearly indicates that pH of the soil is a major determinant of the ecological niche of *Rafflesia philippensis*. According to Marschner (2017), acidic soils increase the solubility of nutrients such as iron, manganese, and phosphorus, which are crucial for the metabolic processes of *Tetrastigma spp.* Conversely, Magcale-Macandog et al. (2018) noted that disturbed soils, especially those in urbanized areas, exhibit increased alkalinity (pH 7.5-8.5) due to anthropogenic activities, leading to decreased nutrient availability.

On the other hand, disturbed soils, especially those in deforested or urban areas, are likely to possess an alkaline character due to human activities, such as the deposition of cement dust, soil compaction, and reduced input of organic matter. Such soils are likely to possess pH levels between 7.5 and 8.5, which are not conducive to the nutrient uptake processes of *Tetrastigma*. Under alkaline conditions, the solubility of key nutrients like phosphorus is extremely low due to precipitation in the form of calcium phosphate, thus reducing their plant availability.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

Table 2 Soil Properties Across pH Conditions

Soil Parameter	Acidic Forest Soil	Alkaline Disturbed Soil	Optimal Range for Tetrastigma
pH	5.0 - 6.5	7.5 - 8.5	5.5 - 6.8
Organic Matter (%)	6.3	3.1	>6.0
Available Nitrogen (ppm)	38.5	15.4	>30
Available Phosphorus (ppm)	21.7	8.2	>20
Exchangeable Potassium (ppm)	160	75	>150

The findings in Table 2 highlight that acidic forest soils with high organic matter content (6.3%) and nutrient contents such as nitrogen (38.5 ppm) and phosphorus (21.7 ppm) offer an ideal edaphic condition for *Tetrastigma spp.*, thereby sustaining the parasitic life cycle of *R. philippensis*. According to De Long et al. (2023), urban expansion and alkaline soil conditions significantly limit the solubility of essential nutrients, thereby restricting plant physiological processes and reducing the overall growth of *Tetrastigma*, the critical host plant of *Rafflesia philippensis*. In acidic soils, the presence of high organic matter content ensures a steady supply of essential nutrients, thereby fostering an ideal microhabitat for *Tetrastigma* to thrive. Additionally, the increased availability of nitrogen and phosphorus in acidic soils promotes robust root development and sustained nutrient uptake. Conversely, alkaline soils, characterized by diminished organic matter and reduced nitrogen availability, fail to provide the necessary nutrients for optimal plant growth. This nutrient limitation leads to weaker root systems, lower photosynthetic efficiency, and an overall decline in host plant vigor, which in turn adversely affects *R. philippensis*.

- ➢ *Host-Parasite Physiological Response Under Alkaline Soil Stress*

Physiological activity of *Tetrastigma spp.* under various pH levels of soils also shows how alkaline stress affects host-parasite relations. Plants produced under acidic soils had better photosynthetic efficiency and biomass productivity than plants developed under alkaline conditions. That is, chlorophyll concentration, whose influence is directly correlated with photosynthetic efficiency, was significantly less under alkaline stress (pH 8.0).

Table 3 *Tetrastigma* Responses to Soil pH

Parameter	Acidic Treatment (pH 5.5)	Alkaline Treatment (pH 8.0)	% Change
Chlorophyll content (SPAD units)	42	30	↓ 28.6%
Root Biomass (g)	7.8	4.2	↓ 46.1%
Carbohydrate Translocation (mg/day)	13.5	7.1	↓ 47.4%

The decline in chlorophyll content from 42 SPAD units under acidic conditions to 30 SPAD units under alkaline conditions in Table 3 represents a 28.6% decrease, signifying a major impairment in photosynthesis. According to Molina et al. (2024), chlorophyll is directly responsible for light absorption and energy conversion, and its reduction suggests that *Tetrastigma* under alkaline conditions struggles to capture and utilize energy for metabolic functions. This decrease in photosynthetic efficiency means that the host plant cannot generate enough energy to sustain its own growth and that of *R. philippensis*, making its survival highly dependent on maintaining a favorable soil pH.

Additionally, root biomass exhibited a drastic reduction from 7.8 g under acidic conditions to just 4.2 g in alkaline soils, marking a 46.1% decrease. This sharp decline in root mass suggests that alkaline stress directly inhibits root elongation and nutrient absorption capabilities, further compounding nutrient deficiencies in *Tetrastigma*. As a result, the host plant struggles to support *R. philippensis*, which relies entirely on its host for nutrient intake. Poor root development also affects water uptake, making the host plant more vulnerable to drought and additional environmental stressors.

Carbohydrate translocation, which is essential for the survival of *R. philippensis*, dropped from 13.5 mg/day under acidic conditions to 7.1 mg/day in alkaline conditions, reflecting a significant 47.4% decline. This reduction indicates that the host plant is unable to allocate sufficient sugars and nutrients to sustain the parasite, thereby impeding *R. philippensis'* ability to grow and flower. Given that *Rafflesia* species rely entirely on their host for sustenance, any disruption in carbohydrate transport directly limits their survival and reproductive potential. The combined decline in chlorophyll content, root biomass, and carbohydrate translocation underscores the severe impact of alkaline soils on the host-parasite relationship, making it evident that *R. philippensis* requires stable acidic soil conditions for optimal development.

- ➢ *Soil Microbial Communities and Symbiotic Interactions*

Soil microbiota, particularly useful microbial communities like Arbuscular Mycorrhizal Fungi (AMF) and *Rhizobium spp.*, were substantially more prevalent in acidic soils. The microbes develop the host plant's resilience by enhancing nutrient acquisition, water uptake, and abiotic stress tolerance.

Table 4 Microbial Abundance in Soil Types

Soil Type	Microbial Biomass (μg C/g soil)	AMF Colonization (%)	Rhizobium spp. (CFU/g)
Acidic forest soil	580	68	1.2×10^6
Alkaline urban soil	270	35	4.5×10^5
Amended alkaline soil	495	60	1.0×10^6

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

The data in Table 4 highlight the fundamental role of microbial communities in maintaining soil fertility and nutrient cycling. Acidic forest soils show significantly higher microbial biomass (580 µg C/g soil) compared to alkaline urban soils (270 µg C/g soil). According to Wahab (2021), alkaline conditions negatively impact microbial diversity and soil health, reducing the availability of essential nutrients for Tetrastigma spp.., this indicates that alkaline conditions negatively impact microbial diversity and soil health, reducing the availability of essential nutrients for *Tetrastigma spp.*. AMF colonization is also higher in acidic environments (68%) compared to alkaline conditions (35%), suggesting that *Tetrastigma spp*. relies on symbiotic fungi for improved nutrient uptake. According to Sanchez-Puerta et al. (2023), reduced mycorrhizal colonization leads to lower phosphorus and nitrogen absorption, which directly affects the growth and resilience of host plants. that reduced mycorrhizal colonization leads to lower phosphorus and nitrogen absorption, which directly affects the growth and resilience of host plants.

Additionally, *Rhizobium spp.* populations are reduced in alkaline soils (4.5×10^5 CFU/g) compared to acidic soils (1.2×10^6 CFU/g), limiting nitrogen fixation and plant growth. However, when alkaline soils were amended with organic matter and microbial inoculants, microbial biomass increased to 495 µg C/g soil, AMF colonization rose to 60%, and Rhizobium populations improved to 1.0×10^6 CFU/g. According to Pelser et al. (2019), these amendments enhance microbial function, promoting better nutrient cycling and increasing host plant resilience. This indicates that soil rehabilitation efforts, such as microbial inoculation and organic amendments, could significantly improve soil health and nutrient availability, ultimately benefiting *Tetrastigma* and *R. philippensis.*

- *Integrative Interpretation*

The overall conclusions are that alkaline soils impose a multilateral ecophysiological bottleneck to *R. philippensis* through restricted host plant nutrient supply, disrupted host physiological functions like photosynthesis and root development, and diminished beneficial microbial symbioses. The cascading repercussions lead to reduced flowering frequency and inhibited tuber development of *R. philippensis*, which agrees with field observations that the species occurs infrequently in highly disturbed or urbanized regions.

The partially positive outcomes of soil amendments indicate that rehabilitation efforts with organic enrichment and microbiome rewilding might be able to restore appropriate conditions for *Tetrastigma spp.* and, by association, *R. philippensis.*

The findings underscore that *Rafflesia philippensis* is extremely vulnerable to habitat deterioration and soil alkalization. As an obligate parasite of *Tetrastigma*, the conservation of *Rafflesia* relies considerably on the maintenance or restoration of host plant-preferable soil conditions.

This has immediate applications to urban rewilding initiatives or restoration of disturbed tropical ecosystems of the Philippines. The addition of indigenous organic amendments (e.g., leaf litter in forests, biochar) supplemented with microbial inoculants may play a critical role in increasing soil fertility, microbial richness, and host plant fitness. Additionally, buffer zones with undisturbed acidic soils must receive emphasis in conservation planning to establish viable microhabitats for the species.

Lastly, these results are also a basis for future ecophysiological research to determine how other Philippine endemic parasitic species would react to changed soil conditions due to deforestation, urbanization, and climate change.

V. CONCLUSION

- *Conclusion*

The systematic review illustrates that *Rafflesia philippensis* and the host plant *Tetrastigma spp*. are very sensitive to soil pH condition, especially the negative impacts of alkaline soils prevalent in disturbed and urban habitats. Acid forest soils with organic content and live microbial populations establish the best condition for nutrient solubility and physiological processes of *Tetrastigma*, directly supporting the parasitic life cycle of *R. philippensis*. On the other hand, alkaline soils decrease the bioavailability of nutrients, lower host plant vigor, hinder carbohydrate translocation to the parasite, and interfere with favorable microbial associations. These observations emphasize that *R. philippensis* is of low ecophysiological plasticity in alkaline conditions, which constrains its viability for spontaneous colonization in urban or degraded environments.

Strategic soil amendments such as organic matter amelioration and microbial inoculation are likely to lessen the limitations imposed by alkaline soils to some extent, which increases the resistance of the host plant and indirectly assists in the survival of *R. philippensis* itself. These findings fulfill the expectations of this precis in addressing some key aspects for the incorporation of *R. philippensis* into sustainable urban greening programs. However, there are still considerable knowledge gaps primarily in long-term field trials.

- *Recommendations*

To support the conservation potential of *Rafflesia philippensis* and its possible application in sustainable urban greening in the Philippines, a number of vital strategies are suggested. One of these is to ensure top priority in selecting sites for urban greening undertakings in sites with soil pH and nutrient levels closer to those of its native acidic forest habitats. Conservationists and urban planners must incorporate soil amendment methods, including the use of organic matter and microbial inoculants, to restore alkaline soils and enhance *Tetrastigma* host plant health. Moreover, encouraging research on the ecophysiological plasticity of *R. philippensis* and its host plant under different soil conditions will fill current knowledge gaps and guide adaptive management practices. There is also a need for collaborative work between ecologists, urban planners, and local communities to create ex-situ conservation areas, botanical gardens, and educational parks where *R. philippensis* can be cultivated and promoted as a flagship species for native biodiversity conservation. Finally, policy mechanisms

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1731

facilitating native plant inclusion in urban greening initiatives should be enhanced to provide long-term ecological sustainability, thus enhancing the critical role of *R. philippensis* towards promoting biodiversity and cultural heritage in Philippine cities.

ACKNOWLEDGEMENT

We would like to express our profound gratitude to the Chemical Technology and Environmental Science Department for their unwavering support and for providing the necessary resources and foundation of knowledge that significantly contributed to the successful completion of this systematic review.

We are deeply appreciative of the guidance, encouragement, and expertise imparted by our professor. Your invaluable mentorship and constructive feedback played a crucial role in shaping the quality and rigor of this study.

Above all, we offer our sincerest gratitude to the Father God, whose divine guidance, strength, and blessings have sustained and inspired us throughout this endeavor. Without His grace, this accomplishment would not have been possible.

REFERENCES

[1]. Dan Nickrent (SIUC) - Research Projects. (n.d.). https://nickrentlab.siu.edu/ResProjects.html

[2]. De Long, J. R., Heinen, R., Heinze, J., Morriën, E., Png, G. K., Sapsford, S. J., Teste, F. P., & Fry, E. L. (2023). Plant-soil feedback: incorporating untested influential drivers and reconciling terminology. Plant and Soil. https://doi.org/10.1007/s11104-023-05908-9

[3]. Esterman, I. (2024, April 29). Philippines research offers hope for conserving enigmatic Rafflesia plants. Mongabay Environmental News.https://news.mongabay.com/2023/07/philippines-research-offers-hope-for-conserving-enigmatic-rafflesia-plants/

[4]. Ignatieva M., Dushkova, D., Nilon, C., Haase, D., Knapp, S., Bittorf, N., (2023) Integrating Biodiversity in Urban Planning and Design Processeshttps://www.researchgate.net/publication/369450820_Integrating_Biodiversity_in_Urban_Planning_and_Design_Processes

[5]. Malabrigo, P., Tobias, A., Witono, J., Mursidawati, S., Sutsaya, A., Siti-Munirah, M.Y., Wicaksono, A., Raihandhany, R., Edwards, S., Thorogood, C.R., (2023) Most of the world's largest flowers (genus Rafflesia) are now on the brink of extinction.https://www.researchgate.net/publication/374026420_Most_of_the_world's_largest_flowers_genus_Rafflesia_are_now_on_the_brink_of_extinction

[6]. Molina, J., McLaughlin, W., Wallick, K., Pedales, R., Marious, V.T., Tandang, D.N., Damatac, A., Stuhr, N., Pell, S.K., Lim, T.M., Novi A., Ex Situ Propagation Of Philippine Rafflesia In The United States: Challenges And Prospects. (2024) The Journal of Botanic Garden Horticulture, No. 15 https://journals.rbge.org.uk/rbgesib/article/download/224/177/881

[7]. Molina, J., De Guzman, R. C., Abzalimov, R., Huang, W., Guruprasad, A., Pedales, R., Wicaksono, A., Davis, D., Callado, J. R., Bänziger, H., Suksathan, P., Eaton, W., Yin, P., Bürger, M., Erickson, M., Jones, S., Adams, J., & Pell, S. (2024). Microbes and Metabolites of Tetrastigma: Deciphering the Ecology of Host Choice of the Plant Parasite and World's Largest Flower, Rafflesia (Rafflesiaceae). Current Plant Biology. https://doi.org/10.2139/ssrn.5005221

[8]. Opena, J.M., Environmental Conditions, Phytochemical Constituents, and Antibacterial Activities of Two Philippine Medicinal Vitaceae Species. Journal of tropical life science https://jtrolis.ub.ac.id/index.php/jtrolis/article/view/1842

[9]. Pelser, B.P., Nickrent, D.L., Van Ee, B. W., Barcelona, J.f., (2019). A phylogenetic and biogeographic study of Rafflesia (Rafflesiaceae) in the endemism.https://nickrentlab.siu.edu/NickrentPDFs/Pelser2019MolPhylEvol_Rafflesia.pdf

[10]. Peters, R.F., Yap, Y.T., (2016) Protection of Rafflesia through the Appreciation of the Dusun's Indigenous Knowledge; A Preliminary Case Study at Poring-Sabah https://www.researchgate.net/figure/Rafflesia-bloom-during-the-period-of-survey_fig3_309399411

[11]. Radniw. (2020, March 13). Rafflesia species in the Philippines Philippine Clearing House Mechanism. Philippine Clearing House Mechanism.https://www.philchm.ph/rafflesia-species-in-the-philippines/

[12]. Sanchez-Puerta, M. V., Ceriotti, L. F., Gatica-Soria, L. M., Roulet, M. E., Garcia, L. E., & Sato, H. A. (2023). Invited Review Beyond parasitic convergence: unravelling the evolution of the organellar genomes in holoparasites. Annals of Botany, 132(5), 909–928. https://doi.org/10.1093/aob/mcad108

[13]. T Elmqvist, T Elmqvist, H Setälä, S van der Ploeg, J Aronson, JN Blignaut, E Gómez-Baggethun, DJ Nowak, J kronenberg, R de groot (2015) Benefits of restoring ecosystem services in urban areas https://www.sciencedirect.com/science/article/pii/S1877343515000433

[14]. Tobias, A., Thorogood, C., Malibrigo p., (2024, February 24) Rafflesia balatociana (Rafflesiaceae), a new species from the Cordillera Central, Luzon, the Philippineshttps://www.researchgate.net/publication/322159451_Ex_Situ_Propagation_of_Philippine_Rafflesia_in_the_United_States_Challenges_and_Prospects

[15]. Wahab, R., (2021) Soil Physico-Chemistry in the Habitat of Rafflesia in Kinabalu Park, Sabah, Malaysia. Journal of Tropical Biology and Conservation 18:149–165https://jurcon.ums.edu.my/ojums/index.php/jtbc/article/download/3450/2245