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From pots to soil: a first verified record of outdoor *Leucocoprinus birnbaumii* (Corda) Singer in Pahang, Malaysia

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Received September 7, 2025, Accepted in revised form October 7, 2025
Available online October 28, 2025
DOI: 10.24191/bioenv.v3i3.116

ABSTRACT. *Leucocoprinus birnbaumii*, commonly known as the Flowerpot Parasol, is a saprophytic fungus that typically grows in pots and greenhouses. Although this striking yellow species is cosmopolitan, it is uncommon to encounter the species in soil or in non-cultivated environments. In Malaysia, the outdoor occurrence of this species is recorded from unverified citizen science observations. But many of these public observations are based on immature fruiting bodies, which are easily confused with other yellow fungal species and carry a possible risk of misidentification. This study provides the first verified record of outdoor *L. birnbaumii* fruiting in the soil, a habitat rarely reported for the species. Although it expands the knowledge of its ecological range, its absence in the current survey suggests that the species does prefer humus rich and composted soil in plant pots rather than open ground. Detailed macro- and micromorphological characteristics of the species are also presented to provide reliable reference material for citizen scientists and emphasizes the importance of specimen-based documentation in fungal biodiversity studies. Species monitoring and conservation strategies are also highlighted to ensure this attractive fungal species is protected against extinction risk.

Key words: non-cultivated setting, plantpot dapperling, potted parasol, lepiotaceous fungus

1. INTRODUCTION

The genus *Leucocoprinus* belongs to the family Agaricacae, which is a globally dispersed monophyletic group of saprotrophic fungus. This lepiotaceous fungal genus can be found in tropical and subtropical regions across the world (Verma & Pandro, 2018). The ability of *Leucocoprinus* to decompose helps ecosystems recycle nutrients, which improves soil fertility and the health of the entire ecosystem. There are several key characteristics to identify *Leucocoprinus* species as they have distinguishing physical features. They often have a delicate, slender stipe (stem) that are frequently decorated with an annulus (ring) at the upper part. *Leucocoprinus* species typically have convex pileus (cap) when they are young, which progressively flatten out as they get older. The colour of *Leucocoprinus* fruiting bodies is one of their most distinctive features. While some species have bright yellow, others have brown, white or cream-colored fruiting bodies. Under the pileus, there are free lamellae (gills), which are often crowded together. In general, *Leucocoprinus* has a white spore print, which is a helpful trait for identification although a brown spored-print species was recently reported (Suarez et al., 2021). Additionally, the pileus and the stipe commonly

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experiencing color changing when wounded, either yellow or pinkish (Verma & Pandro, 2018; El-Fallal et al., 2019; Ijaz et al., 2023).

Among these, *L. birnbaumii* is the most common and widespread. The species is best known as plantpot dapperling or flowerpot parasol, due to its occurrence in the flowerpots and greenhouses (Adikaram et al., 2020; Ijaz et al., 2023). This yellow striking fungus was first described in 1785, which was later described and named as *Agaricus birnbaumii* by Corda (1839). In 1961, the species was positioned into the genus *Leucocoprinus*, establishing its scientific name as *Leucocoprinus birnbaumii* (Singer, 1962). In Malaysia, reports of *L. birnbaumii* are extremely scarce. The first published report was almost three decades ago, dated back in 1997 by Pegler (Lee et al., 2012), where the species was found in Sabah. The availability of the herbarium material was unknown; therefore, the status of the specimen collected remains unverifiable. Recently, 38 observations were made by local citizen scientists in iNaturalist, which are mostly from the pots, and some are outdoors. These observations are indeed valuable in highlighting species distribution and engaging the public in fungal documentation. However, many of the observations consisted of immature fruiting bodies, blurry images and aged specimens, thus hindering key diagnostic features such as striated margin, lamella arrangement, and the presence of annulus on the stipe. As a result, misidentification remains a concern. *L. birnbaumii* can resemble several other taxa, including *L. tricolor*, a morphologically similar species with one observation in iNaturalist by a local citizen scientist. *L. tricolor* also possesses bright yellow fruiting bodies and are commonly found in flowerpots and greenhouses. The minute differences are the brown spot in the middle of the pileus, brown squamules, and a chrome yellow stipe base (Kuo, 2015; Smith, 1981). Since both species exhibit a high degree of morphological similarity, field identification becomes complicated and unreliable. Verified, specimen-based records are therefore necessary to distinguish *L. birnbaumii* from its closely resembled species as well as to refine its distributional data.

During a fungal survey at UiTM Pahang Jengka Campus, two specimens believed to be *L. birnbaumii* were recovered. Its occurrence in Malaysia is particularly rare and even rarer when the specimens were found fruiting outdoor in open ground. This study therefore provides the first vouchered document of *L. birnbaumii* in Malaysia, expanding knowledge of its distributional and ecological range. Detailed morphological characteristics of *L. birnbaumii* are also presented in this work for future use as primary diagnostic tools by amateur mycologists and citizen science community in the field.

2. METHODOLOGY

2.1. Specimen collection

The specimens were found growing outdoors at UiTM Pahang Jengka Campus (3°45'03.1"N 102° 33'40.6"E) during rainy season in November 2023. After thorough macroscopic observations, the collected specimens were then placed into the paper bag to prevent or reduce any damage to the specimens (Lodge et al., 2004). Specimens were brought to the laboratory for microscopic observations. The specimens were later dried by using a commercial food dehydrator for 6 to 8 hours and were stored at 4°C.

2.2. Identification of fungal specimens

Identification was made based on credible published works on *L. birnbaumii* around the world (Kibby, 2019; Adikaram et al., 2020; Ijaz et al., 2023). Fruiting bodies of the fungal species were photographed *in situ* and the habitat where the species recovered was noted. For macroscopic observations, the specimens were more focused on the outer characteristics of the specimens which include pileus, lamellae, annulus, and stipe. Measurements of the pileus and stipe were also recorded. The specimens were purposely bruised to see any color changes. The substrates were also recorded. Microscopic observations focused on structures such as basidiospores, basidia, and cystidia on the lamella under two microscopes. At first, observations were made by using a light microscope (CX41, Olympus) equipped with a Dino Lite Dino-Eye Eyepiece Camera, followed by Scanning Electron Microscopy (SEM) (JEOL-JSM-5600) equipped with EDX (OXFORD Instruments X-MAX Link-ISIS-300) attached to a camera and a computer. For SEM, a small fragment (~1 mm) of dried specimens was mounted on aluminum stubs with a double-sided tape and was coated with gold palladium. The size of basidiospores was measured by SEM because it provided a clearer observation of colorless tissue images.

3. RESULTS AND DISCUSSION

Morphological characteristics of the specimens in this study are all in agreement with previous recorded data (Dutta et al., 2011; Kibby, 2019; Adikaram et al., 2020; Ijaz et al., 2023). The most notable and unique characteristic of *L. birnbaumii* is the color of its fruiting body, which is bright, sulfuric yellow that is different from other members of *Leucocoprinus*. *Leucocoprinus tricolor* is reported to be morphologically similar, but this species has a brown spot at the center of the pileus, brown squamules, and chrome yellow stipe base, becoming more visible upon maturity. In this study, the specimens recovered possessed a pileus that was spherical in shape with deep yellow color during immature stage (**Figure 1A**) before it turned to convex, umbonate, and the color changed to light yellow (**Figure 1B**). There were floccose squamules scattered loosely on top of the pileus and a darker yellow spot in the middle with sulcate-striate margins (**Figure 1C**). The pileus was almost translucent due to the thin layer. The lamellae were delicate, free, and yellow in color (**Figure 1D**). Thin, moveable, and uplifted annulus was present on the stipe of one of the specimens (**Figure 1E**) but fell off on another, leaving remnants on the pileus margin (photo not shown). The stipe was bulbous base, stout and sturdy during immature stage but became slender and fragile when reaching mature stage (**Figure 1F**).

Microscopically, the basidiospores under the light microscope were elongated, ellipsoid shape, thick-walled, with germ pores inside (**Figure 2A**). The structure of the basidiospores was clearer under SEM (**Figure 2B**), as the shape of spores were more detailed, showing asymmetrical shape with an indentation at the middle, smooth surface, and obvious hilar appendage (**Figure 2C**). The measurement of *L. birnbaumii* basidiospores was 8.3 µm x 5.2 µm. The basidia was elongated, long club-like structure with sterigma at the tip of the basidia (**Figure 2D**). The number of basidiospore-bearing sterigma was four (tetrasterigmatic) in total but only two sterigmas were observed in this study due to the angle of the microscopic view.

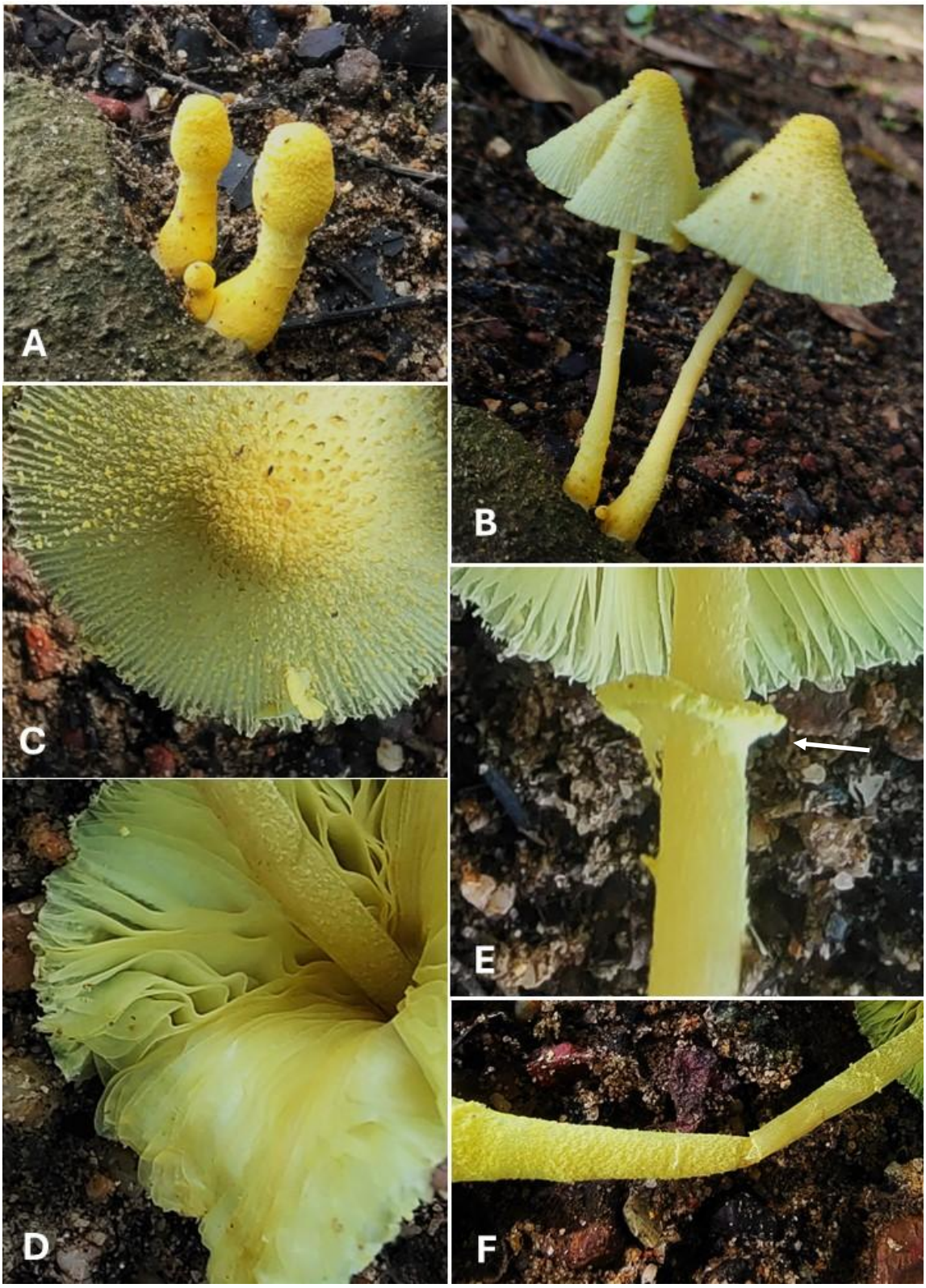

Figure 1. Macromorphological characteristics of *Leucocoprinus birnbaumii*. **A**. Specimens during immature stage. **B**. Specimens during mature stage. **C**. Pileus with floccose squamules and sulcate-striate margins. **D**. Delicate lamellae with yellow color. **E**. Thin, moveable, and uplifted annulus on the stipe (arrowed). **F**. A slender and fragile stipe during mature stage

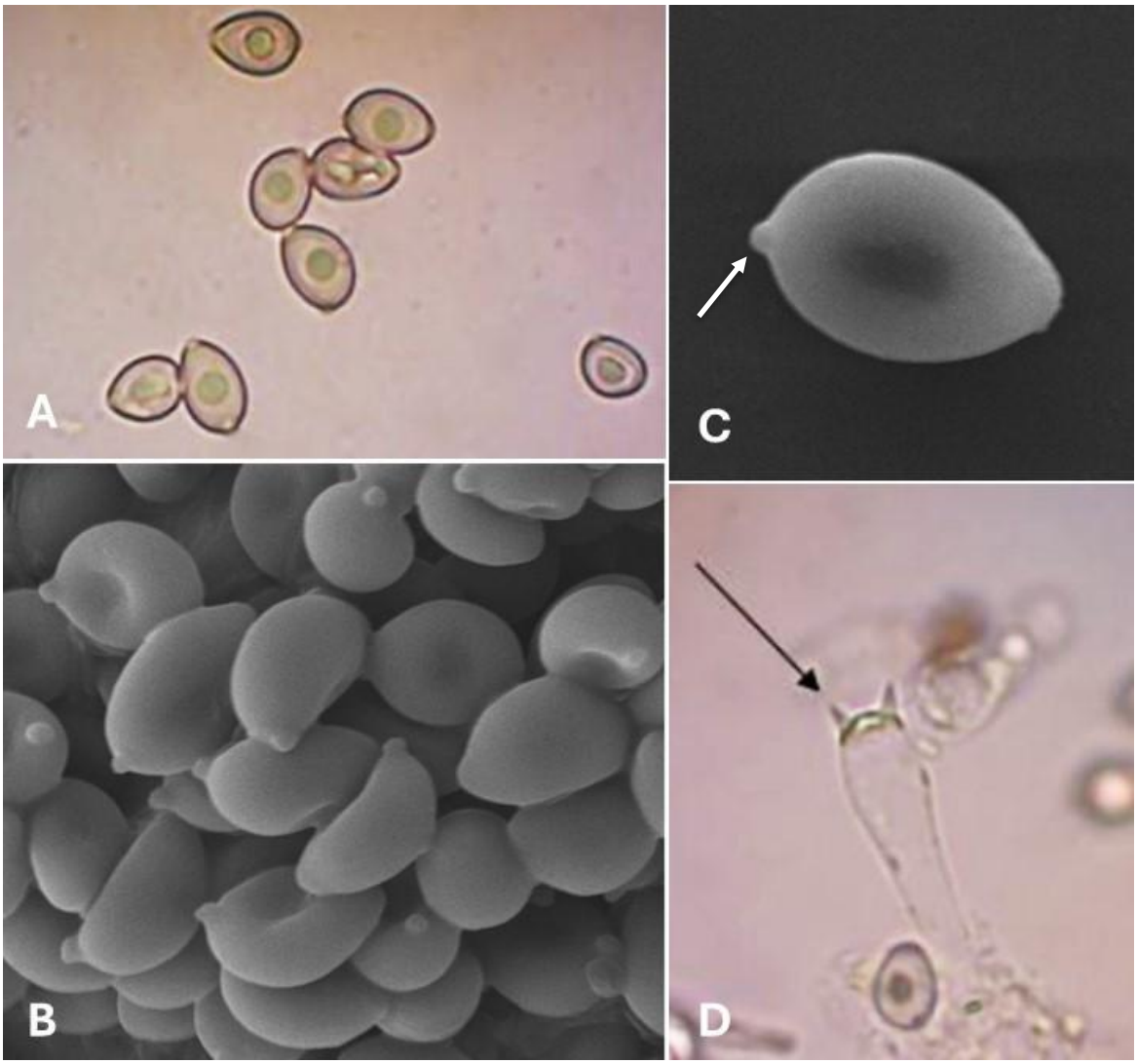

Figure 2. Micromorphological characteristics of *Leucocoprinus birnbaumii*. **A**. Basidiospores under 40x light microscope. **B**. Basidiospores under 3kx SEM. **C**. A hilar appendage on the basidiospores (arrowed). **D**. One of the basidia with sterigma (arrowed).

Only a few verified reports on outdoor *L. birnbaumii* worldwide (Dutta et al., 2011; Greeshma et al., 2016; Kibby, 2019), demonstrating its scarcity occurrence in non-cultivated environments. This current work adds to the latest record of this species fruiting outdoor. The sighting of this species in outdoor soil is noteworthy, given that this species typically grows indoors, in plant pots, on decomposing and dead plant debris, and in greenhouse environments (Adikaram et al., 2020; El-Fallal et al., 2019; Dutta et al., 2011). This is consistent with its common name, which is known as flowerpot parasol, plantpot dapperling, or yellow houseplant mushroom (Adikaram et al., 2020). Several factors may explain its presence in this uncommon habitat. The species was spotted during a rainy reason in November 2023 where increased rainfall favored its outdoor sporulation and survivability. It was also found growing under a tree which may provide a shading and sufficient moisture of the campus ground, enabling successful fruitification. Despite this, repeated surveys at the same site in 2024 and mid 2025 have not yielded any fruiting bodies of the species. The absence of recent fruiting reflects that the species indeed prefer humus rich and composted soil in plant pots that offers constant moisture, food source, and less competition rather than open ground. The occurrence of the species in 2023 was probably triggered by transient favorable microclimatic conditions that are not

replicated in subsequent years. As a member of the genus *Leucocoprinus*, *L. birnbaumii* contributes to the decomposition of organic matter which leads to nutrient recycling and soil fertility. However, its role as a decomposer is mainly associated with the indoors only and is traditionally regarded as a 'greenhouse weed'. Since it can be found outdoor, this current observation expands its ecological role where it may also contribute to nutrient recycling in natural habitats when favorable conditions permit.

Despite its global distribution, *L. birnbaumii* is rarely documented in Malaysia, either outdoors or indoors. Earliest report of this species was in 1997 where the species was discovered in Sabah (Lee et al., 2012). The herbarium material was not mentioned, thus remains unverified. Recent records by citizen scientists have listed 38 observations but the uploaded images are mostly immature fruiting bodies, and some are blurry, carrying possible risk of misidentification with other taxa. This present study includes key morphological diagnostic features of *L. birnbaumii* from mature specimens. It strengthens the reliability of species distributional data in Malaysia and could serve as reference material for both researchers and citizen scientists seeking to confirm the identity of the species in the field. This study also helps bridge the gap between community-based observations and formal taxonomic ethics, ensuring true fungal distribution and accurate biodiversity databases. Nevertheless, community-based records on platforms such as iNaturalist provide valuable preliminary information by highlighting potential occurrences and stimulating public engagement with fungal biodiversity.

Overall, the discovery of *L. birnbaumii* on the campus ground therefore warrants for conservation approaches, particularly at the site where the specimens were recovered. Maintaining habitat stability including minimal soil disturbance and providing shade cover to stimulate moisture contents are among approaches that can be implemented. The use of environmental DNA (eDNA)-based monitoring could assist in detecting belowground persistence of the fungus even in the absence of visible fruiting bodies. This approach has proven effective in detecting IUCN Red List soil fungi in Northern Europe (Copoț et al., 2024) which also can be initiated in tropical fungal species including rarely encountered *L. birnbaumii*.

4. CONCLUSION

This current work documents the first vouchered record of *L. birnbaumii* fruiting in outdoor soil in Malaysia, expanding the known ecological range of a species typically associated with indoor, humus rich, and composted soils. The outdoor occurrence of *L. birnbaumii* is uncommon since the species prefers plant pots and greenhouses that provide constant moisture, rich organic matter as food source, and less competition with other soil dwellers. As a saprobic fungus, the species may be involved in organic matter decomposition, presenting its ecological significance in nutrient recycling on the site where the species was found. This study also provides a reliable reference for future identifications by integrating comprehensive macro- and micromorphological characterization of this species. This documentation also helps address the roles of expert validation to complement citizen science observations, many of which solely rely on photographic records. Apart from this, its apparent absence during repeated surveys in 2024 and mid 2025 underlines the short-lived nature of fungal fruiting, requiring conservation approaches and long-term monitoring of this attractive yellow fungus. This can be done by maintaining habitat stability including minimal soil

disturbance and providing shade cover to stimulate moisture contents. The use of eDNA surveys would be beneficial in detecting the presence of this species belowground although the visible fruiting body is unavailable.

ACKNOWLEDGMENTS

Authors gratefully acknowledge Mrs. Zairus binti Ismail for specimen preparation and Mrs. Hjh. Norasidah binti Haron for SEM imaging. The authors also thanked anonymous reviewers for their critical comments.

AUTHOR CONTRIBUTIONS

Amir Malik bin Halit –prepare the manuscript (main author); Muhammad Asiff bin Mohamed Azhar –field assistant; Amirul Syahmi bin Aziz – field assistant; Dr. Farah Ayuni binti Farinordin – sampling team; Dr. Nur Amalina binti Mohd. Izam – sampling team; Dr. Nurul Farizah binti Azuddin – data validation and proofread the manuscript; Dr. Hafizi bin Rosli – data validation; Dr. Nor Azliza binti Ismail – prepare the manuscript (corresponding author).

FUNDINGS

This study was supported by UiTM Pahang Jengka campus under Dana Dalaman Negeri (600-TNCPI 5/3/DDN (06) (006/2022) grant.

COMPETING INTEREST

The authors declare that there are no competing interests.

COMPLIANCE OF ETHICAL STANDARDS

Not applicable.

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