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Observations on the *Astraeus* spp. of Southwestern India

Pavithra M, Greeshma AA, Karun NC and Sridhar KR*

Department of Biosciences, Mangalore University, Mangalagangotri, Mangalore 574 199, India

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Abstract

Astraeus is a widespread genus of gasteromycete in tropical, sub-tropical and temperate regions. During mycological survey, two distinct species of *Astraeus* were recovered from the Southwestern India. *Astraeus hygrometricus* was frequent in forests of foothill region of the Western Ghats. In fire affected scrub jungles of the west coast, *Astraeus odoratus* was common and represents second report from the Indian Subcontinent. *Astraeus* spp. recovered were ectomycorrhizal in a variety of native and exotic tree species growing in sandy loam/gravel/pebble-rich lateritic soils. Tender *A. hygrometricus* occurring in forests of foothill region of the Western Ghats serve as traditional nutritional delicacy and sold in local markets during rainy season.

Key words – *Astraeus* **–** Ectomycorrhizae **–** edibility **–** gasteromycete **–** macrofungi

Introduction

The gasteroid fungus *Astraeus hygrometricus* was first described in early 18th century as *Geastrum* by Persoon (1801). Subsequently, Morgan (1889) confirmed its identity as a distinct taxon *Astraeus* followed by more precise descriptions by many investigators (e.g. Lloyd 1902, Coker & Couch 1928, Cunningham 1944). *Astraeus* belongs to the family Diplocystidiaceae (Boletales, Agaricomycetes, Basidiomycota) (Binder & Bresinsky 2002, Kirk et al. 2008). This genus has worldwide distribution especially in the sandy soils of forests of Africa, Asia, Australia, Europe, Mexico, North America and South America (Lloyd 1902, Coker & Couch 1928, Cunningham 1944, Dring 1964, Nouhra & Toledo 1998, Phosri et al. 2004, Fangfuk et al. 2010).

Until now, up to 10 species have been described worldwide [(*Astraeus asiaticus* Phosri, M.P. Martin & Walting, *A. hygrometricus* (Pers.) Morgan, *A. koreanus* (V.J. Staněk) Kreisel, *A. morganii* Phosri, Walting & M.P. Martin, *A. odoratus* Phosri, M.P. Martin & Whalley, *A. pteridis* (Shear) Zeller, *A. sirindhorniae* Walting, C. Phosri, N. Suwannasai, A.W. Wilson & M.P. Martin, *A. smithii* Walting, M.P. Martin & Phosri, *A. telleriae* M.P. Martin, Phosri & Walting and *A. thailandicus* Petchart)] (Petcharat 2003, Phosri et al. 2013, Hembrom et al. 2014). Although *Astraeus* is superficially similar to *Geastrum*, it differs in certain characteristics especially lack of peristome and columella, consists of larger basidiospores than *Geastrum* and possesses highly branched long capillitial hyphae (Phosri et al. 2004). *Astraeus* is ectomycorrhizal and colonize a wide variety of forest tree species (e.g. *Dipterocarpaceae*, *Fagaceae*, and *Pinaceae*) unlike *Geatrum* with a few exceptions (e.g. *G. saccatum* and *G. triplex* are ectomycorrhizal) (Hibbett et al. 2000, Phosri et al. 2004, Fangfuk et al. 2010, Karun & Sridhar 2014). According to Cannon & Kirk (2007), convergent evolution might have occurred among *Astraeus* and *Geastrum*.

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*Corresponding Author: Kandikere R. Sridhar – e-mail – kandikere@gmail.com

Astraeus constitutes one of highly prized edible mushrooms in several parts of Asia (Mortimer et al. 2012). Tender basidiomata of *Astraeus* spp. are harvested in wild and marketed in India, Japan, Laos and Thailand (Ogawa 1992, Sanmee et al. 2003, Phosri et al. 2004, 2007, Dell et al. 2005, Butkrachang et al. 2007, Karun & Sridhar 2014). *Astraeus* spp. are distributed widely in the Indian subcontinent (Himachal Pradesh, Jharkhand, Karnataka, Kerala, Orissa, Punjab, Uttarakhand, Uttar Pradesh and West Bengal) (Ahmad 1950, Phosri et al. 2004, 2013, Pradhan et al. 2010, 2013a, b, Mohanan 2011, Pyasi et al. 2011, Hembrom et al. 2014, Karun & Sridhar 2014, Semwal et al. 2014). Due to meager information on *Astraeus* spp. especially in the Southern India (Bhagwat et al. 2005, Karun & Sridhar 2014), traditional knowledge of its edibility in the foothill regions of the Western Ghats and their association with a variety of forest tree species stimulated the present study. Thus, morphology, distribution, association with tree species, traditional knowledge and edibility of two *Astraeus* spp. found in Southwestern India have been dealt in this paper.

Materials & Methods

Study sites and observations

Based on the traditional knowledge on edible mushrooms, surveys were undertaken in and around Karkala forests (Udupi District, Karnataka) located in the foothill region of the Western Ghats (13°12' N, 74° 58' E). Specific forest locations consist of *Astraeus* include Chennibettu (67 m asl), Hebri (86 m asl) and Muniyalu (67 m asl). These are natural forest locations predominantly possess gravel, sandy and loamy lateritic soils. *Astraeus was* also seen in buffer zones of forest-grassland (or abandoned paddy fields) of Chennibettu. Another species of *Astraeus* was recovered from the fire affected scrub jungle in Konaje (90 m asl), near Mangalore University Campus (Dakshina Kannada District, Karnataka) (12°49'N, 74°55'E). This location is adjacent to a road with rocky escarpment consisting of sandy, gravel and laterite soil.

General and specific morphological characteristics of *Astraeus* spp. obtained were compared with literature in the monographs (Jordan 2004, Phillips 2006, Mohanan 2011) and detailed descriptions (Phosri et al. 2004, 2013, Pyasi et al. 2011, Hembrom et al. 2014). Field photographs were taken using zoom camera (Sony DSC-HX100V and Nikon D40). Light microscopic details of *Astraeus* spp. were obtained using an Olympus Microscope (CX41RF) with camera attachment. For scanning electron microscopic (SEM) analysis, spores from mature fruit bodies were treated with ethanol series (70%, 80%, 90%, 95% and twice in 100%) and air-dried for overnight. Spores were mounted on stubs using sticky tabs and sputter coated with gold and observed in SEM (Joel, JSM 6380 LA, Japan). Snaps were taken by a digital camera (Nikon D40) mounted on a Stereomicroscope (Nikon, D40 USA).

For preservation of *Astraeus* spp. in herbarium of the Department of Biosciences, blotted specimens were transferred into water-ethanol-formaldehyde (14:5:1) in air-tight containers.

Results

Based on macro- and micro-morphological characteristics, *Astraeus* sp. found in Chennibettu has been assigned to *A. hygrometricus*, while another *Astraeus* sp. found in Konaje has been assigned to *A. odoratus*. Morphological details and diagnostic features are given along with their illustrations.

Astraeus hygrometricus (Pers.) Morgan (Fig. 1A–H; Fig. 2A–J) (# MUBSPMKRSMF-CBKA)

Basidiomata: Creamish grey bulb surmounting a star-shaped pale purple grey base, which raises the spore sac above the surrounding substrate (Fig. 1G; Fig. 2C); scattered or in small groups (4–10), annual, particolous (Fig. 1A–C, F, H), infrequent to rare, taste excellent, odour mealy, edible (at immature stage) (Fig. 1D, E), ectomycorrhizal and measures 3 (3.5–4.6) 6.2 cm diam × 1.5 (1.6–2.3) 2.5 cm tall (n=10) (Fig. 1G; Fig. 2C). Almost all the fruit bodies are partially buried in

laterite soil (Fig. 1A, H). Majority of them are unopened or partially opened at apex with irregular crack of 4–7 petal-like lobes (Fig. 1G). With sufficient moisture, the lobes recurves, remain flat on the floor, further undergoes division about 7–13 lobes (Fig. 1G; Fig. 2C) and on drying lobes incurves towards centre (Fig. 2D). In most instances the lobes have tendency of incurving enclosing the spore sac. The spore sac degrades after the release of spores. The whole spore sac will be eliminated or its papery remnant remains at the centre of leathery incurved or flat lobes (Fig. 2 D–F). These left out lobes also have the capacity to recurve once imbibed with water and incurve on drying (Fig. 2D, E).

Immature basidiomata hypogeous, creamish, at first a small mycelial mass, with age globose to sub-globose to irregular, coarsely fibrous and arachnoid and measures 1.4 (1.5–2.5) 3 cm diam × 1.2 (1.4–2.3) 2.5cm tall (Fig. 1A–C, F–H) (n=25). At maturity becomes epigeous. Immature washed basidiomata has typical baby potato-shape (Fig. 1D), besides many have 2 or 3 fused lobes (Fig. 1E) and each one at this stage is edible and ready for sale (1D, E). Immature fleshy basidiomes without or with a small black portion is edible than those have partial or intense purple brown colouration (Fig. 2A, B). Immature and mature basidiomes are directly attached to highly branched roots of host plants (Fig. 1H).

Fig. 1 – *Astraeus hygrometricus*: Partially hypogeus immature fruit bodies in sandy loam (deliberately exposed while sampling A, B) and gravel-/pebble-rich laterite soil (natural set up in field C, F, H); immature fruit body attached to highly branched roots (arrows) of *Hopea parviflora* (H); different stages of fruit bodies (G); cleaned immature fruit bodies ready for sale/cook (D, E); cleaned 2–3 fused immature fruit bodies (E) (Scale: 1 cm).

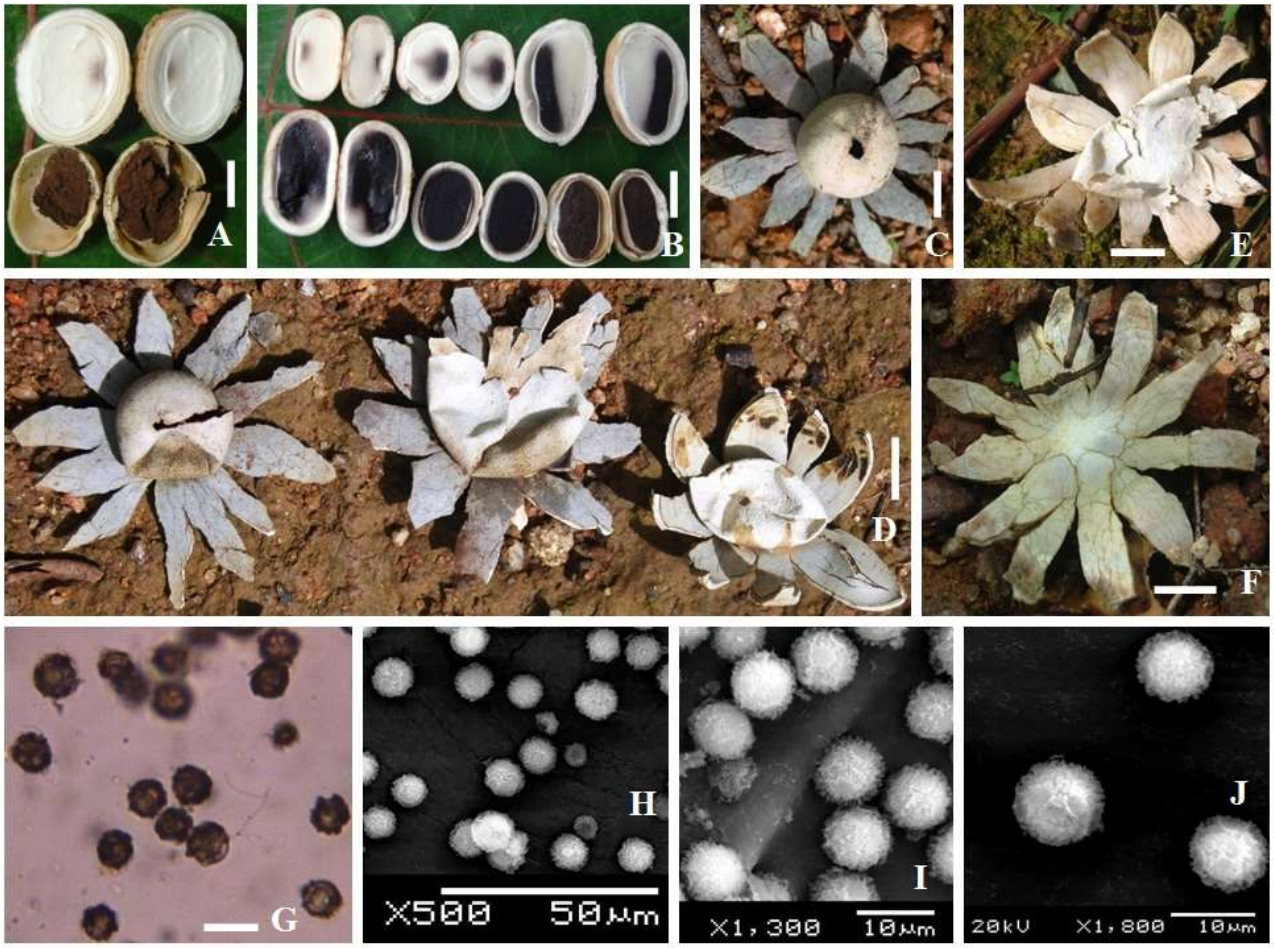

Fig. 2 – *Astraeus hygrometricus* in Chennibettu: Cross sections of immature and developing fruit bodies (A, B) (note several layers of outer wall in top 2 of A and shrunken interior in bottom 2 of A); fully matured (C) and partially degraded (D–F) fruit bodies on pebble-rich laterite soils (note: irregular opening in gleba in C; partially bleached papery gleba in D and E); ornamentation in basidiospores seen under light microscope (G) and scanning electron microscope (H–J) (Scale: A–F, 1 cm; G, I and J, 10 µm; H, 50 µm).

Exoperidium: At maturity epigeous, exoperidium splits into 7–13 hygroscopic petal-like lobes; incurved when dry and recurved when moist ± saccate (Fig. 1G; Fig. 2C). Pseudoparenchymatous layer was at first pinkish cream, becoming pale purple grey to greyish brown with age (Fig. 1G; Fig. 2C); at first fleshy, thin and smooth, becoming leathery with vertical and reticulate cracking with age. Mycelial layer was not encrusted with soil, radially fissured and there is a basal attachment point to the belowground mycelia.

Endoperidial body: Sub-spherical, 0.9 (1–1.2) 2 cm diam (n=10) sessile and devoid of apophysis (Fig. 1G; Fig. 2C).

Endoperidium and gelba: Endoperidium at first ash grey and finely warty, becoming purple grey to creamish grey and smooth with age, thin, papery and opening by a slit or tear forming an irregular apical pore (Fig. 1G; Fig. 2C). Gleba at first white, fleshy, firm, with age becoming purple, finally become brownish and powdery (Fig. 1G; Fig. 2D, E).

Basidiospores: Purple brown, spherical, warty and measures 6.6 (7.9–12.5) 13.2 × 5.3 (6.6–12.5) 13.2 µm (inclusive of ornamentation) (n=25) (Fig. 2G). Ornamentations on spores are clear, almost regular and consistent with less folds in SEM pictures (Fig. 2 H–J).

***Astraeus odoratus* Phosri, Walting, M.P. Martin & Whalley (Fig. 3A–K; Fig. 4A–I) (# MUBSPMKRSMF-FRKO)**

Basidiomata: Brownish grey bulb surmounting a star-shaped, reflexed orange brown base, which raises the spore sac above the surrounding substrate; scattered or in small groups (4–8), annual, particolous (Fig, 3A, F; Fig 4A), infrequent to rare, taste and odour not distinctive, inedible, ectomycorrhizal and measures 4.4 (4.5–7.5) 7.7 cm diam × 2.2 (3.4–5.4) 5.7 cm tall (n=10) (Fig. 3F–J). Mature fruit bodies are usually above the laterite soil (Fig. 3F). During maturity, exoperidium irregularly cracks into 4–5 lobes and further breaks into 5–8 lobes (Fig. 3F–J). In moist condition, lobes curves out extensively and their tips take shelter on the ground (Fig. 3F). Under dry conditions, lobes neither incurve nor become flat (Fig. 3F–J). Usually the degraded gleba remains attached at the centre under wet or dry conditions (Fig. 3K).

Immature basidiomata hypogeous, creamish, at first a small mycelial mass, with age globose to sub-globose, coarsely fibrous, arachnoid and measures 1.2 (1.7–3.5) 3.9 cm diam × 0.9 (1–1.8) 2.9 cm tall (n=25) (Fig. 3A, B). Immature fruit body shows fleshy interior with layered sac (Fig. 3C, D), interior portion becomes brown and shrinks at later stage (Fig. 3E). At maturity becomes epigeous.

Fig. 3 – *Astraeus odoratus* in Konaje: Immature fruit bodies on loamy laterite floor (A) (arrows pointing charcoal pieces); immature fruit bodies of different size (B); sectioned immature (C, D) and maturing (E) fruit bodies (arrows pointing charcoal pieces in C and D); a troop of mature fruit bodies on loamy laterite floor (arrows pointing roots of *Hopea ponga*) (F); top view (G) and side views (H–J) of mature fruit bodies; stages of spent fruit bodies with attached gleba (K) (Scale: 1 cm).

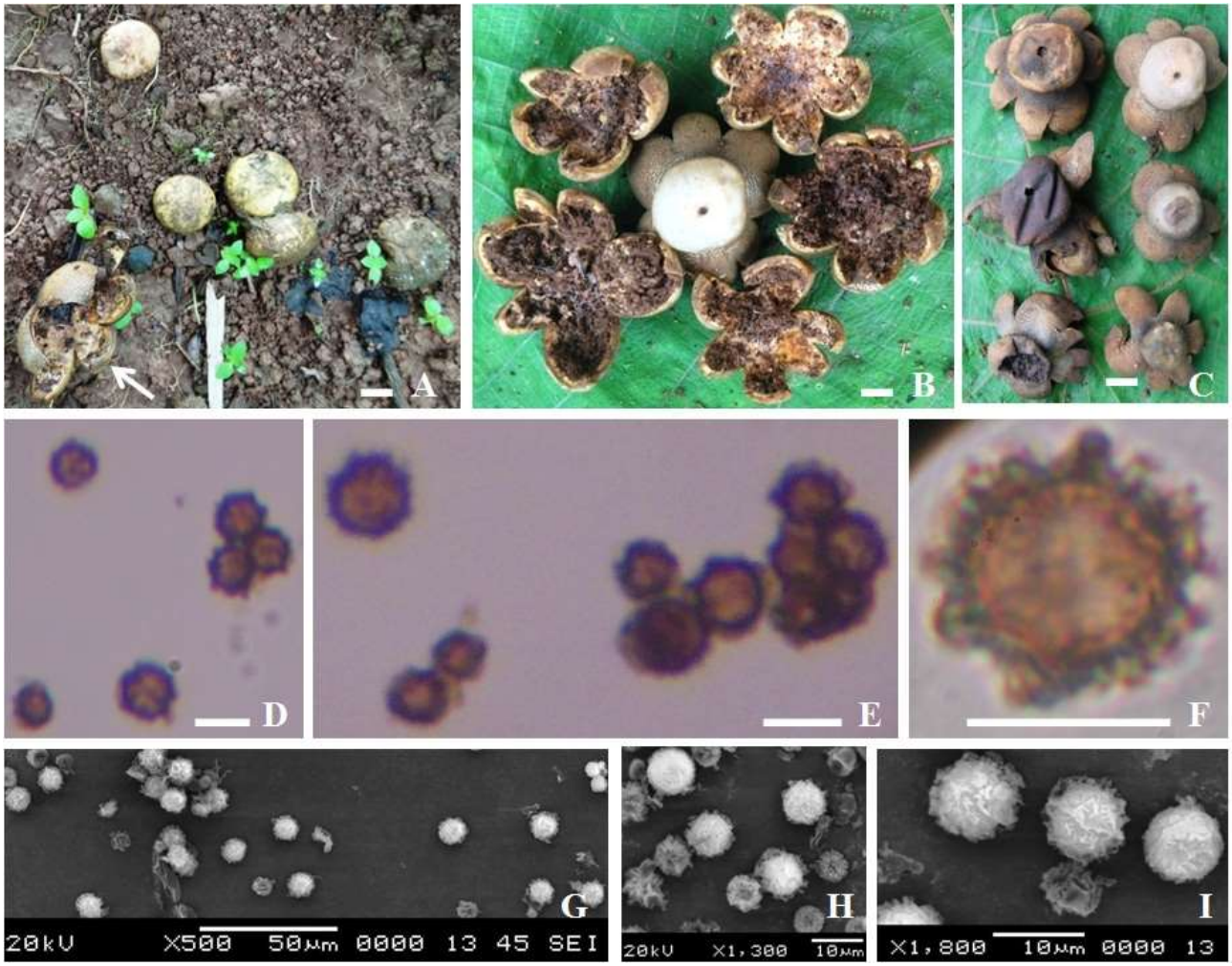

Fig. 4 – *Astraeus odoratus* in Konaje: Immature and mature fruit bodies on loamy laterite soil (A) (arrow pointing tilted mature fruit body showing hairy lobes); top view of upright and tilted mature fruit bodies (B) (note prominent hairy lobes in tilted fruit bodies); mature and spent fruit bodies of different stages (C); ornamented basidiospores seen under low (D), high (E, F) power light microscope and scanning electron microscope (G–I) (Scale: A–C, 1 cm; D–F, H, I: 10 µm; G, 50 µm).

Exoperidium: At maturity epigeous, exoperidium splits into 5–8 non-hygroscopic petal-like lobes; curl upwards and inwards under the endoperidial body ± involute (Fig. 3F–J). Pseudoparenchymatous layer at first pale orange becomes orange brown to brownish orange with age; at first fleshy, thick and smooth, becoming leathery, with fissured mosaic-like cracking with age (Fig. 3G–J). Mycelial layer was not encrusted with soil, radially fissured and there is a basal attachment point to the belowground mycelia. Posterior side of the mature basidiomata shows characteristic hairy/arachnoid feature seen on dry or partially dry conditions (Fig. 4A, B). As mature fruit body disconnects with roots, strong wind tilts it exhibiting hairy lobes of posterior region (Fig. 4A).

Endoperidial body: Sub-spherical, 1.85 (2.3–3.3) 3.4 cm diam (n=10), sessile and devoid of apophysis (Fig. 3F–J).

Endoperidium and gleba: Endoperidium at first grey brown and finely warty, becoming brownish grey and smooth with age, thin, papery and opening by a slit or tear forming an irregular apical pore (Fig. 3F–J). Gleba at first white, fleshy, firm, becomes purple with age, finally brownish and powdery (Fig. 3F–K; Fig. 4C).

Basidiospores: Purple-brown, spherical, warty and measures 6.5 (7.89–12.49) 13.15 × 7.89 (8.54–13.15) 13.8 µm (inclusive of ornamentation) (n=25) (Fig. 4D–F). Ornamentations on spores are inconsistent, irregular and possess more folds on surface (Fig. 4F–I).

Discussion

In spite of high diversity of macrofungi in different biomes of varied geographic locations of the Indian Subcontinent, meager information is available on *Astraeus*. Until now, *A. hygometricus* was the only species reported from India and the second species *A. odoratus* was added recently by Hembrom et al. (2014). It has been reported from the Rajmahal Hills, sacred grove of Mandro Fossil Park and Dalabari Village of Jharkhand. In our study, *A. odoratus* found in the scrub jungle showed higher dimensions of basidiomata as well as basidiospores compared to the variety reported by Hembrom et al. (2014). On the contrary, dimensions of basidiomata, endoperidial body and basidiospores are smaller compared to the Thailand variety reported by Phosri et al. (2004). Rest of the properties including ornamentation in basidiospores are comparable with Indian as well as Thailand varieties (Phosri et al. 2004, Hembrom et al. 2014). A comparison of characteristics of *A. hygrometricus* and *A. odoratus* recorded in our study has been given in Table 1.

Table 1 Comparison of *Astraeus* species recovered from the Southwestern India (*based on traditional knowledge of local dwellers).

	***Astraeus hygrometricus* (Fig. 1 & 2)**	***Astraeus odoratus* (Fig. 3 & 4)**
Location	Forest Chennibettu, Karkala	Scrub jungle Konaje, Mangalore
Substratum	Sandy and laterite soil	Sandy and laterite soil
Immature fruit body (cm) (n=10)	1.4 (1.5–2.5) 3 diam × 1.2 (1.4–2.3) 2.5 tall	1.2 (1.7–3.5) 3.9 diam × 0.9 (1–1.8) 2.9 tall
Mature fruit body (cm) (n=25)	3 (3.5–4.6) 6.2 diam × 1.5 (1.6–2.3) 2.5 tall	4.4 (4.5–7.5) 7.7 diam × 2.2 (3.4–5.4) 5.7 tall
Number of rays/petals	7–13	5–8
Folding of exoperidium	Incurved when dry, recurved when moist; ± saccate.	Curls upwards and inwards under the endoperidial body; ± involute
Texture of pseudo-paranchymatous layer	At first fleshy, thin and smooth, becoming leathery with vertical, reticulate cracking with age	At first fleshy, thick and smooth, becoming leathery with fissured mosaic- like cracking with age
Colour of pseudo-paranchymatous layer	Pale purple grey to greyish brown	Orange brown to brownish orange
Colour of endoperidium	Purple grey to creamish grey	Grey brown to brownish grey
Endoperidial body (cm) (n=10)	0.9 (1–1.2) 2	1.9 (2.3–3.3) 3.4
Colour of gleba	Purple to brown	Purple to brown
Basidiospore (µm) (n=25)	6.6 (7.9–12.5) 13.2 × 5.3 (6.6– 12.5) 13.2	6.5 (7.9–12.5) 13.2 × 7.9 (8.5–13.2) 13.8
Colour of basidiospores	Purple brown	Purple brown
Ornamentation of spores	Consistent, almost regular and possess less folds on surface	Inconsistent, irregular and possess more folds on surface
Ectomycorrhizal host tree species	*Anacardium occidentale*, *Artocarpus hirsutus*, *Holigarna arnottiana*, *Hopea parviflora*, *H. ponga*, *Phyllanthus emblica* and *Syzygium cumini*	*Hopea ponga*
Fresh weight of immature fruit body (n=25)	0.9–5.6 g	3.2–10.4 g
Edibility of immature fruit body	Edible*	Inedible*

Habitats and hosts

In India as well as far-east countries, *Astraeus* spp. dominates in the forest and scrub jungles in lateritic soils. In our study, *A. hygrometricus* was mainly confined to lateritic soils in natural

forests and their adjacent open places (grass lands and abandoned paddy fields). The immature basidiomata were solitary or in cluster of 4–10, fully or partially buried (0.5–1 cm) and sometimes visible along with pebbles of laterite soil as bone-white mycelial mass. Colonies of *A. hygrometricus* have been reported to grow in lateritic soils in the western (Karnataka and Kerala) and eastern (Orissa and West Bengal) parts of India (Pradhan et al. 2010, 2013a, b, Mohanan 2011, Karun & Sridhar 2014, Manna & Roy 2014). These were also occasionally found amidst *Areca* mixed plantation in lateritic soils of the west coast of Mangalore (Karun & Sridhar 2014).

Astraeus spp. are ectomycorrhizal with plant families belonging to Betulaceae, Dipterocarpaceae, Ericaceae, Fagaceae and Pinaceae (Wilson et al. 2012). In our study, *A. hygrometricus* was ectomycorrhizal in tree species like *Artocarpus hirsutus, Holigarna arnottiana, Hopea parviflora, H. ponga, Phyllanthus emblica* and *Syzygium cumini*. Several ectomycorrhizal (*Boletus* sp., *Hygrocybe* sp., *Russula* sp. and *Scleroderma citrinum*) and non-ectomycorrhizal (*Omphiolatus olearius* and *Psilocybe* sp.) macrofungi were associated *A. hygrometricus*. Besides native tree species, *A. hygrometricus* was ectomycorrhizal in *Acacia auriculiformis* (invaded exotic tree species) and *Anacardium occidentale* (a major plantation crop of the Southwestern India). This is also an important ectomycorrizal fungus in the *Shorea robusta* in Sal forests in Orissa (Pyasi et al. 2011). They were also predominant in oak and pine forests (Surcek 1998) and ectomycorrhizal in *Pinus densiflora* in Japan (Fangfuk et al. 2010). *Alnus, Castanea, Eucalyptus* and *Pseudotsuga* were also hosts of *A. hygrometricus* (Trappe 1967, Molina 1979, Malajczuk et al. 1982, Nouhra & De Toledo 1998). *In vitro* inoculation of spores of *A. hygrometricus* to *Pinus densiflora* resulted in formation of sheath, rhizomorphs and Hartig net in roots (Fangfuk et al. 2010).

Astraeus odoratus were collected mainly from the fire affected scrub jungle in Konaje village growing in lateritic soils in small troops of about 4–8. They were ectomycorrhizal in common tree species *Hopea ponga*. This mushroom was also associated with tree species *Shorea robusta* in Rajmahal Hills and Dalabari region of Jarkhand (Hembrom et al. 2014). There is a general notion that burning reduces the diversity of saprophytic macrofungi, but ectomycorrhizal fungi survive in subsoil along with roots. Sysouphanthong et al. (2010) opined that burning stimulates the growth of selected macrofungi especially *A. hygrometricus*. Besides *A. odoratus* is ectomycorrhizal in *Hopea ponga* in our study, it has also been reported as ectomycorrhizal with dipterocarps (*Dipterocarpus tuberculatus* var. *tuberculatus* and *D, obtusifolius* var. *obtusifolius*) in Northern Thailand (Kennedy et al. 2012). *In vitro* inoculation of spores and cultured mycelia of *A. odoratus* to *Dipterocarpus alatus* by Kaewgrajing et al. (2013) resulted in positive correlation with seedling growth. In Northern Thailand, yield of *A. odoratus* was significantly increased in burnt floors of dipterocarp-oak forests and serve as an important culinary delicacy as well as household income (Kennedy et al. 2012).

Indigenous knowledge

Astraeus spp. are known for several economic values especially edibility, medicinal properties and plant growth promotion as ectomycorrhizae. Generally, *A. asiaticus, A. hygrometricus, A. odoratus* and *A. thailandicus* are edible; *A. koreanus* and *A. pteridis* are inedible; edibility of rest of the species (*A. morganii, A. sirindhorniae, A. smithii* and *A. telleriae*) is yet to be established. Our study revealed that local people collect immature *A. hygrometricus* during early monsoon (June) to late monsoon (September). Usually, the highest yield will be during July and August. In mushroom dominant regions (forests, buffer zones and grass lands in laterite fields), local people identify troops of *A. hygrometricus* by scratching the surface of soil and looking for white matrix. Wherever white matrix seen on the surface or subsurface, it is a perfect indication that troops of immature fruit bodies prevail in its surroundings. Entire family of some tribes in and around Karkala region harvests tender *A. hygrometricus* throughout the day during rainy season for their livelihood. Harvesters find it easy to fetch more mushrooms in open and buffer zones than in typical forest locations. If bulk quantity of mushrooms is harvested, it can be preserved without processing under soil up to 3–4 days and desired quantity will be fetched for daily use. This indigenous method of preservation is also in practice in Eastern lateritic parts of India (Manna et al.

2014). Harvested mushrooms will be cleaned in water to remove debris and hairy structures on the surface, wrapped in clean wet cloth and preserved as such or in refrigerators. Usually cleaned mushrooms will be cooked and consumed on same day or subsequent day. Collected tender *A. hygrometricus* reaches the local markets same day and sold in bulk or retail depending on the demand and reaches the nearby distribution centers (e.g. Moodbidri and Mangalore).

Before cooking, each immature basidium will be cut and ascertain its tenderness having white flesh inside. Those having fully white part or a small spec of black spot in the margin will be considered for eating and those having extended black regions will be discarded. In vernacular language (Kannada), this mushroom is called 'Kall-anabe' meaning 'stone mushroom'. This is one of the highly prized mushrooms costing Rupees 300–500 per kg, which is similar to the *Termitomyces* harvested in the Western Ghats and west coast region (Karun & Sridhar 2013). A recent survey in the west coast revealed occurrence of *A. hygrometricus* in *Areca* plantation and likely consumed as traditional source of food (Karun & Sridhar 2014).

The highest yield of *A. hygrometricus* was during July in the eastern lateritic region of India (Manna & Roy 2014). In Thailand, *A. hygrometricus* has a long history of edibility and available in the rural markets (Phosri et al. 2013). This mushroom along with others (*A. asiaticus* and *A. odoratus*) will be harvested in wild from the Northern and North-Eastern part of Thailand for marketing (Dell et al. 2005, Butkrachang et al. 2007, Fangfuk et al. 2010). Another most edible species include *A. thailandicus*, which will also be collected and sold in the markets of Thailand (Petcharat 2003). There is a mixed opinion about the edibility of *A. odoratus* found in Konaje Village of Mangalore in our study.

Astraeus serve as herbal medicine in China and India (Mallick 2010). Ethnic tribes of Orissa in India, use *Astraeus* spp. traditionally for medicinal purposes (Panda & Tayung 2014). Immunoenhancing activity of *A. hygrometricus* has been reported by Chakraborty et al. (2004) and Mallick (2010). The ethanolic extract of *A. hygrometricus* possesses significant free radical scavenging, lipid peroxidation inhibition and also possesses excellent anti-inflammatory activity comparable to the standard drug diclofenae (Biswas et al. 2010). Besides, ethanolic extract of *A. hygrometricus* also showed cardioprotective, chemoproventive, hepatoprotective and hypoglycemic potential (Biswas et al. 2011a, b, 2012, Biswas & Acharya 2013). Anticandidal and leishmanicidal activities of *A. hygrometricus* have been reported by Lai et al. (2012).

Outlook

Exploration on *Astraeus* spp. has multiple benefits as they are edible (at least some species), medicinal (many of them) and ectomycorrhizal (almost all) in a variety of forest tree species. According to Hembrom et al. (2014), careful attention on exploration of *Astraeus* in the Indian Subcontinent yields more than widely accepted *A. hygometricus*. External appearance of *Astraeus* similar to *Geastrum* may be another reason for ambiguity and less attention. Phosri et al. (2013) suspected that *Geastrum lilacinus* described by Massee (1889) is an *Astraeus* species due to larger basidiospores. In addition to precise morphological observations, molecular approaches are certainly necessary to understand the *Astraeus* complex.

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