

Auritella foveata, a new species of Inocybaceae (Agaricales) from tropical India

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Summary. *Auritella foveata* C. K. Pradeep & Matheny is described as new from mixed evergreen forests in tropical India. The species is distinctive due to the combination of a pitted-rugulose pileus, smooth subglobose spores, and chains of elongated thick-walled cheilocystidia. The latter two traits characterise the tropical African species *A. aureoplumosa* (Watling) Matheny & Bougher. Phylogenetic analysis of a supermatrix of *rpb1*, *rpb2*, and nLSU-rRNA gene regions supports the placement of *A. foveata* as sister to the remaining species of *Auritella*, a genus with a paleotropical and southern hemisphere distribution. A key to all eight species of the genus is provided together with illustrations of the new species.

Key Words. Basidiomycota, biodiversity, ectomycorrhizal fungi, palaeotropics, systematics.

Introduction

India is exceedingly rich in fungal diversity (Manoharachary *et al.* 2005). Indeed, fungi from Indian tropical rainforest ecosystems may be as diverse as in temperate and boreal forests (Riviere *et al.* 2007). However, documentation and description of agaric fungi from tropical India and Sri Lanka has proceeded at a slow pace (Natarajan *et al.* 2005; Pegler 1986). Despite the challenges of collecting fungi in the humid tropics and the lack of attention to basidiomycetes there, several noteworthy species have been documented from India of late (Kumar *et al.* 2007; Kumar & Manimohan 2009; Peintner *et al.* 2003; Reddy *et al.* 2005; Thomas *et al.* 2002; Vrinda *et al.* 1997), and phylogenetic analyses indicate that inclusion of tropical fungi is necessary to understand patterns of diversification and historical biogeography for some groups (Matheny *et al.* 2009). Here we document a new species of *Auritella* Matheny & Bougher, itself a recently recognised genus of putative ectomycorrhizal (ECM) basidiomycetes in the mushroom family Inocybaceae Jülich (Matheny & Bougher 2006a). *Auritella* now comprises eight species known so far from tropical Africa, tropical India, and temperate Australia.

Materials and methods

Gross morphological descriptions are based exclusively on fresh material collected from Kerala State, India.

Colour coding follows that of Kornerup & Wanscher (1978) with colour descriptions in quotation marks followed by plate-row-column designations in parentheses. Approximation to Ridgway (1912) was also made with colour designations capitalised and not placed in quotes. Microscopic characters were studied on dried material using hand cut sections of basidiomata revived in a 3% solution of KOH and examined under a Leica DME 1,000 compound microscope. The mean quotient (Q) of spore length divided by spore width was calculated from measurements of 20 spores. Line drawings were made with assistance of an attached drawing tube. DNA was extracted from the holotype (TENN063905), with a portion designated as the isotype (TBGT9631, K), following procedures outlined in Matheny *et al.* (2010). Nuclear gene regions ITS1+5.8S+ITS2 (ITS), the large subunit ribosomal RNA (LSU), and the second largest subunit of RNA polymerase II (*rpb2*) were amplified and sequenced following protocols in Matheny (2005) and Matheny *et al.* (2010). Sequence comparisons were performed with those on GenBank. LSU and *rpb2* sequences were added to a supermatrix of *rpb1*, *rpb2*, and LSU data of 53 taxa including eight outgroups of Crepidotaceae and Tubariaceae from Matheny (2005). Intron regions were excluded. Seven models of molecular evolution were partitioned according to 1st, 2nd, and 3rd codon positions and the LSU region as in Matheny (2005). A total of 2,853 nucleotide sites were analysed and subjected to maximum likelihood (ML) analysis using RAXML v7.0.3 (Stamatakis 2006). 1,000

Accepted for publication January 2012.

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rapid bootstrap inferences were performed with all free model parameters estimated by RAxML using a GTRGAMMAI model and empirical base frequencies. A GTRCAT model was used for rapid bootstrapping with a final ML search conducted under the specified GTRGAMMAI models with joint branch length optimisation. Species of Tubariaceae and Crepidotaceae were used as outgroups based on Matheny *et al.* (2006). *Tubaria vinicolor* (Peck) Ammirati, Matheny & Vellinga was used for rooting purposes. Three new sequences have been deposited at GenBank (GU062738, GU062739, GU062740). All other GenBank accession numbers are available in Alvarado *et al.* (2010). The combined data set is available upon request and online at http://www.bio.utk.edu/matheny/Site/Alignments_%26_Data_Sets.html.

Taxonomy

***Auritella foveata* C. K. Pradeep & Matheny, sp. nov.**
Pileus 5 – 22 mm, e convexo plano interdum umbonatus, foveatus, senatus vel brunneolus. Lamellae adnexae, subconfertae, brunneae vel umbrinae. Stipes 10 – 32 × 1.5 – 4 mm, centralis, aequalis vel basi leviter attenuatus, ad basim squamatus, argillaceus vel pileo concolor, basi albus. Odor nullis. Sporae 5.5 – 6.5 (7.5) × 4.5 – 6.0 µm, laeves subellipsoideae. Basidia necropigmentata et tetrasporigera. Pleurocystidia nulla. Cheilocystidia 22 – 63 × 8 – 16 µm, pigmentata, pedicellata, clavata vel vesiculosa, tunica modice crassa. Holotypus: TENN063905, India tropica in terram (isotypus TBGT9631, K(M)168023). MycoBank 518686.

Pileus 5 – 22 mm diam., convex, campanulate to plano-convex, often with a low obtuse umbo, margin incurved in youth, surface with small depressions or with a pitted appearance throughout, non-striate, non-fibrillose, non-squamulose, shiny and polished, dry, colour 'golden brown' (5D7) or near Raw Sienna when young to 'cognac' (6E7) or Sudan Brown to 'teak brown' (6F5) or Clove Brown with a darker disc, context thin, up to 1 mm thick, 'orange white' (5A2) or near Tilleul Buff or pale cinnamon pink, odour none. *Lamellae* adnexed, moderately close with lamellulae of 2 – 4 varying lengths, 'brown' (6E5) or Verona Brown in youth later becoming 'chocolate brown' (6 F4) to 'burnt umber' (6F6) or near Brussels Brown when mature, up to 3 mm broad, edges concolorous with faces and entire. *Stipe* 10 – 32 × 1.5 – 4 mm, central, cylindrical or compressed, equal or tapered to the base, surface squamulose throughout with straight to recurved scales, towards

the base with fewer scales, surface 'grayish orange' (5B5) to 'cognac' (6E7), white mycelial mat present at the base, context hollow and concolorous with pileus context. *Basidiospores* 5.5 – 6.5 (7.5) × 4.5 – 6.0 µm, Q=1.13, smooth, subglobose to ovoid, thick-walled with a guttule, in deposit 'burnt umber' (6F6). *Basidia* 36 – 48 × 5.5 – 7.5 µm, cylindrico-clavate, 4-sterigmate, necropigmented. *Cheilocystidia* 22 – 63 × 8 – 16 µm, clavate, vesiculose to cylindrico-clavate with a long pedicel, thick-walled, with yellowish brown contents. *Pleurocystidia* none. *Hymenophoral trama* regular, hyphae 2 – 4 µm wide, thin-walled, hyaline, subhymenium pseudoparenchymatous. *Pileipellis* a trichoderm with elements 23 – 51 × 6 – 27 µm, almost similar to cheilocystidia in shape, thick-walled, with yellowish brown contents, pileal trama composed of interwoven hyphae 2 – 9 µm diam., thin-walled, hyaline. *Caulocystidia* 36 – 89 × 9 – 11 µm, clavate to vesiculose with a long pedicel, thick-walled, with yellowish brown contents. Clamp connections present in all tissues. Figs 1 and 2.

DISTRIBUTION. India, Kerala State, Thiruvananthapuram district, Kallar. Known only from the type locality.

SPECIMENS EXAMINED. INDIA. Kerala: Thiruvananthapuram district, Kallar, 26 Dec. 2005, leg. C. K. Pradeep TENN063905 (holotype, MycoBank MB 518686), TBGT9631 (isotype), K; *ibid.*, 4 Aug. 2006, leg. C. K. Pradeep TBGT9901; *ibid.*, 17 Oct. 2006, leg. C. K. Pradeep TBGT10030; *ibid.*, 2 Nov. 2006, leg. C. K. Pradeep TBGT10077; *ibid.*, 23 Oct. 2007, leg. C. K. Pradeep TBGT10650; *ibid.*, 7 Aug. 2008, leg. C. K. Pradeep TBGT11650.

HABITAT. Solitary to scattered or in groups on ground in association with roots of *Dipterocarpus indicus* Bedd. (Dipterocarpaceae) and *Xanthophyllum arnotianum* Wight (Xanthophyllaceae) in mixed evergreen forests.

CONSERVATION STATUS. IUCN category (2001) Data Deficient (DD).

ETYMOLOGY. The specific epithet *foveata* (Latin), refers to the pitted appearance of the pileus.

NOTES. The combination of smooth, subglobose, yellowish brown basidiospores, necropigmented basidia, chains of thick-walled and pigmented cheilocystidia, absence of metuloid pleurocystidia, and habitat on ground in an Old World tropical forest supports a morphological and ecological alliance with the genus *Auritella* of the Inocybaceae (Matheny & Bougher 2006a, b). The subglobose spores and chains of cheilocystidia are reminiscent of those in *A. aureoplumosa* Watling (Matheny & Bougher) known only from Cameroon (Watling 2001). *A. foveata* is easily

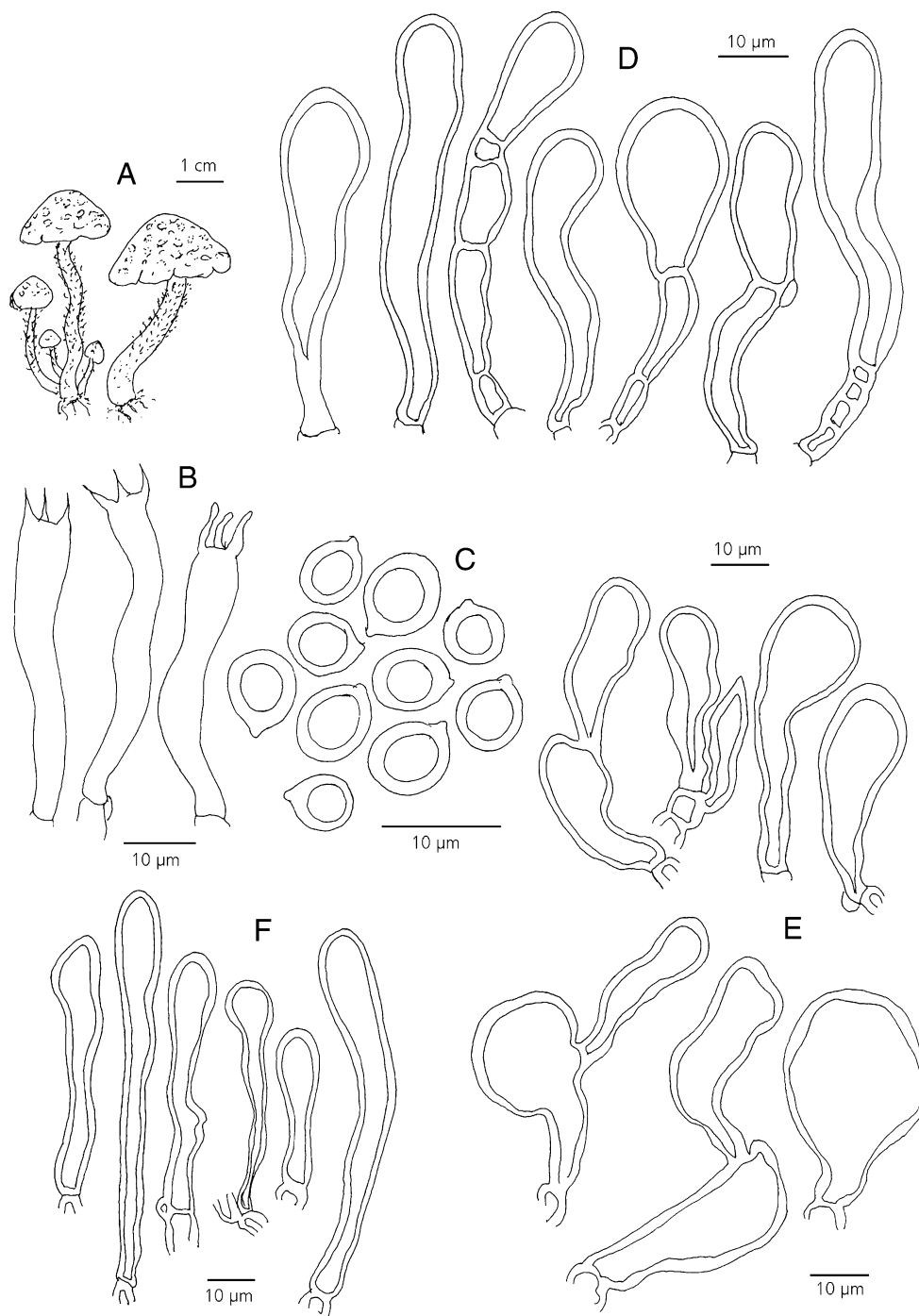


Fig. 1. A – F Line drawings of basidiomata and anatomical features of *A. foveata*. All drawings are based on the holotype. **A** basidiomata; **B** basidia; **C** basidiospores; **D** cheilocystidia; **E** terminal elements of the pileipellis; **F** caulocystidia. DRAWN BY C. K. PRADEEP.

distinguished from *A. aureoplumosa* by the unusual pitted pileus surface, putative association with dipterocarps, and tropical Asian distribution. Blastn results of ITS, LSU, and *rpb2* revealed extreme dissimilarity with previously published ITS sequences,

84 – 91% similarity with other LSU sequences of *Auritella*, and 83 – 84% similarity with species of the Mallocybe clade and *Tubariomyces*, respectively (Alvarado *et al.* 2010). ML analysis of a supermatrix of three unlinked gene regions (two of which were

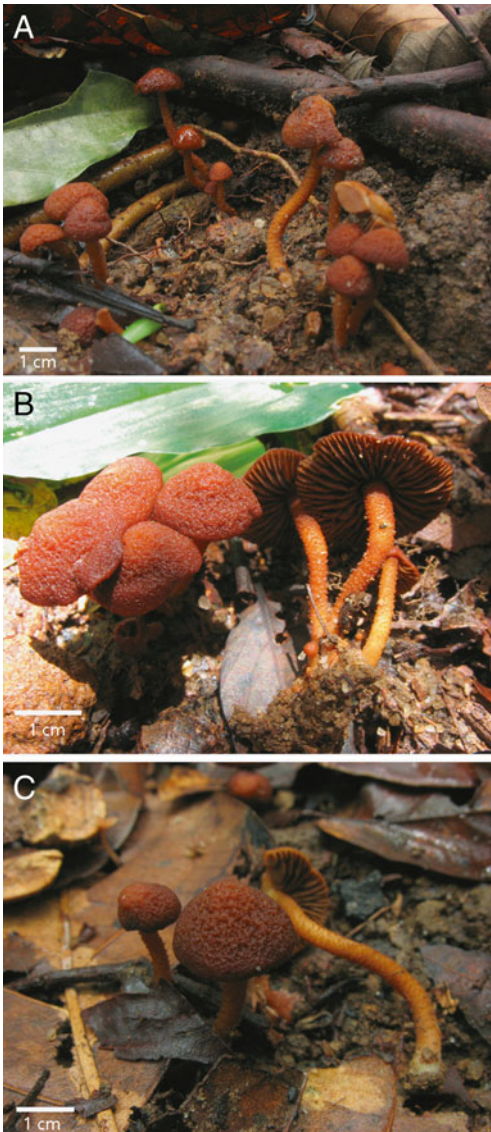


Fig. 2. A – C. *Auritella foveata* (type) in situ.

sequenced from the type of *A. foveata*) support the placement of *A. foveata* in *Auritella* with 93% bootstrap support (Fig. 3). Remaining *Auritella* species from Africa and Australia are strongly supported as monophyletic with 100% bootstrap support. *Auritella* is shown as sister to the Inosperma clade but with poor (<50% bootstrap) support.

The discovery of *Auritella foveata* pushes back in time the age (35 – 105 Ma) of the crown group node of *Auritella* (Matheny *et al.* 2009) and thus is a significant discovery. One might extrapolate that the split between *A. foveata* and all other known *Auritella* species may have occurred during the early Paleogene or late Cretaceous. The most likely ectomycorrhizal host of *A. foveata* based on fruiting observations is *Dipterocarpus*, the family of which (Dipterocarpaceae) is known only from the fossil record in India since the mid Miocene (Awasthi 1996) or slightly earlier (Kundu 2008). A recent origin for dipterocarps has been suggested (Malloch *et al.* 1980), and a mid Miocene split between Sarcolaenaceae and Dipterocarpaceae has been reported based on a molecular clock analysis (Wikström *et al.* 2001). If this is true, then either *A. foveata* switched plant associates over time, or additional taxa remain to be discovered along its present branch that associate with different ECM plant hosts, or *Auritella* is younger than estimates made by Matheny *et al.* (2009). However, some authors have discussed a Gondwanan or Cretaceous origin for dipterocarps (Aubreville 1976; Dayanandan *et al.* 1999; Indrioko *et al.* 2006; Moyersoen 2006) based on disjunct distribution of fossil and extant taxa and poor dispersal ability. Despite controversy over the age of Dipterocarpaceae, the hypothesis of a Gondwanan distribution for *Auritella* appears to be strengthened with the addition of a subcontinental Indian lineage to a clade that includes African and Australian lineages. However, for this hypothesis to be robust, the phylogenetic position of African *A. aureoplumosa* (based only on one LSU sequence from the type) must be inferred with more confidence.

Key to Species of *Auritella*

1. Basidiomata secotioid *A. geoaustralis*
Basidiomata agaricoid 2
2. Occurring in Australia 3
Occurring in Africa or India 6
3. Basidiospores >10 µm long *A. arenacolens*
Basidiospores <10 µm long 4
4. Cheilocystidia narrow, 6 – 9 µm wide, often flexuous, tissues exuding yellow pigment in alkali solution *A. serpentincystis*
Cheilocystidia broad, 7 – 16 µm, oblong-clavate or skittle-shaped, not flexuous, tissues not exuding yellow pigment in alkali solution 5
5. Basidiospores ochraceous-tawny under the light microscope, eastern Australia in distribution *A. dolichocystis*
Basidiospores ochraceous-buff under the light microscope, western Australia in distribution *A. chamaecephala*

- 6. Pileus squamulose, occurring in wet tropical forests of Africa (Cameroon, Gabon) 7
- Pileus smooth but with pitted surface, occurring in wet tropical forests of India *A. foveata*
- 7. Spores globose, stipe squamulose *A. aureoplumosa*
- Spores elliptic, stipe smooth *A. erythroxa*

Acknowledgements

We thank Jean-Marc Moncalvo for introducing the two co-authors and Aaron Wolfenbarger for technical assistance. Research funds were provided to the senior author from the National Science Foundation

(DEB-0949517). The remaining co-authors are thankful to the Ministry of Environment and Forests, Govt. of India, New Delhi for financial assistance. Suggestions and corrections made by two anonymous reviewers are appreciated.

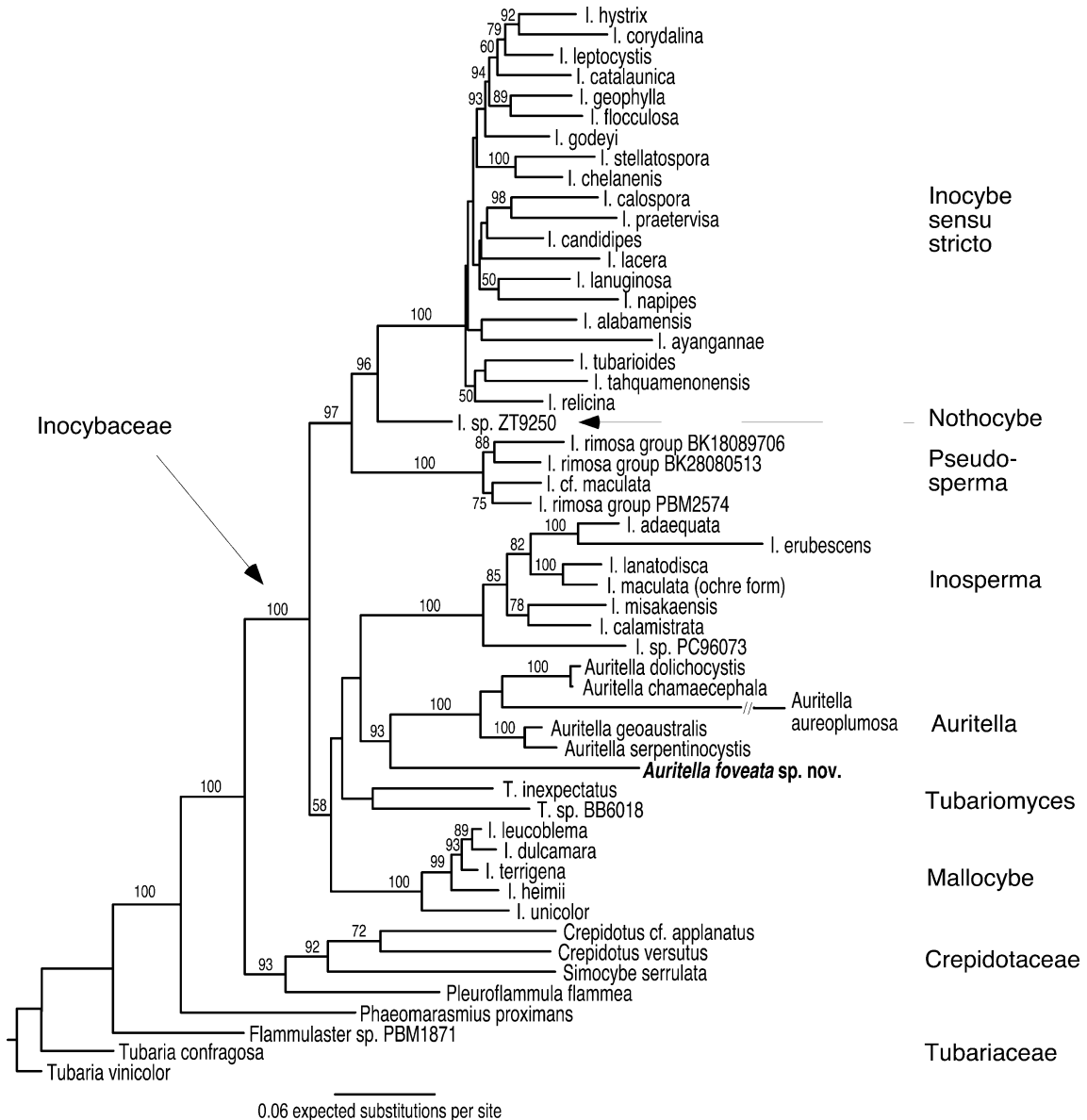


Fig. 3. Phylogeny of the Inocybaceae based on a supermatrix of *rpb1*, *rpb2*, and LSU nucleotide sequences inferred from maximum likelihood (ML) analysis. Numbers above and below branches are bootstrap proportions from 1,000 ML bootstrap replicates. Clade nomenclature follows Matheny (2005) and Matheny et al. (2009) with the exception of the Mallocybella clade, which has been formally described as the genus *Tubariomyces* in Alvarado et al. (2010). The tip labelled *Auritella foveata* is highlighted in bold and italicised font.

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