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Are the scrub jungles of Southwest India potential habitats of *Cordyceps*?

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ABSTRACT

During routine survey of macrofungi, six species of *Cordyceps* were recovered in the scrub jungles of southwest Karnataka. Reports on occurrence of *Cordyceps* and allied species in the Western Ghats and southwest coast are documented with comments on the *Cordyceps* recorded in this preliminary study.

Keywords: *Ascomycetes*, *Cordycepitaceae,* entomophagous fungi, Western Ghats, southwest coast

INTRODUCTION

Bipartite and tripartite interactions (plant-insect-fungus) are the most fascinating subject matter in biology and such complex associations at different levels lead to difficulties in precise classification (e.g. parasitism, antagonism and mutualism). The genus *Cordyceps* (*Ascomycota, Sordariomycetes, Hypocreales, Cordycipitaceae*) consists of about 500 species distributed globally as endoparasitic fungi (Sung *et al*., 2007). *Cordyceps* spp. have the capacity to parasitize a wide range of insects and their larva resulting in production of a variety of morphologically distinct and diverse perithecia (Sung *et al*., 2007; Kepler *et al*., 2012). The fruit bodies of *Cordyceps* are the most expensive biological resource and an integral part of traditional Chinese medicine for the past two millennium (Jordan *et al*., 2008; Shrestha and Bawa, 2013; Dong *et al*., 2015). Several studies have confirmed that fruit bodies of *Cordyceps* are endowed with a plethora of biologically active compounds and more specifically cordycepin (3'-deoxyadenosine) possesses therapeutic potential in immunomodulation, induction of apoptosis, combat hyperlipidemia and useful in cancer therapy (Wen *et al*., 2014; 2017). Structurally and functionally versatile bioactive compounds were isolated from different *Cordyceps* (e.g. cordyanhydrides, cordypyridones, cordytropolone, cycloaspeptide, epicoccin, gliocladicillin, trichocladinol, trichothecanes and spirotenuipesines) (Sharma, 2004; Isaka *et al*., 2005; Lo *et al*., 2013). In this communication occurrence of six *Cordyceps* species on insects and larvae in the lateritic scrub jungles of southwest coast of Karnataka has been documented.

LITERATURE

In the Indian Subcontinent, high altitude Himalayan regions (e.g. Uttarkhand, Bhutan, Nepal and Tibet) are the potential habitats supporting a variety of *Cordyceps* species (Winkler, 2008; Cannon *et al*., 2009; Shrestha and Bawa, 2013, 2014; Quan *et al*., 2014; Baral *et al*., 2015; Negi *et al*., 2015; Baral, 2017). In comparison, relatively there are seldom reports on the *Cordyceps* in Western Ghats and west coast of India. *Cordyceps unilateralis* parasitizing ants in the Western Ghats from Balehonnur (Chikmagalur District, Karnataka) in 1961 seems to be the first report (Nag Raj, 1962) (**Table 1**). During 2001-2008, four species of *Cordyceps* (*Cordyceps forquignoni, C. militaris* and *C. superficialis* and *Ophiocordyceps blattae*) have been reported on adult insects (e.g. beetles) and larvae from the state of Maharashtra (Nanaware, 2002; Patil *et al*., 2014). During 2011-2012, *Cordyceps nutans* has been reported on the pentatomid bug (*Nezara viridula*) in Tillari (Sindudurg District, Maharashtra) (Patil *et al*., 2014). Subsequently, Kumar and Aparna (2014) reported *Cordyceps* sp. on the coconut root grubs (*Leucopholis coneophora*) in the coconut plantations of Kasargod (Kerala) followed by another *Cordyceps* sp. associated with the same root grubs in Kudlu (Kasargod District, Kerala) as well as Sringeri (Chikmagalur District, Karnataka) (Prathibha, 2015). *Ophiocordyceps nutans* has been reported by Sridhar and Karun (2017) on the pentatomid bug (*Halyomorpha halys*) in B'Shettigeri and Makutta (Kodagu District, Karnataka).

Table 1: Entomophagous *Cordyceps* spp. recorded from southwest India (?, not defined).

	Host	Location	Reference
Cordyceps forquignoni (Peck) Sacc.	?	?, Maharashtra	cf. Patil *et al*. (2014)
Cordyceps militaris (L.) Fr.	?	?, Maharashtra	cf. Patil *et al*. (2014)
Cordyceps nutans Pat.	*Nezara viridula* (Pentatomidae)	Tillari, Maharashtra	Patil *et al*. (2014)
Cordyceps superficialis (Peck) Sacc.	Larvae of *Torrubia superficialis* (Coleoptera)	Malkapur, Maharashtra	Nanaware (2002)
Cordyceps unilateralis (Tul. & C. Tul.) Sacc.	Ants (Formicidae)	Balehonnur, Karnataka	NagRaj (1962)
Cordyceps sp.	*Leucopholis coneophora* (Scarabaeidae)	Kasargod, Kerala	Kumar and Aparna (2014)
Cordyceps sp.	*Leucopholis coneophora* (Scarabaeidae)	Kasargod, Kerala	Prathibha (2015)
		Sringeri, Karnataka	Prathibha (2015)
Ophiocordyceps blattae (Petch) Petch	Adult insect and dead larvae	Panhala, Maharashtra	Nanaware (2002)
Ophiocordyceps nutans (Pat.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora	*Halyomorpha halys* (Pentatomidae)	B'Shettigeri, Karnataka	Sridhar and Karun (2017)
		Makutta, Karnataka	Sridhar and Karun (2017)

FIELD SURVEY AND OBSERVATIONS

In routine explorations of macrofungi in the west coast of India (2011 onwards), we found for the first time many *Cordyceps* parasitizing different insects and larvae in three locations of the lateritic scrub jungles near Mangalore (12º48'N, 74º55'E; 100-115 m asl) during the midst of southwest monsoon (July-August 2018). General morphological features of the *Cordyceps* species collected are given in **Table 2** and **Figure 1 (a-f)**. The first location in our study, from where four *Cordyceps* species were documented, is a slope of thorny scrub jungle adjacent to Mangalore University Campus (**Fig. 1b-e**). In the second location, two *Cordyceps* were documented which is a plain with

Table 2: *Cordyceps* spp. located in the lateritic scrub jungles of southwest Karnataka (+++, most common; ++, frequent; +, rare).

	Feature	Location
Cordyceps sp. 1 (Fig. 1a) (+)	Light yellowish-white unbranched perithecia on a grass hopper (arrow)	*Terminalia paniculata*-dominant plain scrub jungle
Cordyceps sp. 2 (Fig. 1b) (+)	Deep yellowish-white branched perithecia on a larvae (arrow)	Slope of mixed scrub jungle
Cordyceps sp. 3 (Fig. 1c) (++)	Deep violet branched perithecia on a purple larvae (arrow)	Slope of mixed scrub jungle and plain medicinal garden
Cordyceps sp. 4 (Fig. 1d) (+++)	Deep yellow branched perithecia on oval cocoon (white arrow) of unknown insect (black arrow)	Slope of mixed scrub jungle and *Terminalia paniculata*-dominant plain scrub jungle
Cordyceps sp. 5 (Fig. 1e) (++)	Deep red branched perithecia on a spherical cocoon (arrow)	Slope of mixed scrub jungle
Cordyceps sp. 6 (Fig. 1f) (++)	Whitish branched perithecia on an adult insect (arrow)	*Terminalia paniculata*-dominant plain scrub jungle

dominance of trees of *Terminalia paniculata* (**Fig. 1a, d, f**), while from the third location which is a medicinal garden of Mangalore University, only one species of *Cordyceps* was documented (**Fig. 1c**). One of these species (probably *C. militaris*) was most common (**Fig. 1d**), three were frequent (**Fig. 1c, e, f**) and two were rare (**Fig. 1a, b**). During the period of collection in sampling locations (July-August 2018), the humidity, air temperature and soil temperature ranged from 81-85%, 26-27ºC and 24-25ºC, respectively. This is the first report of morphologically distinct species of *Cordyceps* occurring in a narrow stretch of geographic location of the lateritic scrub jungles of southwest coast of India.

DISCUSSION

There is a drastic difference in the geology, climatic conditions, altitudinal regimes, wild life, phytogeography and endemism between the Himalayas and the Western Ghats. Sridhar and Karun (2017) argued that *Ophiocordyceps sinensis* in the high altitude cold climatic conditions of Himalayas and *O. nutans* in the high altitude warm climatic conditions of Western Ghats might have evolved simultaneously. Occurrence of *Cordyceps* and allied species in the Western Ghats (previous and present study yielded 14-15 species) similar to Himalayas opens up ample opportunities to explore the evolutionary lines of *Cordyceps* in these two hotspots of biodiversity. Sigdel *et al*. (2017) have correlated the occurrence of *Cordyceps* in Nepal with soil nutrients, vegetation and insect population. There is plenty of scope for future investigations with collective efforts (agronomists, botanists, entomologists and mycologists) to expose the extent of diversity of entomopathogenic fungi in the Western Ghats and southwest India. Further studies on the

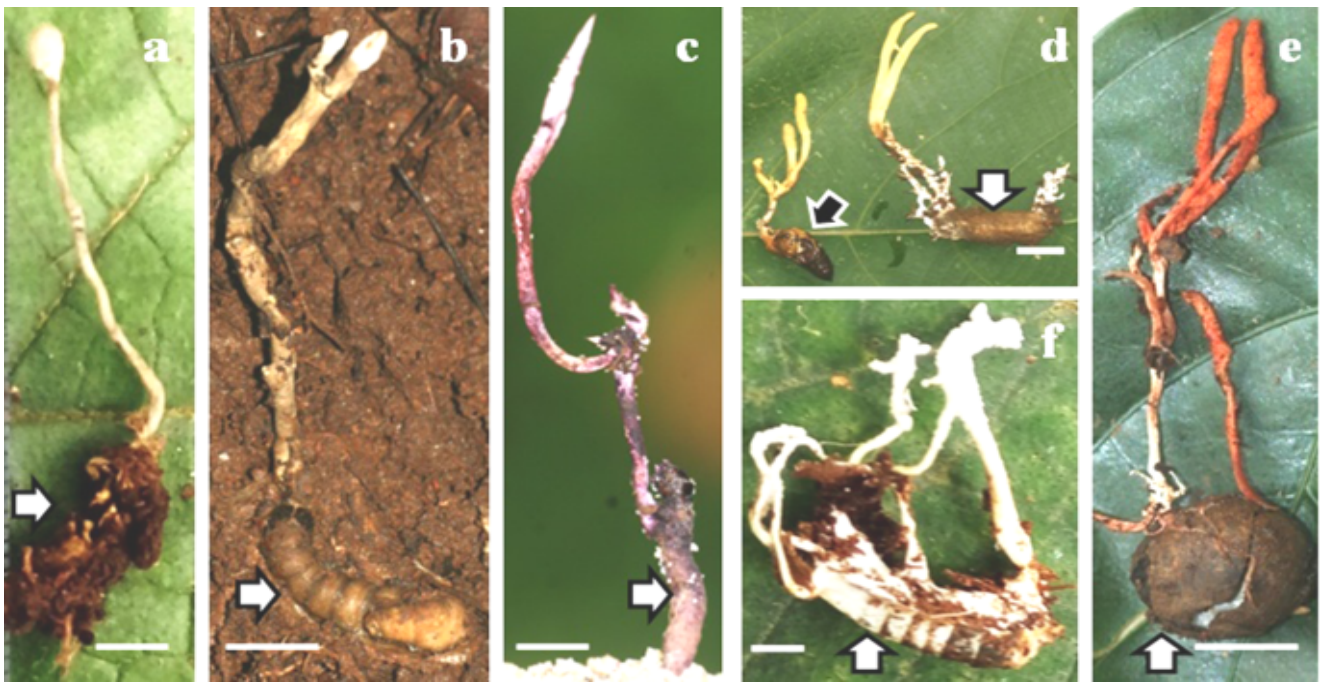

Fig. 1. *Cordyceps* species grown on insects and larva: On grass hopper (a); on yellowish larvae (b); on purple larvae (c); on oval-shaped cocoon and insect (black arrow) (d); on spherical cocoon (e); on unknown adult insect (f) (Scale bar: 1 cm).

morphology and molecular systematics of *Cordyceps* species collected are in progress in our laboratory.

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