

SPECIES OF CORDYCEPS¹

E. B. MAINS

(WITH 2 FIGURES)

Recently the writer had the privilege of studying specimens of *Cordyceps* in the Farlow Herbarium of Harvard University, the Mycological Herbarium of the New York Botanical Garden, and the Mycological Collections of the United States Bureau of Plant Industry, and he wishes to express his appreciation to D. H. Linder, F. J. Seaver and J. A. Stevenson for the help and facilities afforded. Results of this study are included in the following account. One species, *Cordyceps myrmecophila*, obtained by A. H. Smith during the summer of 1939 is also discussed.

CORDYCEPS UNILATERALIS (Tul.) Sacc.

This is a very interesting species on ants. It is fairly common in the tropics but has been rarely collected in the United States, being reported only from Michigan (as *C. formicivora* Schroet., 17), Maine (16) and North Carolina (9). There is also a specimen in the Herbarium of the New York Botanical Garden on the ant, *Camponotus castaneus* var. *americanus* collected by M. E. Smith at A. and M. Collège, Mississippi, and another in the Mycological Collections of the United States Bureau of Plant Industry, on an ant collected by L. E. Miles at Wiggins, Mississippi.

Cordyceps monticola sp. nov.

Clavis capitatis, 2-2.5 cm. longis, stipitibus subcinereis, 1.5-2 mm. crassis, capitibus subglobosis, brunneo-cinereis, 3 × 3-4 mm.; peritheciis immersis, fusoido-ovoideis, 600-660 × 200-240 μ; ascis cylindricis 420-510 × 5-6 μ; ascosporis filiformibus, articulis ascosporarum 6-8 × 1.5 μ (FIG. 1, A & B).

In *Gryllotalpa hexadactyla*, Vonore, Tennessee, VI. 1935, G. L. Williams.

This specimen has several capitate clavae arising between the head and thorax of the insect and one from between the thorax

¹ Papers from the Department of Botany and the Herbarium of the University of Michigan.

and abdomen. The stipes are light-gray and coalesce for part of their length. Two of the clavae have brownish-gray, globoid heads which are punctate with the dark brown ostioles. The type specimen is in the Mycological Collections of the United States Bureau of Plant Industry.

CORDYCEPS¹

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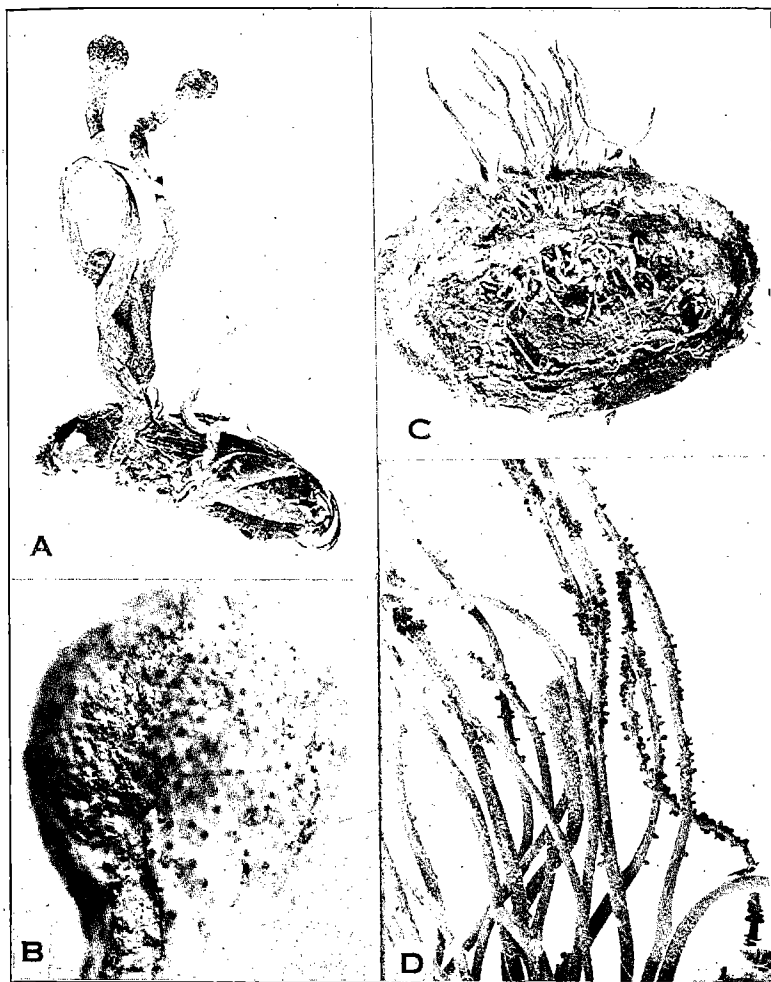


FIG. 1. A, B. *Cordyceps monticola*, type specimen. A, clavae arising from *Gryllotalpa hexadactyla*, × 2.4; B, head showing ostioles of embedded perithecia, × 12. C, D. *Cordyceps crinalis*, type specimen. C, clavae arising from larva in cocoon, × 1; D, clavae showing superficial scattered perithecia, × 10.

Under the name *Cordyceps Gryllotalpae*, Lloyd (8) has reported a collection in the Herbarium of the New York Botanical Garden. This was apparently named by Curtis but not published. Lloyd gives a photograph but no description other than that the specimens are immature. On account of the lack of description and immature condition it is not possible to determine whether this is the same as the Tennessee collection.

Lloyd also states on very insufficient evidence that *Cordyceps Gryllotalpae* and *C. joaquiens* are the same. The latter was described by Hennings (5) and the host doubtfully given as the larva of a beetle. *Cordyceps monticola* differs in a number of important respects.

Petch (15) has reported *Cordyceps amazonica* Henn. on mole cricket from Trinidad. This species has much smaller perithecia and asci than *C. monticola*.

CORDYCEPS GRACILIS Mont. & Dur.

Among the specimens of *Cordyceps* in the Curtis Collection of the Farlow Herbarium of Harvard University is a collection with the following data: "*Sphaeria entomorrhiza* Dicks. inter folia ad larvum, Hillsboro, N. C. 1863." There is one capitata clava arising from the head of a caterpillar. The clava is 1.5 cm. long with a stalk 2 mm. thick and a globose, smooth head, 4 mm. in diameter. The caterpillar is surrounded by mycelial strands.

As has been pointed out by Lloyd (6) and others, Dickson's name has been generally misapplied to *Cordyceps gracilis*. Petch (14) has questioned the occurrence of *C. gracilis* in America and has concluded that the fungus reported as such is *C. Glaziovii* P. Henn., a similar species on beetle larvae in South America. There seems no question but that the Curtis specimen is *C. gracilis*. Both the host and the development which Petch emphasizes are those of *C. gracilis*.

CORDYCEPS CRINALIS Ellis ex Lloyd.

In 1892, Ellis and Everhart (4) under the name *C. Sphingum*, published a detailed description and illustration of a *Cordyceps* collected at Newfield, N. J. In 1920, Lloyd (8) stated that Ellis

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1920, Lloyd (8) stated that Ellis

had named the specimen *Cordyceps crinalis* but afterwards had
concluded that it was *C. Sphingum*. Lloyd decided that it was not
C. Sphingum and that Ellis' manuscript name should apply.

The specimen in the Herbarium of the New York Botanical
Garden bears the name *Cordyceps crinalis* Ellis & Ev. with a line
drawn through the specific name and *C. Sphingum* written under-
neath. It also bears the following statement, "on larva enclosed
in its cocoon attached to a decaying limb lying on the ground in the
swamp, Newfield, Aug. 7, '87." The cocoon has been opened ex-
posing the lepidopterous larva within. The clavae are now some-
what broken. They are numerous, brownish-gray, filiform, up to
4.5 cm. long, and 0.2-0.3 mm. thick (FIG. 1, C & D). The peri-
thecia are chestnut-brown, superficial, free, scattered or crowded
on the upper part of the clavae, ovoid with obtuse apices, 310-
360 × 180-240 μ. The asci are slightly fusoid, 150-180 × 8-9 μ,
narrowing to 3-4 μ above. The ascospores are filiform, somewhat
overlapping in the ascus, 1.5 μ thick, obscurely multiseptate. Ellis
and Everhart state that there were approximately 30 clavae which
were about 5 cm. long and that a few were sparingly branched
above.

This as Lloyd has indicated is a valid species. It is closely re-
lated to *Cordyceps acicularis* from which it differs in having
smaller perithecia and asci and more numerous caespitose clavae.
Cordyceps acicularis has been reported only on larvae of beetles.

CORDYCEPS RICKII Lloyd.

Cordyceps Rickii was published by Lloyd (8) in 1920 with a
brief description and several figures. Lloyd compared it with *C.*
submilitaris from which he concluded it was distinct. Petch (14)
in 1933 decided that it was synonymous with *C. martialis* in which
species he also placed *C. submilitaris*. Later Petch (16) has sug-
gested that *C. Rickii* might be *C. Melolanthae*.

The collections of this species (37238 type, 41268 and 41275) in
the Lloyd Herbarium, now in the Mycological Collection of the
United States Bureau of Plant Industry have been examined.
Usually several clavae arise from a large white larva of a beetle.
The clavae are club-shaped or irregularly furcate, 3.5-6 cm. long
(FIG. 2, A). The stipes are brown, 3-5 mm. thick and often co-

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alesce. The fertile portion is light brown to brownish-yellow, and is up to 2 cm. long and 5–10 mm. thick. The perithecia are entirely embedded and are ovoid, $540\text{--}600 \times 200\text{--}240 \mu$.

Cordyceps Rickii is very distinct from both *C. submilitaris* and *C. martialis*, both of which have orange to red clavae. It does not differ greatly from *C. Melolanthae*. The latter tends to have somewhat thicker clavae with the fertile stroma irregularly distributed more or less in patches on the upper part of the clavae. The differences, however, are not sufficient to separate them as species and *C. Rickii* should be considered a synonym of *C. Melolanthae*.

CORDYCEPS (TORRUBIELLA) ARACHNOPHILA Thaxter.

This name was published by Thaxter (20) in 1914 in an article concerning the genus *Aschersonia*. No description is given, only the statement that in some cases the perithecial stages of *Aschersonia* "might at first be mistaken for a common *Cordyceps (Torrubiella) arachnophila* which is often found on leaves with or without its imperfect or *Isaria (Gibellula)* condition." No description of this species has been located.

In the Farlow Herbarium, however, there is a collection (Farlow Herb. no. 6169) on a spider made by R. Thaxter, Aug. 2, 1896, at Cranberry, N. C., which is labeled *Cordyceps arachnophila*. This has a few perithecia associated with a *Gibellula* stage. There is also another collection of this species (Farlow Herb. no. 4122) under an unpublished name. This contains a number of small spiders bearing perithecia and the *Gibellula* stage. The spiders are covered with a white or yellowish cottony mass of mycelium, only the legs sometimes showing. The perithecia are brown and develop directly from the mycelial covering (FIG. 2, B). They are conical ovoid, $840\text{--}1200 \times 300\text{--}360 \mu$. The asci are narrowly cylindrical, $600\text{--}660 \times 5\text{--}7 \mu$ and the ascospores filiform, nearly as long as the asci and are 1.5μ wide and multiseptate, the septa $6\text{--}10 \mu$ apart. The conidial stage develops on clavae which are up to 7 mm. long, 0.1–0.2 mm. thick and which enlarge at the apices up to 0.2–0.4 mm. The clavae are covered with a network of brownish, septate hyphae from which the conidiophores arise. The hyphae and conidiophores have rough walls. The conidiophores are up to 180μ long and 8μ wide. The terminal cell is

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distinct from both *C. submilitaris* and *C. melolanthae*. The latter tends to have somewhat orange to red clavae. It does not have the fertile stroma irregularly distributed in the upper part of the clavae. The difficulty to separate them as species and as a synonym of *C. Melolanthae*.

ARACHNOPHILA Thaxter.

Thaxter (20) in 1914 in an article on *Arachnophila*. No description is given, only mentions the perithecial stages of *Ascherichia* for a common *Cordyceps* (Torrubiella) often found on leaves with or without *Gibellula* condition." No description of

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This contains a number of small perithecia in the *Gibellula* stage. The spiders are in a yellowish cottony mass of mycelium, growing on the host. The perithecia are brown and embedded in the mycelial covering (FIG. 2, B). They are 300-360 μ . The asci are narrowly cylindrical, the ascospores filiform, nearly as long as the asci, 8μ wide and multiseptate, the septate stage develops on clavae which are 0.5 mm. thick and which enlarge at the tip. The clavae are covered with a network of hyaline filaments from which the conidiophores arise. The conidia have rough walls. The conidium is 4-6 μ long and 8 μ wide. The terminal cell is

smooth, hyaline, and slender and supports a spherical head which is 36-42 μ in diameter and consists of brownish, clavate, radiating cells from which hyaline cylindrical conidia are produced. The conidia are $4-6 \times 1-1.5 \mu$. The conidial stage is apparently *Gibellula araneorum*.

The lack of perithecial clavae and the development of perithecia on the mycelial covering would place this species in the genus

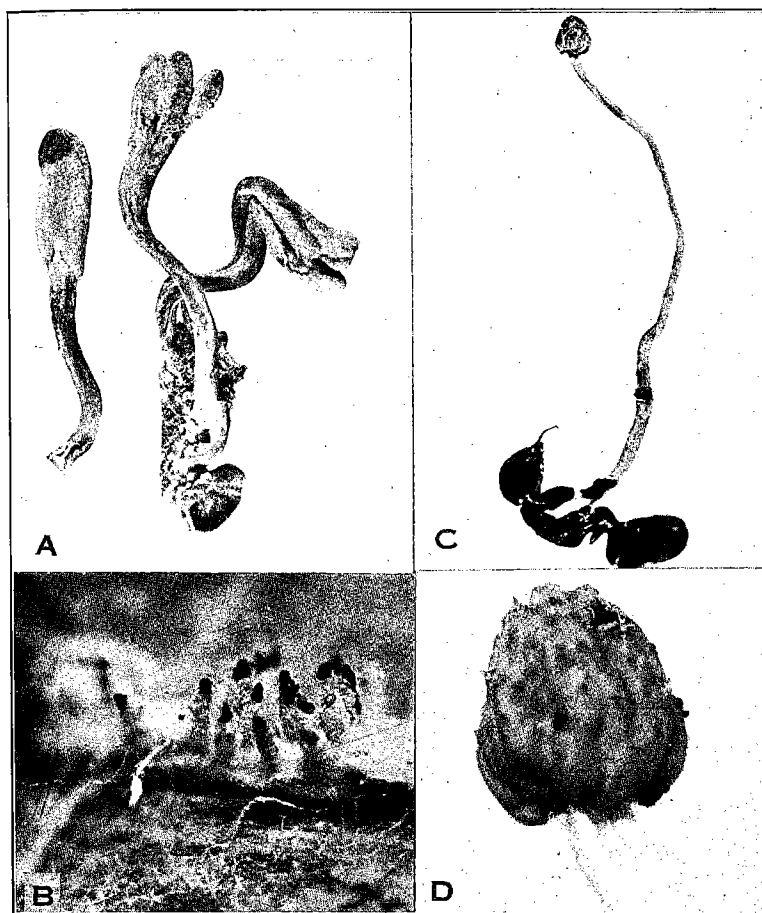


FIG. 2. A, *Cordyceps Rickii*, type specimen, $\times 1$; B, *Torrubiella Gibellulae* showing perithecia, $\times 10$; C, D, *Cordyceps myrmecophila*: C, clava arising from an ant, $\times 2.4$; D, head showing obliquely embedded perithecia, $\times 12$.

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Torrubiella. In 1932, Petch (13) announced the discovery of perithecia associated with *Gibellula aranearum* in collections from Ceylon and Trinidad to which he gave the name *Torrubiella Gibellulæ*. His description of the species differs from the above in having smaller perithecia and asci. However a study of collections of *Torrubiella Gibellulæ* in the Farlow Herbarium determined by Petch indicates that the species ranges in size up to the measurements given above. Since Thaxter's name was published without a description it must therefore be listed as a nomen nudum under *Torrubiella Gibellulæ* Petch.

CORDYCEPS CUSU Pat.

In 1895 Patouillard (12) gave the name *C. Cusu* to a specimen from San Jorge, Ecuador. The host is given as the larva of a beetle and it is stated that all the clavæ were sterile. The specimen in the Patouillard collection in the Farlow Herbarium of Harvard University was examined. It apparently is a sterile plant of *Cordyceps Rickii* and the name therefore should be placed in the synonymy of *Cordyceps Melolanthæ*.

CORDYCEPS COCKERELLII Ellis.

Ellis (3) described a species as *Ophionectria Cockerellii* from specimens received from T. D. A. Cockerell and a short time later (2) changed the name to *Cordyceps Cockerellii*. Cockerell (2) stated that the hosts were the moths, *Philampelus vitis* and *Coccytius antoëus*. These specimens are in the Herbarium of the New York Botanical Garden. One specimen is covered with a meager yellowish mycelium from which a few sterile protuberances arise. The perithecia are scattered in small groups on the mycelial covering of the moth. They are superficial, free, reddish brown, ovoid, $600-900 \times 300-400 \mu$. The asci are cylindrical, $200-230 \times 5 \mu$ and the ascospores are filiform, nearly as long as the asci. The other specimen consists of a few short clavæ bearing immature superficial perithecia.

As Lloyd (7) has pointed out *C. Cockerellii* is *C. Sphingum*, a very variable species in which sometimes clavæ are not produced and the perithecia develop on the mycelial covering of the host.

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(13) announced the discovery of *Clavula araneorum* in collections from which he gave the name *Torrubiella Gibelii*. This species differs from the above in its host. However a study of collections in the Farlow Herbarium determines that the species ranges in size up to the size of *Clavula*. Thaxter's name was published therefore and should be listed as a nomen nudum *Clavulae* Petch.

The name *C. Cusu* to a specimen whose host is given as the larva of a beetle whose clavae were sterile. The specimen in the Farlow Herbarium of Connecticut. It apparently is a sterile species and the name therefore should be placed in *Melolanthae*.

as *Ophionectria Cockerellii* from which Cockerell and a short time later *Cordyceps Cockerellii*. Cockerell (2) collected *Phyllosticta vitis* and *Cordyceps* are in the Herbarium of the University of Connecticut. One specimen is covered with a fungus in which a few sterile protuberances are scattered in small groups on the surface. They are superficial, free, reddish-brown, 10-400 μ . The asci are cylindrical, 10-400 μ . The asci are filiform, nearly as long as the ascospores, and consists of a few short clavae bearing perithecia.

C. Cockerellii is *C. Sphingum*, a species in which sometimes clavae are not produced and the host has a mycelial covering of the host.

CORDYCEPS ACICULARIS Rav. ex Berk.

This species was published by Berkeley (1) in 1857 and was based on a collection made by Ravenel in South Carolina. The host is given as a caterpillar. Ravenel issued the species under the name *C. carolinensis* in his *Fungi Caroliniani Exsiccati* IV—29. Specimens of this number have been examined from the collections of the Farlow Herbarium, the New York Botanical Garden, the Academy of Natural Science of Philadelphia and the Mycological Collections of the United States Bureau of Plant Industry. The hosts of all of these are larvae of a beetle of the type commonly known as wire worms. Petch (14) also reports that the specimens in the herbaria of Kew and the British Museum including the specimen cited by Berkeley (Rav. 1276) are on the larvae of a beetle. The species apparently has been reported only for South Carolina and Pennsylvania (11). Specimens examined from several herbaria add collections from Connecticut, New Hampshire and Ontario.

The following description is taken from these collections: Clavae ochraceous to grayish-brown, slender, 2-10 cm. long, 0.3-1.0 mm. thick, the apices acuminate and sterile; perithecia superficial, free, scattered or irregularly crowded on the upper portion of the clavae, ovoid, 360-400 \times 270-300 μ ; asci somewhat clavate, 190-240 \times 7-10 μ ; ascospores narrowly fusoid, 100-220 \times 2.5-3.5 μ , overlapping in the ascus, septa obscure, apparently not breaking into segments.

Specimens examined: South Carolina, Rav. *Fungi Car.* IV, 29; Lower Bartlett, N. H., Sept. 3, 1901, R. Thaxter (Farl. Herb. 4030); West Haven, Conn., 1888-1889, R. Thaxter (Farl. Herb. 6131); West Haven, Conn., Oct. 1888, R. Thaxter (Farl. Herb. 6136); Toronto, Canada, June 10, 1899, J. Fletcher (Farl. Herb.); Toronto, Canada, Oct. 1898, C. W. Nash (Myc. Coll. B. P. I.); Laurel Run, Hunt Co., Penn., Aug. 13, 1937, B. B. and L. O. Overholts (20215).

Only two of these collections (Farl. Herb. 4030 and Overholts 20215) bear perithecia. Petch (14) has also noted that many of the collections of this species are sterile. He places the species in *Ophiocordyceps*.

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CORDYCEPS RAVENELII Berk. & Curt.

Berkeley (1) published *C. Ravenelii* in 1857 in the same article with *C. acicularis* but on the following page. Petch (14) considers this species the same as the latter and therefore places the name in synonymy with *C. acicularis*. However according to Berkeley's description and illustration, and the specimen in Ravenel's Fungi Caroliniani, *C. Ravenelii* has club-shaped clavae with obtuse or at the most acute apices which are often sterile and tends to be much darker in color, frequently chocolate-brown. Berkeley gives the hosts as larvae of *Ancylonycha* or *Rhizotrogus* beetles of the Scarabiidae. These larvae are grubs of the June beetle type. Other collections from the United States also have this type of larvae. This is apparently a valid species.

The following description is taken from the specimens listed below: Clavae chocolate-brown, club-shaped, 3–10.5 cm. long, 1.5–2.5 mm. thick below, swelling above to 2–4 mm., the apices obtuse or acute, usually covered with perithecia, sometimes sterile; perithecia superficial, free scattered or crowded on the upper portion of the clavae, dark brown, ovoid, $300\text{--}480 \times 240\text{--}300 \mu$; asci narrowly clavate, $180\text{--}240 \times 6\text{--}10 \mu$; ascospores cylindric, $160\text{--}190 \times 2 \mu$, somewhat overlapping in the asci, multiseptate, the cells 22–30 μ long, tardily breaking into segments.

Specimens examined; South Carolina, Ravenel Fungi Car. IV, 28; Cranberry, N. C., Aug. 1887, R. Thaxter (Farl. Herb. 4050); West Chester, Penn. (N. Y. Bot. Gar.); Ross Run, Hunt Co., Penn., May 16, 1937, L. O. Overholts (20050); Intervale, N. H., July 1, 1901, R. Thaxter (Rel. Farl. 613); South Portsmouth, Ky., John Butler (Lloyd Coll. 41279); Great Smoky Mts. Nat. Park, Aug. 18, 1938, A. H. Smith (10327).

CORDYCEPS MYRMECOPHILA Ces.

Cordyceps myrmecophila was distributed by Rabenhorst in Koltzschii Herb. Myc. 1033 and a description published in Bot. Zeit. 4: 877. 1846. The species is described as having capitate clavae with slender stipes and ovoid heads which are sterile at the base and ridged above with the perithecia embedded, except for their apices. The color is given as ochroleuca and the host

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taken from the specimens listed club-shaped, 3-10.5 cm. long, 1.5- oved to 2-4 mm., the apices obtuse perithecia, sometimes sterile; peri- or crowded on the upper portion 1, 300-480 \times 240-300 μ ; asci nar- μ ; ascospores cylindric, 160-190 n the asci, multiseptate, the cells nto segments.

Carolina, Ravenel Fungi Car. IV, ' R. Thaxter (Farl. Herb. 4050); ot. Gar.); Ross Run, Hunt Co., rholts (20050); Intervale, N. H., arl. 613); South Portsmouth, Ky.,); Great Smoky Mts. Nat. Park, 3227).

s distributed by Rabenhorst in l a description published in Bot. s is described as having capitata ovoid heads which are sterile at the perithecia embedded, except given as ochroleuca and the host

an ant. Nylander (10) has reported the species on the ant, *Formica rufa*, from Finland. He describes the asci as approximately 300 \times 6-7 μ .

The species apparently has been rarely collected and information concerning it is scanty. Saccardo (18) has reported it from Italy, Finland, Britain, North America, Ceylon and Borneo. Since ichneumon flies and beetles as well as ants are listed as hosts probably other species of *Cordyceps* are included. Seaver (19) has questioned the report of the species for North America.

During the summer of 1939, A. H. Smith collected a number of specimens of a *Cordyceps* on ants in the state of Washington. From these the following description has been derived.

Clavae capitate, arising from the thorax of the hosts, slender, 1-4 cm. long, the stipes 1 mm. thick, light yellow, the heads ovoid, 2-2.5 \times 1.8-2 mm., ochraceous, acute, longitudinally ridged; perithecia narrowly obovoid, 660-890 \times 240-275 μ , embedded obliquely with the ostioles slightly projecting upward; asci cylindric, 500-630 \times 4-6 μ ; ascospores filiform, nearly as long as the asci, multi-septate, soon breaking into one-celled fragments, 8-10 \times 1.5 μ (FIG. 2, C & D).

On ants, Port Ludlow, May 30 (13865); Lake Crescent, June 2 (13955), June 3 (14006), June 7 (14157); Joyce, June 9 (14206); Storm King, Olympic Mts., June 12 (14276); Elwha River, June 23 (14575); Mt. Angeles, June 28 (14652).

Apparently these collections are *C. myrmecophila*. Previous descriptions do not mention the oblique perithecia but statements concerning the sterile base and ridged condition of the head indicate that the original specimens probably have oblique perithecia. The asci of the Washington collections are much longer than the measurement given by Nylander. However it is often difficult to obtain entire asci.

The species is closely related to *Cordyceps sphaecocephala* which develops on wasps and bees. As the Tulasnes (21) have pointed out, it is a smaller species.

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