SPARASSIS RADICATA, AN UNDESCRIBED FUNGUS ON THE ROOTS OF CONIFERS

JAMES R. WEIR

WITH FIVE FIGURES IN THE TEXT

In August, 1912, the writer collected several specimens of a species of Sparassis growing on the roots of various conifers in the Priest River Valley, Idaho. Lloyd, to whom specimens were sent, pronounced it an undescribed species. Cotton of the Pathological Laboratory at Kew who was advised by Lloyd of the writer's specimens stated that the plant was unknown to him. Since collecting the first specimens, the writer has studied the plant in several regions of the Northwest and finds that of the many peculiarities of the species the most surprising discovery is its evident parasitism on the roots of conifers. Although this fact was noted in 1912, it was not until the plant was carefully studied in its relation to its several hosts that this phase in its life history could be satisfactorily determined.

DESCRIPTION OF THE FUNGUS

Since the fungus does not agree with any known member of the genus, it is described as new.

Sparassis radicata n. sp.

Fruiting structure large, 12 to 22 cm. broad, 10 to 16 cm. high, dilated above, compact, fleshy, tough, whitish, creamy yellow with age, branched; branches numerous, horizontal or vertical, anastomosing, sometimes forming labyrinth-like cavities, more often compactly arranged, very thin, fan-shaped with wavy, sometimes deeply lobed margins, occasionally striated, amphigenous or unilateral, depending on the position of the branch; stalk, sclerotioid, tuberculate, firm, solid, sometimes branched, 20–30 cm. long, 5–8 cm. broad; spores, (50) range 2.8–4.0 $\times$ 2.8–5.5 μ, standard size 3.9 $\times$ 5.1 μ, ovoid, hyaline.

Type locality. Priest River, Idaho.

Habitat. Living roots in coniferous trees.

Range. Oregon, Idaho, Washington, Montana, and British Columbia.

Type material. In the Office of Investigations in Forest Pathology, Bureau of Plant Industry, Missoula, Mont.

GENERAL MORPHOLOGY AND TAXONOMY OF THE GENUS SPARASSIS

The genus Sparassis was established by Fries[1] and placed in the Clavariaceæ because of its frondose habit, fleshy consistency, and the belief that the spores were produced on all surfaces of the sporophores. It has recently been shown by Cotton[2] that the hymenium of Sparassis is not amphigenous but that the flattened branches with the exception of those in the center of the sporophore, are unilateral. On the basis of the flattened sporophore and the inferior hymenium Cotton suggests that Sparassis should be removed from the Clavariaceæ and placed in the Thelephoraceæ. He points out that in the Merisma section of the genus Thelephora are species with upright, partly unilateral sporophores either terrestrial or growing on wood which in many respects have the characters of Sparassis. In points of smoothness of the hymenium he further suggests that Sparassis is allied to Stereum but since the relationship to Stereum is not very close sees no reason why the genus Sparassis should not be transferred to the Thelephoraceæ without reference to any particular genus. Sparassis would then be distinguished as a genus of the Thelephoraceæ having fleshy, flattened, horizontal or vertical anastomosing branches with unilateral structures. The same view is entertained by Lloyd[3] who thinks the definition as laid down by Fries "fertile on both sides" should be corrected. Whether or not this view should be adopted in view of the fact that there is considerable irregularity in the formation of a unilateral sporophore is doubtful. In young sporophores of *Sparassis crispa* (Wulf.) Fr. examined by the writer, also of *Sparassis radicata*, the hymenium is by no means confined to the lowermost portion of the flattened branches but is found more or less uniformly over all free surfaces. This is particularly true, as Cotton points out, for those branches in the center of the sporophore but with a more pronounced unilateral structure toward the periphery. The hymenium of *Sparassis radicata* is formed very rapidly on the reverse side of the peripheral lobes when changed from their origninal position. A few specimens with unusually vertical lobes showed an amphigenous hymenium throughout making it seem probable that the lobes only become unilateral when they develop in a position allowing the influence of gravity to be more active on one side than another. There are, however, very few unilateral fungi, if any, that, under proper conditions of growth, will not when reversed develop the hymenium on the upper side.

[1] Fries. Systema mycol., I, p. 462.

[2] Cotton, A. D. On the structure and systematic position of Sparassis. Trans. British Myc. Soc. **1911**: 336–339.

[3] Lloyd, C. G. Letter No. 61, note 400.

Both Quélet[4] and Patouillard[5] noted the affinities of Sparassis with certain groups in the Thelephoraceæ but apparently without definite knowledge of the hymenial development in the genus. Somewhat later Maire[6] separated Sparassis from the Clavariaceæ making it the type of a special family, the Sparassideæ. Although Maire's classification was adopted by Lotsy,[7] critical work on the development of the hymenium, permanency

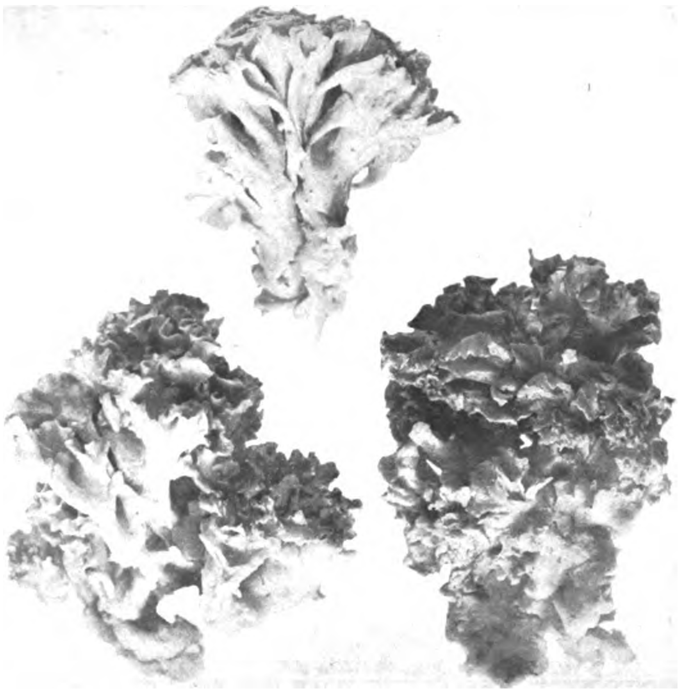

FIG. 1. SPARASSIS RADICATA

Small fruiting structures from a large sclerotioid stalk attached to the roots of *Pinus monticola.*

of the unilateral structure of the branches under various factors of growth and so forth is very much needed before the change should be accepted.

Lloyd has made the suggestion to the writer that the genus Sparassis falls naturally into two sections: first *S. crispa*, which is more of a fleshy

[4] Quélet. Flora mycologique de la France. Paris. 1888.

[5] Patouillard. Les Hyménomycètes d'Europe. Paris. 1887.

[6] Maire. Recherches cytologiques et taxonomiques sur les Basidomycètès. Annexé au Bull. Soc. myc. France. **18**:—. 1902.

[7] Lotsy. Vorträge über botanische Stammes geschichte. I. Jena. 1905.

nature especially near the base of the branches and is very closely related to Clavaria, and a second section consisting of species with thin lobes such as *S. spathulata* in the United States, *S. laminosa* of Europe, and *S. radicata* which has thinner lobes than either of the former. This seems to be a very logical arrangement. He further suggests[8] that *Sparassis laminosa* and *S. spathulata* are probably indentical. Their sporophores are certainly very similar.

THE ROOT STALK OF SPARASSIS RADICATA

Sparassis radicata (fig. 1) differs chiefly from *Sparassis crispa* (Wulf.) Fr. (*S. ramosa* Schäff.) which is reputed common in the eastern United States and in Europe, *S. laminosa* Fr. of Europe, and *S. spathulata* Schw. (*Stereum spathulatum* Schw.) (*sparassis Herbstii* Pk.) of America in the thinness of its lobes and by its very pronounced perennial sclerotioid rootstalk from which the sporophore develops annually (fig. 2). Since the rootstalk is usually attached to the deeper lateral roots of its host, it is often of a surprising length especially if a thick deposit of forest litter has accumulated around the base of the tree. Specimens have been found 50 cm. in length but the average is from 20 to 31 cm. No record exists of such a rootstalk for any other species. *Sparassis crispa* has a rooting base but it is not known to be perennial. It is possible that this phase of development is common to the other two species but has been overlooked. Sometimes the underground stalk is divided into two secondary ones each supporting a sporophore (fig. 2). The spongy character of the upper portion of the rootstalk soon merges into a very hard, compact mass and at the point of attachment to the root has very much the appearance of true cellular structure with the component filaments arranged longitudinally. The periphery of the stalk at the surface of the ground is composed of hyphae very much modified into a hard encrusting layer and may sometimes have a resinous appearance. The mycelium at the base of the stalk usually cements the earth into a hard stone-like body often of large dimensions. The fungus has not been found growing in the soil unattached to woody material. It is doubtful if it ever does so occur. All specimens so far collected were found at the base of trees.

The structure of the rootstalk is not that of a true sclerotium although it functions as such, is permanent and produces new sporophores from year to year. The stubs of old sporophores are plainly evident on the old root stalk (fig. 3) and as high as ten have been found on a single specimen. It was expected that the roctstalk would have great power of regeneration. This was tested on July 3, 1915 by cutting off a half-grown

[8] Lloyd, C. G. Letter No. 44, note 51, 1913.

sporophore. By August 30 a fully mature sporophore of average size had developed from the cut surface. On the former date also, a large rootstalk was severed from the roots of a Douglas fir, the fruiting end cut squarely off and the stalk buried loosely in moist forest soil. After a slightly longer time than that required for regeneration from the one attached to its host, a small fertile sporophore appeared from the normally

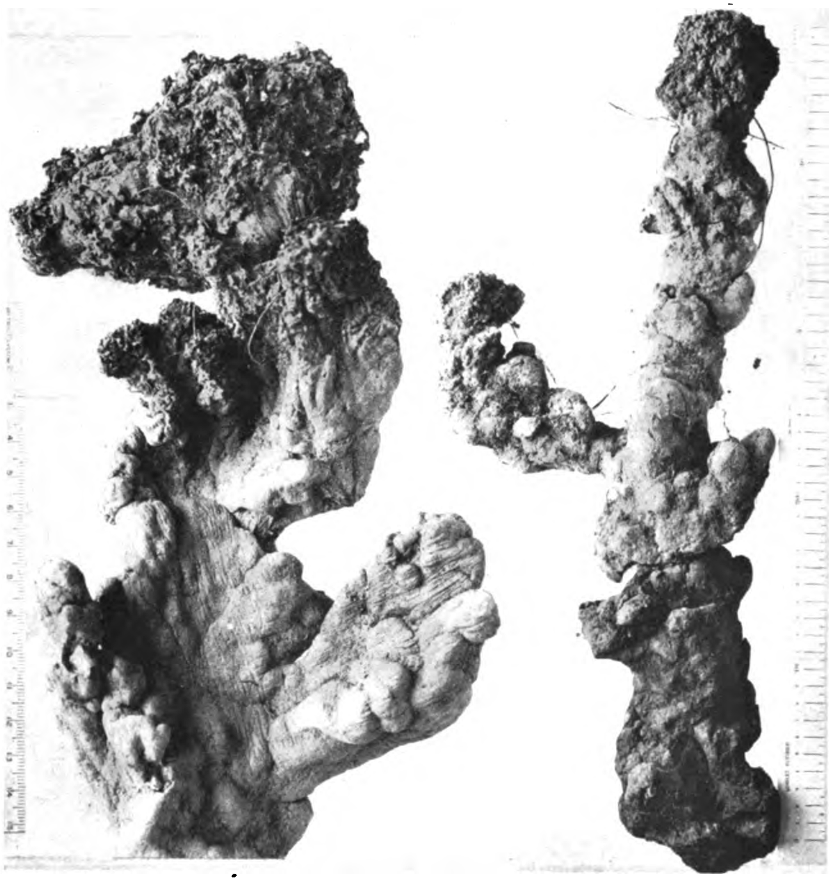

FIG. 2 FIG. 3

FIG. 2. SCLEROTIOID STALK OF SPARASSIS RADICATA

Showing lateral fruiting branch and tuberculate surface.

FIG. 3. UPPER PORTION OF SCLEROTIOID STALK OF SPARASSIS RADICATA

The remains of the sporophore of the season, two of the previous season, and two branches which produced sporophores in former years are shown. The fruiting nature of the latter was evident before the specimen was washed and dried.

fruiting end, showing not only the evident polarity[9] of the rootstalk but that it is a reserve structure of considerable reproductive power.

The formation of sclerotioid bodies from which their fructifications are developed is common to a number of Polypores. Chief among these noted in western United States are *Polyporus berkeleyi*,[10] *P. umbellatus*,[11] *P. frondosus*, and *Lentinus* sp., parasitic on the roots of conifers and probably unnamed. The latter species has a true sclerotium.[12] Lloyd[13] lists the following species growing from sclerotia-like structures and separates them as a distinct group of the section Ovinus of Polyporus: *Polyporus tuberaster* (Japan, China, and Europe), *P. Goetzii* (Africa), *P. Sapurema* (Brazil), and *P. Mylittæ* (Australia). Three other species also with sclerotia but not included in this section are *P. basilapidiodes* (Australia), *P. sacer* (Africa), and *P. rhinocerotis* (Malay).

The formation of sclerotioid bodies seems to be common to the Clavariaceæ. Some of the large species of Clavaria are observed to spring from large globose masses which when sectioned exhibit a very compact structure and are known to last over for more than one year. This has been observed by the writer for *Clavaria aurea*, *C. amethystina* and *C. formosa*. The members of the interesting genus Typhula always, so far as observed, produce sclerotia from which the sporophore is produced. In view of the fact that the sclerotia-forming habit seems to be more or less common to the Clavariaceæ, together with the fleshy consistency of the sporophores, flattened or cylindrical anastomosing branches, large size of many species, amphigenous hymenium, constant in most genera, irregular in others, it seems that this family is very well defined. The removal of the genus Sparassis to the Thelephoraceæ, which possesses few or none of these characters, would be, it seems, an unnatural arrangement.

[9] Weir, James R. Untersuchungen über die Gattung Coprinus. Flora n.s. **103**: 301-305. 1911.

[10] Weir, James R. Some observations on Polyporus berkeleyi. Phytopath. **3**: 101–103, pl. 9. 1913.

Later observed by Lloyd, Letter No. 60, note 391, 1915; and Letter No. 59, note 306, 1915; and by Overholts, The Polyporaceæ of the Middle Western United States. Washington University Studies **3**: 23, pl. 2. 1915.

[11] Lloyd, C. G. Letter No. 58, note 277, 1915; and Overholts in The Polyporaceæ of the Middle Western United States. Washington University Studies. **3**: 24, pl. 2. 1915.

[12] Petch, T. The pseudo-sclerotia of Lentinus similis and L. infundibuliformis. Ann. Roy. Bot. Gard. Peradeniya **6**: 1–18, pl. 1. 1915.

[13] Lloyd, C. G. Synopsis of the Section Ovinus of Polyporus. 74–76. Oct. 1911. Cincinnati, Ohio.

THE DISEASE CAUSED BY SPARASSIS RADICATA

The observation that possibly some members of the genus Sparassis are parasitic on the roots of forest trees has been made by others. In a letter to the writer, dated January 7, 1916, Doctor Cotton writes: "*Sparassis crispa* has been found frequently, and from its intimate connection with the roots of Pinus and other conifers we are strongly inclined to suspect that it is parasitic."

Kirchmayr,[14] it appears, was the first to entertain the suspicion that Sparassis had symbiotic or parasitic tendencies. Working with *Sparassis crispa*, he found that the stalk of this species penetrated deep into the earth at the base of the tree (*Föhre*). Boring into the roots from which the fungus appeared to have sprung, he found that after passing through a zone of healthy wood the auger encountered diseased wood. This wood was of a brown color, gave out a strong odor of turpentine, and was very soft so that the auger readily pushed through it. Two trees when cut showed that the brown rot extended up into the heartwood of the trunk for a distance of two meters. The decayed wood could be rubbed into a fine powder and gave out an odor of turpentine. The decay resembled that produced by *Polyporus sulphureus*, the checks extending vertically and paralleling the annual rings. The checks were lined with a fine mycelial layer which was encrusted with granules of calcium oxalate. Large peices of the cubical checked wood could be removed from the hollow in the heartwood. The heartwood in the larger roots was also decayed, while the sapwood was infiltrated with pitch ("*verkient*"). The decayed wood largely dissolved in ammonia producing a thick brown liquid which on neutralization held a brown deposit in suspension.

The author was unable to demonstrate the relation of the mycelium of *Sparassis crispa* with that in the diseased wood. He calls attention to the fact that the shrinkage of the wood in the form of cubes with surfaces covered with a fine white mycelial layer, brown color, odor of turpentine, and ability to be rubbed into a fine powder are characteristic of the decay produced by *Polyporus schweinitzii*. In the writer's experience the rot of *Polyporus schweinitzii* may not always be accompanied by the production of sporophores until a long time after the wood is well advanced in decay. Since direct connection of the mycelium of the base of the sporophore with that of the decayed wood was not discernible, it seems quite probable that the investigator has made an incorrect diagnosis.

A careful examination by the writer of six trees, the roots of which bore the fructification of *Sparassis radicata* has not revealed, with one excep-

[14] Kirchmayr. Über den Parasitismus von Polyporus frondosus Fr. und Sparassis ramosa Schäff. Hedwigia 54: 334–337. 1914.

tion, the presence of such decay as described by Kirchmayr. The exception was a case in which an old decayed sporophore of *Polyporus schweinitzii* was found buried in the litter at the base of the tree. The rot in a part of the root to which the Sparassis was attached showed the characteristic decay of *Polyporus schweinitzii* but could be easily distinguished from the decay produced by the former species. This strengthens the writer's assumption that the trees examined by Kirchmayr might possibly have been infected with *Polyporus schweinitzii* or *P. sulphureus*,

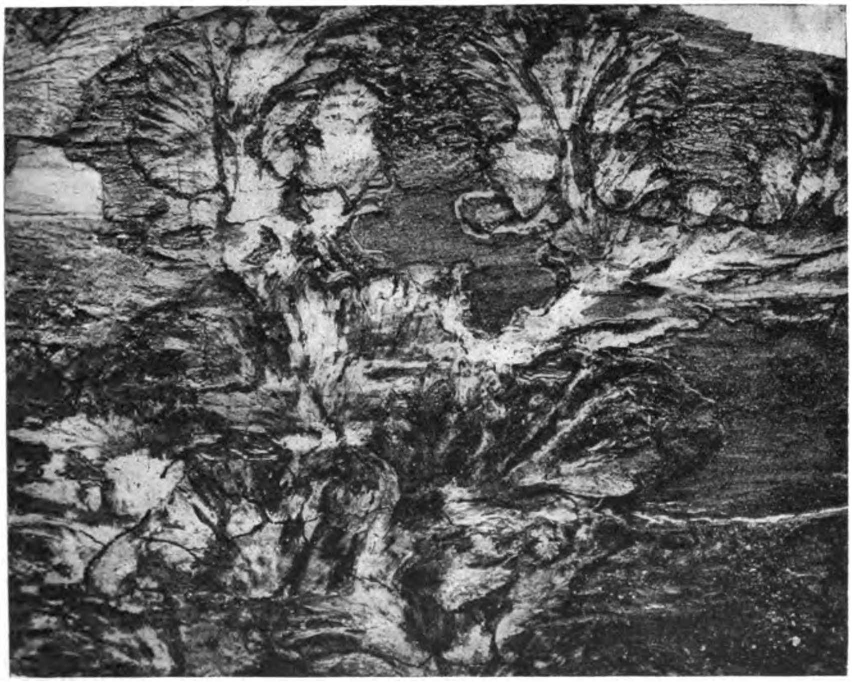

FIG. 4. FAN-SHAPED MYCELIUM OF SPARASSIS RADICATA IN THE BAST OF A ROOT OF DOUGLAS FIR

the rot of which is similar and is also mentioned by the author in connection with his description. It is possible that *Sparassis radicata* produces a different decay from that of *Sparassis crispa*. If this is true, it is at least an argument in favor of the former being specifically different from *Sparassis crispa*.

The great depth to which the rootstalk of *Sparassis radicata* penetrates the forest soil has made the investigation of the diseased roots difficult. When attached to the deepest lateral roots, a considerable excavation was necessary before the point of attachment was revealed. In the case of two of the trees examined dynamite was used to expose the infected roots over a considerable area. This method was found serviceable since the thicker roots were broken up in such a manner as to expose the diseased wood and the mycelium beneath the bark to good advantage. In most cases the earth was carefully dug away from around the rootstalk leaving the entire fruiting body of the fungus standing free.

Upon removing the bark from any of the infected roots to which the fungus is attached, a yellowish white mycelium is exposed. This mycelium develops in the living bast and ramifies in all directions in fan-shaped layers (fig. 4). After the death of the root, small rhizmorphs develop from the border strands of the original mycelial layer. These

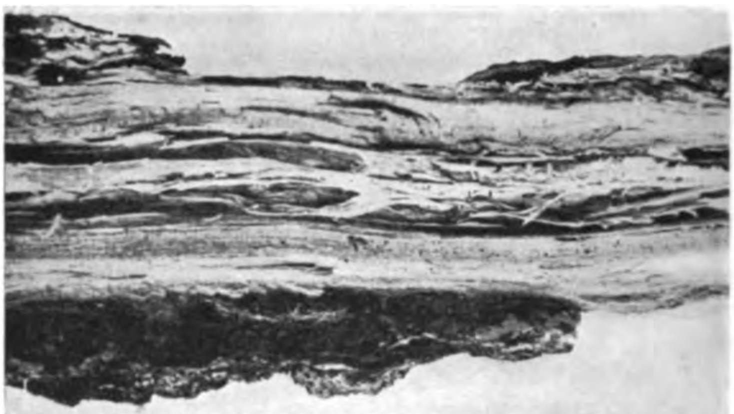

FIG. 5. TYPICAL DECAY OF HEARTWOOD CAUSED BY SPARASSIS RADICATA IN THE ROOT OF A DOUGLAS FIR

strands break up into mycelial filaments and penetrate the outer sapwood producing a brown or yellowish, laminated, carbonizing rot. The shrinkage of the diseased wood causes very small, narrow, elongated pits or shrunken areas to appear but they are not lined with mycelium. As is the case in some other rots, the initial stage of decay occurs principally in the region of the medullary rays which may become wholly disorganized before the surrounding tissues are affected. Very small brown rhizomorpha occasionally develop in the decayed wood either paralleling the tracheids or extending in zigzag lines. The early stage of decay is always preceded by a reddish color. A jet-black line sometimes marks the boundary of the decayed wood. The completely decayed root shrinks slightly away from the bark leaving a space which is eventually filled with a thick, mycelial mat from which the rootstalk takes its origin. The greatest decay occurs at the point where the rootstalk is attached and is at first confined principally to the sapwood. Small roots originating from larger ones to which the rootstalk is attached are usually decayed throughout. The early decay of the heartwood in the larger roots is probably prevented by the large amount of pitch which they contain. Eventually the heartwood is invaded but is not broken down uniformly. Elongated pits filled with a white mycelium are formed in different parts of the wood, often anastomosing in such a manner as to leave long pieces of partially decayed or solid wood which may be very readily removed (fig. 5). Sunken areas on these pieces correspond to similar pits on pieces which have become wholly disorganized. These elongated pits are often bounded by a white mycelium arranged in the form of a network. The tissue in the heartwood is brittle but can not be rubbed into a fine powder as described by Kirchmayr for wood attacked by *Sparassis crispa*. The rot of the heartwood is always of a darker color than that of the sapwood. In Douglas fir it is brown; in spruce, of a more yellowish color. Away from the seat of first infection the mycelium may advance into the innermost heartwood causing the formation of a pitchy zone next to the sapwood. The diseased wood may be drawn out of such roots in strips leaving a hollow cylinder. The cambium and outer bast are always, however, permeated by the mycelium in the characteristic fan-shaped masses. The action of the mycelium in the resin ducts of the bast causes a flow of pitch which may cement the soil to the root in stone-like masses.

The fact that the fungus can maintain its activity in the cambium in roots deep in compact, mineral soil is very unusual. Some of the root fungi which attack primarily the heartwood may follow the roots to a considerable depth, and *Armillaria mellea* and *Fomes annosus* habitually attack the cambium to a considerable distance in the mineral soil, but in the experience of the writer no other species has developed this ability to as great an extent as *Sparassis radicata*. The decay is apparently confined to the roots proper, never having been traced beyond the surface of the soil. In case of an excessive accumulation of forest débris around the base of the tree the decay may extend higher up on the lateral roots than is ordinarily the case when this accumulation of materials does not occur.

Only two species of fungi are definitely known to parasitise the roots of coniferous trees in the temperate zone, viz, *Fomes annosus* and *Armillaria mellea*. *Rhizina inflata*[15] may possibly be grouped here but in northwestern United States seems to be confined principally to seedlings.

[15] Weir, James R. Observations on Rhizina inflata. Jour. Agr. Research **4**: 93–95. 1915.

There are a number of fungi which attack the roots of forest trees, are not strongly parasitic and do not cause a rapid browning of the foliage and rapid death. Their action is confined mainly to the heartwood of the roots and the base of the trunk. The most common of these is *Polyporus schweinitzii*. Other species which are either wholly confined to the roots and bases of trees or extend into the roots from infection through wounds on the trunk are *Trametes Pini*, *Echinodontium tinctorium*, *Polyporus sulphureus*, *Poria weirii*, and so forth. In the light of the present status of the study it can not be stated just how rapidly *Sparassis radicata* causes the death of its host. It has not been found on reproduction or young trees. The plant is not abundant but sufficient data have been assembled to show that it may be placed in the same group with *Armillaria mellea* and *Fomes annosus*.

To date only four trees, two Douglas firs (*Pseudotsuga taxifolia*), one white pine (*Pinus monticola*), and one spruce (*Picea engelmanni*) have been found to have succumbed to the action of the fungus. The conclusion that the death of these trees was caused by *Sparassis radicata* was arrived at because of the absence of any other fungus or factor which has heretofore been accredited as causing the death of trees. Several unhealthy trees with the fungus on their roots have been studied, but the common root fungi were present making a correct diagnosis impossible. The fungus has in every case, however, been found to cause the death of the living parts in the roots to which it was attached.

HOSTS AND DISTRIBUTION OF THE FUNGUS

Sparassis radicata is very widely distributed in the Northwest, having been found by the writer in British Columbia, Washington, Oregon, Idaho, and Montana. *Sparassis crispa* as reported from California is very probably based on this species.

The fungus has been found attacking the roots of the following conifers: *Pseudotsuga taxifolia*, *Picea engelmanni*, *Pinus monticola*, and *Larix occidentalis*. Its occurrence on the roots of broad-leaf species has not been noted by the writer. Kirchmayr cites instances of the occurrence of *Sparasssis crispa* on oak and beech and other broad-leaf species.

SUMMARY

The large species of Sparassis in the western United States is found to differ in a number of details from *Sparassis laminosa*, *S. crispa*, and *S. spathulata*, and is described as new under the name *Sparassis radicata*.

The fungus is chiefly distinguished by its thin lobes and an unusu-

ally large perennial rootstalk which is of the nature of a sclerotium and from which new sporophores are developed from year to year.

The most important feature in the life history of the species is its parasitism on the roots of conifers. The mycelium attacks the bast of the roots and later the wood, producing a yellow or brown, carbonizing rot.

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