Indian Species of Synchytrium.

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Species of *Synchytrium* are abundant and widely distributed in India, and up to the present time fifty-nine species have been reported from that country. Prior to 1945 only six species were known to occur there, according to Butler and Bisby (1931), but since that time interest in these fungi has increased greatly with the result that fifty-three species have been added within a decade and a half. Most students of these obligate parasites, however, have created new species without intensive study of the developmental stages at different season of the year and cross inoculation studies to determine the host range of the species. Consequently, many of these are poorly known, and it is not evident from the descriptions in the literature whether they are long — or short-cycled. That many species which were previously diagnosed as short-cycled are really long-cycled became evident when Lingappa (1952) reexamined such species in the living state. My study of herbarium specimens of the India species has confirmed these observations in several instances.

The present contribution is a result of this study and is presented as a supplement to the observations of numerous mycologists in India who have studied these obligate parasites. It is presented also to emphasize the need of more intensive study at different seasons of the year, and to summarize the available information on Indian species of *Synchytrium*. It is based on a study of types and other specimens in the Herbarium Cryptogamiae Indae Orientalis (HCIO), Division of Mycology and Plant Pathology, New Delhi, the Commonwealth mycolocigal Institute (CMI), the Herbarium of Agra College, Agra, and the Royal Botanic Gardens, Kew, (K). I am very gryteful to Directors J. C. F. Hopkins, G. Taylor, and R. S. Vasudeva, and Drs. Grace M. Waterhouse, S. Sinha, and B. G. Nikam for the loan of these and other specimens. Also, I wish to express my thanks to Dr. B. T. Lingappa for the generous gift of specimens which he collected and identified. Unfortunately, I have not been able to secure and study type specimens of all Indian species, and for this reason I do not regard this contribution as complete.

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Synchytrium rytzii.

This species was created by Sydow and Butler in 1907 for a parasite on *Anisomelis ovata* which they placed in the subgenus *Pycnochytrium* because only resting spores were found. In 1912, however, they reported it on three additional hosts, *Peristrope* sp., *Justicia* sp., and *Leucas aspera*, and created three forms of it on these hosts on the basis of distribution, size, appearance and structure of the galls, size and method of gemination of the resting spores, and the size of the sporangia. According to them, form *a* differs from *S. rytzii* on *Anisomelis ovata* by the aggregation of galls in crusts, its slightly to completely composite galls, the shape of the infected cell and its lack of residue, and the size of the resting spores, average 96 μ. Form *b* on *Justicia* has smaller resting spores, average 79 μ, which germinate in the living host without a dormant period and give rise to external sori of sporangia which are 18—30 μ in diameter. In form *c* on *Leucas aspera* the infected cell is quite small and bears 2 to 4 resting spores which average 78 μ in diameter. These germinate in the living host cells also and functio nas prosori. In this form, however, the sporangia are smaller, 12—24 μ, than in form *c*.

In studying these and other herbarium specimens, Mhatre and Mundkur (1945) reported only resting spores in *S. rytzii*, and limited it in host range to *Anisomelis ovata*, *Leucas* sp. and *L. aspera*. Sydow and Butler's forms *a* and *b* on *Peristrophe* and *Justicia* were segregated to constitute a new species *S. lepidagathidis*. Lingappa (1952) found *S. rytzii* on these hosts as well as on *Orthosiphon pallidus* and reported that it develops prosori, sori, sporangia and resting spores. I have examined HCIO specimens 653, 1379, 1382, 2035, 20476, Nikam and Kulkarni's collection on *Leucas aspera* at Gwalior (1959), as well as those collected by Lingappa, and in all of these prosori, sori, sporangia, resting-sporegalls and resting spores were present, which confirms Lingappa's discoveries. From these observations I interpret the germinating resting spores in the living host, which were reported by Sydow and Butler, as evanescent initial cells which functioned as prosori and gave rise to sori of sporangia. In the material studied their walls are amber colored and only 2 to 2.6 μ thick in contrast to those of the resting spores which are 3.8 to 5—2 μ thick and brown in color. Furthermore, the empty prosori in the base of the infected cell had collapsed. This does not occur generally when thick-walled resting spores germinate as Lingappa (1955, fig. 54, 57) showed for this species. According to these observations and interpretations, *S. rytzii* is a long-cycled species which belongs in the subgenus *Microsynchytrium*.

The differences in size and structure of the galls, size and shape of the infected cell, size of the resting spore and lack or presence of residue around it, which were noted by Sydow and Butler, fall within

the range of variation which a species might exhibit on different hosts, in my opinion. Nevertheless, these differences as well as the variations in the size of the sporangia should be studied more intensively in living as well as in fixed and stained sections of material. Host range studies may possibly reveal biological races within this species.

Synchytrium collapsum.

This is the second Indian species created by Sydow and Butler in 1907 for a fungus on *Clerodendron infortunation*, and they described it as a member of the subgenus *Pycnochytrium* which develops only resting spores. Mhatre and Mundkur studied the type (HCIO, 654) and other specimens and described only resting spores also. Lingappa (1952), however, found prosori, sori, sporangia and resting spores in living material collected in September, and demonstrated that *S. collapsum* is a long-cycled species. Later (1955) he germinated the resting spores and thus completed our knowledge of its life cycle. In a collection (HCIO, 2006) made by Butler, 8—10—1913, in Bengal I found numerous cupulate sporangial galls with collapsed, empty prosori in them in addition to resting-spore galls and resting spores, and my observations thus confirm those of Lingappa.

Synchytrium lepidagathidis

As noted above Mhatre and Mundkur segregated Sydow and Butler's forms *a* and *b* of *S. rytzii* on *Peristrophe* and *Justicia*, combined them with a species which had been collected on *Lepidagathis* sp., *L. cristata* and *Dicliptera* sp., and named it *S. lepidagathidis*. They reported only resting spores in this species, but in 1952 Lingappa found prosori, sori, sporangia and resting spores in living specimens on *Andrographis paniculata*, *Dicliptera roxburghiana*, *Justicia diffusa*, *J. quinqueangularis*, *Peristrophe bicalyculata*, and *Rungia parviflora* var. *pectinata*. He made a careful comparison of the resting spores on these host with those on the hosts listed by Mhatre and Mundkur and came to the conclusion that his fungus was *S. lepidagathidis*. In specimens 10355 (type), 10355A, 2020, 2023, 20472, 20473, 20477, 2048, HCIO, I found prosori, sori sporangia and resting spores and confirmed Lingappa's observations. Accordingly, *S. lepidagathidis* also is a long-cycled species which belongs in the subgenus *Microsynchytrium*.

Whether or not it is distinct from *S. rytzii* is open to question, however. Its resting-spore galls are reported to be simple, but in the material noted above simple to composite galls are present. Apparently, the host reaction may vary to a marked degree as I have found when *S. macrosporum* is grown on different hosts, and it is doubtful that *S. lepidagathidis* is always diheterogallic. Its hosts are acanthaceous

and overlap those of *S. rytzii*. The differences in the prosori, sori, sporangia and resting spores of both species are not very great, and on these grounds I believe *S. lepidagathidis* may prove to be identical with *S. rytzii*.

Synchytrium lagenariae

Mhatre and Mundkur created *S. lagenariae* for a species on the leaves of *Lagenaria vulgaris* which Mony collected at Pusa, August 31, 1918. Here also they described only resting spores, but in examining this type material as well as specimen. 25549 on *Luffa aegyptica*, 25450 on *L. acutangula*, 25451 on *Cucumic sativus*, 2452 on *Citrullus vulgaris* var. *fistulosus* and 25453 on *Curcurbita pepo*, HCIO, I found sporangial galls with empty prosori, sori and sporangia in addition to resting-spore galls with resting spores. Accordingly, this species is long-cycled and belongs in the subgenus *Microsynchytrium*. *Synchytrium luffae* Sinha (HCIO, 25449 and 25450), *S. cucumis — sativa* Sinha (HCIO, 25451), and *S. fistulosus* Sinha (HCIO, 25452) in herb. are identical to the fungus in type specimen 2019, and should be listed as synonyms of *S. lagenariae*.

Lingappa (1952, 1955a) regarded this species as well as *S. trichosanthidis* as identical with *S. wurthii* which Rytz (1907) described on another cucurbit, *Gymnopetalum cochinchinense*, from fixed material sent him by Wurth from Java. Rytz found only resting spores in this material but noted that these had germinated in the living host without a long dormant period and given rise to sori of sporangia. Lingappa believed that Rytz overlooked the thin-walled prosori, but, in my opinion, it is probable that the germinated spores found by Rytz were evanescent prosori. In that event *S. wurthii* and *S. lagenariae* are fairly similar, and Lingappa's view may prove to be correct. However, until *S. wurthii* is collected again in Java, studied intensively in living material and compared developmentally and morphologically with *S. lagenariae* on different hosts, it is prudent to maintain them as distinct species. In the event *S. lagenariae* is identical with *S. wurthii* its host range includes *Bryonopsis laciniosa*, *Coccinia indica*, *Cucurbita maxima*, *Momordica charantia* and *Trichosanthis dioica* in addition to the hosts listed above.

Synchytrium trichosanthidis

Mhatre and Mundkur created this species for a fungus they found on herbarium specimens of *Trichosanthes dioica*, *Citrullus vulgaris* and *Cephalandra* sp. Here again they reported only resting spores. However, in the type material (10365, HCIO), I found two types of galls: large cupulate empty ones which look like sporangial galls with collapsed empty prosori in their base, and smaller ones bearing resting spores. Sometimes resting spores occurred in the basal

sheath cells of the sporangial galls. No sori and sporangia were found in the larger galls, but because of the presence of empty prosori I believe these developmental stages will be found on this host when collections and observations are made on it at different seasons of the year.

In specimens labeled *S. trichosanthidis* on *Cucumis melo* var. *pubescens* (25548, HCIO) which Sinha collected in 1956 and 1957, sporangial galls with prosori, sori and sporangia are present in addition to resting-spore galls and resting spores. The sheath cells of the sporangial galls are commonly infected with resting spores and in such cases are unusually large. Similar developmental stages were found on *C. melo* var. *ultissimus* collected by Gupta and Sinha in September 1948 at Agra, which Sinha kindly sent to me. Also, similar developmental stages were found in cotypes 10363 and 10364, HCIO, on *Citrullus vulgaris* and *Cephalandra* sp., respectively. The fungi on these hosts are very similar to *S. lagenariae*, and I believe they are identical with it.

The appearance of the fungus on *Trichosanthes dioica* and the reaction of this host to infection, however, are different in the material I examined, and it may prove to be a different species from the ones collected on the other cucurbitaceous hosts. As noted previously, Lingappa (1952, 1955b) believed that *S. trichosanthidis* as well as *S. lagenariae* are identical with *S. wurthii*.

Synchytrium sesamicola

This species was created by Lacy (1950) for a parasite on *Sesamum indicum* which he described as developing only resting spores. However, in the type material I found large empty cupulate galls which are different in appearance from those which bear resting spores. In the base of some of these were amber colored, thin-walled collapsed vesicles which I interpret to be empty prosori. Accordingly, from these observations *S. sesamicola* appears to be a long-cycled species, as reported by Lingappa (1955).

Sinha and Gupta (1951) described a new species, *S. sesami*, on the same host from Agra which forms large single galls or scarlet crusts of coalescing galls on the young shoots, leaves and stems. These galls vary from 300—400 μ in diamter on the leaves to 600—700 μ on the stems and contain solitary, spherical, 172—201 μ, smooth, olive-btown resting spores with an epispore 10—13 μ thick. However, in a collection of this species by Gupta in 1954 (HCIO, 22115) I found sporangial galls with empty prosori, sori, and sporangia in addition to resting-spore galls and resting spores. The prosori are subspherical, 80—90 μ, or ovoid, 75—87 × 90—98 μ, with an amber-brown wall, 1.8—2 μ thick. The sori are subspherical 90—102 μ, ovoid, 72—96 × 102—116 μ, or flattened on the lower surface and contain

50—92 sporangia which are golden-yellow, polyhedral and 19—28 μ in greatest diameter. The resting spores are dark amberbrown, ovoid, spherical, 55—186 μ, with a smooth wall, 3.4—4.6 μ thick. Sinha and Gupta reported that the epispore is 10—13 μ thick, but they probably included the adhering layer of residue in their measurements.

In another collection on *Sesamum indicum* from Agra, August, 1955, which Sinha sent me similar sporangial galls, empty prosori and sori with sporangia in addition to resting-spore galls and resting spores were found. The resting spores varied markedly in size, depending on the degree of injection. In areas where most of the epidermal cells were infected the spores were as small as 40 μ in diameter. Also, the sheath cells of the sporangial galls were infected frequently, and in such instances the spores were heaped up in masses similar to what I (1957) described for *S. cinnamomeum*.

If Gupta's and the 1955 collections are representative, *S. sesami* is a long-cycled species like *S. sesamicola*, and seems to be identical with it. Accordingly, I am listing it as a synonym of *S. sesamicola*.

Synchytrium melongenae

This fungus was collected and described by Gupta and Sinha (1951) as a short-cycled species which develops relatively small, 56—76 μ, spherical, solitary resting spores in spherical to oval galls on leaves of *Solanum melongena* at Agra. I have studied their type material and can confirm in general their observations on the resting spores, although I found the spores to vary from 40 to 92 μ with a wall only 4.8 to 6.2 μ thick and yellow contents. In addition to the composite resting-spore galls I found several larger empty cupulate ones which looked like sporangial galls which had discharged their sporangia. These were thoroughly soaked and dissected apart, but no sori or sporangia were found. In the apex of some, however, occurred a collapsed, dark-amber vesicle or cell which looked very much like an empty prosorus. In light of these observations I suggest the possibility that *S. melongenae* may be a long-cycled species which forms prosori, sori and sporangia in addition to resting spores. At least, it should be studied more intensively at different seasons of the year. In the event it proves to be long-cycled as suggested it may turn out that Lingappa's, (1953) *S. akshaiberi* on the same host at Banaras may be identical with it.

Synchytrium micranthum

This species was created by Singh (1954) for a fungus on *Micranthus oppositifolius* which he collected in Bihar. He described sporangial sori, 68,5—145.8 μ in diameter, which bear 100 to 150 sporangia, 22.2—35.9 in diameter, in addition to ovate and spherical resting

spores, 55.5 to 142.2 μ in diameter. My study of the type material (HCIO, 2213) confirms his observations that this is a long-cycled species. Singh, however, did not report the presence of a prosorus, ans it is not certain from his description whether or not the initial cells is transformed directly into a sorus. In the type specimens which I examined empty prosori were present in the base of the host cell with sori of sporangia lying above them. These prosori were subspherical, 130—166 μ, with smooth, amber wall 2.5—4.2 μ thick. The sori were subspherical, 60—144 μ, or ovate, 102—114×132—180 μ. The resting spores were abundant in separate or confluent composite galls, and in some instances the sheath cells of sporangial galls were infected with resting spores.

Although germination of the resting spores has not been observed, I believe this species will prove to be a member of the subgenus *Microsynchytrium*. When its life cycle and host range are fully known, it may possibly prove to be identical with *S. lepidagathidis* which occurs on numerous acanthaceous hosts in India.

Synchytrium alysicarpi

Ramakrishnan and Sundaram (1954) created this species for a fungus on *Alysicarpus vaginalis* which had been collected at Walayar by Sundaram and Rao (September 19, 1953). They described it as follows: "Galls numerous, on stems and leaves, reddish-orange in color, galls on stem swollen, sometimes irregularly lobed; on leaf amphigenous, becoming cupulate and whitish with age; hypnospores numerous, embedded within hypertrophied cells and surrounded by proliferating tissue, subglobose or oval, orange brown, thick-walled, wall differentiated into a thickened endospore surrounded by a laminated thicker exospore, with granular contents, 53—130× 50—98 μ, sorus subglobose or elliptical, made up of several sporangia, orange-yellow contents, 25×22 μ (19—43×19—37), rounded or polygonal, due to pressure." They did not report the presence of a prosorus, but one of their figures suggestes its presence in the upper part of the infected cell.

The fleshy outgrowths induced by this species on the stem, as shown in their fig. 1, resembles very closely those caused by S. *cookii* on *Alysicarpus monilifer* as shown by Lingappa (1953). I examined a portion of Sundaram and Rao's material (HCIO, 22500), but it was a poor sample and yielded nothing significantly different. Nevertheless, I believe *S. alysicarpi* will prove to be identical with *S. cookii* when it has been studied intensively. Its resting spores and sporangia are similar in size to those of *S. cookii*.

Recently I received some leaves of *Alysicarpus* sp. from G. B. Nikam at Gwalior, India which are infected with a species of *Synchytrium*. This material was collected by Nikam and Kulkarni on

Aug. 10, 1959 at Gwalior. Only resting spores are present and these occur in abundance on the lower surface of the leaves and on stems in large, protruding, light-yellow to slightly reddish galls. The spores are spherical, 156—180 μ, subspherical, 180—206 μ, or ovoid, 160—190×175—200 μ, with a dark-amber wall, 4—5.2 μ thick, and hyaline granular content. They are enveloped by a fairly thick layer of residue which fills the remainder of the host cell. The galls are subspherical to ovoid in general outline, 200—276 μ high by 208—280 μ broad, with a sheath 2—4 cells thick. The sheath cells are greatly enlarged.

The resting spores of this fungus are considerably larger than those of *S. alysicarpi* and *S. cookii*, with hyaline instead of yellow contents, and on these grounds it appears to be a different species. No outgrowths or malformations were present on the stems *Alysicarpus* sp. like those induced by *S. cookii* on *A. monilifer*.

Another unidentified species of *Synchytrium* was collected by Nikam and Kulkarni, 8—10—1959, at Gwalior, India on *Corchorus* sp. and kindly sent to me. This is the first species to be collected on *Corchorus* or any other member of the *Tilliaceae* in nature, although I (1960) have succeeded in infecting species of this family with *S. macrosporum* under greenhouse conditions. Only resting spores are present in the Gwalior fungus, and these are subspherical, 140—168 μ, or ovoid, 152—165×170—178 μ, with a smooth, amber-brown wall, 4.6—5.3 μ thick, which is enveloped by a relatively thick layer of brownish-red residue and light-yellow contents. The galls occur on the leaves, petioles and stems and are dark-brown, large and protruding, flattened on top with a well-defined apical pore, 208—468 μ broad by 208—312 μ high with sheaths 3—5 cells thick. The sheath cells are greatly elongate and enlarged outward, and most of the galls appear to "sit" on the palisade layer. In other galls the base is embedded in the palisade, and occasionally the base of the gall causes a protrusion on the opposite side of the leaf. Apparently, this is a short-cycled species, but its identity is uncertain. In the material I studied there were no characteristics which distinguishes it sharply from other short-cycled species with similar spores.

Nikam and Kulkarni collected, 8—17—1959, a third species at Gwalior on *Ipomoea* sp., which is the first record of *Synchytrium* on a member of this genus in nature. Apparently, this is a short-cycled species also inasmuch as only resting spores were present. On the material sent me the galls were sparse on the under side of the leaf, relatively small, and did not protrude conspicuously. In fixed and stained sections, they were embedded largely in the leaf with their base protruding slightly or equally on the opposite side of the leaf. In size they were 98—274 μ high by 70—168 μ broad with a sheath 1—3 cells thick. In several cases the upper port of the infected cell was exposed with only a basal fringe of sheath cells, and these galls

often appeared to be simple. The spores were ovoid, 64—90 × 70—120 μ, spherical to subspherical, 144—168 μ, thick with a smooth, dark-amber wall, 4.8—6 μ and lemon-yellow content. They filled the host cell almost completely and had little or no enveloping residue.

Synchytrium vulgatum.

Mhatre and Mundkur identified as *S. vulgatum* Rytz a parasite which had been collected by Khan and others on leaves of *Launea asplenifolia* and *Conyza* sp. Inasmuch as they found only resting spores which resembled those of Rytz's fungus, they assumed that it was the same species. Later Ligappa (1952) examined Kahn's collection at New Delhi and found thin-walled prosori and sporangia in some of the galls. Their presence as well as sori and resting spores in this fungus was verified by a study of living material which he collected on *Launea asplenifolia*, and it became evident that Mhatre and Mundkur's identification was incomplete and incorrect. As a result, Lingappa (1955) created a new species for this fungus and named it *S. launeae*. I studied samples of the same specimens (HCIO, 10358, 10359) that Mhatre and Mundkur examined, and in both of these a few large empty cupulate galls were present in which empty prosori occured. In this respect then my observations confirm those of Lingappa that this is not *S. vulgatum*.

Synchytrium emiliae.

This species was created by Ramakrishnan and Sundaram (1953) for a fungus they found on the petioles and lamina of *Emilia sonchifolia* at Bantawal, South Kanara. They described it as follows: "Galls numerous, on petioles and lamina, minute, crowded, yellow brown, amphigenous; hypnospores spherical, solitary or sometimes two in each gall, dark brown, 47—124 μ, wall thick, 3-layered, epispore dark brown, up to 15 μ thick; sporangial sorus yellow; subglobose or oval, 98—140 × 65—93 μ, made up of numerous sporangia; sporangia rounded or angular by pressure, thin-walled, 19 × 15 μ (16—22 × 12—19), yellow." They reported further that "the sorus escapes out of the resting spore as a yellowish globular body with numerous sporangia," which suggest that they observed germinating resting spores.

I examined their material (HCIO, 20421) and found numerous sporangial galls in which were empty prosori, sori, and sporangia. The prosori were subspherical to spherical, 50—110 μ, with a dark brown encrusted wall, 2—2.6 μ thick. The sori were subspherical, 64—130 μ, or flattened on their lower surface and bore 60—140 sporangia which were polyhedral, 17 to 24 μ in diameter. The resting spores were predominently spherical to subspherical, 45—120 μ, with

a dark brown wall, 4.8—5.2 μ thick, and an enveloping encrusted layer of residue. These occurred usually in composite galls, but the sheath cells of the sporangial galls also were frequently infected with resting spores so that they appeared heaped up.

Although Ramakrishnan and Sundaram's description suggests that they observed germinating resting spores, my observations lead me to believe they saw evanescent prosori which were forming sori.

It may be noted here that Petch (1926) earlier described *S. fuscum* on *Emilia sonchifolia* in Ceylon, and the question has been raised whether or not *S. emiliae* is identical with it. He reported only resting spores and described their contents as dividing into hyaline globose zoospores. I studied a fragment of the type material in the herbarium of the Peradeniya Department of Agriculture, (PDA) but it yielded very little new information. A few large cupulate and empty galls were present, and in two of these a collapsed prosorus-like vesicle was present. However, in the extype material (Kew, spec. 3367) from Galboda, Ceylon, numerous sporangial galls, prosori, sori, sporangia, resting spore galls and resting spores are present, and these are similar to those found in Ramakrishnan's collection at Bantawal. On the basis of these observations and comparisons I believe that *S. emiliae* is identical with *S. fuscum* and belongs in the subgenus *Microsynchytrium* instead of *Pycnochytrium*.

Synchytrium vernoniae.

This species was created by Gupta and Sinha (1951) for a fungus on the stems of *Vernonia patula* which they collected at Agra in September, 1948. They described the galls as scattered, single, rarely compound, and spherical, 350—600 μ in diameter. Each gall contained a spherical, 106—149 μ, or ovoid, 88—99×132 μ, dark brown resting spore with an epospore, 8—10 μ thick. In a portion of their specimen (HCIO, 20026) I found the resting spores to be generally as they described them, except that the wall was only 4 to 5.6 μ thick. In addition to the resting-spore galls a few larger, cupulate empty ones were present and looked like sporangial galls. No prosori, sori, and sporangia were found in them, but the difference in appearance of these galls suggested that *S. vernoniae* might prove to be a long-cycled species. The sheath cells of the galls were frequently infected by resting spores and had a heaped;up appearance somewhat similar to that I (1957) described for *S. cinnamomeum*. Similar galls were observed in a species on *Vernonia cinera* which B. G. Nikam sent me from Gwalior in 1958. In additional infected material of *V. patula* received from Nikam in 1960 from Gwalior, sporangial galls with prosori, sori, and sporangia were present as wall as resting spores, and their presence show that *S. vernoniae* is long-cycled and probably belongs to the subgenus *Microsynchytrium*.

Synchytrium hibisci.

Gupta and Sinha (1951) established this species for a fungus which develops solitary, spherical, 182—210 μ, smooth, resting spores, with an epispore 20 μ thick, in scattered or confluent, spherical, 500—700 μ, galls on the leaves and stems of *Hibiscus esculentus* at Agra. In CMI specimen 53271 small galls are present and form an almost uniform brown scarf over the surface of the leaf. Fixed and stained sections of the leaf contain uniformly stained bodies in the galls which are quite unlike resting spores of *Synchytrium*. On the basis of these observations, I concluded that *S. hibisci* was a doubtful or invalid species. However, in specimens received from Singha at Agra College the lower part of the stem is covered with large separate or confluent galls with bear 1 to 3 resting spores These spores range in size from 115 to 230 μ in diameter with a dark-amber wall, 3.8 to 4.6 μ thick, and yellow content. Gupta and Sinha, as noted above reported the wall to be 20 μ thick, but is is probable that they included the enveloping reddish-brown residue in their measurements.

Synchytrium travancorieum.

This name relates to a fungus which T. S. Ramakrishman collected on *Impatiens chinensis* and deposited as type specimen 23860 in the Herbarium Cryptogamiae Indae Orientalis. So far as I know it as not been diagnosed, but from study of a portion of this material I am certain that it is a species of *Synchytrium*. A few sporangial galls with empty prosori, sori and sporangia were present in addition to resting-spore galls and resting spores. On the basis of the meager information at hand I am offering the following description, realizing fully that it will have to be emended considerably as more data are obtained.

Prosori usually solitary, subspherical, 60—114 μ, with amber walls, 2—2.8 μ thick, collapsing and lying in base of infected cell when empty. Sori spherical to subspherical, 72—130 μ, ovoid or flattened on lower surface. Sporangia, 110—160 per sorus, polyhedral, 20—30 μ. Planospores unknown. Resting spores solitary, subspherical, 54—72 μ, to ovoid, 60—80×72—96 μ, with a dark-amber wall 3.6—4.2 μ thick; residue sparse or usually lacking; germination unknown.

Compositely dihomeogallic, galls scattered on leaves or aggregated along midrib, frequently confluent and sometimes compound. Sporangial galls lowly mound-shaped, 220—260 μ broad by 80—150 μ high; sheath 1—3 cells thick. Resting spore galls small, low, 170—208 μ broad by 78—130 μ high; sheath 1—2 cells thick; sheath cellwalls usually thickened and lignified.

Type spec. 23860, HCIO, New Delhi.

On leaves petioles and stems of *Impatiens chinensis*, Kohayan, T. C. State, India.

Obviously this is a long-cycled species which probably belongs in the subgenus *Microsynchytrium*, but I hesitate to diagnose it as a new species on the grounds that only a small amount of material was available for study. The only other species known to occur on *Impatiens* in nature is *S. impatientis* Cook (1951), a parasite of *I. biflora* in Louisiana, U.S.A. which I (1955) found to be long-cycled. In general it is considerably larger than *S. travancorieum* so far as the latter is known, but further studies may possibly prove them to be identical or closely related.

The life cycles of other Indian species, *S. ajarekari*, *S. melongenae (S. akshaiberi)*, *S. biophytii*, *S. cassiae*, *S. cookii*, *S. crustaceum*, *S. maculans*, *S. meliloti*, *S. millingtonicolum*, *S. minutum*, *S. nyctanthidis*, *S. oroxyli*, *S. phyllanthi*, *S. rhynchosiae*, *S. thirumalachari*, *S. trichodesmatis*, and *S. zorniae*, are now fully known from Lingappa's (1952, 1953, 1955a, 1955b, 1955c) excellent supplementary studies and need not be discussed further. I have examined the types of his species (HCIO) as well as his prepared slides of them and can confirm his observations. Other species such as *S. ampelocissi*, *S. anemones*, *S. biophytum*, S. *celosiae*, *S. cessampelum*, *S. cymopsae*, *S. desmodicolum*, *S. gei*, *S. micranthum*, *S. phaseoli-radiati*, *S. physalidis*, *S. phyllanthicolum*, and *S. stereospermi* are incompletely known and will require additional intensive study before their relationships and classifications are fully understood.

Possibly *S. akshaiberi* is the sorus and sporangial stages of *S. melongenae*, and *S. biophytum* and *S. phyllanthicolum* may prove to be the resting spore stages of *S. biophyti* and *S. phyllanthi*, respectively.

The short-cycled species which form only resting spores and parasitize *Phaseolus* and other legumes have been subject to considerable disagreement among Indian mycologists. *Synchytrium indicum* (*S. phaseoli* Patel et al.) on *Phaseolus mungo* is a doubtful species, as will be indicated further on. In 1951 Gupta and Sinha created *S. phaseoli-radiati* for a fungus which they found on *Phaseolus radiatus*, *P. mungo*, *Cajanus cajan* and *Crotalaria junceae* because it appeared to be quite different from *S. indicum*. In the same year Pajak established *S. ajrekari* for a parasite on *P. mungo*. *Synchytrium phaseoli-radiati* is reported to have resting spores 165—200 μ in diameter with an epispore 13—16.5 μ thick, which are borne in single, rarely compound cupulate, sherical galls, 400 to 600 μ in diameter. *Synchytrium ajrekari*, on the other hand, is described as having resting spores 114— to 270 μ in diameter with a wall, 8—11.5 μ thick. Safeeula and Govindu (1952), apparently without studying Gupta and Sinha's material, maintained that *S. phaseoli-radiati* is identical with *S. ajrekari* and, therefore, a synonym of it. In studying

Gupta and Sinha's material (CMI, 253266) of *S. phaseoli-radiati* I found the galls to be unicellular or simple, and rarely composite. In *S. ajrekari*, on the other hand, Lingappa (1952) figured the galls as being composite on *P. mungo*, and I have confirmed his observations from a study of his material. Similar galls are present in specimens of *S. ajrekari* collected by Payak on *P. radiatus* at Poona (HCIO, 19810) and by Pargi (HCIO, 20114) at Banaras. However, the specimens (HCIO, 20017) collected by Sinha and Gupta (August 22, 1948) at Agra on *P. radiatus* and labeled *S. ajrekari* is not a *Synchytrium* species. The large, light-amber bodies in the galls are probably the eggs of an insect or microscopic animal. Similar galls and bodies were found in another collection of *P. radiatus* made by Sinha and Gupta on September 12, 1948 at Agra which Sinha kindly sent me. From examination of these specimens it appears that *S. ajrekari* will infect *P. radiatus* as well as *P. mungo*, and that it differs from *S. phaseoli-radiati* by the reaction it induces in the same host, *P. mungo*. Obviously, more intensive study of living as well as fixed and stained sections of these two species is essential before their exact identity and relationships are fully known.

So far only six representatives of the subgenus *Woroninella* have been reported from India — *S. atylosiae*, *S. dolichi*, *S. decipiens (S. aecidioides)*, *S. minutum (S. puerariae)*, and *S. umbilicytum*. *Synchytrium cajani* in herb (HCIO, 20089) is a questionable species and is probably identical with *S. umbilicatum*. The latter species was described as *Aecidium umbilicata* by Berkeley and Broome (1875) on *Phaseolus grahamianus*. Petch (1909) described it as *A. cajani* on *Cajanus cajan* and later (1918) on as *Woroninella umbilicata*. In 1950 Petch and Bisby stated that the same species apparently occurs on *Phaseolus calcarius*, *Cajanus cajan*, *Atylosia rugosa*, *A. condollei*, *Dunbaria heynei*, *Crotalaria walkeri*, and *Glycine javanica*. In 1954 *Ramakrishnan* and *Sundaram* reported it as *Woroninella umbilicata* on *Cajanus cajan* at Cinchona (Anamalais) in India. However, their herbarium specimen is labeled *S. cajani* (type 20889, HCIO). The fungi reported by Petch (1909) and Petch and Bisby on *Atylosia condollei* and *A. rugosa* apparently are *S. atylosiae*, as Gäumann (1927) has indicated. Whether or not the fungi on the other hosts are one species remains to be proven, in my opinion. Ramakrishnan and Sundaram noted that the sporangia of their species were bright orange in contrast to the hyaline sporangia previously reported for *S. umbilicatum*, and this is probably the reason why they labeled their specimens *S. cajani*. I have studied their type material and can confirm their observations on the size and shape of the sori and sporangia. However, the sporangia are hyaline, which shows that in the six years since the material was collected they have lost their bright orange color.

Synchytrium atylosiae, *S. decipiens*, *S. dolichi* and *S. minutum* are well known, and I have confirmed the identifications by a study of the specimens in the Herbarium Cryptogamiae Indae Orientalis and the Commonwealth Mycological Institute. I have some reservations, however, regarding the Ramakrishnan's identification (1950) of *S. crotalariae*. They described the sporangia as being slightly larger, 17—20×34 μ, than those of other Indian *Woroninella* species, but these differences are not great enough to justify the creation of a new species. *Synchytrium umbilicatum* parasitizes *Crotalaria* also, and Ramakrishnan's species may prove to be identical with it.

Woroninella species are quite common on legumes in tropical and subtropical countries, and are very similar in development and morphology. Therefore, to identify them more sharply, host range experiments must be made with each species to supplement studies on the morphological variations which they exhibit on the same and different hosts. My study (1954) of *S. decipiens, (S. aecidioides)* produced unexpected results when attempts were made to grow it on a large number of different legumes.

Doubtful Species

Additional species to those mentioned above have been reported from India, but a study of specimens of these in the Herbarium Cryptogamiae Indiae Orientalis and the Commonwealth Mycological Institute has shown that they are doubtful or invalid species. These are described below.

S. piperi Mhatre and Mundkur, 1945. Lloydia 8: 136.

This species was created for what Mhatre and Mundkur believed to be *Synchytrium* species in the leaves of *Piper betle* which had been collected by B. R. Topany (May 24, 1921) at Alibog, Bombay. They described the galls as minute white dots, somewhat deep-seated in the leaves, which bear a single, spherical, 30—38 μ, smooth, thin-walled, light brown resting spore. I observed these dots in a portion of the type (HCIO, 10366), and other material (HCIO, 22681), but found nothing that resembles the resting spores of *Synchytrium*. Deep-seated and fairly uniformly distributed, thin-walled, amber bodies are present throughout the leaves in fixed and stained sections of these specimens, but they do not relate to *Synchytrium*. Also, in fixed and stained sections of *S. piperi* collected by M. I. Thirumalachar at Bangalore (January 26, 1946) and sent to the herbarium of the University of Wisconsin, I found similar bodies throughout the leaves. If the specimens which I have studied are representative, I do not believe *S. piperi* is a species of *Synchytrium*.

S. indicum (Patel et al.) Karling, 1953. Mycologia 45: 282.

S. phaseoli Patel, Kulkarnia and Dhande, 1949. Current Sci. 18: 342.

This fungus was described as a short-cycled species, *S. phaseoli*, on *Phaseolus mungo* at Poona, but inasmuch as its specific name had been preempted by Weston's (1934) *S. phaseoli*, I renamed it *S. indicum*. Patel et al. described the resting spores as unusually small, spherical, 18—26.6 μ, to slightly ellipsoidal with a thick, smooth, brown wall. No galls *per se* were present on the host, but the leaves were covered on both sides with quadrilateral to polygonal crusts, 1×1—2 mm in diameter. Payak (1951) examined the material collected by Patel et al. and found that the so-called sporangia in the intercellular spaces of the mesophyll were similar to the oospores of downy mildews. Accordingly, he questioned the validity of this fungus as a member of *Synchytrium*. Lingappa (1952) also examined the herbarium specimens at the Agricultural College at Poona and found no trace of the fungus. In view of the small size of the resting spores reported by Patel et al. and the observations of Payak and Lingappa I do not think this is a species of *Synchytrium*. However, I have not been able to secure specimens for study.

S. borreriae Lacy, 1950. Indian Phytopath. 3: 159.

The resting spores of this species on *Borreria hispida* has been shown by Lingappa (1956) to be the cysts of an endophytic alga.

S. khandalensis Payak and Thirumalachar, 1956. Sydowia 10: 38.

This species was described as having globose, ovate to spherical resting spore, 110—175 μ in diameter, with a reticulate or areolate exospore, 7.1—15 μ thick. These are borne in glistening, lemon-yellow to brownish composite galls on both surfaces of the leaves of *Blepharis asperrima* and *Asystasia dalzelliona* at Khandula, Bombay. Previously, Payak (1953) listed two species, *S. asytasiae* and *S. khandalensis* for this organism, but as indicated above he and Thirumalachar merged them.

In the type material (HCIO, 26540) on *B. asperrima* and the specimen (HCIO, 26541) on *A. dalzelliana* I found that the reticulate or areolate bodies described above are not resting spores of *Synchytrium*. They occur singly in small galls or in groups of large protruding galls, and each is surrounded by a hyaline envelope. They are predominantly pyriform with a blunt peg at one end, but may be ovoid to elongate also. The wall is unusaully thick and sculptured by regular or irregular polygons. The points of convergence of the polygons may protrude outward as blunt spines over the periphery. The content of these bodies is markedly different from that of *Synchytrium* resting spores, and I believe they may be the eggs or cysts of an insect or possibly cysts of an alga.

Key to Indian species

The known Indian species which I regard at present to be valid may be classified in various subgenera according to the following

key. In the list of species presented below in the subgenera, those in parentheses are regarded as possible synonyms of the immediately preceding ones.

A. Long-cycled; life cycle including summer sporangial sori and resting spores.

1. Mature initial cell or thallus functioning as a prosorus; contents emerging to form a thin-walled vesicle which cleaves into sporangia and becomes a sorus within the infected cell.

a. Resting spore functioning as a prosorus in germination; contents emerging to form a thin-walled superficial sorus which cleaves into sporangia.

Subgenus *Microsynchytrium*

Synchytrium melongenae (S. akshaiberi), S. biophyti, S. cassiae, S. collapsum, S. cookii (S. alysicarpi), S. crustaceum, S. lagenariae, S. launae, S. lepidagathidis, S. maculans, S. nyctanthidis, S. oldenlandiae, S. oroxyli, S. phyllanthi, S. rytzii, S. sesamicola (S. sesami), S. trichodesmatis, S. trichsanthidis, and *S. zorniae.* Resting spore germination has not been observed in *S. micranthum, S. stereospermi,* and *S. travancorieum,* but these species will probably prove to be species of this subgenus when they are fully known.

b. Resting spore functioning as a sporangium in germination and forming planospores directly.

Subgenus *Mesochytrium*
Synchytrium endobioticum

2. Mature initial cell or thallus developing directly into a sorus of sporangia; sporangia delimited by cleavage within the sorus and freed by the rupture of its wall.

a. Resting spores functioning as sporangium in germination and giving rise directly to planospores.

Subgenus *Synchytrium (Eusynchytrium)*

(Unless *S. desmodicolum* belongs here, this subgenus is not represented in India so far as our knowledge goes.)

b. Resting spore functioning as a prosorus in germination; contents emerging to form a superficial vesicle or incipient sorus which cleaves into sporangia.

Subgenus *Exosynchytrium*

(This subgenus is not represented in India so far as our knowledge goes.)

B. Short-cycled, life cycle including only sporangial sori, or resting spores.

1. Only resting spores known.
   a. Resting spore functioning as a prosorus in germination.

Subgenus *Pycnochytrium*

Synchytrium ajrekari, *S. meliloti*, *S. millingtonicolum*, *S. rhinchosiae*, *S. thirumalachari*, and *S. viticola*. Resting spore germination has not been observed in *S. ampelocissi*, *S. anemones*, *S. biophytum*, *S. celosiae*, *S. cessampelum*, *S. cymopsae*, *S. gei*, *S. phaseoli-radiati*, *S. physalidis*, and *S. phyllanthicolum*, but they will probably prove to be members of this subgenus when they are fully known.

2. Only sporangial sori and sporangia known.
   a. Mature initial cell or thallus developing directly into a sorus of sporangia. Sporangia delimited by cleavage within the incipient sorus; freed by rupture of sorus wall and appearing as powdery masses in open aecidium-like pustules.

Subgenus *Woroninella*

Synchytrium alytosiae, *S. crotalariae*, *S. decipiens (S. aecidioides)*, *S. dolichi*, *S. minutum (S. puerariae)*, and *S. umbilicatum (S. cajani)*.

Summary.

1. Species of *Synchytrium* are abundant in India, and up to the present time fifty-nine species have been reported from that country. However, a study of the types and other specimens has shown that several of these are identical, or not fully known, and require further intensive study. Several others have been found to be invalid.
2. *Synchytrium rytzii*, *S. collapsum*, *S. lepidagathidis*, *S. lagenariae*, *S. trichosanthidis*, *S. sesamicola*, *S. micrantum* and *S. fuscum* (*S. emiliae*) were found to be long-cycled, and belong, thus, in the subgenus *Microsynchytrium*.
3. *Synchytrium luffae*, *S. cucumis-sativa* and *S. fistulosa* in herb. (HCIO) appear to be identical with *S. lagenariae*. *Synchytrium sesami*, *S. alysicarpi*, *S. akshaiberi*, *S. biophytum*, and *S. phyllanthicolum* appear to be identical with *S. sesamicola*, *S. cookii*, *S. melongenae*, *S. biophytii*, and *S. phyllanthi*, respectively.
4. Species previously identified as *S. vulgatum* have been found to be long-cycled and identical with *S. launeae*.
5. *Synchytrium indicum* (*S. phseoli*), *S. khandalensis*, *S. borrariae* and *S. piperi* are invalid.
6. On the basis of their life cycles and development the known valid species may be classified provisionally in five subgenera:
   Microsynchytrium, *Mesochytrium*, *Synchytrium* (*Eusynchytrium*), *Pycnochytrium* and *Woroninella*.

Bibliography.

Berkeley, M. J. and C. E. Broome. 1875. Enumeration of the fungi of Ceylon. Jour. Linn. Soc. 14: 29—140.

Butler, E. J. and G. R. Bisby. 1931. The fungi of India. Sci Monogr. Coun. Agric. Res. India 1: 1—237.

Cook, M. T. 1951. Species of *Synchytrium* in Louisiana VI. Two new species on *Impatiens* and *Smilax*. Mycologia **42**: 103—107.
Gäumann, E. 1927. Mykologische Mitteilungen III. Ann. Mycol. **25**: 165—177.
Gupta, S. C. and S. Sinha. 1951. Further additions to the Synchytria of India. Indian Phytopath. **4**: 7—10.
— 1955. Two new species of *Synchytrium*. Indian Phytopath. **8**: 78.
Karling, J. S. 1953. *Micromyces* and *Synchytrium*. Mycologia 45: 276—287.
— 1954. Host range of *Synchytrium aecidioides*. Sydowia **9**: 441—447.
— 1955a. Additional species of *Synchytrium* with prosori. Bull. Torrey Bot. Club **82**: 446—462.
— 1955b. Host range of *Synchytrium australe*. Sydowia **9**: 441—447.
— 1957. *Synchytrium cinnamomeum*. Bull. Torrey Bot. Club **84**: 237—242.
— 1960. Inoculation experiments with *Synchytrium macrosporum*. Sydowia **14**: 138—169.
Lacy, R. C. 1950. Studies on some Indian Synchytria I. Four new species from Bihar. Indian Phytopath. **3**: 155—161.
Lingappa, B. T. 1952. Contributions to the knowledge of the Indian species of the genus *Synchytrium* DeBary et Woronin. Thesis. M. S., Coll. of Agric., Banaras Hindu Univ. pp. 1—123, pls. I—XXII, figs. 1—35.
— 1953. Some new species of *Synchytrium* from Banaras. Mycologia **45**: 288—295.
— 1955a. Some new Indian species of *Synchytrium*. Lloydia **18**: 129—142.
— 1955b. Resting spore germination in *Synchytrium* in relation to classification. Amer. Jour. Bot. **42**: 841—850.
— 1955c. Occurrence of *Synchytrium minutum* in India. Current Sci. **24**: 271—272.
— 1956. *Synchytrium borreriae*, an endophytic alga. Mycologia **48**: 427—432.
Mhatre, J. R. and B. B. Mundkur. 1945. The *Synchytria* of India. Lloydia **8**: 131—138.
Mishra, J. N. 1953a. An undescribed species of *Synchytrium* on *Ampelocissus latifolia*. Current Sci. **22**: 152.
— 1953b. Three new species of *Synchytrium* from Bihar. Proc. Bihar Acad. Sci. **2**: 55—61.
Patel, M. K., Y. S. Kulkarnia and G. W. Dhande. 1949. A new *Synchytrium* on *Phaseolus mungo*. Current Sci. **18**: 171.
Payak, M. M. 1951. A *Synchytrium* disease of udid beans. Current Sci. **29**: 193—194.
— 1953. Some records of fungi from Bombay State. Sci. and Culture **18**: 342—343.
— and M. J. Thirumalachar. 1956. Notes on some fungi collected in Bombay State (India). Sydowia **10**: 38—40.
Petch, T. 1909. New Ceylon fungi. Ann. Roy. Bot. Gard. Peradeniya **4**: 299—307.
— 1918. Additions to Ceylon fungi. Trop. Agric. **1**: 162.
— and G. R. Bisby. 1950. The fungi of Ceylon. Peradeniya manual no. VI. Ceylon Govt. Press, pp. 1—111.
Ramakrishnan, T. S. and K. Ramakrishnan. 1950. Additions to the fungi of Madras — VII. Proc. Ind. Acad. Sci. Sect. B, **22**: 67—79.
— and N. U. Sundaram. 1953. Additions to the fungi of Madras-XV. Proc. Ind. Acad. Sci. Sect. B, **35**: 187—194.
— 1954a. Additions to the fungi of Madras-XVI. Proc. Ind. Acad. Sci. Sect. B, **40**: 17—23.
— 1954b. Notes on some fungi from South India-III. Indian Phytopath. **7**: 61—67.
— 1954c. Notes on some fungi from South India-IV. Indian Phytopath. **7**: 140—151.

Rytz, W. 1907. Beiträge zur Kenntnis der Gattung *Synchytrium*. Centralbl. Bakt. Parasitenk. u. Infekt. II, **18**: 635—655, 799—825.

Safeeula, K. M. and H. C. Govindu. 1952. Notes on two *Synchytrium* species. Current Sci. **21**: 319—320.

Singh, G. P. 1954. Two species of *Synchytrium* from Bihar. Current Sci. **23**: 369.

Sydow, H. 1914. Beiträge zur Kenntnis der Pilzflora des Südlichen Ostindiens-II, Ann. Mycol. **12**: 484—490.

— and E. J. Butler. 1907. Fungi Indae orientalis, pars II. Ann. Mycol. **5**: 485—515.

— 1912. Fungi Indae orientalis. Ann. Mycol. **10**: 243—480.

Weston, W. H. 1930. *Phycomycetes*. In Chardon and Toro, Mycological explorations of Columbia. Jour. Dept. Agric. Puerto Rico **14**: 315—225.