VII. *On the Life-History of Puccinia Jasmini-Chrysopogonis, nov. sp.*
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(Plate LVI. figs. 14-23.)

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IN a recent paper on the life-history of an æcidium on *Jasminum grandiflorum* I alluded to the existence of an æcidium on another species of Jasmine, namely *J. humile*, L., and drew attention to the remarkable attitude of our three Jasmines towards the Uredineæ. Whilst *J. grandiflorum*, L., alone of these will harbour *Uromyces Cunninghamianus*, *J. humile* only will bear the æcidium I am about to describe, and *J. officinale*, L., will not suffer itself to be attacked by either. And again, while the æcidium on *J. grandiflorum* is an autœcious species, that on *J. humile* is heterœcious, the other host being a grass, *Chrysopogon Gryllus*, L. The parasite on *J. grandiflorum* exhibited several very anomalous peculiarities, but the only feature of peculiar interest in the species I am about to describe is the extraordinary abundance and wide distribution of the teleutosporic stage as compared with the comparative scarcity of the æcidial stage. This disproportion in the distribution of the two stages I noted in my Descriptive List of the Simla Uredineæ*, long before I knew that they were related to one another. And, indeed, this peculiarity misled me in my long-continued attempt to discover the life-history of the æcidium, for so abundantly distributed a teleutospore I felt sure must be related to one of our more abundant æcidia. I was at last led to suspect the relationship, with, however, little hope that the suspicion was well founded, by observing last autumn that the grass was largely attacked close to a bush of Jasmine which I had previously noticed had been unusually largely attacked by the æcidium. Before, however, going on to a description of the experiments I made to establish the relationship I will shortly describe the systematic characters of the fungus.

ÆCIDIAL STAGE.

This stage of the parasite makes its appearance at the commencement of July, shortly after the monsoon rains have set in, *i.e.* during very moist weather, and continues to be met with throughout July and August. The æcidium is very conspicuous (Pl. LVI. fig. 14), the mycelium giving rise to large circular or irregularly circular patches on the leaf-blades, usually about 8 millim. to 1 centim. in diameter, reddish brown with a halo of yellow above, and the same below before the æcidia have made their appearance,

* *Æcidium Jasmini*, in Journal of Asiatic Society of Bengal, vol. lvi. pt. ii. no. 3, 1887, p. 366; and *Puccinia Chrysopogi*, in the same Journal, vol. lviii. pt. ii. no. 2, 1889, p. 247.

but a little lighter in colour, especially the yellow halo. These attacked areas of the leaf-blade are somewhat thickened. The petioles are also frequently attacked, when they become brown in colour and thickened. The stem is sometimes, but not often, attacked. In this case the whole stem is uniformly enlarged; and the largest stem-hypertrophy I saw was 1.5 centim. in length by 4 millim. in diameter.

The *spermogonia* are of the usual character, but sometimes irregular in shape (fig. 23), and are formed only on the upper leaf-surface. They precede the eruption of the *æcidia* by a very short interval; and, indeed, I have often seen ripe spermogonia on the upper leaf-surface whilst the lower surface bore young, still unopened peridia. They are deeply set, their bases reaching down to the inner level of the palisade-cells. They measure about $126\ \mu$ in depth by $157\ \mu$ in breadth, and have a tuft of paraphyses protruding about $63\ \mu$ from the mouth.

The *æcidia* burst always from under a leaf-surface. They contain very brilliant orange-red spores, and are deeply sunk within the laminal tissue, their bases resting often on the inner ends of the palisade-cells (Pl. LVI. fig. 22).

The *peridia* are very short tubes, densely packed together, bursting at the summits in a stellate manner. The tube consists of a single layer of flat cells, more or less hexagonal, and measuring about $26 \times 22\ \mu$ (Pl. LVI. figs. 19 & 20, *b*). These cells are thick-walled, and contain orange-red oil-globules in their cavities. They are arranged in an imbricate fashion, the upper end of each cell overlapping the lower end of the cell above *internally* (Pl. LVI. fig. 22).

The *mycelium* is colourless and ramifies between the parenchyma-cells. The hyphæ are remarkably straight, and not so convoluted as usual. In the leaf-blade they are most numerous among the spongy cells, but twigs run up also between the palisade-cells to the upper epidermis-cells; and haustoria, in the shape of simple small tubular intrusions, are formed abundantly in the palisade- and upper epidermis-cells. The mycelium gives rise to hypertrophy of the spongy cells; but the palisade-cells retain their normal proportions and shape. In the stem mycelial filaments may be seen everywhere, but sparingly in the central pith-cells: here the mycelium is most abundant in the cortical parenchyma-cells, which are very considerably hypertrophied. Haustoria similar to those described above are met with in these cells.

The *æcidiospores* are of a very brilliant orange-red colour, oval, covered externally with shallow tubercles, and measure when fresh $26 \times 20.2\ \mu$ on an average (Pl. LVI. fig. 20, *a*). They do not germinate readily in water, but when they do they throw out straight unbranched tubes with a decided tendency to spring up into the air instead of into the water. Into these tubes the brilliantly coloured contents of the spore wander. Each spore has from 7 to 8 germ-pores. The spores are turned deep blue by sulphuric acid.

TELEUTOSPORIC STAGE.

Uredospore pustules appear in July, when the *æcidial* stage is in existence. They are very brilliantly orange-red, mostly epiphyllous, but largely also hypophyllous. Pustules primarily break out from the upper leaf-surface, but afterwards the same mycelium produces pustules below also. They are round or slightly oval, and very numerous.

The spores are, like the æcidiospores, very brilliant in colour (orange-red). They do not germinate readily in water, but some always do, throwing out a single, long, twisted unbranched tube. They are also very large, measuring when fresh $33-23 \times 26-23 \mu$, or on an average $28.7 \times 26.5 \mu$. When scraped off they often retain a portion of the stalk (Pl. LVI. fig. 21). They are sparsely spiny and contain an indefinite number of germ-pores. There are no paraphyses.

The *teleutospore* pustules are well raised, deeply convex, plump, oval or broadly linear, and dark brown. They are both epi- and hypophyllous, but oftener epiphyllous. The spores are oval, and well rounded at both ends, slightly constricted at the septum, and very thick-walled (fig. 15). There is little or no special thickening at the free end. They are firmly adherent, and when scraped off retain a portion of stalk. They are dark brown, smooth on the surface, and measure $43 \times 24 \mu$ at the septum. A clear nuclear vesicle is visible in each cell. Young teleutospores are often seen in fully developed uredo pustules. They germinate only after a winter rest. After lying 24 hours in water it will be seen that they have thrown out promycelia—one from a point near the apex of the spore, and the other from a point near the septum (Pl. LVI. fig. 15), into the distal ends of which the orange-red contents of the spore wander, leaving the spore-walls still deep brown. The end then divides into four compartments, each producing a sporidium at the end of a short pointed sterigma (Pl. LVI. fig. 16). But frequently and very characteristically, after the promycelium has divided into four parts, the sterigmata form uncommonly long tubes, usually much twisted (Pl. LVI. fig. 18, *a, b*). In such cases they do not form sporidia. I do not know whether a similar growth occurs in nature, but if it does the sterigmatous tube must attack directly without the intervention of a sporidium. This curiously abnormal formation of sterigmata is by no means uncommon, and, indeed, in water-cultivations it is as common as the more normal course sketched above. The sporidium is large, oval, and coloured, and frequently emits a germ-tube before it is detached from the sterigma. The germ-tube is usually characteristically spiral, and rarely straight (Pl. LVI. fig. 16). Very frequently, instead of a regular germ-tube being emitted, the sporidium immediately forms a secondary sporidium (Pl. LVI. fig. 17). The primary sporidium measures $14 \times 12 \mu$, and the secondary about two-thirds this.

I now proceed to describe some of the experiments I made to establish the connection between these two phases of the life-history of the parasite.

I. A. A twig was inoculated on the 7th May with sporidia of teleutospores from *Chrysopogon*, freshly collected and had lain 24 hours in water. On the 20th (13 days) small points of attack were noticed, and on one leaf three groups of spermogonia on three separate areas of invasion.

I. B. Another twig of the same branch was inoculated the same day with the sporidia of *Puccinia Caricis-filicinæ*; but this twig remained perfectly free from attack.

The whole branch began to wither on the 27th without twig I. A making any further progress, and the experiment came to an end.

II. On the 8th May some leaves were inoculated with the sporidia of *Puccinia coronata* (from *Piptatherum holciforme*, Roem. & Schult.). On the 20th (12 days) I noticed a single spermogonial patch on one leaf. But as on that date I had obtained clear proof from Experiment I. A that *Puccinia Chrysopogonis* was the related teleutospore, I attributed the single spot of attack to the accidental contamination of my inoculating material, and re-inoculated the leaves with the sporidia of *P. Chrysopogonis*, again freshly gathered and placed in water 24 hours previously. On the 30th (10 days) several distinct spots of attack were observed, and 8 leaves (other than that accidentally inoculated) presented small orange-yellow spermogonial spots, some leaves with 2 to 4 such distinct spots. On the following day (31st) I carefully counted the leaves of the twig. It had 66 leaves in all, 13 of which bore spermogonial patches; 9 of these latter bore each a single spot of attack, whilst 4 bore from 2 to 4 distinct spots each. On the 6th June I counted 20 spots of distinct attack on 15 leaves, some very large and typically brilliant in colour. On the 26th June most patches bore open ripe æcidia.

III. On the 23rd May I inoculated a twig with sporidia derived from teleutospores gathered on the 11th February and kept in my laboratory since. The spores had lain 24 hours in water, and had produced an immense number of sporidia. On the 30th (7 days) I noticed several spots of initial attack, *i. e.* characteristic points of upheaval, and one spermogonial patch. On the 1st June this twig, which bore in all 90 leaves, showed 13 leaves with spermogonial patches. On the 6th June I counted 15 spermogonial spots on 9 leaves (the other 4 had dropped). On the 19th some well-developed young æcidia were noticed, but the twig thereafter withered, and the experiment was closed on the 21st.

IV. On the same date, viz. 23rd May, another twig was inoculated with the same material, and kept under a separate shade. Four leaves were found very distinctly attacked on the 1st June (9 days); on the 6th I counted 36 spots on 17 leaves; on the 19th many leaves bore young, well-developed æcidia.

V. On the 23rd June I inoculated another twig with sporidia derived from the spores of *P. Chrysopogonis*, freshly gathered, which had lain 24 hours in water. On the 27th, when I left Simla for three days, there was no sign whatever of attack; but on my return on the 30th (7 days) I found the leaves extensively attacked in the spermogonial stage; 13 leaves were so attacked, with brilliant yellow spots, and on one leaf I counted 12 distinct foci of attack. On the 7th July I counted the leaves again carefully. One branch of the twig had 32 leaves, of which 16 were conspicuously attacked; the other branch had 38 leaves, of which 20 were attacked. Thus 36 of 70 leaves were attacked, and many in several places. Most of the leaves which escaped attack were the lower older ones.

VI. I made only one experiment in the reverse direction, namely the production of uredospore pustules with æcidiospores; but this was so successful that, taken with the evidence afforded by the preceding experiments, no others were at all necessary. I uprooted a healthy plant of *Chrysopogon* which I found, and put it into a pot in a gardener's box in my verandah. It remained there perfectly healthy for about three

weeks. I then gathered some twigs of Jasmine bearing numerous ripe æcidia, and laid these over the grass. In about ten days most leaves bore the very characteristically brilliant uredospore pustules, which I have already described.

These experiments conclusively prove the genetic relationship between the æcidium and the *Puccinia*. The accidental contamination noted in Experiment II., designed to test the possible connection with *P. coronata*, is interesting in showing that even in such inoculations misleading results may easily be obtained, and that a single successful inoculation is by no means sufficient to establish relationship. Although I had no doubt that the result was due to accident, I nevertheless re-applied the sporidia of *P. coronata* (from *Piptatherum holciforme*) with great care to another twig of Jasmine, but without any result. With regard to control experiment, I may note that all nature acted as a control over my results. The season during which my positive results on Jasmine were obtained was much too dry to allow of natural attack to take place. I did not find any æcidium on Jasmine naturally until the beginning of July, and then only in the spermogonial stage, when all my experiments had been concluded. Experiment I. A and the first stage of Experiment II. may, however, be regarded as control experiments.

I propose naming this fungus *Puccinia Jasmini-Chrysopogonis*. The use of a compound specific name in the case of *heteræcious* species is, I think, so distinctly advantageous that it may be allowed to outweigh the general objection taken to such names in botanical nomenclature.

PUCCINIA JASMINI-CHRYSOPOGONIS, n. sp.; spermogoniis profunde immersis enormibus 126 μ longis 157 μ latis, paraphysibus ex ore 63 μ projectis; æcidiis immersis maculas orbiculares vel irregulariter orbiculares diametro 8 mm.-1 cm., rubro-brunneas margine flavas efformantibus; pseudoperidiis cylindraceis, brevibus, dense aggregatis, apice stellatim erumpentibus, ex cellulis hexagoniis membranis crassis globulos oleaceos rubro-aurantiacos gerentibus, circa 26 $\times$ 22 μ diam. compositis; æcidiosporis eximie rubro-aurantiacis ovalibus, tuberculatis, 26 $\times$ 20.2 μ diam., 7-8 poros gerentibus; uredosporis in soros orbiculares vel ovaes congestis, rubro-aurantiacis, 33-23 $\times$ 26-23 μ , sparsim spinosis aliquot poros gerentibus, pedicello persistenti, paraphysibus nullis; teleutosporis in soros ovaes vel late lineares fusco-brunneos congestis, ovalibus apice rotundatis ad septum constrictis, membranis crassis, levibus, 43 $\times$ 24 μ ad septum pedicello persistenti; sporidiis ovalibus prim. 14 $\times$ 12 μ , secund. aliquid minoribus.

DESCRIPTION OF PLATE LVI. FIGS. 14-23.

Fig. 14. From photograph, showing numerous æcidial patches. Natural size.

Fig. 15. Teleutospore, with lower ends of two promycelia, showing points of emergence from each cell. $\times 350$.

Fig. 16. Upper end of promycelium, showing sterigmata, and one sporidium still adherent. Also a detached sporidium, showing spiral germ-tube. $\times 350$.

Fig. 17. Sporidia forming secondary sporidia. $\times 350$.

Fig. 18. Abnormal, but common form of sterile sterigmata; *a*, young, *b*, older and convoluted. $\times 350$.

Fig. 19. Peridial cells in outline, seen flat. $\times 350$.

Fig. 20. *a*. Æcidiospore, $\times 350$. *b*. Detached peridial cells, $\times 350$.

Fig. 21. Uredospores. $\times 350$.

Fig. 22. Transverse section through æcidium. $\times 150$.

Fig. 23. Transverse section through spermogonium. $\times 150$.

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