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A STUDY OF THE SPECIES OF COLLETOTRICHUM CAUSING RIPE FRUIT ROTS IN QUEENSLAND

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SUMMARY

Seven species of *Colletotrichum* known to cause ripe fruit rots in Queensland are compared with respect to spore measurements, cultural characters, temperature reactions, and host range determined by field collection and artificial inoculation.

The characteristic features of these organisms are discussed and on the evidence available it is found desirable to designate a new form of *C. gloeosporioides* and one new species.

I. INTRODUCTION

The ripe fruit rots are a common source of loss in Queensland, especially in fruit of a tropical and subtropical nature. Of the pathogens associated, by far the most common are species of the genus *Colletotrichum*. Members of this group are particularly adapted to this form of activity. Their capacity for maintaining a saprophytic existence on dying host parts ensures an effective source of inoculum. In addition, by forming latent infections throughout the growing period of the fruit the parasite is rendered largely independent of environmental conditions at the time of ripening, not to mention the protection afforded from the action of fungicides.

A number of distinct species of *Colletotrichum* are associated with ripe fruit rots in Queensland and more than one species may be responsible for similar diseases on the one variety of fruit. The present paper is an attempt to place these species in their correct position and at the same time summarize their main characteristics. It is hoped that the information presented will assist future determinations and that the importance of individual diseases will be more clearly appreciated.

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Taxonomy within the genus *Colletotrichum* has long been in an unsatisfactory position and many poorly defined species exist. Arx (1957*a*, 1957*b*) attempted the difficult task of clarifying the position. While this work has brought about a very useful simplification and drawn attention to the need for a drastic reduction in the number of species, it is inevitable that within the synonyms listed by Arx there will be species or groups of species which on further investigation will be shown to merit separate status. This has been borne out in the present work, where use has been made of a previously described variety to designate one such group.

The following species are dealt with here: *Glomerella cingulata* (Stonem.) Spauld. & Schrenk, stat. conid. *Colletotrichum gloeosporioides* Penz.; *G. cingulata* var. *minor* Wr., stat. conid. *C. gloeosporioides* var. *minor* var. nov.; *C. musae* (Berk. & Curt.) Arx (*Gloeosporium musarum* Cke. & Mass.); *Colletotrichum atramentarium* (Berk. & Br.) Taubenh.; *C. dematium* (Pers. ex Fr.) Grove; *C. orbiculare* (Berk. & Mont.) Arx; *C. acutatum* sp. nov. With the introduction of a variety the original species *G. cingulata* should strictly be designated *G. cingulata* var. *cingulata*. However, in this paper reference to this species as originally understood has been made simply by the omission of a varietal name when confusion is unlikely to occur.

The characters used in describing these organisms are spore size, cultural type, temperature relationship and host range. Reference to some physiological reactions of a few species is given by Simmonds (1963) but no general comparisons have been made with respect to physiology.

II. COMPARISON OF SPECIES

(a) Spore Measurements

Imperfect stage.—For many species of *Colletotrichum*, reliance has to be placed on conidial measurements, the perfect stage occurring rarely or not at all. With spores as small and characterless as those of *Colletotrichum*, small differences, although valid, are often difficult to demonstrate, and because of individual variability, overlapping between species inevitably occurs.

As pointed out by Wollenweber and Hochapfel (1949), extreme values are of little use when comparing spore measurements of species of *Colletotrichum* unless accompanied by the mean, as the coverage is usually too broad for delimiting species. It is for this reason that many of the older descriptions are so difficult to interpret. In Table 1 extremes have been replaced by the range of mean values for different collections or isolations. These individual means are based on the measurement of 15 spores in each case.

TABLE 1

CONIDIAL MEASUREMENTS OF SEVEN SPECIES OF *Colletotrichum* AS THEY OCCUR IN QUEENSLAND

Species	No. of Collections or Cultures	Range of Means (μ)	General Mean (μ)	Description
C. gloeosporioides	36	11·9–17·0 x 3·6–5·8	13·8 x 4·8	A broad oblong spore with rounded ends
C. gloeosporioides var. *minor*	133	11·1–17·7 x 3·1–5·0	14·0 x 3·7	An oblong spore appreciably narrower than the above; end rounded, sometimes tapering towards one end
C. musae (From Simmonds & Mitchell 1940) .. Recent collections	8 8	12·2–14·6 x 4·9–5·8 11·5–14·0 x 4·0–5·1	.. 13·0 x 4·6	Somewhat shorter than *C. gloeosporioides*, with some spores tending to be oval rather than oblong
C. acutatum	35	8·3–14·4 x 2·5–4·0	11·1 x 3·1	Spores very variable in size; majority short, narrow, with pointed ends; some collections with more numerous long spores
C. orbiculare .. .. (setae)	22 (4)	10·0–13·5 x 3·1–4·5 (61·5–84·3 x 3·3–4·8)	11·7 x 3·7 (69·1 x 4·1)	A short oblong spore with rounded ends; resembles a small *C. gloeosporioides*
C. atramentarium	7	17·1–20·5 x 3·0–4·1	19·3 x 3·5	A long slender spore; ends slightly attenuated
C. dematium .. .. (setae)	10 (5)	19·1–26·4 x 2·6–3·3 (112–206 x 4·3–6·4)	21·7 x 2·8 (158 x 5·7)	A slender crescent shaped spore

The general shape of the spore is often sufficiently distinctive for specific recognition when familarity has been achieved, and the chief distinguishing features have accordingly been included in Table 1 and illustrated in Figure 1. Confusion can occur between the narrower strains of *C. gloeosporioides* and the broader strains of *C. gloeosporioides* var. *minor,* and consideration of cultural characters is sometimes necessary for definite placing. The restrictive host range of *C. musae* prevents confusion with the above two.

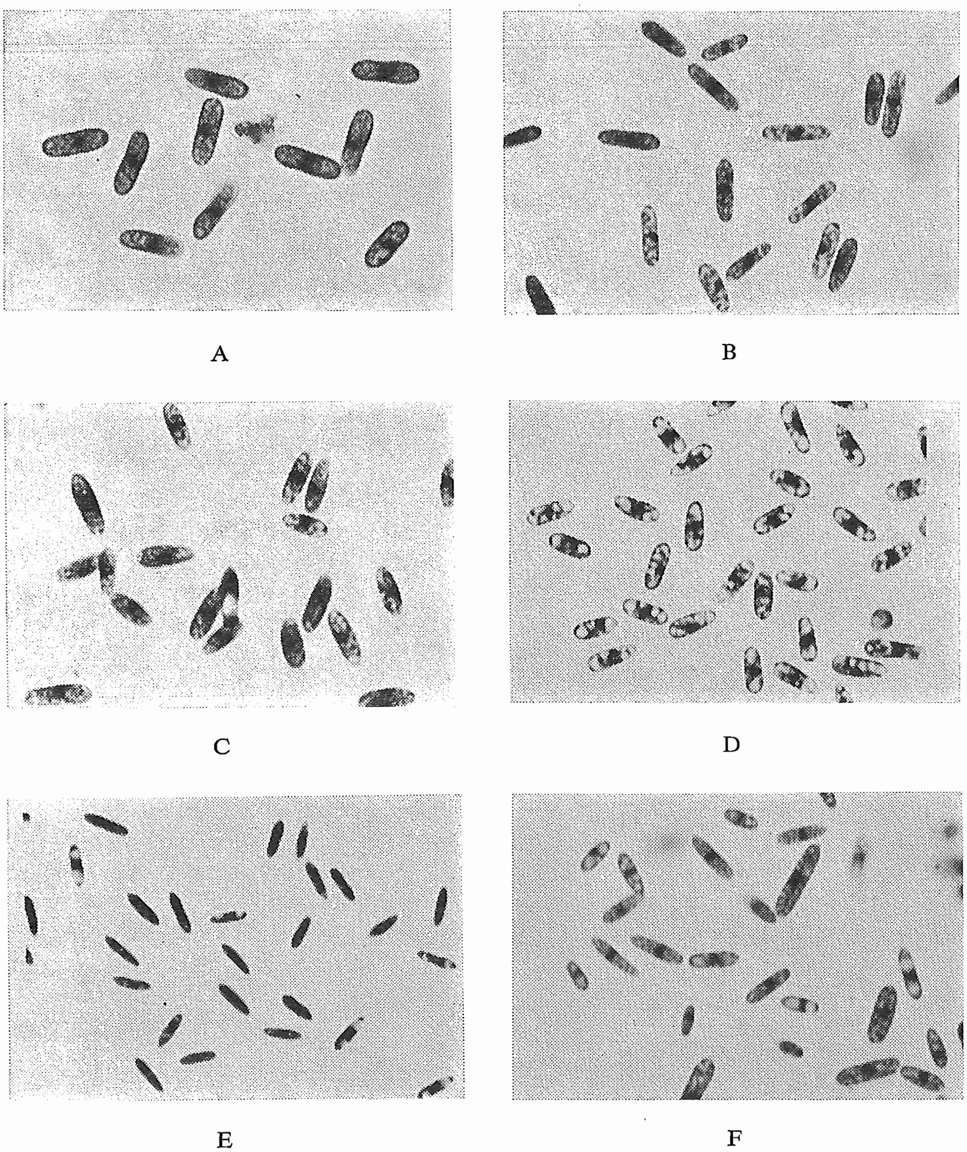


Fig. 1.—Conidia of *Colletotrichum* spp. (x 586). (A) *C. gloeosporioides;* (B) *C. gloeosporioides* var. *minor;* (C) *C. musae;* (D) *C. orbiculare;* (E) *C. acutatum* small-spored form; (F) *C. acutatum* larger spored form. (Photos. by William Manley.)

The spore measurements of the two varieties of *C. gloeosporioides* were investigated in some detail, since it was early considered from host range and cultural characters that these two forms must be distinct. Mean length and breadth of a number of collections and cultures were examined by the Chief Biometrician (Mr. P. B. McGovern), with the results summarized in Table 2. When assigning a particular spore collection to one or other of the two groups, cultural characters were taken as the final criterion. Unless the cultural grouping was definite, the particular collection was not included in the listings. Where spores were taken direct from fruit, the group was ascertained by culturing from the same spot.

TABLE 2

ANALYTICAL COMPARISON OF CONIDIAL MEASUREMENTS OF *Colletotrichum* SPP.

Organism	No. of Collections or Cultures	Mean Length (μ)	s.e. Means	Mean Breadth (μ)	s.e. Means
A. *C. gloeosporioides* . .	36	13·8	± 0·23	4·8	± 0·075
B. *C. gloeosporioides* var. *minor*	133	14·0	± 0·12	3·7	± 0·039
C. *C. acutatum*	30	11·1	± 0·26	3·1	± 0·082
		A, B > C (1% level)		A > B A, B > C (1% level)	

Perfect stage.—*Glomerella cingulata,* the perithecial stage of *C. gloeosporioides,* frequently occurs both on the host plant and in culture. On the papaw, lesions which will give rise to perithecial or conidial isolates respectively are often recognizable macroscopically. Perithecia of *G. cingulata* var. *minor* have been seen on rare occasions and then only in culture. The appearance of the ascospore of the two forms is very similar except for size. Typically, both ascospores are faintly brown with poorly staining contents. So far as possible, measurement was restricted to this type. Ascospore measurements are given in Table 3 and an analytical comparison in Table 4.

TABLE 3

ASCOSPORE MEASUREMENTS OF *Glomerella cingulata* AND *G. cingulata* VAR. *minor*

Organism	No. of Collections or Cultures	Range of Means (μ)	General Mean (μ)
G. cingulata	29	16·1–20·6 x 4·7–7·1	18·3 x 5·4
G. cingulata var. *minor*	25	13·5–16·8 x 3·5–4·9	15·6 x 4·2

TABLE 4

ANALYTICAL COMPARISON OF ASCOSPORE MEASUREMENTS OF *Glomerella cingulata* AND *G. cingulata* VAR. *minor*

Organism	No. of Collections or Cultures	Mean Length (μ)	Mean Breadth (μ)
G. cingulata	29	18·3	5·4
G. cingulata var. *minor*	25	15·6	4·2
Difference of means		2·7	1·2
s.e. of differences		$\pm$ 0·31 Significant at 1% level	$\pm$ 0·13 Significant at 1% level

Perithecia of the other species dealt with have not been observed in the course of this work and it is possible that perfect stages do not exist here.

(b) Cultural Characters

Practically all cultural work has been carried out with potato dextrose agar medium in petri dish culture. Various other media have been tried from time to time but these seemed to do little to reduce existing variation. Tube cultures are often unsatisfactory for observing essential differences. Cultural characters change considerably with time and subculturing and it is desirable to work with fresh isolates.

In the course of this work, hundreds of isolates have been examined. The majority conform to the characters of specific groups with sufficient constancy to enable them to be classified with reasonable accuracy. However, there is always the odd isolate difficult to place, and the absence of spore formation in many cases eliminates this means of checking identity. These unusual forms are not included in the descriptions which follow. Examination of isolates has been taking place at varying intervals over the past 15 years and it does appear that in the case of *C. gloeosporioides* and its variety *minor* certain periods have been characterized by the prevalence of a particular cultural type. It would be unwise therefore to state any one of these to be the normal form. Both these organisms are characteristically variable in cultural appearance and in this respect differ from the other fruit-rotting species dealt with here.

Glomerella cingulata, stat. conid. *Colletotrichum gloeosporioides*

G. cingulata var. *cingulata* is a fast-growing species. Perithecial, conidial and sterile cultures are obtained from field isolations.

Perithecial form.—Aerial mycelium is fine, white to light grey, of moderate elevation and somewhat sparse and open. The substrate is light cream with or without a grey or olive diffusion. A pinkish tinge may be present. Typically there are produced black glomerate perithecial bodies which stand up conspicuously from the surface and are not embedded in the mycelium as is the case with var. *minor*. Smaller, scattered, sooty perithecial elements may be present also. Mature ascospores are commonly available from these cultures (Figure 2).

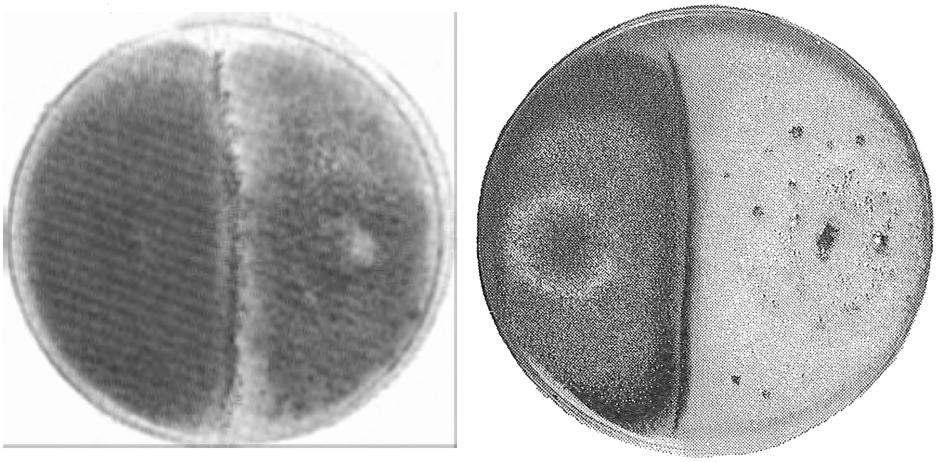
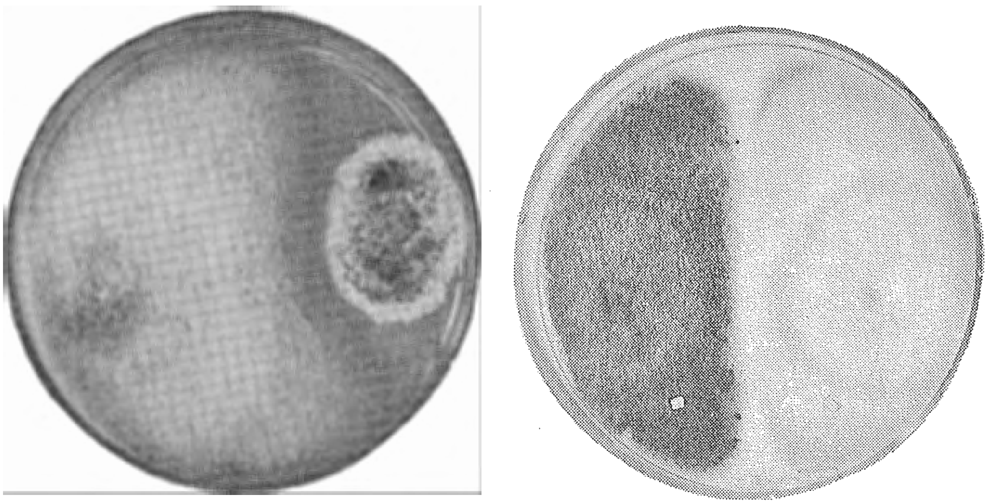


Fig. 2.—Plus and minus types of *Glomerella cingulata* (right-hand plate) and *G. cingulata* var. *minor* (left-hand plate). 15 and 11 days' growth on P.D.A. respectively.

Conidial and sterile forms.—Aerial mycelium is fine, of low elevation and usually fairly dense. From above, the general colour is white to light grey, or it may appear darker corresponding to a dark substratum beneath. In the latter case the margin is usually white or pinkish. From below, the substrate may be light coloured or dark in the centre, with a light coloured or pinkish margin (Figure 3).



A B

Fig. 3.—(A left) *Colletotrichum gloeosporioides* var. *minor;* (A right) *C. acutatum;* (B left) *Glomerella cingulata* minus type; (B right) *G. cingulata* sterile type. 10 days' growth on P.D.A.

One characteristic type commonly isolated from passion-fruit has low, fairly compact, white, aerial mycelium on which are scattered conspicuous black bodies. These may have conidia associated with them and so function as sporodochia. Apart from this particular type, conidial production in culture is usually scanty or nil.

Glomerella cingulata var. *minor* stat. conid. *C. gloeosporioides* var. *minor*

This is a fast-growing species with mycelium distinctly coarser in macroscopic appearance than *G. cingulata* var. *cingulata.* Field isolations are almost entirely restricted to conidial or sterile types. In these the aerial mycelium is cottony or woolly and typically abundant and well elevated from the surface of the medium, in contrast to that of the variety described above. The colour is white or various shades of grey. From below, the colour of the substrate is white to cream or various densities of greyish olive or olive. Forms with a less elevated and less abundant aerial mycelium occur from time to time and these can be difficult to distinguish from the more elevated cultural types of *C. gloeosporioides* unless accompanied by conidia (Figures 2 and 3).

The production of conidia is characteristically more common and abundant than in *C. gloeosporioides.* This may take the form of conidia scattered throughout the mycelium giving a general pinkish tinge to the culture, or they may appear as pink masses formed in acervuli or associated with black sporodochia-like bodies.

On the few occasions when perithecia of *G. cingulata* var. *minor* appeared in culture the latter was not of a special type, as in the case of *G. cingulata,* but was similar to a grey cottony conidial or sterile form commonly obtained from field isolations. Large glomerate bodies if present are less numerous and less conspicuous, as they are more or less hidden in the mycelium. Small sooty perithecial elements scattered over the mycelium may accompany the glomerate bodies or occur alone (Figure 2).

Colletotrichum musae (*Gloeosporium musarum*)

The cultural characters of this organism were dealt with at some length by Simmonds and Mitchell (1940). Although three cultural types are recognized, the normal form is the one commonly obtained in field isolations. This is characteristic and uniform for the species. Aerial mycelium is white to light grey, loose and open and not greatly elevated. Spores are produced early and in abundance directly on the mycelium or on acervuli developed over the surface of the medium. This gives the colony a characteristic pink appearance.

Colletotrichum acutatum

C. acutatum is a relatively slow-growing species. Aerial mycelium is moderately dense and fairly well elevated. The surface may be finely tufted. The advancing margin is usually abrupt. Colour is at first white but after a few days there appears from the centre a greyish aggregated overlay, so the final colour is grey or greyish brown. This overlay sometimes has a crystalline appearance. From below the substrate is white or cream with sometimes a creamy pink diffusion. Darker patches if present are usually irregular. More recently a series of isolates was obtained from papaw in which the culture as a whole was a bright pink. Other characters apart from colour proved to be normal (Figure 3).

The production of conidia in this species is characteristically abundant. This appears to be distributed throughout the mycelium, although massed conidiophores in the nature of acervuli may occur. The superficial spore masses seen in *C. gloeosporioides* var. *minor* are met with less often. Sometimes salmon-coloured spore masses can be seen through the media from below although not obvious from above.

The colour of spores in mass of *C. gloeosporioides* var. *minor* and *C. acutatum* differs slightly, the former tending to pink and the latter to salmon. One series of inoculations on papaw examined with reference to Ridgway's "Colour Standards and Nomenclature" referred the spores of *C. gloeosporioides* var. *minor* to bitter sweet pink and those of *C. acutatum* to capucine orange.

Colletotrichum orbiculare

Growth is characteristically slow (Table 5). When first isolated aerial mycelium is usually fine, scanty and of low elevation. Sometimes the surface is almost powdery. Typically the colour is pinkish, usually becoming grey to dark grey in the centre with a pinkish margin which may have a submerged edge. From below, the substratum is dark in the centre with a fairly broad cream or pinkish margin. With subculturing, the pink colour tends to become lost and the aerial mycelium may increase to a grey, fairly compact growth of moderate elevation, when the culture is no longer very distinct from types developed by other species.

Conidia are often produced by fresh isolations and these may appear as small pink spore masses scattered over the surface.

Colletotrichum atramentarium

In fresh isolates from the tomato, aerial mycelium is fine, scanty and remains close to the surface. The general colour is white to pale pink. From the centre develops a well-defined black speckling due to the formation of the sclerotial bodies characteristic of this species. From below, the substrate is speckled grey in the centre with a pinkish margin. With subculturing, the pinkish colour tends to disappear and sectors of a denser, more elevated, grey mycelium appear. If the sclerotium-forming habit is completely lost there is little in the appearance of the culture to distinguish it from some other species.

Colletotrichum dematium

Aerial mycelium is fine, white or grey and somewhat scanty, or in some isolates more abundant and moderately elevated. Colour is usually dark in the centre with a broad white margin. In a fruiting culture the setae may give the surface a finely tufted appearance. From below, the substratum is dark grey or speckled grey with a white margin. Scattered dusky acervuli are present in fruiting cultures. Spore masses are usually straw-coloured but sometimes pale pink.

Cultural Types obtained from Single Ascospores

Edgerton (1914) described plus and minus strains of a *Glomerella* obtained from several different hosts. Lucas, Chilton, and Edgerton (1944) studied the progeny of single ascospore isolations from an American strain of *G. cingulata*, from *Ipomoea*, which they separated into seven or more different types. Struble and Keitt (1950) used similar methods to investigate an isolate of *G. cingulata* from apple and showed that the cultural types obtained differed somewhat from those obtained from *Ipomoea*.

Ascospore isolations have been made from the Queensland *G. cingulata* and *G. cingulata* var. *minor*. Cultural types obtained from the former could be correlated fairly well with those described from *Ipomoea*, while those obtained from the latter resembled more closely Struble and Keitt's types from apple. A description of the Queensland types is given below. The terminology used is, as far as correlation is possible, that of the authors cited above.

(i) *Glomerella cingulata*

(*a*) *Plus type*.—This is the same as has been described earlier for the perithecial form of *G. cingulata* obtained from field isolations. It forms a definite perithecial line with minus types (Figure 2).

(*b*) *Minus type*.—Slight to scanty amounts of open, wispy, grey or black aerial mycelium occur over a dark background. From below, the substrate is dark olive to black, typically mottled but not always so. Numbers of small, globular, immature or occasionally mature perithecial elements are embedded in the surface. Conidia are usually scarce but occasionally more plentiful. Minus types form a definite perithecial line with plus types. When used in artificial inoculation experiments they are characteristically non-pathogenic (Figures 2 and 3).

(*c*) *Sterile*.—Aerial mycelium is close, white and appressed to the surface, forming a dense white mat without elevated hyphae. From below, the substrate is white, cream or pinkish with sometimes grey or olive developing out from the centre and imparting a darker appearance to the surface view. The name sterile is chosen from the terms conidial and sterile used by Lucas, Chilton, and Edgerton (1944), as conidia are usually rare or absent and no perithecial line is formed with plus or minus types. It is not unusual for cultures of the sterile type to be obtained in field isolations (Figure 3).

(*d*) *Yellow*.—Aerial mycelium is scanty and white on a background of light yellow. The rate of growth is similar to that of other forms but pathogenicity is reduced and spore size abnormal. This type is not obtained in field isolations.

(ii) *Glomerella cingulata* var. *minor*

(*a*) *Plus type*.—Aerial mycelium is relatively coarse, cottony, grey, of moderate elevation and density and may be slightly aggregated. From below, the substrate is grey in various degrees of density. The general appearance is similar to that of a common non-perithecial form obtained from field isolates. The distinguishing feature is the presence of a few large glomerate perithecial bodies, more or less embedded in the mycelium, and numerous small sooty perithecial elements scattered in patches over the surface. A dendritic perithecial line is formed with minus colonies. Colonies of the plus type have been obtained only rarely from field isolations (Figure 2).

(*b*) *Minus type*.—In general, this is similar to the minus type of var. *cingulata* but it shows more variability. Aerial mycelium is grey or black and is poorly developed over a dark substrate. Immature perithecial elements are normally present but vary in numbers and are sometimes absent. In contrast to the minus type of var. *cingulata,* conidia are abundant with the pinkish spore masses showing over the surface as the culture ages. This type forms a perithecial line with plus colonies but this has a dendritic margin and lacks the well-defined straight outline of the one formed between var. *cingulata* plus and minus types. The minus type has not been obtained from field isolations (Figure 2).

(*c*) *Conidial and sterile*.—There may also be obtained from ascospores various types similar to those described from field isolations, including a non-perithecial form similar to the plus type. In some of these, production of conidia is plentiful whereas in others, similar in other respects, conidia are few or absent. Whether these represent the conidial or sterile types of American authors is uncertain (Figures 2 and 3).

(*d*) *Yellow*.—A yellow isolate similar to the one produced by *G. cingulata* is occasionally obtained. This is not found in field isolates.

(c) Appressoria

Some authors (Sutton 1962) have suggested using the characters of the appressorium as one criterion for separating species of *Colletotrichum*. The size and shape of the appressoria formed by the species discussed here were briefly investigated but the differences did not appear to be sufficient to warrant a more detailed examination. Mean length lay mostly between 8 and 9μ and mean breadth between $6 \cdot 0$ and $6 \cdot 5\mu$. The appressoria of *C. atramentarium* were somewhat larger, with a mean length of $11 \cdot 3\mu$, while those of *C. musae* were shorter, with a mean of $7 \cdot 7\mu$. The majority examined were more or less obovate but in all species a varying number of individuals were definitely lobed or angular. Those of *C. acutatum* were on the whole more regular and those of *C. musae* less so.

(d) Temperature Reactions

Reaction to temperature is a useful criterion for separating some species of *Colletotrichum*. This character was investigated for the species *Glomerella cingulata* var. *cingulata, Colletotrichum gloeosporioides* var. *minor, C. acutatum, C.*

orbiculare and *C. dematium*. Three or four typical isolates were used in each case. The procedure consisted in inoculating potato dextrose agar slopes in tubes or medicine bottles with uniform circles cut from a young P.D.A. culture of the test fungus. These were held at room temperature overnight until growth was just commencing to show and then incubated in the compartments of a multiple-temperature incubator over the range 15° to 36°C. The temperature interval between compartments was approximately 1·5°. After 4 days the growth was recorded as diameter of colony less diameter of original inoculum (Figure 4).

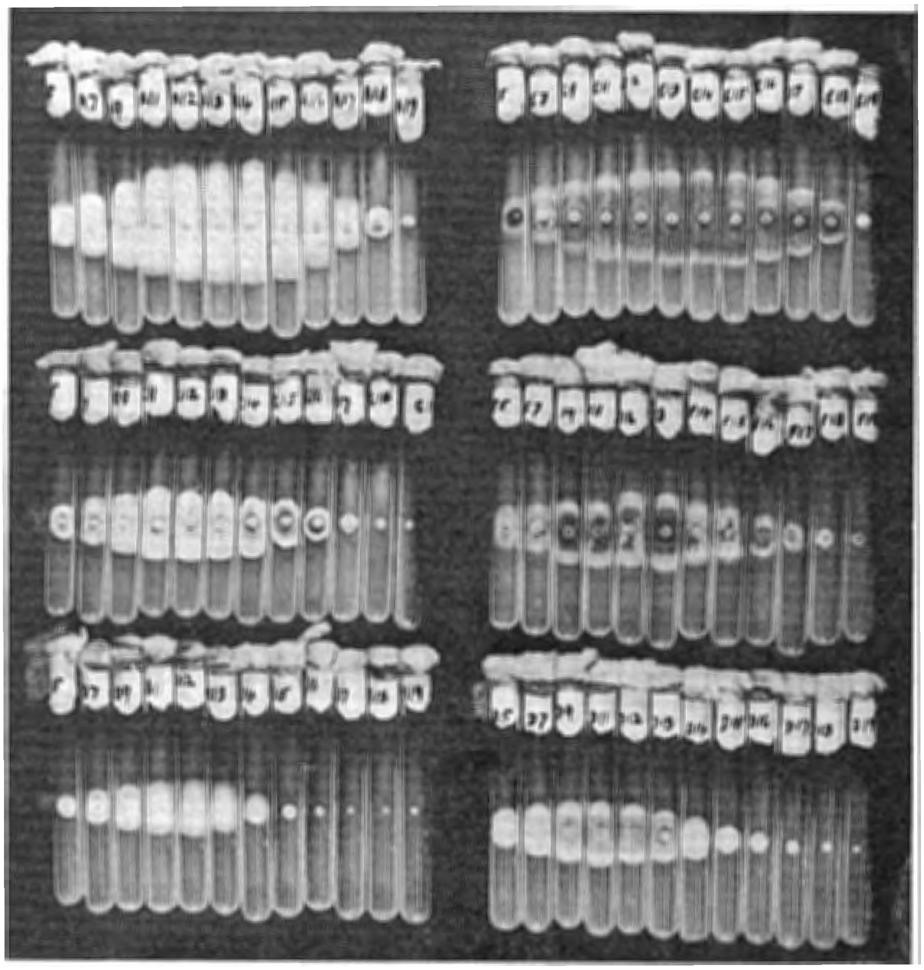


Fig. 4.—Four days' growth of *Colletotrichum* spp. at temperatures (°C) of (5) 15.5; (7) 19.4; (9) 21.9; (11) 24.6; (12) 26.0; (13) 27.3; (14) 28.7; (15) 30.2; (16) 31.6; (17) 32.8; (18) 34.5; (19) 36.3. (Upper left) *C. gloeosporioides* var. *minor;* (upper right) *C. dematium;* (mid left) *C. acutatum;* (mid right) *C. atramentarium;* (lower left) *C. acutatum* pink type; (lower right) *C. orbiculare.*

TABLE 5

TEMPERATURE DATA FOR FIVE SPECIES OF *Colletotrichum*

Species	No. of Isolates	Optimum (°C)	Maximum (°C)	Mean 4–day Growth at Optimum (cm)
Glomerella cingulata	3	26·5 — 28·5	35·5	6·3
C. gloeosporioides var. *minor* . .	5	26·0 — 28·5	35·5	7·3
C. dematium	3	27·5 — 29·5	37·0	5·1
C. acutatum	4	25·0 — 26·5	33·0	3·8
C. orbiculare	3	24·5 — 26·5	33·5	2·7

In Table 5 is given the range of optima for the different isolates and the mean 4-day growth at the optimum temperature. The mean growth of the isolates over the temperature range used is expressed graphically in Figure 5. The curve for *C. musae* (*G. musarum*), adapted from Simmonds and Mitchell (1940), has been included here for comparison.

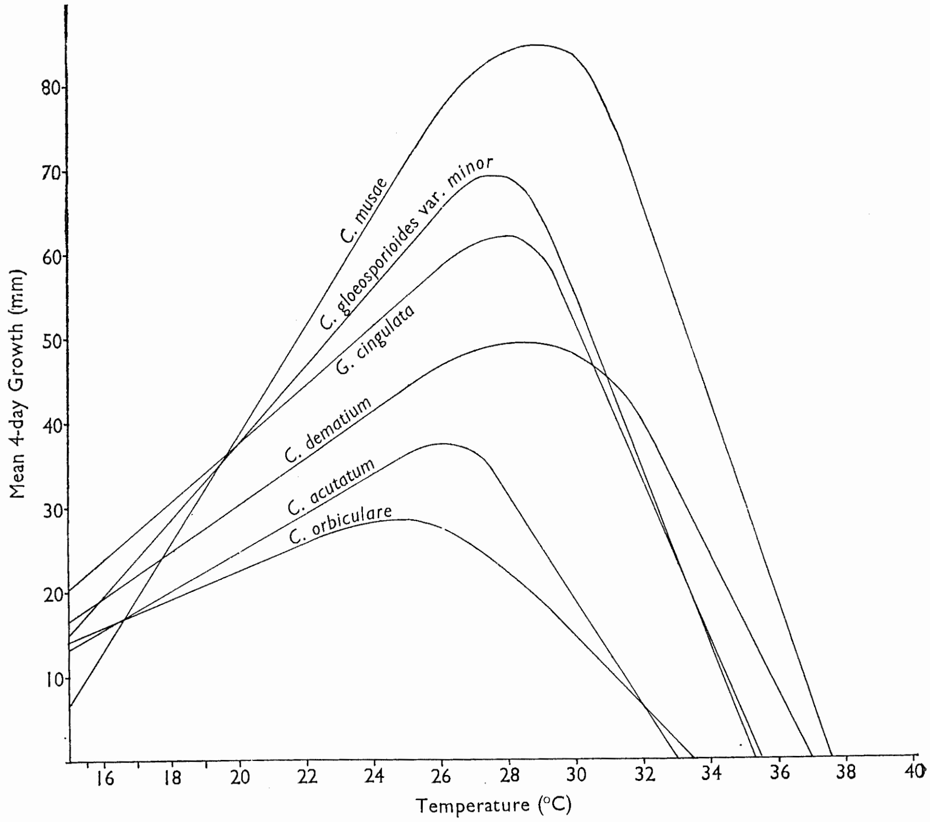


Fig. 5.—Growth-temperature curves of six species of *Colletotrichum*. Mean 4 days' growth on P.D.A.

Edgerton (1915) investigated the temperature curves of 49 cultures of *Colletotrichum* isolated from 22 different hosts. These fell into six groups—

Gloeosporium musarum, Glomeralla cingulata, Gloeosporium fructigenum, Colletotrichum lagenarium, a slow-growing unnamed species from apple, and *C. lindemuthianum.*

In general, the Queensland results agree with those of Edgerton. *C. musae* is a fast-growing species with a high optimum and maximum. *G. cingulata* resembles this species but growth rate and optimum are somewhat lower, and in the Queensland isolates also the maximum. *C. orbiculare* (*C. lagenarium*) in contrast is slow-growing and has a low optimum and maximum.

Temperature reactions of the isolates grouped by Edgerton (1915) as *G. fructigenum* closely resemble those of the Queensland *C. acutatum.* In fact, there is nothing in Edgerton's description to indicate they are not the same organism. However, the spore dimensions usually attributed to *G. fructigenum* set it apart from *C. acutatum* and the former is perhaps more correctly considered a synonym or form of *C. gloeosporioides.* The four isolates of *C. acutatum* employed here were from papaw. Sturgess (1957), using isolates from strawberry, obtained a somewhat higher optimum for this species. Two recent isolates from strawberry leaves showed an optimum of 26·8°C.

Colletotrichum gloeosporioides var. *minor* is, as would be expected, very similar to *G. cingulata. C. dematium* is a moderately fast-growing species with a relatively high optimum and maximum.

(e) Host Range

Over the years, species of *Colletotrichum* have been isolated on many occasions from fruit and vegetative parts of economic plants in Queensland. The pathogenicity of the various species to their usual hosts is well established. In cases where a species has been recovered from a particular host only occasionally and no pathogenicity tests have been carried out, the nature of the lesion and the circumstances of the isolation have been taken as evidence for or against its presence in a pathogenic capacity.

In the course of this work it became evident that one species of plant may be host for more than one species of *Colletotrichum,* so with this genus the identity of the host is not necessarily sound evidence for the identity of the pathogen. However, some fruit which are particularly prone to anthracnose are subject to attack by only one organism. Two such are mango and banana. In contrast, papaw and capsicum are remarkably hospitable hosts.

A host list of the species of *Colletotrichum* affecting fruit in Queensland is given in Table 6. Non-fruit hosts are included to complete the picture. In most cases specific identity of the pathogen has been determined by both cultural characters and spore measurements. The number of collections from which the particular species was obtained is entered under the particular host-parasite combination concerned. These figures do not necessarily give a true indication of the relative frequency of occurrence on the different hosts except in the case of banana, papaw, mango, avocado and strawberry, each of which has received a considerable amount of attention. It is hoped that the present paper will open the way for an extension to this list.

TABLE 6

HOST RANGE OF FRUIT-ATTACKING SPECIES OF *Colletotrichum* IN QUEENSLAND

Host	*C. gloeosporioides* var. *gloeosporioides*	*C. gloeosporioides* var. *minor*	*C. acutatum*	*C. orbiculare*	*C. dematium*	*C. atramentarium*	*C. musae*
AGAVACEAE							
Phormium tenax Forst. (New Zealand flax)		1					
ANACARDIACEAE							
Mangifera indica L. (mango)		23					
ANNONACEAE							
Annona reticulata L. (bullock's heart) ..		1					
A. squamosa L. (custard apple)		4					
BIGNONIACEAE							
Parmentiera edulis DC.			1				
CARICACEAE							
Carica papaya L. (papaw)	34	86	13		11		
COMPOSITAE							
Carthamus tinctorius L. (safflower)				2			
Xanthium spinosum L. (Bathurst burr) ..				1			
CUCURBITACEAE							
Citrullus vulgaris Schrad. (watermelon) ..		1		5			
Cucumis melo L. (rockmelon)				2			
C. sativus L. (cucumber)		1		4			
JUGLANDACEAE							
Juglans regia L. (walnut)			2				
LAURACEAE							
Persea americana Mill. (avocado)		20	2				
LEGUMINOSAE							
Lupinus angustifolius L. (New Zealand blue lupin)		2					
Medicago denticulata Willd. (burr medic) ..		1					
M. sativa L. (lucerne)		1			2		
MORACEAE							
Artocarpus heterophyllus Lam. (jack fruit) ..		1					
Ficus carica L. (fig)		1					
F. pumila L. (climbing fig)		2					
MUSACEAE							
Musa sp. (Cavendish banana, green fruit) ..	2	2					
(Cavendish banana, ripening fruit)							140
MYRTACEAE							
Psidium guajava L. (guava)		2					
ORCHIDACEAE							
Dendrobium sp., &c.	2	7					
OXALIDACEAE							
Averrhoa carambola L. (five-corner) ..		3					
PASSIFLORACEAE							
Passiflora edulis Sims and f. *flavicarpa* Degener, and hybrids (passion-fruit) ..	9	2					
PINACEAE							
Pinus elliotii Engelm. (slash pine)			1				

TABLE 6

HOST RANGE OF FRUIT-ATTACKING SPECIES OF *Colletotrichum* IN QUEENSLAND—*continued*

Host	*C. gloeosporioides* var. *gloeosporioides*	*C. gloeosporioides* var. *minor*	*C. acutatum*	*C. orbiculare*	*C. dematium*	*C. atramentarium*	*C. musae*
ROSACEAE							
Fragaria × *ananassa* Duchesne (strawberry)			11				
Malus sylvestris Mill. (apple)		7	1				
RUTACEAE							
Citrus limon (L.) Burm. f. (lemon)		1					
C. paradisi Macf. (grapefruit)		3					
C. reticulata Blanco (mandarin)		4					
C. sinensis Osbeck (sweet orange)		5					
Flindersia brayleyana F. Muell. (Queensland maple)			1				
SOLANACEAE							
Capsicum frutescens L. var. (capsicum) ..	1	1	2		1	1	
Lycopersicon esculentum Mill. (tomato) ..		1	3		1	4	
Solanum melongena L. (eggfruit)			3				
S. tuberosum L. (potato)						5	
STERCULIACEAE							
Theobroma cacao L. (cocoa)		1					
THEACEAE							
Camellia japonica L. (camellia)		1					
UMBELLIFERAE							
Apium graveolens L. var. *dulce* (Mill.) Pers. (celery)			1	5			

Matthews (1953, 1955*a*, 1955*b*) investigated leaf spots occurring on a number of garden plants and weeds in the Brisbane district. In each case the associated organism was isolated, its cultural and morphological characters were described and cross inoculations were carried out. As a result of this work the causal organism was considered to be *Glomerella cingulata* (Stonem.) Spauld. & Schrenk, but no attempt was made to distinguish between varieties of this species. However, on the basis of the information supplied by Matthews in her papers, separation into *G. cingulata* and *G. cingulata* var. *minor* can be made with a fair degree of accuracy. Isolates from azalea (*Rhododendron indicum* Sweet), *Hoya australis* R.Br. and *H. carnosa* R.Br., and a few from stock (*Matthiola incana* (L.) R.Br.), were probably *G. cingulata.* The other hosts investigated yielded isolates resembling *G. cingulata* var. *minor* or its imperfect state. These included stock, cabbage and broccoli (*Brassica oleracea* L. var.), alyssum (*Lobularia maritima* (L.) Desv.), wallflower (*Cheiranthus cheiri* L.), oleander (*Nerium oleander* L.), violet (*Viola odorata* L.), cestrum (*Cestrum parqui* L'Herit.), and pigweed (*Portulaca oleracea* L.).

Artificial Inoculations

Artificial inoculations were carried out from time to time with a small range of fruit. The method usually employed was to insert a portion of mycelium, with or without accompanying spores, into a small triangular cut in the surface of the fruit, which were then incubated at room temperature in a moist chamber.

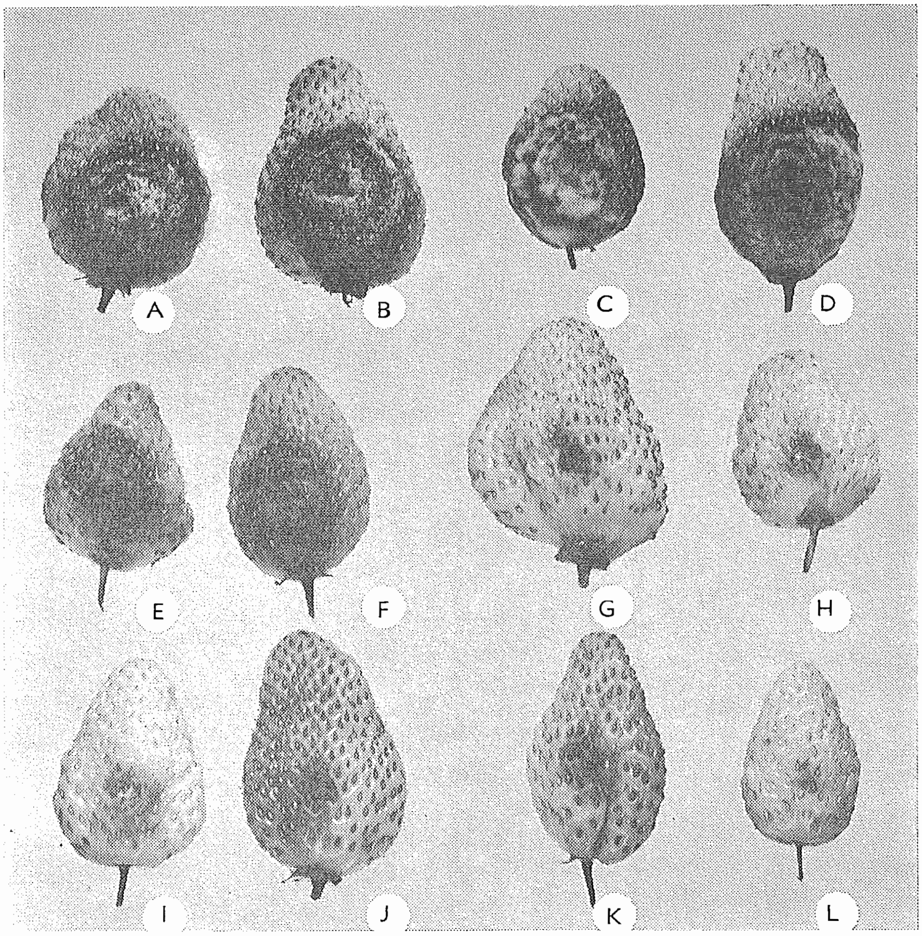


Fig. 6.—Strawberry fruit (cv. Phenomenal) inoculated with species of *Colletotrichum* illustrating + and — pathogenicity rating. (A,B) *C. acutatum* ex strawberry (+); (C) *C. gloeosporioides* var. *minor* ex custard apple (+); (D) *C. gloeosporioides* var. *minor* ex five-corner (+); (E,F) *C. gloeosporioides* var. *minor* ex apple (+); (G) *Glomerella cingulata* minus type ex papaw (—); (H) *G. cingulata* plus type ex papaw (—); (I,J) *C. musae* ex banana (—); (K) *C. gloeosporioides* var. *minor* ex mango (—); (L) uninoculated wound only (—).

The extent of lesion development even with the same organism is liable to vary considerably with the interplay of such factors as variety and condition of the fruit employed, ambient temperature, and the history of the culture used as inoculant. A direct comparison of the size of lesions developed in separate series of experiments is therefore unjustified. In the inoculations discussed here an endeavour was made to include on each fruit an organism known to be pathogenic to the particular host employed. Activity was measured by the diameter of the lesion produced, and an organism was recorded as pathogenic only if this diameter was equal to at least half of the diameter of the largest lesion on the particular fruit examined. This attempts to eliminate the smaller type of lesion often produced on fruit, especially if mature, by organisms which can hardly be regarded strictly as pathogenic. Figure 6 illustrates this method of recording.

Working on this basis, Table 7 gives the total number of positive and negative infections which have been obtained in the individual inoculations attempted. Inoculants are grouped according to host of origin so that some idea of cross-inoculation potential may be obtained.

TABLE 7

PATHOGENICITY OF *Colletotrichum* SPP. RECORDED AS THE NUMBER OF POSITIVE AND NEGATIVE LESIONS DEVELOPED IN ARTIFICIAL INOCULATION OF SIX FRUIT HOSTS

Species Employed and its Original Host	Papaw		Apple		Avocado		Banana		Mango		Strawberry	
	+	−	+	−	+	−	+	−	+	−	+	−
G. cingulata												
Papaw	140	44	0	4	7	2	2	3	0	14	1	4
Passion-fruit ..	15	10							2	2	5	1
Miscellaneous ..	10	11			1	2	7	3	1	8		
C. gloeosporioides var. *minor*												
Papaw	152	31	6	2	15	4	4	14	6	13	3	0
Apple	12	4	34	8			1	3	2	1	3	0
Avocado	39	13	10	4	22	0	5	14	7	21		
Custard apple ..	36	2	2	0	7	0	4	2	0	4	3	0
Citrus	9	7	6	2			0	3	1	3		
Mango	11	9	1	5			2	7	31	0	0	3
Miscellaneous ..	16	5	5	0			0	3	0	2		
C. musae												
Banana	1	5	0	6			22	0	1	14	0	3
C. acutatum												
Papaw	52	15	6	0	3	1	4	2	5	3		
Strawberry	9	5	2	0			0	7	2	0	4	0
Tomato and capsicum	6	0	4	0								
Miscellaneous ..	6	4					0	4				
C. orbiculare												
Celery	0	4										
Watermelon ..	0	4	0	4								
C. atramentarium												
Tomato	5	3	2	1								
Capsicum	2	0	0	2								
C. dematium												
Papaw	30	8	0	5					2	14		
Tomato and capsicum	4	0	2	0								

The results of the artificial inoculations so far as they apply confirm the host range determined by field collections. As a rule, a particular isolate was most active in attacking the host from which it was originally obtained. This was particularily noticeable in the case of banana and mango, which are less favoured hosts except for their own normal pathogen. *C. musae* and the mango strain of *G. cingulata* var. *minor* also show restricted activity towards hosts other than the normal one. On the other hand, papaw was susceptible to most of the organisms tested. This may be partly due to the absence of a fungi-toxic reaction in the skin of this fruit; it is possible to demonstrate one in banana, mango and avocado (Simmonds 1963).

III. NOTES ON INDIVIDUAL SPECIES

Glomerella cingulata stat. conid. *Colletotrichum gloeosporioides*

G. cingulata in its typical form has a restricted host range as a fruit pathogen in Queensland. It is the cause of a common and characteristic ripe fruit rot of the papaw and a skin blemish of passion-fruit, especially of hybrids between the purple and yellow varieties. Spore measurements, the appearance of cultures of the plus type and the black, somewhat corrugated, spot produced on papaw are all characteristic. Cultures of the sterile types are apt to be somewhat nondescript and not always readily identified.

Glomerella cingulata var. *minor* stat. conid. *Colletotrichum gloeosporioides* var. *minor*

This specialized form of *C. gloeosporioides* has a wide host range and is the most commonly met member of the genus in Queensland. It is an important cause of ripe fruit rotting of papaw, avocado, mango and apple and is found less frequently injuring a number of other economic plants. *C. gloeosporioides* var. *minor* is quick-growing and develops an abundance of aerial mycelium in culture. Normal spore size is characteristic, but collections in which the size approaches the lower range for *C. gloeosporioides* may require cultural examination for definite identification.

For many years it has been apparent that two distinct forms of *G. cingulata* exist in Queensland. To unite these under the same name would only serve to obscure the many differences. Wollenweber and Hochapfel (1949) appear to have met with a *Glomerella* showing the same divergence from the original *G. cingulata* (Stonem.) Spauld. & Schrenk as the one under discussion. Their nomenclature for the perfect stage has accordingly been adopted and is the one used here.

Since the perfect stage of this variety is met with only rarely in Queensland, it is desirable for practical convenience to have a distinguishing name for the conidial state also. Wollenweber and Hochapfel consider the imperfect state of their *G. cingulata* var. *minor* to be *Gloeosporium elasticae* (Thüm.) Cke. & Mass., of which they list several synonyms, mainly species occurring on fig and coffee.

Conidial measurements given by Wollenweber and Hochapfel for this species are within the range obtained for *C. gloeosporioides* var. *minor* in Queensland. In view of the accepted synonomy of *Gloeosporium* with *Colletotrichum,* it would be inadvisable to perpetuate the former generic name. Unfortunately, *Colletotrichum elasticae* is already occupied by *C. elasticae* Tassi. Apart from the fact that a species name is not readily available, it would seem preferable to designate the conidial state of a variety of *G. cingulata* as a variety of *Colletotrichum gloeosporioides.* The name *Colletotrichum gloeosporioides* Penz. var. *minor* var. nov. is therefore proposed and is used in this article. A formal description appears later.

It is possible that some of the references in literature to *G. cingulata* are to organisms similar to var. *minor.* For example, some of those described by Small (1926) as *Colletotrichum coffeanum* Noack appear to have characters in common with this variety. A culture from tea in Malaya and one from avocado in Southern Rhodesia obtained through the courtesy of the Commonwealth Mycological Institute were similar in appearance to *C. gloeosporioides* var. *minor* in Queensland.

Colletotrichum musae (*Gloeosporium musarum*)

Gloeosporium musarum Cke. & Mass. was originally described from Queensland material and the organism under discussion here is undoubtedly this species. In the literature it has been referred to under this name up to the present time. With the general acceptance of *Colletotrichum* as the correct generic name for those organisms formerly separated under *Gloeosporium* and *Colletotrichum,* it seems scarcely justifiable to continue to use the binominal *Gloeosporium musarum* and a transfer to *Colletotrichum* is desirable. After examining type and other material, Arx (1957*a*, 1957*b*) concluded that *Gloeosporium musarum* Cke. & Mass. is a synonym of *Colletotrichum musae* (Berk. & Curt.) Arx (*Myxosporium musae* Berk. & Curt.). In this paper *Colletotrichum musae* has accordingly been used as the name for the banana anthracnose organism.

C. musae is the most host-specific of the organisms dealt with and is moreover very constant in morphological and cultural characters. Conidial measurements are similar to these of *C. gloeosporioides,* while cultural characters resemble those of a cultural type *C. gloeosporioides* var *minor* which appears occasionally. Arx (1957) regards the fungus as a host-specific form of *C. gloeosporioides.* It is a rapid grower with a high optimum and maximum temperature similar to this species. The host-parasite relationships of this organism in Queensland have been investigated in some detail (Simmonds and Mitchell 1940; Simmonds 1941, 1963).

The perfect state of *G. cingulata* has been obtained from time to time from banana (Ashby 1931; Hoette 1935), but these recordings have not been definitely linked with *Colletotrichum musae.* It seems more likely that they represent a separate and less frequent association with banana, such as the isolates from green banana fruit in Queensland (Table 6).

Colletotrichum acutatum

This organism first came to notice in association with one of the ripe fruit rots of papaw. It was later shown to be the cause of a serious fruit rot of strawberry (Sturgess 1957) and a less frequent pathogen of a number of other hosts. Conidia of this species are characteristically variable in length and in the main possess pointed ends. Some of the larger spores could be mistaken for those of *C. gloeosporioides* var. *minor,* but smaller more typical ones usually accompany them. Occasionally collections with abnormally long spores are found but these commonly revert to the normal length on sub-culturing. Cultures are characteristic and show little variation. They almost invariably yield an abundance of conidia for further confirmation.

It is possible that some of the named species of *Colletotrichum* refer to this one. However the brevity of older descriptions and the custom of quoting extremes rather than means for spore measurements render it difficult to make any accurate comparisons. It is not one of the 11 species of *Colletotrichum* now recognized by Arx (1957). With some reluctance the Queensland organism has therefore been described as a new species. A formal description appears at the end of this article.

Colletotrichum orbiculare

This fungus is responsible for a characteristic leaf, stem and fruit spotting of various cucurbits. It is usually considered to be restricted in pathogenicity to members of the Curcurbitaceae, but in Queensland the host range has been extended to three plants outside this family. *C. orbiculare* is a slow-growing species with a low optimum temperature. This and the characteristic spore and cultural characters make this species one of the easiest to identify. Host specificity occurs and isolates from celery and safflower do not rot watermelon.

Colletotrichum atramentarium

In Queensland this species is restricted to members of the Solanaceae. It is the most common of the species of *Colletotrichum* causing a ripe fruit rot of tomato, but it is not of frequent occurrence. It is also responsible for a somewhat indefinite amount of damage as a potato root-rotting organism. *C. atramentarium* is readily identified by its long narrow conidia and the characteristic speckled culture resulting from the formation of sclerotia.

Colletotrichum dematium

C. dematium is the only species dealt with here which possesses a sickle-shaped spore. This and the prominent setae make identification easy. Cultures are somewhat characterless unless spore production is in evidence. This fungus is responsible for a conspicuous ripe fruit rot of papaw. It is not uncommon but is of less importance than the other species of *Colletotrichum* attacking this host.

IV. FORMAL DESCRIPTIONS

Colletotrichum gloeosporioides Penz. var. *minor* var. nov. ob sporas minores distincta

Mycelium in cultu copiosum. Conidia $14 \cdot 0 \times 3 \cdot 7\mu$ (plerumque $11 \cdot 1$–$17 \cdot 7 \times 3 \cdot 1$–$5 \cdot 0\mu$). Status perithecialis *Glomerella cingulata* (Stonem.) Spauld. et Schrenk var. *minor* Wr.

Causing economic damage in the fruit of *Mangifera indica* L., *Carica papaya* L., *Persea americana* Mill., *Malus sylvestris* Mill. and on many other hosts in Queensland.

Colletotrichum acutatum sp. nov.

Mycelium in cultu lente crescens partim tenue hyalinum, partin crassum fuscum septis manifestioribus. Chlamydosporae adsunt. Conidia longitudine pervariabilia, $11 \cdot 1 \times 3 \cdot 1\mu$ (plerumque $8 \cdot 3$–$14 \cdot 4 \times 2 \cdot 5$–$4 \cdot 0\mu$), extremitatibus plerumque acutatis. Appressoria plerumque obovata.

Hab. in fruit of *Carica papaya* L., *Fragaria* × *ananassa* Duchesne, *Lycopersicon esculentum* Mill. in Queensland.

Diagnostic features of the conidia are the small size, the variability in length in the one collection, and the pointed ends.

On P.D.A. the cultural type is characteristic and relatively constant (pp. 444-5). The colony is moderately slow-growing, with an optimum temperature of 25 to 26·8°C. Mycelium is slender and hyaline, with broader, stout, much septate, dark mycelium appearing later. Terminal and intercalary chlamydospores of various size may be present; these are hyaline or more commonly dark when developing from the dark hyphae.

On the host, conidia are produced in acervuli. In culture they appear to be formed throughout the mycelium, although massed conidiophores in the nature of acervuli may occur. Spore masses are salmon-coloured and when they are formed in culture are often more or less hidden in the mycelium. Setae have not been observed in association with acervuli but scattered, poorly developed setae appear occasionally in culture.

Conidiophores are slender, two to three times the length of the spore and about half the width, or they may be shorter and stouter. Appressoria are rarely lobed and the germ pore is often poorly defined.

The host range and other characteristics of this species have been discussed in more detail in the foregoing pages. Representative dried cultures are deposited in the Herbarium of the Botany Department, University of Queensland, and in the Herbarium of the Commonwealth Mycological Institute, England.

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TYPE SPECIMENS OF COLLETOTRICHUM GLOEOSPORIOIDES **VAR.** MINOR **AND** COLLETOTRICHUM ACUTATUM

By J. H. Simmonds, M.B.E., M.Sc.

The above organisms were described in the *Queensland Journal of Agricultural and Animal Sciences* 22: 437-459, 1965. It was there stated that representative dried cultures had been deposited in the Herbaria of the Botany Department of the University of Queensland and the Commonwealth Mycological Institute. Unfortunately, no single specimen was designated as a type. The type of the name concerned is as follows:

Colletotrichum gloeosporioides Penz. var. *minor* J. H. Simmonds (*Qd J. Agric. Anim. Sci.* 22: 437-459, 1965). Type: IMI 117612, isolated from *Carica papaya,* Ormiston, 1965. Paratypes: IMI 117613-117616; BRIU 2438-2441.

Colletotrichum acutatum J. H. Simmonds (*Qd J. Agric. Anim. Sci.* 22: 437-459, 1965). Type: IMI 117617, isolated from *Carica papaya,* Ormiston, 1965. Paratypes: IMI 117618-117623; BRIU 2431-2437.

S. G. Reid, Government Printer, Brisbane