STUDIES ON SOUTH INDIAN FUSARIA.

I. FUSARIUM VASINFECTUM ATK., WITH A NOTE ON ITS VARIETIES AND FORMS.

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During a study of the wilt disease of cotton in South India the author was able to isolate from wilted cotton plants and from 'wilt-sick' soil a large number of Fusaria which required identification. Preliminary work indicated that a number of these isolates belonging to the section *Elegans* appeared to be identical with *Fusarium vasinfectum* Atk. or its varieties or forms as set forth in the classification of Wollenweber and Reinking (1935). [Snyder and Hansen's proposals (Snyder and Hansen, 1940) have many difficulties in the way of their general acceptance.] Detailed study, however, was necessary to settle the identity of the various isolates. Representative isolates from soils and wilted cotton plants were therefore compared with cultures of *F. vasinfectum* and its varieties and forms obtained from the Centraalbureau voor Schimmelcultures, Baarn, Holland.

Comparisons made between the author's isolates and those obtained from Baarn were in respect of the following: (i) morphology, mainly spore shape, size, etc.; (ii) cultural characters, mainly colour; (iii) growth rate in standard media; and (iv) pathogenicity to cotton plants. The results form the subject matter of the present communication.

METHODS.

Altogether seven representative single spore isolates were chosen for the present investigation. Of these, S 7 and S 21 were isolated by the author from 'wilt-sick' cotton soil from Udamalpet (Coimbatore District, Madras State) using the root burial technique (Subramanian, 1946); S 17, S 19, S 20A, S 20B and S 20C were from vascular systems of wilted cotton plants collected from Udamalpet. The following cultures obtained from the Centraalbureau voor Schimmelcultures were also included for purposes of comparison: *Fusarium vasinfectum*, *F. vasinfectum* f.1, *F. vasinfectum* f.2, *F. vasinfectum* v. *lutulatum*, *F. vasinfectum* v. *zonatum*, *F. vasinfectum* v. *zonatum* f.1, and *F. vasinfectum* v. *zonatum* f.2.

Standard mycological technique was employed throughout the investigation.

The need for using a number of different media in studies on the genus *Fusarium* has been emphasised by many workers. The object of this recommendation is primarily to bring isolates, where necessary, to a state of 'hochkultur' suitable for study. No difficulty was experienced in bringing the present isolates to a state of 'hochkultur' since all of them sporulated satisfactorily on oatmeal agar. This medium was therefore used to study spore shape and size in the case of the various isolates. Steamed rice prepared according to Leonian (1929) was used to ascertain colour production by the various isolates. In recording observations on colour, Maerz and Paul's (1930) 'Dictionary of Color' was used. The numbers used in Tables 2 and 3 refer to the numerical designations attached to different colours in Maerz and Paul's Color charts.

Methods followed in pathogenicity tests were as follows: the inoculum in each case consisted of the fungus grown for four weeks in sterilised garden soil + 2 %

powdered Quaker oats + modified Shive's * solution. Inoculum was mixed with partially sterilised garden soil (saturation capacity 30 %) in the proportion of 10%, and 480 g. of the mixture were weighed into each pot. Control pots had sterilised garden soil + 2% powdered Quaker oats + modified Shive's solution, without any fungus, mixed with partially sterilised garden soil in the proportion of 10%. Seeds of susceptible K. 2 variety of cotton (*Gossypium arboreum* v. *neglectum* f. *indica*) were sown six per pot after delinting with concentrated sulphuric acid and surface sterilisation with 1/1,000 aqueous mercuric chloride. There were twenty-five such pots for each isolate. Moisture level of soils in pots was maintained approximately at 50–60 % of saturation capacity. Plants were under observation for over nine weeks. Infected plants were plated out on acidified potato dextrose agar and the fungi growing out compared with the isolates used for inoculation in each case.

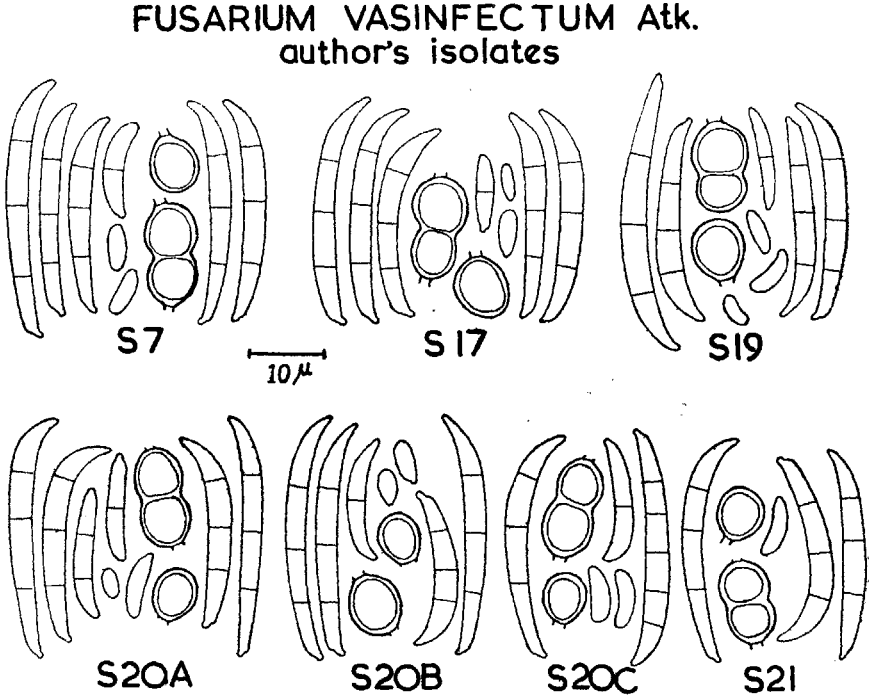
Results.

Morphology and Cultural Characters.

Observations regarding the formation of sporodochia, pionnotes, sclerotia, etc. by the isolates studied in four different media, viz., oatmeal agar, potato dextrose agar, sterilised pigeon pea stems and steamed rice at two temperatures (20° and 30°C.) are given below:—

(1) Typical sporodochia were produced only by isolates S 7, S 20B and cultures of *F. vasinfectum* v. *lutulatum* and *F. vasinfectum* v. *zonatum* f.1.

(2) All isolates and cultures studied developed pionnotes on oatmeal agar.



Text-fig. 1.

* Modified Shive's solution conforms to the following specification: prepared according to McLean and Cook (1941) with addition of 1·0% sugar.

TABLE 1.

Measurements (in microns) of conidia and chlamydospores of the author's isolates of Fusaria grown on oatmeal agar for 21 days at room temperature (30°C.).

Isolate.	Conidia.						Chlamydospores.			
	0-septate.		1-septate.		3-septate.		1-celled.*		2-celled.	
	Mean.	Range.	Mean.	Range.	Mean.	Range.	Mean.	Range.	Mean.	Range.
S 7 ..	8×2·5	(4–12×1–4)	13×2·8	(9–19×2–4)	32×3·3	(26–39×2–5)	8·7	(6–12)	12×8	(10–15×6–9)
S 17 ..	8×2·4	(4–12×1–4)	13×2·8	(8–17×2–4)	31×3·4	(24–39×3–5)	8·7	(6–12)	13×8	(11–15×6–10)
S 19 ..	8×2·5	(4–14×1–4)	13×2·8	(8–19×2–4)	32×3·4	(24–40×2–5)	9·0	(6–12)	12×8	(10–14×6–9)
S 20A ..	8×2·4	(4–14×1–4)	12×2·7	(6–17×1–4)	30×3·4	(21–39×2–5)	8·5	(5–10)	13×9	(9–15×7–10)
S 20B ..	8×2·5	(3–12×1–4)	15×2·7	(9–20×1–4)	33×3·2	(26–40×2–5)	8·7	(6–12)	12×8	(10–15×6–10)
S 20C ..	9×2·5	(4–14×1–4)	14×3	(8–19×2–4)	32×3·5	(26–37×3–5)	8·7	(6–12)	12×8	(10–14×7–9)
S 21 ..	9×2·9	(4–14×1–4)	13×2·8	(8–19×2–4)	32×3·6	(28–37×3–5)	8·6	(6–12)	12×8	(10–14×6–10)

* Measurements refer to the diameter.

TABLE 2.

Showing cultural characters of author's isolates of Fusaria grown on steamed rice incubated at 30° C.

Fungus.	11 days.	21 days.	30 days.
S 7	Aerial mycelium abundant, cottony, white on top of slant, but coloured below with following: 41 B 2, 41 C 1, 43 D 1, 43 C 2, 43 C 3 (Ageratum blue), 44 F 4 (Vestal), 45 G 5 (Crushed violets), 46 I 5 (Oto mauve), 47 J 5.	Unchanged. Coloured with following shades of rose, pink and violet: 3 A 9 (Sandust-variety), 3 G 1 (Corinthian Pk.), 6 D 3 (Livid Br.), 46 H 1, 47 J 2 (Indian purple).	Unchanged. Colour same as at the end of 21 days.
S 17	Aerial mycelium abundant, white cottony on top of slant but just below coloured with following: 1 C 2 (Peach blossom), 2 G 8 (Rose leaf), 3 F 3 (Bridal rose), 45 I 6 (Livid Pr.).	Growth fluffy, compact and not cottony, pale white on top. Coloured predominantly pink, with following shades: 1 B 1 to 1 C 2 (Peach blossom) to 1 E 3 to 2 G 2 to 2 I 2 (Rose Marie) to 3 G 1 (Corinthian Pk.) to 5 E 3 (Nectar) to 6 D 3 (Livid Br.) Also shades of 43 C 3 (Ageratum blue).	Unchanged. Colours same as at the end of 21 days.
S 19	Aerial mycelium abundant, cottony and of a 3 A 2 colour on top and below coloured with following shades: 3 D 2, 3 F 3 (Bridal rose), 3 I 2 (Vassar rose), 3 J 8 (Tango Pk.) 4 I 8 (Colonial rose), 47 H 6.	Mycelium loosely fluffy and slightly cottony, white on top but below coloured with following shades: 1 A 2 to 1 C 2 (Peach blossom) to 2 I 2 (Rose Marie) to 3 J 3 (Mayflower) to 5 E 3 (Nectar).	Unchanged. Coloured as follows: 1 A 2 to 1 C 2 (Peach blossom) to 2 I 2 (Rose Marie) to 3 J 3 (Mayflower) to 5 E 3 (Nectar); 4 I 8 (Colonial rose), 4 K 9 (Doge).
S 20A	Aerial mycelium present, not cottony, but somewhat short and woolly on the rice grains. On top pale white but coloured below with: 1 B 2, 1 C 2 (Peach blossom), 42 D 1 (Dawn), 43 E 3, 44 F 4 (Vestal).	Mycelium fluffy, not cottony, forming a dense mat of short hyphae pale white to pink. Intensity of shades: 1 B 7 (Pink 1 T), 1 C 7 (Pink 2 T), 1 D 7 (Rose Breath) to 1 G 7 (Debutante Pk. La France Pk.); 42 B 1 (Zephyr) to 42 B 2.	Unchanged. Colours same as at the end of 21 days.

S 20B	Aerial mycelium present, somewhat cottony, white on top but coloured below as follows: 1 G 7 (La France Pk.), 2 F 7 (Blossom Venetian Pk.), 3 G 7 (Lilac), 3 J 3 (Mayflower), 4 J 3 (Azalea), 47 J 7.	Unchanged. Colours as follows: 2 D 2 to 2 I 2 (Rose Marie) to 3 I 2 (Vassar rose), 4 I 8 (Colonial rose) to 5 J 9 (Bois de Rose); 6 D 3 (Livid Br.).	Unchanged, but coloured as follows (with no shade of pink or red): 44 A 6 (Dutch Bl.) to 44 B 6 to 45 E 7 (Rainier Bl.) to 47 C 8.
S 20C	Aerial mycelium present, somewhat fluffy. Tinged with following: 1 D 1, 1 E 8 (Cupid Pk.), 2 I 8 (Jasper Pk.), 3 J 8 (Tango Pk.), 43 C 3 (Ageratum blue), 45 C 3.	Unchanged. Coloured as follows: 6 D 3 (Livid Br.) to 6 E 2, 4 G 1 (Livid V.), 3 G 1 (Corinthian Pk.), 3 E 7 (Powder Pk.), 3 E 8; also 43 C 3 (Ageratum blue); at bottom some development of 10 B 1 (Oyster white+).	Unchanged. Colours same as at the end of 21 days.
S 21	Aerial mycelium present, slightly fluffy, but not cottony. Tinged predominantly with: 43 C 3 (Ageratum blue), 45 A 3 (Platinum).	Unchanged. Coloured as follows: 41 B 2 to 42 D 4 to 43 C 3 (Ageratum blue) to 43 E 4 (Vanda) to 45 D 4. At bottom, 42 B 1 (Zephyr).	Unchanged. Colours same as at the end of 21 days.
Fusarium vasinfectum Atk. ..	Growth not fluffy or cottony. Colours produced were: 3 D 3, 6 I 5 (Raspberry), 6 G 6 (Ruby), 6 B 4 (Claret cup), 6 A 5 (Verninia Pr.), 7 C 5 (Sultana/Old Amethyst), 8 A 5.	Unchanged. Colours were: 3 D 1, 3 I 2 (Vassar rose), 3 G 1 (Corinthian Pk.), 3 A 7, 11 B 2 (Putty seed pearl cartridge buff) to 12 C 4 (Malacca). At bottom: 47 H 3 to 48 L 1 to 48 L 3 (Spanish Russian).	Unchanged. Following colours seen: 12 A 2 (Moonmist), 12 C 1 to 12 C 3 (Old Ivory), 45 G 5 (Crushed violets) to 45 H 6 (Old lilac) to 47 C 5 (Leadville) to 47 J 8 (Prune).
F. vasinfectum v. *lutulatum* ..	Growth not fluffy or cottony, but growth of short hyphae on the rice grains. Tinged with following colours: 1 A 8, 1 B 1, 1 B 7 (Pink 1 T), 1 B 8 (Opera Pink), 1 C 7 (Pink 2 T).	Unchanged. Coloured as follows: 1 B 7 (Pink 1 T) to 1 D 7 (Rose Breath) to 2 E 7 (Hydrangea Pk. Aurore).	Unchanged. Colours same as at the end of 21 days.

TABLE 2—(*Continued*).

Fungus.	11 days.	21 days.	30 days.
F. vasinfectum f.1 ..	Very slightly fluffy. Following colours developed: 1 B 2, 1 B 7 (Pink 1 T), 1 C 7 (Pink 2 T), 1 B 8 (Opera Pk.).	Somewhat fluffy with very little aerial mycelium and coloured as follows: 1 B 7 (Pink 1 T), 1 B 8 (Opera Pk.), 1 C 7 (Pink 2 T), 1 D 7 (Rose Breath), 2 E 7 (Hydrangea Pk. Aurore).	Same as at the end of 21 days.
F. vasinfectum f.2 ..	Details same as for *F. vasinfectum* f.1	Details same as for *F. vasinfectum* f.1	Details same as for *F. vasinfectum* f.1.
F. vasinfectum v. *zonatum* ..	Growth fluffy but not cottony. Aerial mycelium on top pale white to grey, i.e., 13 B 1, 13 B 2 (Sand-Beach Chip+) to 13 D 2 (Bronze Clair). Also, 2 C 8, 2 A 8, 2 A 9, 3 A 9 (Sandust-Vanity), 3 E 7 (Powder Pk.), 48 J 7.	Fluffy aerial mycelium on top coloured pink, i.e., 2 I 2 (Rose Marie) to 4 I 8 (Colonial rose). Other shades noted were: 4 A 8, 4 B 8 (Touquet) to 6 B 9 (Wood rose Sorghum Br.). At bottom: 11 C 2 (Ecru beige).	Aerial mycelium on top of a pale white to 46 D 6 (Plumbago-slate+) colour. Below coloured as: 14 A 3 (Sandy beige Daytona+ sandrift−) to 14 A 6 (Buckskin).
F. vasinfectum v. *zonatum* f.1	Growth not fluffy, aerial mycelium scanty. Tinged with following colours: 11 D 2 (Italian straw), 11 A 2 (Flesh natural Moon-light+), 11 A 4 (Nude Seasan+), 11 A 5 (Pastel Parchment Rose nude).	Pale white aerial mycelium on top only. Tinged below with following shades: 11 A 2 (Flesh natural Moonlight+) to 11 B 3 (Champagne+ Belleek), 11 D 2 (Italian straw), 11 D 4 (Sombrero) to 11 E 4 (Maple).	Same as at the end of 21 days.
F. vasinfectum v. *zonatum* f.2	Growth fluffy, cottony, white on top. Coloured below as follows: 2 E 7 (Hydrangea Pk.), 2 F 8, 2 G 8 (Rose leaf), 2 I 8 (Jasper Pk.), 2 K 8 (Begonia Gaiety), 3 J 8 (Tango Pk.), 51 A 2 (Opal Mauve), 45 D 3.	Aerial mycelium collapsed. Colours developed were: 2 F 7 (Blossom Venetian Pk.), 2 I 8 (Jasper Pk.), 2 K 8 (Begonia Gaiety), 2 J 9 (Springtime), 3 K 9 (Raspberry R).	Same as at the end of 21 days.

(3) Steamed rice was most suitable for formation of sclerotia. The only isolates which produced these were S 17 and S 20A and the culture of *F. vasinfectum* v. *zonatum* f.2.

(4) There was no constancy in the matter of production of aerial mycelium or a stroma. Growth of all isolates was somewhat cottony with white mycelium on sterilised pigeon pea stems. Aerial mycelium developed to some extent on potato dextrose agar, while on oatmeal agar development of aerial mycelium was poor or none at all.

(5) Development of stroma was good particularly on steamed rice. Stromatic colour consisted of pink to violet shades in all isolates and cultures except *F. vasinfectum* v. *zonatum* f.1. In the case of the latter stroma was straw or cream coloured.

Study of spore shape, size, etc. was confined to the author's isolates since it was considered superfluous to gather such data relating to the identified cultures in view of the illustrated descriptions of these already available (Wollenweber and Reinking, 1935), and more especially in so far as no significant differences in spore size between *F. vasinfectum*, its varieties and forms is evident from the descriptions

TABLE 3.

Showing colour reactions of Fusarium vasinfectum, *its varieties and forms, and author's isolates to acid and alkali.*

Culture or isolate.	Reactions to	
	Acid.	Alkali.
Fusarium vasinfectum	Crushed berry 6 F 4	Quaker blue 40 E 5
F. vasinfectum v. *lutulatum* ..	Araby 4 G 10	Hathi grey 37 C 1
F. vasinfectum f.1	Araby 4 G 10	Hathi grey 37 C 1
F. vasinfectum f.2	Araby 4 G 10	Hathi grey 37 C 1
F. vasinfectum v. *zonatum* ..	Mauve rose 7 E 5	Quaker blue 40 E 5
F. vasinfectum v. *zonatum* f.1 ..	No change	No change
F. vasinfectum v. *zonatum* f.2 ..	Tango Pk. 3 J 8	Navy blue 40 E 11
S 7	Colonial rose 4 I 8	Navy 3 40 A 10
S 17	Holly berry 4 L 10	Navy blue 40 E 11
S 19	Holly berry 4 L 10	Midnight 40 A 8
S 20A	Colonial rose 4 I 8	Light wedgewood 37 A 7
S 20B	Livid V. 4 G 1	Ensign 40 J 12
S 20C	Clove Pk. 6 K 5	Glacier blue 39 H 7
S 21	Saraband 6 K 8	Quaker blue 40 E 5

of Wollenweber and Reinking. Data on spore size of the author's isolates are tabulated in Table 1. Spore shape in the case of the author's isolates is illustrated by camera lucida drawings in Text-fig. 1.

All isolates produced microconidia in abundance and these were borne in false heads. They were also found along with macroconidia in slimy masses which were invariably of a cream colour. Microconidia were mostly one-celled, ovoid to reniform. Macroconidia were typically thin-walled, dorsiventral, falcate, 1–3-septate, often constricted and abruptly curved at the apex, mostly pedicellate at base. Both terminal as well as intercalary chlamydospores were produced by all isolates and cultures and there was little difference in their shape or size.

Consideration of conidial shape and size indicate little differences between the isolates studied. Further, comparison would indicate striking similarity of the present isolates to *Fusarium vasinfectum* and its varieties and forms (see Wollenweber and Reinking, 1935).

Colour Production: For studying colour production by the various isolates and cultures, steamed rice in test tubes was used. The inoculated cultures were incubated at 30°C. and records of colour, etc. were made at the end of 10, 21 and 30 days. The colour data are presented in detail (Table 2) since it is considered that they are important. It will be seen that all isolates and cultures except *F. vasinfectum* v. *zonatum* f.1 developed pink colours; the culture of *F. vasinfectum* v. *zonatum* f.1, however, developed pale dull colour, e.g., straw colour.

Colour reactions to acid and alkali: Reactions of cultures and isolates to acid and alkali were ascertained by addition of acid (dilute hydrochloric acid added in drops in sufficient quantity) or alkali (2% KOH solution similarly added in drops) to 30 days' old cultures on steamed rice. The results are presented in Table 3. It was found that the colour reactions to acid as well as alkali were very similar in the case of all isolates and cultures except that of *F. vasinfectum* v. *zonatum* f.1 which was not affected by addition of either acid or alkali. In the case of all other isolates and cultures, colour on addition of acid was some shade of pink or red, and that on addition of alkali was some shade of blue. There were, however, minor variations in the intensity of the pink and red or blue shades between these isolates and cultures.

TABLE 4.

Showing rate of growth (diameter in mm. of colony) of Fusarium vasinfectum, *its varieties and forms, and author's isolates on potato dextrose agar at room temperature (30°C.).*

Culture or isolate.	Days.							
	2	3	4	5	6	7	8	9
Fusarium vasinfectum	26	41	55	71	85	..	..	..
F. vasinfectum v. *lutulatum*	23	34	43	56	67	78	90	..
F. vasinfectum f.1	19	25	31	38	43	50	56	61
F. vasinfectum f.2	26	42	57	75	89	..	..	..
F. vasinfectum v. *zonatum*	22	38	51	67	78	95	..	..
F. vasinfectum v. *zonatum* f.1	23	37	50	66	79	..	..	..
F. vasinfectum v. *zonatum* f.2	26	41	58	75	88	..	..	..
S 7	13	21	28	41	50	59	65	71
S 17	19	27	34	44	56	63	72	82
S 19	20	28	37	49	59	71	78	87
S 20A	21	33	42	53	63	74	84	..
S 20B	20	29	41	52	65	78	86	..
S 20C	21	31	45	57	68	82	93	..
S 21	16	22	29	32	52	62	70	79

Growth rate in culture.

Data on rate of growth of the various isolates and cultures on potato dextrose agar are presented in Table 4. From the data it appeared that there were differences in growth rate between the author's isolates though they were all similar morphologically.

Pathogenicity tests.

The results of pathogenicity tests on cotton plants using the various isolates and cultures are given in Table 5. There were differences between the isolates or

TABLE 5.

Showing results of pathogenicity tests with Fusarium vasinfectum, *its varieties and forms, and author's isolates on wilt-susceptible K2 cotton.*

Culture or isolate.	No. of seeds germinated.+	No. of plants wilted.	Wilt per cent.
Fusarium vasinfectum	117	3*	2·5*
F. vasinfectum v. *lutulatum*	121	28	23·1
F. vasinfectum f.1	129	83	64·3
F. vasinfectum f.2	126	11	8·7
F. vasinfectum v. *zonatum*	121	43	35·5
F. vasinfectum v. *zonatum* f.1	120	5*	4·1*
F. vasinfectum v. *zonatum* f.2	129	22	17·0
S 7	119	6	5·0
S 17	124	44	35·4
S 19	120	80	66·6
S 20A	115	89	77·3
S 20B	128	82	64·1
S 20C	120	32	26·6
S 21	127	81	63·7
Control	136	0	0

+ Total number of seeds sown in each case was 150.

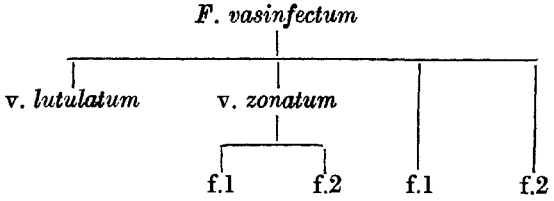
* Fungus isolated from wilted plants was different from the one used for inoculation in each case. Only *Fusarium solani* could be recovered from these diseased plants.

cultures in the matter of pathogenicity. Although much significance should not be attached to results obtained in pot experiments, it is nevertheless obvious that some isolates and cultures exhibited a high degree of pathogenicity, e.g. isolates S 19, S 20A, S 20B and S 21 and the culture of *F. vasinfectum* f.1. Cultures of *F. vasinfectum* and *F. vasinfectum* v. *zonatum* f.1 appeared to be very weakly pathogenic but this fact was not confirmed by the isolations obtained from infected plants from which only *Fusarium solani* could be recovered on plating. Amongst the cultures received from Holland, *F. vasinfectum* f.1 was most pathogenic, *F. vasinfectum* and *F. vasinfectum* v. *zonatum* f.1 not pathogenic at all. It is also obvious from the results that the author's isolates which were all morphologically similar exhibited different degrees of pathogenicity under the conditions of the experiment.

DISCUSSION.

Although the present investigation was primarily aimed at settling the specific identity of certain Fusaria isolated by the author from wilted cotton plants and 'wilt-sick' cotton soil, the inclusion, in this study, of cultures of *Fusarium vasinfectum*, its varieties and forms obtained from the Centraalbureau voor Schimmelcultures, Baarn, has yielded results which have a bearing on the taxonomy of this group of fungi.

The species *Fusarium vasinfectum* is treated in some detail by Wollenweber and Reinking (1935) in their 'Die Fusarien'. The species was first described by Atkinson (1892), but his description is meagre and itself does not enable us to recognise the species. Wollenweber and Reinking (1935) recognise two varieties, *lutulatum* and *zonatum*, two forms, viz., f.1 and f.2, and two forms (f.1 and f.2) for the variety *zonatum*. The forms are treated as entities independent of the varieties or species itself and similarly the varieties are treated as entities independent of the species. A perusal of the arrangement of species, varieties and forms in the Key on page 108 of 'Die Fusarien' would make this clear. It is unfortunate that this method has been followed since it is reasonable to consider *variety* to be of immediately lower rank to species and *form* to be of immediately lower rank to variety. A recognition of this fact would indicate the arrangement in the Key somewhat as follows:



Indeed, much of the difficulty experienced by those who try to identify Fusaria using Wollenweber and Reinking's Key could have been minimised by adopting some such arrangement, although even this arrangement is not satisfactory. It may be mentioned here that amongst the various amendments to the International Rules considered at the Seventh International Botanical Congress recently, the one relating to Article 28 is relevant to the present discussion. This amendment reads as: Insert before first paragraph: 'For nomenclatural purposes, a species and any taxon below the rank of a species is regarded as the sum of the lower taxa, if any. The description of a subordinated taxon which does not include the type of the higher taxon automatically creates a second subordinated taxon which includes the type of the higher taxon.' This amendment, if finally accepted, would certainly put taxonomy on a much better basis than at present, and is of immediate importance in *Fusarium* taxonomy and nomenclature.

It has to be stated, however, that the authors of 'Die Fusarien' were probably constrained to draw up the Key as they have done since in any attempt to follow the arrangement suggested above the distinction between some at least of the different varieties and forms recognised by them is likely to break down.

Apart from the data emerging from the present investigation, close study of the descriptions given by Wollenweber and Reinking (1935) indicate the following:

From the morphological standpoint, *Fusarium vasinfectum*, its varieties and forms have conidia very similar in shape and size. Spore measurements (see Wollenweber and Reinking, 1935, p. 124–26) are similar though 3-septate conidia of *F. vasinfectum* v. *zonatum* and its two forms are slightly longer than the other members of the present group. From the taxonomic standpoint these differences are of little significance though it is not so considered by Wollenweber and Reinking (1935). Range in spore size within the species *F. vasinfectum* is very wide and hence the author feels that slight variations in spore size alone should not be the basis for distinguishing varieties and forms within the species itself. In fact, Wollenweber and Reinking (1935) have stressed on other criteria in this matter. The key characteristics of the various varieties and forms of *F. vasinfectum* as set forth by Wollenweber and Reinking (1935) are as follows:

F. vasinfectum f.1 (Wollenweber, 1931, p. 423) is considered by them to be very similar to *F. vasinfectum* in all respects except that cultures of the former

lack smell. Indeed, the form had been originally given varietal rank by Wollenweber (1913) and, as v. *inodoratum*, was distinguished from *F. vasinfectum* only on the basis of lack of smell in the case of cultures of the former.

F. vasinfectum f.2 (Wollenweber and Reinking, 1935, p. 125) is considered to differ from *F. vasinfectum* solely on account of its doubtful pathogenicity and wilt production on cotton and it is stated that a number of representative isolates from the evacuation of bowels of children suffering from dyspepsia are included in this form.

F. vasinfectum v. *lutulatum* (Wollenweber, 1931, p. 424) is considered to differ from *F. vasinfectum* in possessing somewhat longer conidia and by the occasional appearance of abundant small (0·5 mm. diameter) dark blue sclerotial bodies.

F. vasinfectum v. *zonatum* (Wollenweber, 1931, p. 424) is distinguished from the above variety and forms by the growth of its mycelium in concentric zones, by the absence of dark blue sclerotial stromata, by the pale, nearly yellow colour of its sporodochial and conidial slime and by the few longer and thicker conidia.

F. vasinfectum v. *zonatum* f.1 (Wollenweber, 1931, p. 425) is said to differ from *F. vasinfectum* v. *zonatum* by the pale, cream coloured to lac-ochre-brown, seldom nearly purple, red stromata and occasional presence of vesicular swollen yellow-brown plectenchymatous knots of 0·5 mm. thickness in cultures of rice.

F. vasinfectum v. *zonatum* f.2 (Wollenweber, 1931, p. 425) is considered to differ from *F. vasinfectum* v. *zonatum* and its form 1 in that the first lacks aromatic smell and sclerotia, and has strongly purple coloured stromata, lilac coloured aerial mycelium and richly occurring pionnotes.

It will be obvious from the above summary that in the separation of varieties and forms of *F. vasinfectum*, Wollenweber and Reinking (1935) have used, besides spore size, the following criteria: (1) presence or absence of odour; (2) ability to produce wilt in cotton; (3) presence or absence of dark blue sclerotial bodies; (4) presence or absence of zonation in cultures; and (5) colour of stroma when present. In any classification of the fungi under study, the value of these criteria has to be properly assessed.

(1) Presence or absence of odour has been found to be an unreliable character and is of little help in distinguishing between *F. vasinfectum* and its form 1. Cultures of *F. vasinfectum* and its varieties and forms obtained from the Centraalbureau voor Schimmelcultures did not show any recognisable differences in the production of aromatic odour. This observation confirms that of Kulkarni (1934).

(2) The inability to produce wilt in cotton is one of the criteria suggested for distinguishing between *F. vasinfectum* f.1 and *F. vasinfectum* f.2; the former is considered definitely pathogenic to cotton whereas the ability of the latter to cause wilt in cotton is stated to be uncertain. The pathogenicity tests reported here indicated that both forms 1 and 2 were pathogenic to wilt-susceptible Indian cotton, though the latter was only weakly pathogenic. Higher pathogenicity figures obtained for form 1 are doubtless in keeping with Wollenweber and Reinking's (1935) observations, and the low figures of mortality obtained by inoculation with form 2 appear to confirm the doubtful pathogenicity of this form on cotton suggested by Wollenweber and Reinking (1935). However, *F. vasinfectum* itself was not pathogenic to cotton in the tests carried out by the author. This again is probably in conformity with observations of Wollenweber and Reinking that *F. vasinfectum* causes cotton wilt in N. America, but its form 1 causes cotton wilt in N. America, in Egypt and in India. The culture of *F. vasinfectum* f.1 used in the present investigation is an Egyptian isolate originally obtained from Fahmy who demonstrated its ability to cause wilt in both American and Indian cottons (Fahmy, 1927). Yet, it would appear that we are dealing here with the question of physiologic specialisation, evidence of which in *F. vasinfectum* has been suggested by Mundkur (1936). In any case, much weight need not be attached to pathogenicity of these fungi in classifying them, particularly in view of the observations of Mundkur (1936) on the rôle of environment in the pathogenicity of

parasitic fungi and the resistance which host plants can offer to them. Mundkur showed that Indo-American and American cottons were immune to an American strain of *F. vasinfectum* when growing in Indian soils; similarly, Indo-American cottons growing on American cotton soils proved to be as susceptible as the American cottons to the American strain of the fungus, but were still immune to the Indian fungus. The writer's isolates, which were between themselves morphologically indistinguishable, moreover, exhibited a wide range of pathogenicity. It should also be noted that besides *F. vasinfectum* f.1 and *F. vasinfectum* f.2, other varieties and forms also exhibited pathogenicity on cotton.

(3) The only cultures which produced sclerotia were S 17, S 20A and *F. vasinfectum* v. *zonatum* f.2. No sclerotia were observed in cultures of *F. vasinfectum*, *F. vasinfectum* forms 1 and 2, and *F. vasinfectum* v. *lutulatum*, all of which are considered to produce sclerotia by Wollenweber and Reinking. The author's results further failed to confirm the inability of *F. vasinfectum* v. *zonatum* f.2 to produce sclerotia. Sclerotial formation is obviously a variable character and it would appear that undue emphasis has been laid on this character in the classification of the *Fusarium vasinfectum* group of Fusaria.

(4) No zonation was observed in cultures of *F. vasinfectum* v. *zonatum* and its forms 1 and 2 or in any of the other cultures and isolates studied. The usefulness of this phenomenon, therefore, in distinguishing between these fungi, is doubtful.

(5) Stromatic colour of all isolates and cultures except *F. vasinfectum* v. *zonatum* f.1 was pink to purple; stromatic colour in the case of *F. vasinfectum* v. *zonatum* f.1 alone was cream to ochre. This observation is in agreement with that of Wollenweber and Reinking (1935). Further, neither acid nor alkali could modify stromatic colour of this culture on rice. Indeed, the culture retains in a remarkable manner the stromatic colour originally claimed for it (Link and Bailey, 1926).

The above observations incline the author to consider the following varieties and forms synonyms of *Fusarium vasinfectum* Atk.: *F. vasinfectum* Atk. f.1 Wr., *F. vasinfectum* Atk. f.2 Wr. et Rg., *F. vasinfectum* Atk. v. *lutulatum* (Sherb.) Wr., *F. vasinfectum* Atk. v. *zonatum* (Sherb.) Wr., *F. vasinfectum* Atk. v. *zonatum* (Sherb.) f.2 (Lk. et Bail.) Wr. The distinct stromatic colour exhibited by *F. vasinfectum* Atk. v. *zonatum* (Sherb.) f.1 (Lk. et Bail.) Wr., coupled with its indifference to addition of acid or alkali indicates the need for re-considering its systematic position which is left an open question for the present. It would appear from the present instance that the production of red or blue colour with acid or alkali respectively is not universal within the section *Elegans*. On the basis of the results obtained, the author's isolates are also identified as *F. vasinfectum* Atk. although these isolates exhibited variation in regard to growth rate and pathogenicity on cotton.

Summary.

The results are presented of a study of certain Fusaria isolated from wilted cotton plants and 'wilt-sick' cotton soil from Southern India. All isolates studied belonged to the section *Elegans* and were similar morphologically but exhibited variation in regard to growth rate in culture and pathogenicity on cotton. The isolates were compared in detail with cultures of *Fusarium vasinfectum* Atk. and its varieties and forms obtained from the Centraalbureau voor Schimmelcultures, Baarn, Holland. On the basis of the data obtained, which are presented and discussed in detail, all varieties and forms of *F. vasinfectum* Atk. recognised by Wollenweber and Reinking (1935) with the exception of *F. vasinfectum* Atk. v. *zonatum* (Sherb.) f.1 (Lk. et Bail.) Wr. are considered synonyms of *F. vasinfectum* Atk. The Indian isolates are identified as *F. vasinfectum* Atk.

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