WILT OF PEANUT (*ARACHIS HYPOGAEA* L.) IN QUEENSLAND, WITH PARTICULAR REFERENCE TO VERTICILLIUM WILT

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SUMMARY

Wilt symptoms encountered in peanuts in Queensland are discussed. It is shown that *Verticillium dahliae* Kleb. is the cause of the common condition and that *Fusarium* sp. is unimportant.

Pathogenicity on peanuts is demonstrated for isolates of *Verticillium dahliae* from tomato, plum and eggplant.

The field distribution of Verticillium wilt has greatly increased in recent years. It is suggested that the change to mechanical harvesting has brought this about.

The association of Verticillium wilt with the better class soil is discussed.

The disease is shown to reduce yield of individual plants by 14-60 per cent. Some of this reduction is due to incomplete filling out of the kernels. The variation in maturity in an affected crop is important.

Methods of control involving crop rotation with emphasis on weed control are suggested.

I. INTRODUCTION

Wilt in peanuts in Queensland has been previously described by Morwood (1945), who found both *Fusarium* sp. and *Verticillium* sp. associated with the disease.

The importance of Fusarium wilt of peanuts was regarded as questionable by Garren and Wilson (1951, pp. 262-324) in a general review of the subject. Records of the disease in both Kenya (McDonald 1933; Humphrey 1939) and Georgia (Miller and Harvey 1932) indicate that while *Fusarium* sp. was the cause, the symptoms were that of a root or crown rot rather than a true vascular wilt. There have been numerous recordings of root or crown rot of peanuts with which *Fusarium* spp. have been associated (Hansford 1934; Ken Knight 1941; Anon. 1939; Anon. 1942; Reichert and Chorin 1942; Anon. 1950).

Verticillium dahliae Kleb., *Verticillium* sp. and *Fusarium* sp. have been reported on peanuts in Asia by Golovin (1937). Verticillium wilt has recently been described in the U.S.A. (Smith 1960).

This paper outlines the result of investigations into the problem in Queensland since 1956.

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II. SYMPTOMS AND ISOLATIONS

There are a number of quite distinct symptom expressions associated with wilt in peanuts. The far more common wilt is characterized by an unusual colouration of the leaf in which chlorotic patches appear in the lamina, particularly around the periphery. This symptom is seen first in the lower leaves, usually about flowering time. The light patches later turn brown, giving the plants a scorched appearance. A true wilt is only noted during excessively dry or hot weather when periods of extreme moisture stress occur. Affected plants usually remain stunted and "mature off" more quickly than normal (Figures 1 and 2).

Fig. 1.—Typical symptoms of Verticillium wilt in peanut plant (left), compared with healthy plant (right).

Fig. 2.—Plant on left shows the typical scorched effect of Verticillium wilt.

Except in the most advanced stages the root system appears healthy, but internally there is a pronounced brown to black vascular discolouration extending up the stem and into the leaf bases. Isolations from plants having these symptoms invariably yield *Verticillium* sp.

The second type is characterized by a pronounced wilt of the plant accompanied by yellowing and upturning of the leaves. Although encountered relatively frequently, it affects only isolated plants and is of no economic importance. Plants may be affected at any stage of maturity. In the great majority of cases there is a marked rotting of the tap root, with slight internal discolouration extending up into the crown. Isolations from this condition have yielded *Rhizoctonia solani* Kuehn, *Fusarium* sp. and occasionally *Macrophomina phaseoli* (Maubl.) Ashby. This condition is regarded as more a root rot than a true wilt and is similar to the conditions described in other areas (McDonald 1933; Miller and Harvey 1932).

Plants showing sudden wilt without any other external symptom are occasionally encountered. A brown discolouration of the cortex is apparent through the epidermis but does not extend into the stele. No organism has been consistently isolated from this condition.

In a few isolated instances plants have been observed with symptoms which would normally be regarded as typical of Fusarium wilt. There is a yellowing of the lower leaves and severe wilting, with distinct vascular discolouration extending up the stem and into the leaf bases. *Fusarium* sp. has occasionally been associated with this condition but too infrequently to suggest it as a possible cause.

III. PATHOGENICITY TESTS

Pathogenicity tests on peanut plants have been carried out with four isolates obtained from wilted plants. Two isolates were of *Verticillium* sp. isolated from the commonly occurring condition. The other two isolates were of *Fusarium* sp., one from a plant with pronounced root rot.

Slurry inoculum was prepared from week-old cultures growing on potato dextrose agar. The soil was eased away from the roots of peanut seedlings growing in sterilized soil and the slurry poured down around the plants.

After eight weeks marked symptoms were produced on the plants inoculated with *Verticillium* sp. These in all cases were stunted when compared with uninoculated controls. Leaves were commencing to yellow and some of the plants were developing the typical mosaic pattern on the leaves. Vascular discolouration was apparent in most plants and *Verticillium* sp. was reisolated.

The plants inoculated with *Fusarium* sp. grew as vigorously as the controls. No leaf symptoms were apparent after eight weeks and when the root system was removed from the soil there was no sign of infection.

It is apparent from these tests that *Verticillium* sp. is the cause of the common wilt condition of peanuts in Queensland. Fusarium wilt, if it occurs at all, plays only a very minor role.

IV. DESCRIPTION OF *VERTICILLIUM* SP. FROM PEANUT

The cultural characteristics of the organism were examined, using five separate isolates. These were grown on potato dextrose agar at room temperature. White, fluffy, aerial mycelium developed from the point of inoculation but tended to be restricted towards the margin of the colonies, which were compressed and irregular in shape. After periods of 1–2 weeks black bodies appeared in the substrate, commencing usually around the periphery and point of inoculation. These then gradually appeared over the entire substrate, developing often in concentric rings. After three months three of the isolates appeared black from the presence of these bodies, while in the two other isolates their development was somewhat restricted. Some sectoring was noted in colonies, but although the sectors varied in their production of the black bodies, at no time were they completely absent.

Examined microscopically these bodies appeared to arise by cell division in individual hyphae and were composed of dark-walled thickened cells. They appeared identical with the micro-sclerotia described in detail by Isaac (1949). They were very variable in shape and size, with a range in length from 30 to 210 μ. Non-septate conidia, globose to ovoid in shape, were formed in abundance on potato dextrose agar.

In a series of hyphal tip colonies prepared from two isolates, variation was observed in the number of micro-sclerotia produced. However, no colonies free of these structures were observed.

The growth/temperature relationships of the fungus were determined in a multi-temperature incubator using potato dextrose agar prepared in 4 oz clear bottles. Rate of growth was determined by measurement of the diameter of the colonies, two bottles being used for each determination. The fungus had a minimum just below 5°C and failed to grow at temperatures above 33°C. Optimum growth occurred between 23°C and 26°C. It is obvious from the occurrence of wilt during the hot summer months that *Verticillium* sp. in peanuts is a relatively high-temperature organism.

V. IDENTIFICATION

There has been considerable argument over the validity of the separation of *Verticillium dahliae* Kleb. and *V. albo-atrum* Reinke and Berth. However, the detailed evidence presented by Isaac (1949) and Robinson, Larson, and Walker (1957) indicates that the differences between the two species is constant with regard to micro-sclerotia production and temperature responses. As the peanut organism produced micro-sclerotia and made appreciable growth at 30°C it has been classified as *V. dahliae*. It is pertinent to point out that the type producing micro-sclerotia was the only one encountered during the investigations. It would be indeed confusing if this organism were now grouped with the dark-mycelium strains, an eventuality which would occur if it was classified as *V. albo-atrum*. It seems likely that the micro-sclerotia producing type isolated from peanut by Smith (1960) and described as *Verticillium albo-atrum* is similar to the Queensland organism.

VI. CROSS-INFECTION TESTS

Isolates of *V. dahliae* obtained from plum, tomato and eggplant in Queensland were compared in pathogenicity with the peanut organism on tomato, eggplant and peanut. These isolates all appeared similar with the exception of the one from tomato, which tended to produce micro-sclerotia in greater abundance.

Seedlings of the three test hosts were raised in sterilized soil and inoculated by dipping the roots in a slurry of the test fungus prepared from week-old cultures. The eggplant and tomato plants were removed for examination after 11 weeks and the peanut plants after 17 weeks. Observations were made on general symptom expression but a rating for infection was given on the basis of presence or absence of vascular discolouration. These ratings are listed in Table 1.

TABLE 1

INFECTION RATINGS ON DIFFERENT HOSTS WITH ISOLATES OF *V. dahliae*

Host	Isolate	No. of Plants Inoculated	No. of Plants Infected
Tomato (var. Grosse Lisse) ..	13685 (Tomato)	17	10
	S317 (Plum)	16	0
	K302 (Peanut)	16	3
	13712 (Eggplant)	17	0
	Control (Uninoculated) ..	18	0
Eggplant	13685	17	16
	S317	9	9
	K302	14	14
	13712	12	12
	Control	18	0
Peanut (var. Virginia Bunch) ..	13685	16	12
	S317	16	12
	K302	15	15
	13712	14	14
	Control	15	0

In the tomato host group only those plants inoculated with the tomato isolate showed any visible symptom. These plants were slightly stunted in comparison with the other treatments. The *V. dahliae* reisolates from the infected tomato and peanut groups were similar to the original tomato isolate.

In the eggplant host group stunting of the same order was observed in all isolate groups (Figure 3). The control plants averaged 6·1 in. in height, while the average height of inoculated plants varied from 2·7 in. for the eggplant isolate to 3·4 in. for the plum isolate. *V. dahliae* reisolates which were obtained from each infected group appeared identical, with the exception of the one from eggplant, which showed only slight production of micro-sclerotia.

In the peanut host group considerable stunting occurred with the peanut and tomato isolates (Figure 4), slight stunting with the eggplant isolate and no stunting with the plum isolate or the control. Typical mosaic leaf symptoms were seen in at least some of the plants in the peanut, tomato and eggplant isolate groups. Reisolations from all the groups yielded apparently identical cultures of *V. dahliae* producing abundant micro-sclerotia.

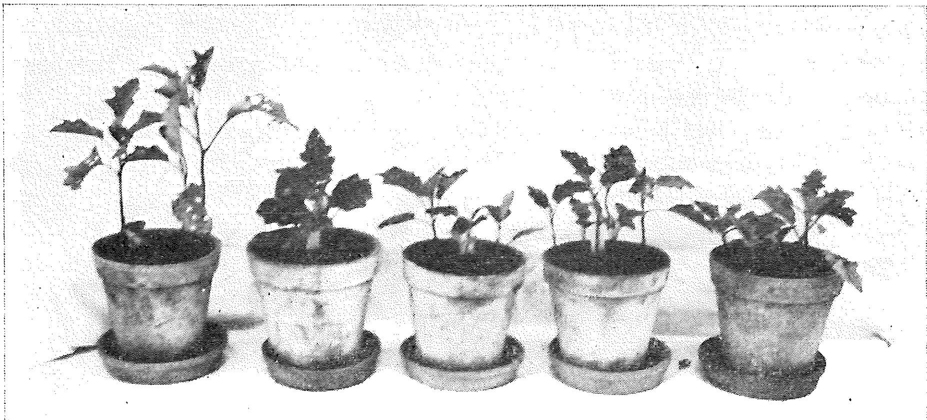

Fig. 3.—Eggplants inoculated with *Verticillium dahliae* from various hosts. Source, from left to right, uninoculated, peanut, eggplant, tomato, plum.

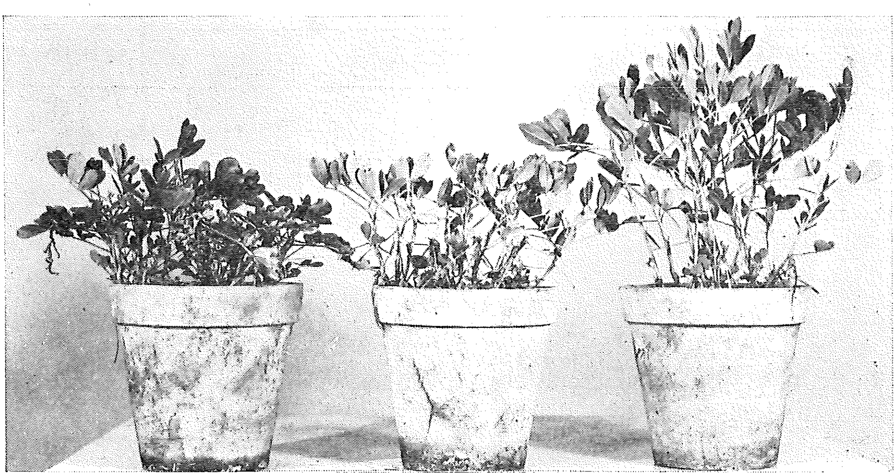

Fig. 4.—Peanuts inoculated with *Verticillium dahliae* from tomato (left) and peanut (centre). Uninoculated plants on right.

It is apparent from these results that while peanut may be infected with *V. dahliae* from other hosts there is some variation in the relative pathogenicity encountered. Thus the peanut and tomato isolates produced more severe symptoms in peanut than the eggplant or plum isolates did.

Smith (1960) concluded that peanuts in New Mexico were susceptible to *Verticillium* from a wide range of plant material.

VII. FIELD STUDIES OF VERTICILLIUM WILT

(i) *Field Distribution.*—In past years wilt in peanuts occurred in relatively small patches and these were usually associated with stationary threshing sites of previous seasons (Morwood 1953). During the last few seasons infections have become more general, with levels close to 100 per cent. being not uncommon (Figure 5). This change in incidence has coincided with the more general use of mechanical harvesting equipment. Plant debris which was previously destroyed on the thresher sites by burning is now spread evenly over the soil surface. Field evidence suggests that this results in a much wider distribution of the organism responsible for wilt. In this way a relatively unimportant disease has assumed rather serious proportions.

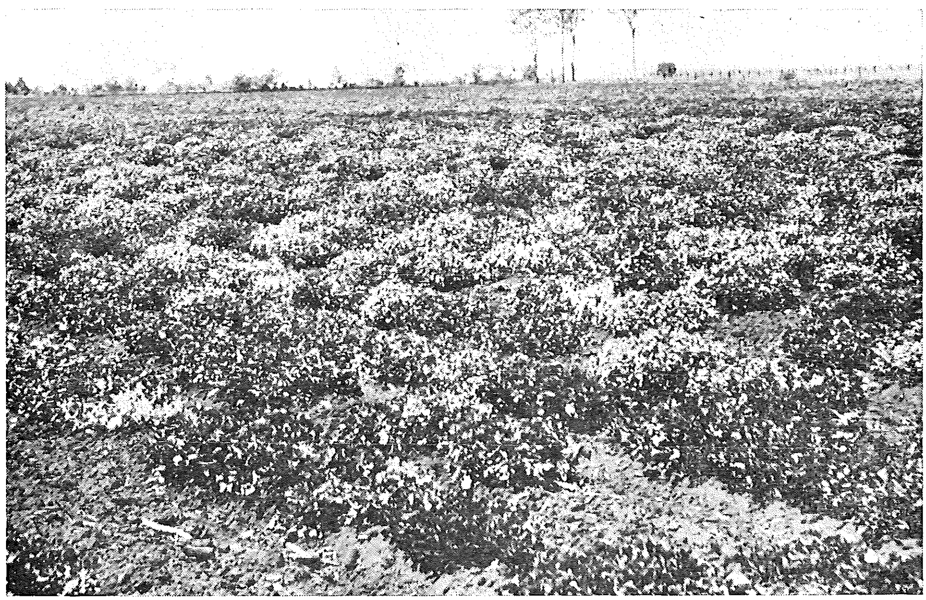

Fig. 5.—View of a field of peanuts showing general infection with Verticillium wilt.

Unlike the incidence recorded in New Mexico (Smith 1960), high rates of infection have not generally been associated with high soil moisture levels. Indeed, during the 1959–60 and 1960–61 seasons, both of which were abnormally dry, the disease was much more widespread than had been previously recorded.

(ii) *Effect of Soil Type and Weed Growth.*—There is great variability in the soil types encountered in the peanut-producing areas of southern Queensland. While Verticillium wilt occurs widely on the more fertile soil types, it is rarely encountered on the poorer class of soil. Nutrition is known to play an important part in the severity of Verticillium wilt in other crops (Garrett 1947; Keyworth and Hewitt 1948; Donandt 1932), the level of nitrogen in the soil being considered of paramount importance. This factor could be the reason for the restriction of peanut wilt to the better soils.

Another factor in this phenomenon could be the higher incidence of weeds susceptible to wilt infection on the better-class soils. On these soils the growth of annual herbaceous weeds is often very prolific, while on the poorer class of soil grass weeds tend to predominate. Close examination has been made of weeds in areas where the disease in peanuts has been severe and Verticillium wilt has been recorded in stinking roger (*Tagetes minuta* L.), Anoda weed (*Anoda cristata* Schlecht.) and Noogoora burr (*Xanthium pungens* Wallr.).

In all three species the disease manifests itself in an uneven yellowing of the lower leaves. This may be accompanied by a stunting and partial wilting of the plants. Brown vascular discolouration is always evident at the base of the stem but may extend up into the leaf bases. *Verticillium dahliae* isolates producing an abundance of micro-sclerotia have been obtained consistently from these plants and appear identical with the peanut organism.

In inoculation tests on peanuts with isolates from *Anoda cristata* and *Tagetes minuta,* typical symptoms of Verticillium wilt are produced.

Both *Tagetes minuta* and *Xanthium pungens* are of widespread occurrence. *Anoda cristata* is more restricted but occurs widely on the better class of soils.

(iii) *Economic Aspects of the Disease.*—Although the presence of Verticillium wilt is widely recognized it is generally accepted as being of little economic importance.

Efforts have been made to assess the effect of the disease by comparing yields of diseased and adjacent healthy plants in affected crops (Table 2). These determinations have necessarily been made in different paddocks each year and this factor, combined with variations in weather conditions, explains the rather wide fluctuations in average yield between seasons.

Samples taken from the second series in the 1960–61 season were used to determine the effect of the disease on kernel weight. In appearance, kernels from diseased plants were rather more wrinkled than those from normal ones. The average weight of five samples consisting of 100 seeds each was 70·1 g for healthy and 63·5 g for diseased. The reduction in yield therefore can be attributed in part to incomplete "filling-out" of the kernels.

TABLE 2

Effect of Verticillium Wilt on Yield of Peanuts During Three Seasons

Season	Rainfall (in.) Feb.-April	Average Yield per Plant (g)		Reduction in Yield (%)
		Healthy	Diseased	
1957–58	15·24	133 (12)*	48 (12)	63·9
1959–60	5·38	154 (12)	123 (12)	20·1
1960–61	6·78	77 (25)	66 (25)	14·3
		77 (20)	61 (20)	20·8

* Figures in brackets indicates number of plants used in the determination.

Although the visual effects of the disease appeared much more severe during the dry seasons (1959–60 and 1960–61), the reduction in yield was not nearly so pronounced as in the season of good late summer and early autumn rains (1957–58).

The reduction in yield even at the lowest level of 14 per cent. is of considerable economic importance. The variation in maturity in a crop resulting from the disease is of equal significance. This often requires the grower to harvest 2–3 weeks earlier than the optimum time, with consequent loss in yield and quality from the healthy bushes.

VIII. CONTROL OF VERTICILLIUM WILT

The value of crop rotation in the control of this disease has been advocated (Morwood 1945). General observations confirm that where rotations are judiciously practised the disease is kept in reasonable check. However, there have been occasions when wilt has assumed serious proportions on land seldom cropped to peanuts. On at least one of these occasions susceptible weeds were found in abundance. Where the disease has been severe it would be wise to pay particular attention to control of herbaceous weeds throughout the rotation.

Reports indicate that *V. dahliae* can survive in the soil for at least four years (Anon. 1954), so rather than adopt the usual maize/peanut rotation, a period to grass in severely infected paddocks could be an advantage. With the change in peanut harvesting methods, whereby diseased plant residue is disseminated much more effectively, the need for this longer type of rotation has become more apparent.

IX. ACKNOWLEDGEMENTS

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