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HEART ROT OF THE DATE PALM

Caused by *Thielaviopsis paradoxa* (DeSeynes) von Höhn

By
R. B. Streets

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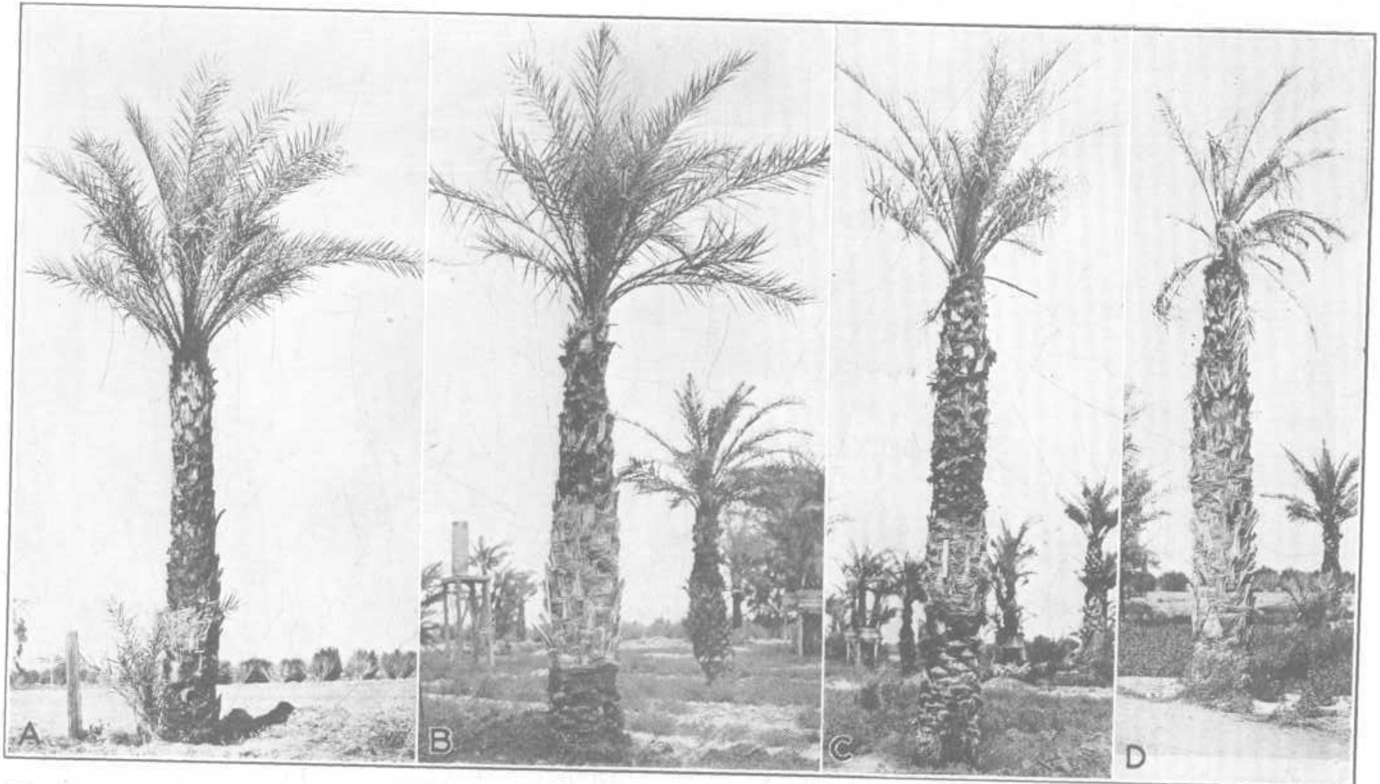

Plate I.—Deglet Noor date palms showing symptoms of heart rot. All palms show reduced leaf area as a result of defoliation and torching (See text). A.—Healthy palm. Note length of new leaves "a" and "b." B, C, and D.—Palms showing progressive stages of heart rot. B.—Palm with earliest recognizable symptoms of heart rot—new leaf growth short, slight drying of tips of lower leaves. C.—Advanced stage—growth has ceased, all leaves show drying. D.—Palm practically dead.

HEART ROT OF THE DATE PALM

Caused by *Thielaviopsis paradoxa* (DeSeynes) von Höhn

By

R. B. Streets

INTRODUCTION

The literature on culture and diseases of the date palm is meager in spite of the fact that dates have been cultivated for at least 3,000 years. One reason is that dates have been grown for many centuries by the native tribes of Asia Minor and North Africa, but only recently have European races taken up the cultivation of dates on a large scale.

While date palms were grown from seed brought into the Southwest by missionaries who came to the country under Spanish rule, commercial date culture really began with the efforts of the United States Department of Agriculture which resulted in the importation of a large number of offshoots from the best palms of North Africa and Asia Minor. Three experimental date orchards were set out, one in the Yuma Valley and one at Tempe in the Salt River Valley (both in cooperation with the Arizona Agricultural Experiment Station) and the third at Indio in the Coachella Valley of California.

The early experimental work was concerned largely with cultural practices, growing of offshoots, processing and packing fruit, spoilage of fruit during ripening, and control of scale insects. Perhaps the scarcity of information on date diseases is also due to the fact that very few troublesome diseases have appeared in the three decades during which dates have been cultivated in the Southwest.

The most important disease has been the souring and rotting of the fruit beginning during the ripening period and causing spoilage in packed fruit which has not been pasteurized. This disease has been discussed by Brown (2). Another disease, Graphiola leaf spot, has been under investigation by the writer for several years.

In 1926, Dr. H. S. Fawcett, plant pathologist of the Citrus Experiment Station at Riverside, California, took up the investigation of date diseases in the Coachella Valley, and in 1929 Dr. L. J. Klotz joined Dr. Fawcett in this work. In 1932 following a series of papers, Fawcett and Klotz (11) published the first comprehensive bulletin on the diseases of the date palm. In North Africa three French investigators, Killian and Maire (14) in Algeria, and Chabrolin in Tunis, have published a number of papers on maladies of the date palm.

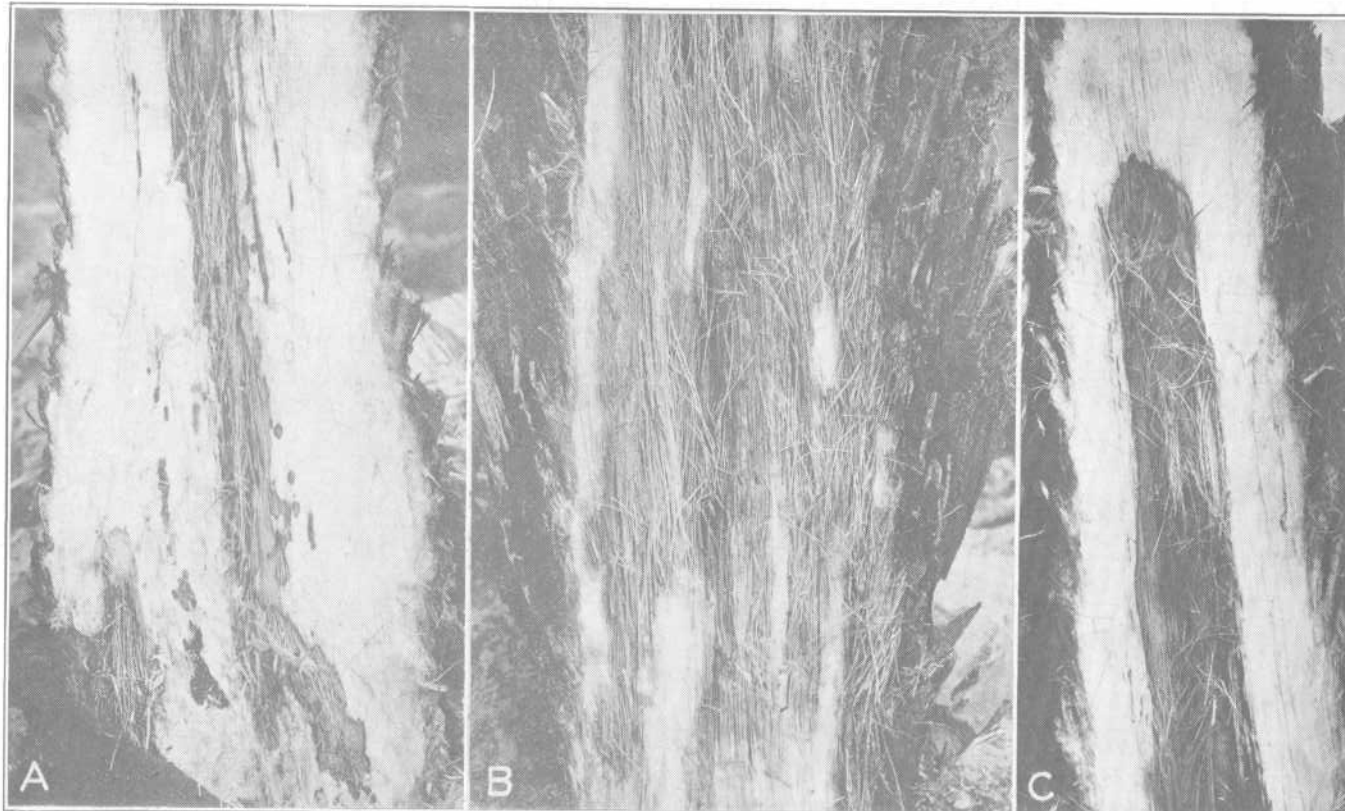

Plate II.—Heart rot in trunks of palms shown in Plate I. Six-foot sections of the trunks were split longitudinally to expose the rot. A.—Basal section of palm B (first stage). B.—Intermediate section of palm D (last stage). C.—Intermediate section of palm E (not illustrated). This cavity contained about two quarts of fermented liquid.

During the month of March, 1925, the writer was called to the Yuma Valley Experiment Station to investigate the sudden death of a number of large date palms. It soon appeared that the palms were apparently suffering from an undescribed heart rot and several weeks were spent in an intensive field study to determine the cause and factors influencing its prevalence. Following this, laboratory studies were started and observations of the palms under field conditions have been continued since the discovery of the disease. One of the greatest obstacles to a thorough study of the disease has been the scarcity of infected palms and healthy palms available for study and inoculation.

Papers reporting studies on this disease were read at the 1925 meeting of the Southwestern Division of A. A. A. S., and in 1930 at the Date Growers' Institute at Indio, California, but no publication has been made prior to this bulletin.

SYMPTOMS

While the symptoms may be best shown by photographs, they may be described as follows: The affected palms at Yuma showed first a retarded development of the new leaves (Plate I, B) which gives the crown of leaves a flattened instead of a rounded outline. The individual pinnae dried out progressively toward the midrib, the older leaves showing injury first (Plate I, C). Soon all the foliage showed injury and the palm died, usually within a few days (Plate I, D).

Eight of the affected palms showing various degrees of injury were dug up and carefully dissected. The leaves and leaf bases showed very little discoloration or other change in early stages of the disease. In later stages some of the palms showed a soft rot of the living tissue of the young leaf bases (the thin portion which becomes the fiber) but this appeared to be a bacterial soft rot of secondary nature. Some of the roots showed a brown discoloration of the thick cortical layer. This should not be confused with the presence of some dead superficial roots always found in healthy date palms.

Those familiar with date culture know that the date palm is quite different from ordinary plants which produce tree fruits, in fact it more closely resembles the corn plant, especially in root and stem structure (Plate II and Plate IV).

The most conspicuous symptoms were found in the trunk. Discolorations of various kinds contrasted sharply with the creamy white normal tissue (Plate II). The affected area appeared to develop progressively from an almost normal color through shades of yellow and brown to a very deep brown which was almost black. The pithy tissue between the

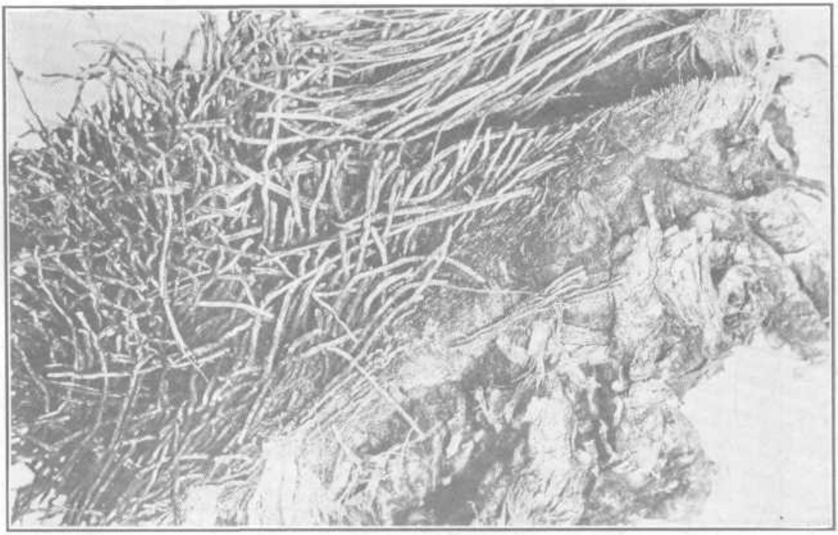

Fig. 1.—Section taken from lower end of trunk near tip showing infected tissues, parenchyma entirely destroyed and dark masses of fungus spores adhering to the fibro-vascular bundles. x1.

cells was completely disintegrated while the vascular bundles were not noticeably affected (Plate V, A and Fig. 1).

The extent to which the trunk tissues were discolored varied considerably and the closeness to the bud region rather than the amount of infection seemed to determine the extent of injury to the palm (Plate III).

CAUSAL AGENT

Microscopic examination showed the presence of a fungus which was especially abundant in the darker discolored tissues. The lightest discolored tissues showed very scant mycelium or none at all.

Petri-plate cultures on agar yielded a large percent of fungus growth (mostly of one type) and a scattering of bacterial and fungus colonies usually found as invaders.

TABLE 1.—ISOLATIONS MADE FROM DISEASED TISSUES OF TRUNK OF DATE PALMS.

	No. cultures	*Thielaviopsis*	Other organisms
Advancing margin	23	20	7
Discolored bundles	22	18	12
Black spores	12	12 Abundant growth	Bacteria and one Penicillium
White spores	12	12 Abundant growth	Bacteria and one Penicillium
Totals	69	62	

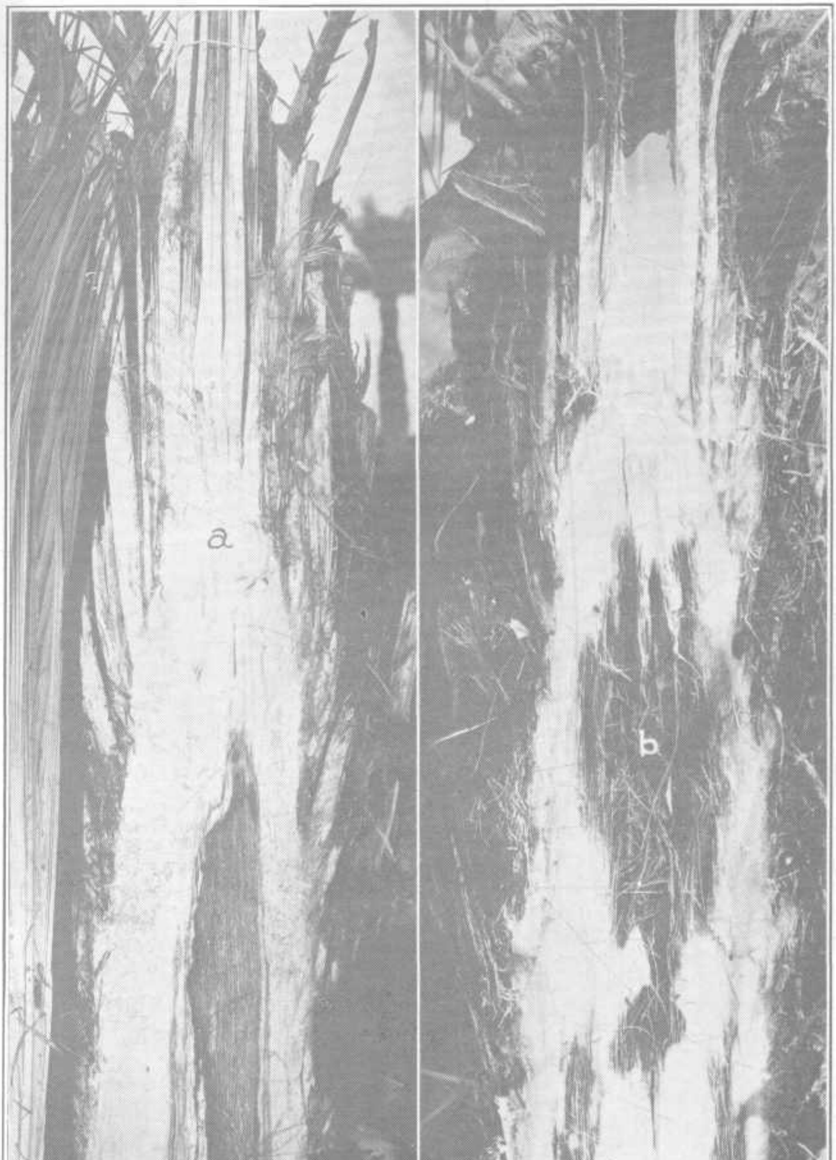

Plate III.—Heart rot attacking the terminal bud. A.—Top section of palm F showing infection approaching terminal bud "a." Invasion of the bud tissues is quickly fatal to the palm. B.—Top section of palm G showing rapid progress of new infection resulting from hole made at "b" 2 weeks before photograph was taken. Old infection advancing from below is shown at "c."

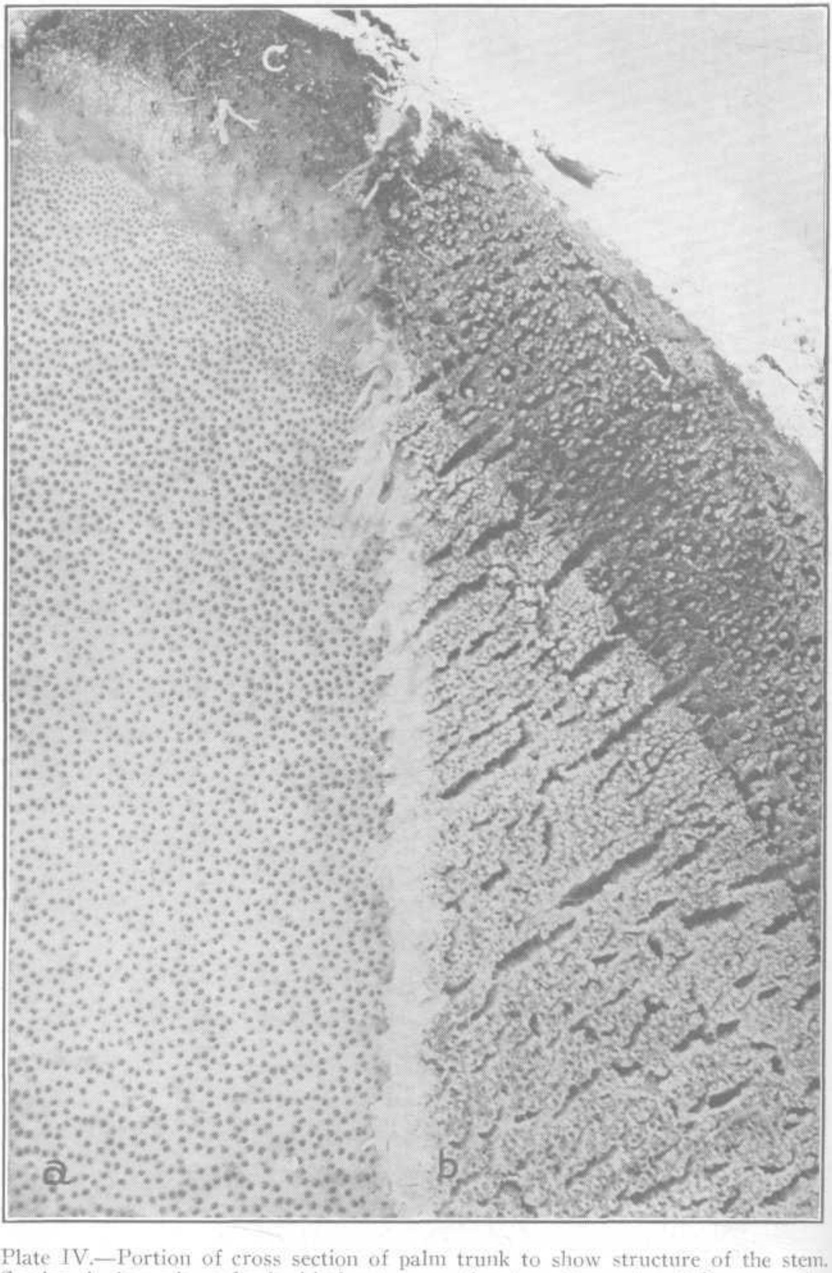

Plate IV.—Portion of cross section of palm trunk to show structure of the stem. Section A shows by a fresh chisel cut across the stem, the scattered fibro-vascular bundles and the white spongy pith between them. Section B shows the drying and cracking of such tissue exposed to the air 24 hours. The dark band C shows a leaf base in cross section. The tissues just beneath the leaf bases are much harder and tougher than the center.

TABLE 2.—ISOLATIONS MADE FROM DISEASED DEGLET NOOR PALM "G." PLATES POURED, YUMA, MARCH 29, 1925 NOTES, MARCH 31 AND APRIL 18.

Tissues cultured	Cultures	*T. paradoxa* in 2 days	Other organisms at end of 20 days
Top of Sec. 1—Dark rot 1 in. diam.	5	5	Arborescent bact. spreader. Several chrom. and 1 mold.
Top of Sec. 1—Very dark rot at narrow place ½ in.	5	5	Gray mold, blue gray mold, and several chromogens.
Base Sec.—Margin near dark rot. Brown spots.	5	4	1 white bact.; 3 chromogens, 3 fluorescent bact
Base Sec.—Margin of black area. Brown spots.	5	5	3 fluorescent bact.; several chromogens.
Top Sec. (Sec. 3)—Brown rot developed from white rot.	5	5	4 fluorescent bact., chromogens, miscellaneous Several molds and Actinomyces.
Sec. 3.—Brown rot developed from light colored rot.	5	4*	Miscellaneous bact., molds, Actinomyces and chromogens.
Sec. 3—Soft tan rot changing from white.	5	4†	3 flurocscent bact.; several chromogens and fungi.
Sec. 3.—Soft tan rot at margin.	5	5	4 fluor. bact. mixed with cream-white spreader. Miscell. others.
Sec. 3.—Advancing margin of rot under bud.	5	4‡	Several fungi and chromogens.
Sec. 3.—Rot under bud.	4	4	3 fluor. bact Miscell. fungi and chromogens.
Total	49	44	
Check—Plain agar.	5	0	3 chromogens—yellow, orange, cream. 3 other creamish colonies.

*Piece from uninfected area sterile.
†Piece from apparently uninfected area gave bacterial colony.
‡One bacterial colony.

Another series of cultures, taken from various parts of the diseased trunk and from areas showing different kinds of discoloration from pallid to very dark, is recorded in Table 2.

T. paradoxa was recovered in 44 of the 49 cultures. The organism develops rapidly at 20-25° C. and is not difficult to secure in pure culture. The plates were poured in the field where facilities for securing still air were lacking and the usual types of air-borne contaminators appeared on the plates and on the check plates which had the same exposure but were not inoculated.

Inoculations made with pure cultures into succulent healthy trunk tissues with usual technique were about 90 percent successful. The organism was re-isolated and compared with the original cultures.

IDENTITY OF FUNGUS

The fungus showed two types of spores: dark, coffee-brown, oval, rather thick-walled spores often in chains of two to eight, (Plate X, D and J); and thin-walled, cylindrical, transparent spores, (white in mass), extruded from the open ends of special branches (Plate X, A). This unusual type of spores suggested a similarity to *Aphanomyces* sp. (causing root rot of canning peas) or *Thielavia* sp. (causing root rot of tobacco) and the fungus was tentatively identified by the writer as *Thielaviopsis paradoxa*. Roldan (25) had just published a paper proving that the fungus causing pineapple rot in the Philippines is *T. paradoxa*, and through the kindness of Dr. G. O. Ocfemia, Pathologist of the Agricultural College at Los Baños, one of Roldan's cultures was secured and was found to agree in cultural characters and spore measurements with the Arizona cultures.

No bacteria were recovered which were able to produce the disease on inoculation, although they were often isolated from infected areas.

INSECT CARRIERS

The decayed tissues attracted particularly the following insects: *Drosophila* spp., called fruit flies or vinegar flies, a medium-sized, black-bodied species, and a tan, red-eyed, smaller species, and a small beetle 3-4 mm. long *(Carpophilus hemipterus)* which feeds on decaying citrus fruits and dates and is known by the name of "sour bug" or "fruit beetle." These insects frequented the freshly decayed tissues and *Drosophila* spp., at least, deposit eggs which give rise to maggots in the wet, decaying tissues. Two species of reddish brown ants (one small and one medium sized) were found to have constructed nests in cavities resulting from decay starting from an offshoot scar. Specimens of all species were given to the University collection.

Plate V.—Enlarged views of decaying stem tissues. A.—Radial section through recently infected tissue showing complete destruction of parenchyma tissues and dark spore masses. x2. B.—Mycelium and abundant conidia (spores) formed on surface of diseased tissue exposed to light and air for forty-eight hours. x2.

Both fruit flies and sour bugs might easily be carriers of the fungus spores and spread the disease. Larsen (18) finds that both are carriers of spores in the case of the pineapple rot.

Fig. 2.—Lower tip of palm D (not illustrated) cut diagonally to show well healed scar where this palm was cut from the mother palm. The infected area "b" comes within an inch of the surface in several places but no connection could be traced. x ¼.

CULTURAL PRACTICES

The orchard had been entirely defoliated and the trunks gone over with gasoline torches (Plate I) to eradicate the Parlatoria scale. It seems evident that this treatment is a severe shock to the tree for it requires 3 years from time of defoliation for the palm to develop a normal crown of leaves and resume the bearing of fruit. The shock in this instance was particularly severe since the second defoliation occurred before the palms had fully recovered from the first. Another condition which might also have been unfavorable was the presence of a sour-clover crop which made necessary more frequent irrigation. Since the entire top had been removed without any injury or pruning of roots an abnormal condition resulted which may have made the palms more susceptible to a parasite like *Thielaviopsis paradoxa*. There appeared to be no cultural practice which could cause the disease.

PORTALS OF INFECTION

Before any treatment or control measure could be suggested it was necessary to find how the organism entered the trunk. Starting from the top the sections showed the tissues of the terminal bud and unexpanded leaves to be bright and healthy.

OFFSHOOT SCARS

Offshoot scars, being usually near or even below the soil line, should prove an easy portal of entry for a wound parasite. Date varieties differ greatly in the size and texture of the tissues at the union of mother palm and offshoot. Deglet Noor has a small and quite woody union (Fig. 2) and yet seems very susceptible to heart rot while Rhars, with a very large connection, appears relatively resistant, suggesting that neither mother-palm nor offshoot is often infected through wounds made in removing offshoots. Careless or inexpert handling of the chisel used in removing offshoots is another matter, and caused infection in a large palm.

The results of microscopic examination of tissues from offshoot scars on healthy and diseased trees are summarized in Table 3:

TABLE 3.—RESULTS OF MICROSCOPIC EXAMINATION OF TISSUES FROM OFFSHOOT SCARS ON LARGE PALMS FOR PRESENCE OF *THIELAVIOPSIS PARADOXA*.

Variety	Size and condition	Off-shoot scars	Fungus + or —	Spores	Condition of tissues examined
Deglet Noor	Large, '09* Diseased	4	+ — + +	Macro-	Brown rot
Deglet Noor	Large, '09 Diseased	4	— — — —	None None	Brownish rot Pallid rot
Deglet Noor	Large	3	— — —	None	Pallid, fermented
Deglet Noor	Large Sl diseased	3	+ + +	Macro-	Brownish rot
Beed Hammur	Large Scars large	3	— — —	None	Decayed, brittle
Rhars	Large, '09 Healthy	3	— — —	None	Pallid rot
Rhars	Large, '09 Healthy	2	+ —	Micro-	Pallid, bundles intact
Offshoot scars infected 7; not infected 15.					

*Planted 1909.

In a total of 22 offshoots examined 7, or less than one-third, showed the presence of Thielaviopsis spores, and it is doubtful if any of these infections were active.

Fig. 3.—Base of palm showing severe mechanical injury and formation of abundant adventitious roots above the point of injury. Such open wounds exposed to heat and drying do not ordinarily develop persistent infections.

INFECTION FROM THE MOTHER-PALM

In the case of two other large palms which had been cut down in an attempt to save the offshoots from the infection which had developed in the trunk, the healthy tissues of the stump exposed without fungicidal treatment became infected and as a result the offshoots died.

LEAF BASES AND SHEATHS

The leaf bases and the sheaths which on drying become the fiber, die gradually after the old leaves are cut off, but they are so dry and fibrous that they do not form a good medium for the growth of most organisms and no definite proof of infection through leaf bases or the leaf axils could be found. Inoculations into the dead part or living part of *old* leaf bases and axils (without deep wounding) were unsuccessful. Leaf bases of living leaves were not inoculated because no evidence of infection through them was found.

Fig. 4.—Crown of large palm showing distortion, dwarfing, and "scorching" of young leaves by the heart rot fungus, Thielaviopsis. This type of injury is called "black scorch."

WOUNDS

Wounds resulting from careless use of tools and cultivating equipment (tractors, discs, etc.) were examined but only two in six showed the presence of Thielaviopsis. Open wounds well above the soil line (such as shown in Figure 3) often dry out thus checking any incipient infection which may have occurred. Another infection was found 6 feet above the ground extending up and down the trunk for 18 inches. The margin was definitely delimited by a black line and probably was not advancing. The lesion was roughly triangular in cross section and tapered at each end.

GOPHER HOLES

Since gophers often injure or kill young palms by gnawing the roots and base of stem, special attention was given to such injuries as portals of infection. Palm "E" showed a rot extending from a gopher hole in the base of the trunk. Palm "F" showed no such injury and yet rotted. Palm "B" had a very definite cavity from gopher injury but the wound was healed and no infection occurred This was, however, in the dense, hard wood near the tip into which the rot appears not to extend

ROOTS

There is abundant opportunity for infection of a palm, either through injuries to the surface roots by cultivation, or possibly by direct penetration of the root tissues. Another very probable portal of infection would be through the adventitious roots (Plate VIII) which appear at intervals in great numbers on the bases of the trunks of some varieties. These roots may persist for some time but finally dry out, only to be followed by another crop under the stimulation of moisture. This unusual root development sometimes proves very detrimental to the palm for the sloughing of the leaf bases and adjoining tissues (Plate VIII, C) and disorganization of the trunk tissues gradually eats into the base of the trunk until the palm is stunted in growth or the weakened trunk comes crashing down in a windstorm.

At the base of palm "G" just above the ground line a radial rot, showing an abundance of Thielaviopsis spores, extended from near the surface almost to the lower end or the trunk, and progresses upward diagonally to the center of the palm; then straight up for nearly 6 feet from which point another small strand of infection extended upward just 2 inches from the side of the trunk to a point just opposite the bud. At the ground line the rot could be traced through several roots (Plates VI a and b), and as this was the only connection of the rot with the surface the evidence points to its entry there.

Inoculations of the roots of apparently healthy palms were usually unsuccessful in the absence of wounds, but lesions appeared on wounded roots although the progress of the fungus was not rapid.

TAXONOMY OF THE FUNGUS

The taxonomy of the fungus has been well reviewed by Roldan (25), Larsen (18), and Patterson, Charles, and Veihmeyer (23) so will be summarized briefly here.

The binomial *Thielaviopsis paradoxa* (DeSeynes) von Höhn., was established by von Höhnel (13) in 1904, replacing the commonly accepted *T. ethacetius* proposed by Went (29) who in 1893 described the "pineapple disease" of sugar cane. Von Höhnel found that the same fungus had also been previously described as *Sporochisma paradoxum*

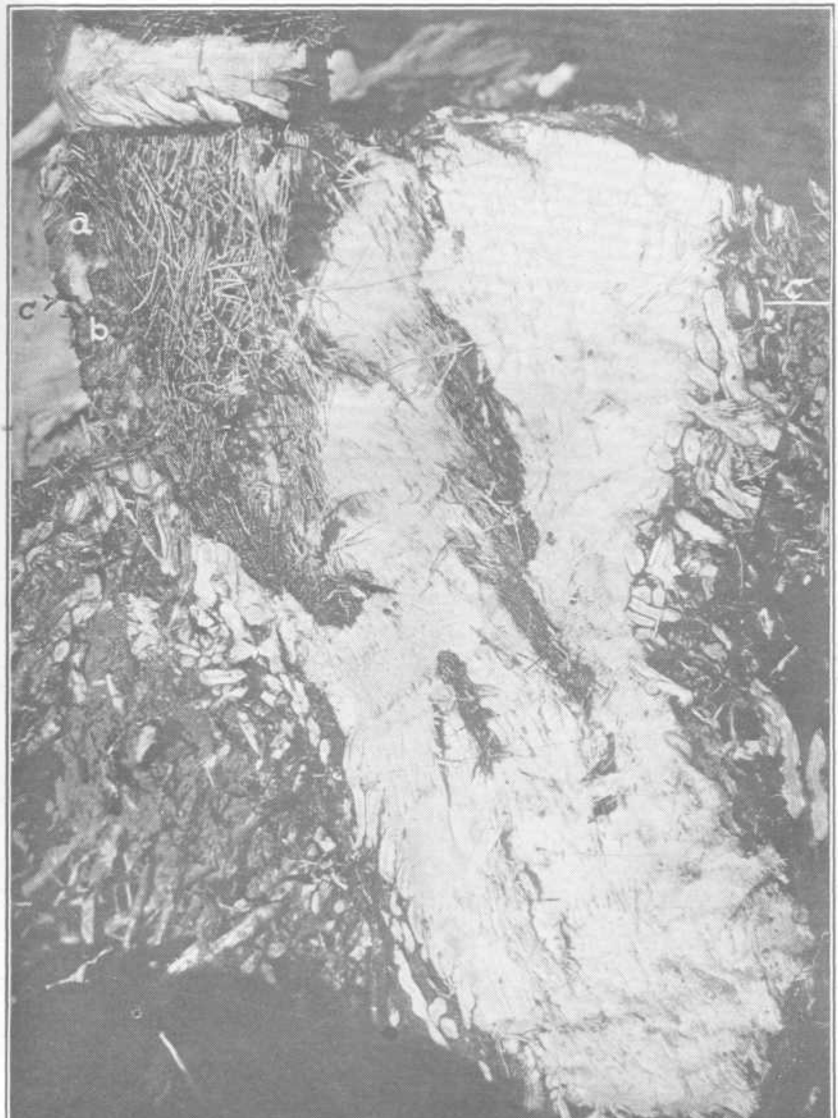

Plate VI.—Base of palm G split longitudinally to show connection of diseased areas with the diseased roots at "a," and also with two diseased roots at "b," below the soil line, "c." The apparently separate infected areas were traced to their connection with the main cavity.

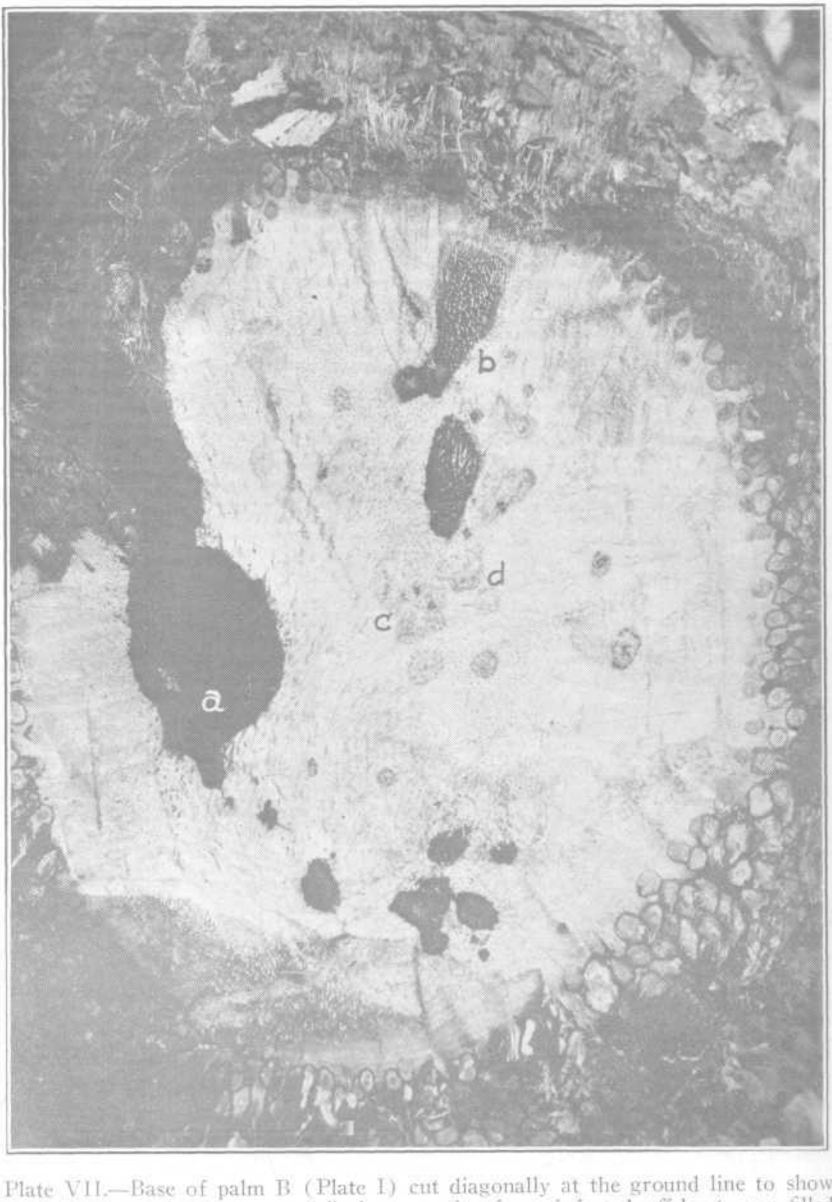

Plate VII.—Base of palm B (Plate I) cut diagonally at the ground line to show infection in various stages. "a" shows cavity from infected offshoot scar filled with crumbling decayed tissue. The margin was definite and no Thielaviopsis was found. Infection at "b" showed connection with diseased adventitious roots, suggesting portal of infection. The lighter-colored, roughly circular areas "c," "d," etc., showed early stages which contained mostly mycelium but a few spores.

in 1886 by DeSeynes who found it causing a rot of pineapple, and in 1892 by Saccardo who changed the name to *Chalara paradoxa* (DeSeynes) Sacc The last three names become synonyms of *T. paradoxa* (DeSeynes) v. Hohn.

Several writers have reported spore forms supposed to be associated with *T. paradoxa*. Butler (4) describes a pycnidial stage which would place the fungus in the genus Sphaeronema The same author (5) later describes as *Sphaeronema adiposum* a fungus attacking ripening or cut sugar cane in India The endoconidia of this species, however, are often brown and spiny. Patterson *et al.* (23) also mention a pycnidial stage but fail to describe it.

Massee (20) found perithecia of *Trichosphaeria sacchari* on decaying cane which had produced microconidia, but no other worker has been able to establish their connection with *T. paradoxa* Dade (8) in 1928 reported having found on cocoa husks perithecia with very fugitive asci which, by cultural experiments, were proved to be related to *T. paradoxa*. Dade referred the perfect stage to the genus Ceratostomella and proposed the name *Ceratostomella paradoxa* (DeSeynes) Dade.

Neither perithecia nor pycnidia, associated with *T. paradoxa* from the date palm, have been observed by the writer or by Fawcett and Klotz (11).

HOST RANGE AND GEOGRAPHICAL DISTRIBUTION

T. paradoxa is known throughout the habitat of the pineapple as the cause of a common and often destructive rot of the pineapple fruit. It is reported as general and severe on leaves, suckers, and fruit in the Philippines by Lee (18) and Roldan (25) and as prevalent and destructive in the Hawaiian Islands by Larsen (18), and from India, Porto Rico, Jamaica, West Indies, and Florida by other authors.

The same fungus causes the "pineapple disease" of sugar cane so called because the infected cane gives off an "acetic ester" odor suggestive of pineapple to some. The damage to sugar cane is generally considered minor, although the rotting of pieces of cane used in propagation may cause loss of stand. Damage to standing cane sometimes occurs. The disease on sugar cane was reported from Java by Went (29), from the Hawaiian Islands by Cobb (6), from India by Butler (4), and from Georgia and Louisiana in the United States by the Plant Disease Reporter (31) and Edgerton (9).

SPECIES OF PALMS ATTACKED

T. paradoxa is also well known as the cause of the stem-bleeding disease of the coconut palm *(Cocos nucifera)* as recorded by Cook (7) in Porto Rico, Lee (19), Roldan (25) and Mendiola and Ocfemia (21) in the Philippines, Sharples (26) in the Malay States, and Sundararaman *et al.* (28) in India. Fulton (12) records infection of a coconut palm in Florida. Ashby (1) in Jamaica, and Orian (22) in Mauritius cite it as causing the "leaf-bitten disease" of coconuts, which seems comparable to our "black scorch" on date palms.

The oil palm *(Elaeis guiniensis)* in Africa suffers from a stem rot which kills many palms in Belgian Congo according to Staner (27) and is reported in Gold Coast by Bunting (3). In India the areca-nut palm *(Areca catechu)* suffers from a stem-bleeding disease, and *Rhapis* sp. and *Phoenix dactylifera* were successfully inoculated by Sundararaman *et al.* (28).

T. paradoxa was found by the writer to be forming cavities in the trunks of the fan palm *(Washingtonia filifera)* and the Guadaloupe palm *(Erythea edulis)*. Many affected palms died, while others, chiefly those which had cavities open to drying, survived. Other species of palms are probably susceptible. It is significant that all of the host plants belong to the monocotyledons.

The occurrence of the organism in the Gulf States and in Florida sugar cane and coconut does not connect it with the date-palm disease of the Southwest. The organism was no doubt imported with young palms from the Old World since the fungus was found in North Africa by Fawcett (10). Date palms have no doubt been injured or killed by this organism for many years but the disease was not recognized until the acute attack at Yuma focused attention upon it.

MORPHOLOGY OF THE FUNGUS

The Arizona cultures (Plate X) agree with the descriptions as given by von Höhnel (13), Larsen (18), and others. The fungus produces two spore forms, macroconidia and microconidia. The macroconidia (Plate X, D, G, and J) are thick-walled, dark-colored, ovate spores measuring 16-19 x 10-12μ. They are borne on the tip of simple conidiophores not swollen at the base. In the tissues they are produced in short chains (Plate IV, C-D; Plate X,J), but in cultures in still air Larsen (18) has seen chains of 75 spores. The macrospores are quite variable in size as shown by the fact that 100 spores measured in stained slides of trunk tissues averaged 13.3 x 10.8μ with a range of 10-16 x 7.5-13μ, while 100 spores from desiccated, disintegrated pith (an "older culture") when mounted in KOH solution averaged 17.9 x 13.9μ with a range of 16-21 x 12-18μ.

The microconidia are of two kinds which differ in size and color.

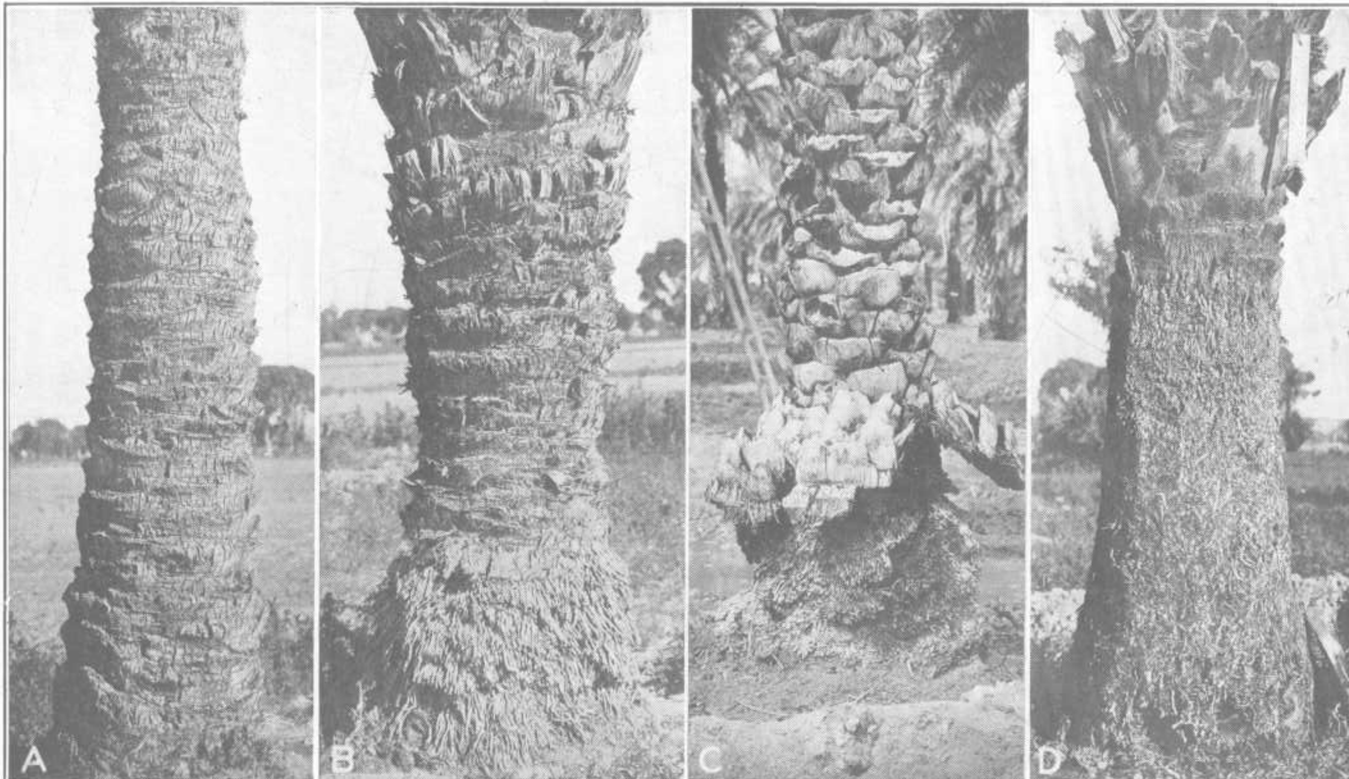

Plate VIII.—Formation and suppression of adventitious roots on date palms. A.—Leaf bases cut away—no adventitious roots. B—Root formation checked by cutting away leaf bases. C—Roots forming even after trimming of leaf bases. D.—Palm trunk trimmed to height of 5 feet to discourage root growth.

The common type is thin walled, cylindrical, hyaline, measuring 10-15μ x 3.5-5μ (Plate X, B) and borne uniseriately within a conidiophore which is constricted at the point of attachment to the mycelium. The microconidiophore (Plate X, A) tapers from a more or less swollen base to the tip from which the microconidia are extruded in fragile chains. The second type is usually larger, barrel shaped, and fuscous to brown, measuring 9-19 x 4.5-8μ, (Plate X,C). These spores sometimes occur on the same conidiophores as the hyaline microconidia. The contents of all three types of spores are extremely variable, since they may appear guttulate, vacuolate, or uniformly granular.

In water or liquid nutrient media, both micro- and macroconidia germinate by a simple germ tube (Plate X, F). On agar macroconidia produce a bulbous swelling from which the germ tube arises (Plate X, E). Microconidia germinate readily but macroconidia require a rest period.

CULTURAL CHARACTERS

The organism grew readily on ordinary culture media including beef-extract agar, potato-dextrose agar, and steamed corn meal. Growth was rapid at laboratory temperatures forming mycelial growth 45-60 millimeters in diameter on nutrient agar petri-plates in 4 days. The fungus is most active in warm, rather than in hot weather, and the outbreaks observed have occurred mainly in the spring months. Klotz and Fawcett (11) state that the optimum temperature for the fungus in culture is 24-27.5° C. (75-82° F.) and that it makes very little growth at 32° C. (90° F.). Heart rot in the trunk may progress during the summer, however, as the tissues never reach the daily maximum air temperature.

The mycelial growth is at first cottony white, but becomes slightly greenish with age. The abundant production of dark brown macroconidia causes the cultures to darken until they may become almost black. Both microconidia and macroconidia are produced freely on young cultures.

PATHOLOGICAL ANATOMY

The mycelium attacks principally the pith parenchyma cells of the trunk. It is usually intracellular penetrating the parenchyma cell walls without pronounced constriction (Plate X, G and H^m). In some cases, however, the pith cells appear to be separating by solution of the middle lamella (Plate IX, H and Plate X, H^n) and in this case the mycelium is intercellular also. The collapse of the parenchyma cells, leaving the bundles apparently sound and intact (Plate V, A) and the

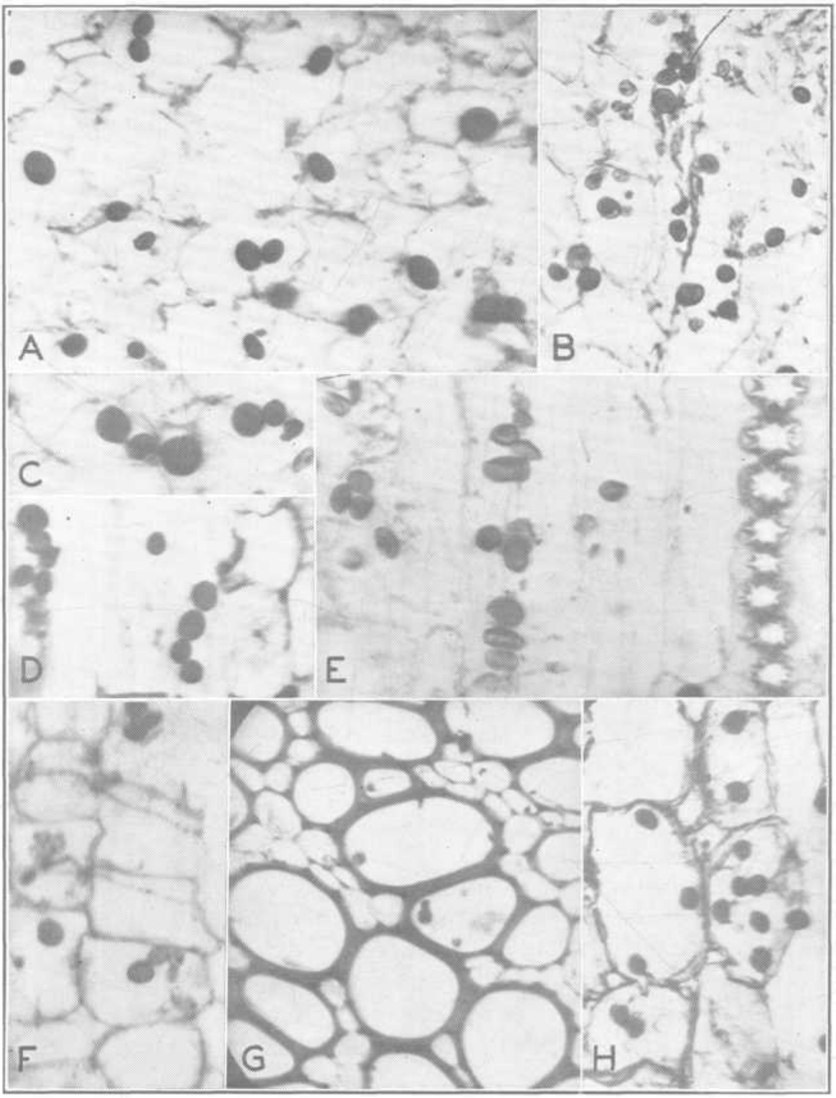

Plate IX.—Photomicrographs of infected tissues from trunk of date palm. A.—Macroconidia in parenchyma cells (cross section). B.—Disintegration of parenchyma cells. C. and D.—Macroconidia produced in chains. E.—Macroconidia in vascular bundle, calcium oxalate crystals at right. F.—Mycelium in parenchyma. G.—Cross section of portion of xylem, no fungus present. H.—Longitudinal section showing solution of middle lamella. x 325 except B. and H. which are x 220.

first stained sections prepared (Plate IX, G), led to the belief that the fibro-vascular bundles were not attacked. A later series of slides showed that the bundles were sometimes invaded by intracellular mycelium (Plate X, I). The meristematic tissues of the bud region were very quickly invaded and disintegrated (Plate III, B), while the hard, dense tissues of the outer part of the trunk were invaded very slowly.

Macroconidia were produced freely in the invaded parenchyma cells of the trunk (Plate IX, A-F), and in the cortical cells of the roots. Microconidia, in the writer's experience, were produced on date tissues only when sections of the infected trunk were split open. After 18 to 24 hours the infected area exposed to moist air was covered with a downy-mildew-like growth composed largely of conidiophores and microconidia (Plate V, B). The microconidia were mostly hyaline but a few were brownish

PATHOGENICITY

REPLANTS IN DISEASED SOIL

Healthy offshoots, set in the orchard in tree holes where palms dying from heart rot had been removed, did not contract the disease although the soil used to fill the holes contained many fragments of infected tissue. In addition to a dozen replants in areas known to be affected, other offshoots replanted where palms had died (very probably from heart rot before the disease was recognized) remained healthy.

VARIETIES AFFECTED

The Deglet Noor variety suffered the greatest loss in Arizona, but since there were many palms of this variety and few of the other varieties, the data are not conclusive. Several Deglet Noor palms which showed preliminary symptoms (drying of foliage—which might have been due to other causes) later recovered. It would be interesting to dissect such a palm to determine if the heart rot, once well started, could be checked by the host plant. Two Rhars palms at the Tempe Date Orchard remained alive for several years after cavities so large that the trunks were practically hollow had developed. The cavities were open and the dead tissue dry and brittle. Abundant macroconidia were found in this material. A palm of the variety Bent el Maroo developed a large lesion when the offshoot chisel gouged a hole in the base of the trunk.

Klotz and Fawcett (11) find the Thoory variety (a bread date) one of the most susceptible to black scorch (also caused by *T. paradoxa*)

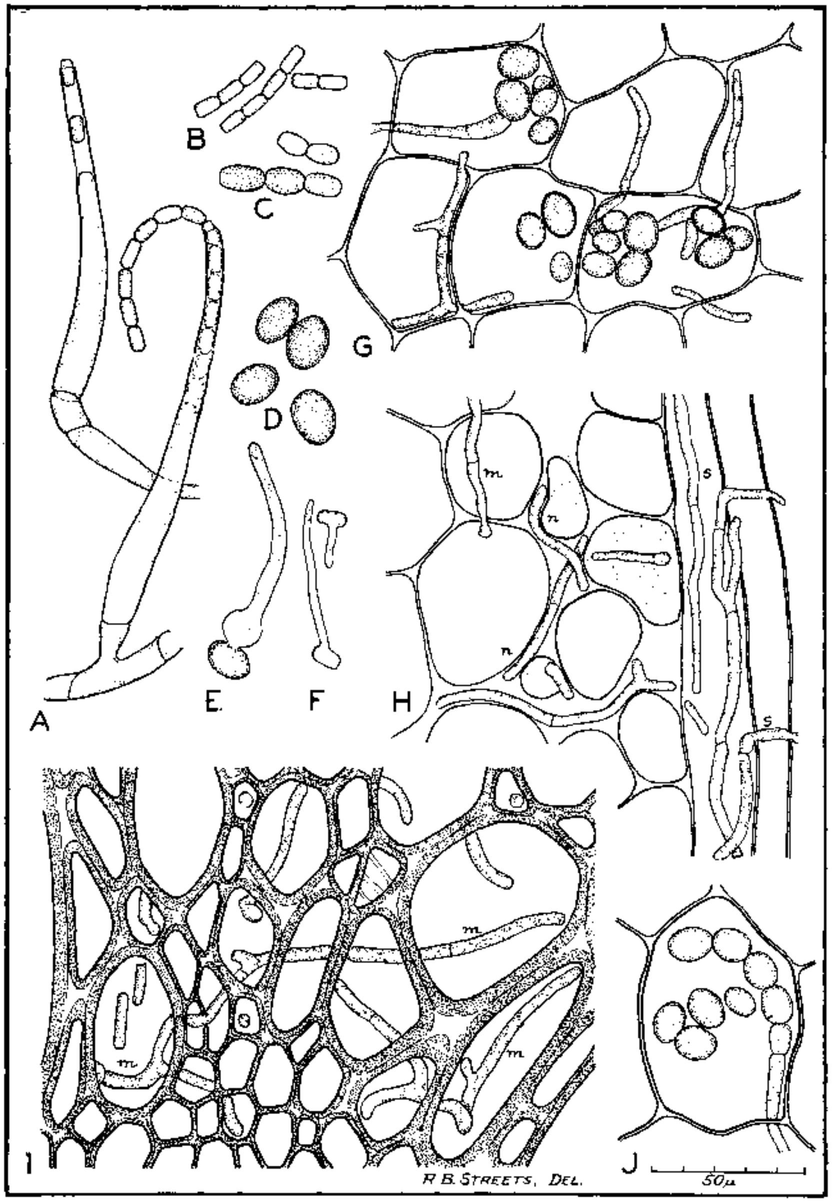

Plate X.—Camera lucida drawings of *Thielaviopsis paradoxa*. x 414. A.—Formation of hyaline, cylindrical endoconidia. B.—Hyaline endospores. C.—Fugaceous conidia. D.—Macroconidia. E.—Germinating macroconidium. F.—Germinating hyaline conidia. G.—Mycelium and macroconidia in parenchyma tissue. H.—Mycelium, inter- and intracellular, in longitudinal section. I.—Cross section of xylem showing fungus hyphae. J.—Chain of macroconidia formed in cell.

and Hayany, Amhat, Saidy, and Halawi at least as susceptible to black scorch as Deglet Noor.

INFECTION WITHOUT WOUNDS

The ability of a fungus to infect its host plants without the aid of wounds is important in relation to control. Larsen (18) found that *T. paradoxa* could infect green pineapple as readily as ripe fruit with or without wounding. Klotz and Fawcett (11) report having successfully inoculated the leaf bases, pinnae, and roots without wounding. It appears, however, that the disease would be more prevalent if invasion of the host in the absence of wounds were the usual method of infection in the orchard.

CONTROL MEASURES

After a number of years of observation this disease appears to be controllable and not a serious menace to date culture under conditions of proper care and intelligent management of the orchard.

SANITATION

The destruction of infected palm trunks, leaves, or litter by burning or burying should be practiced to reduce the amount of inoculum in the orchard. The heavy trunks resist drying for months unless split open to admit air, and may be disposed of by burial. In case the black scorch type of injury to the leaves and inflorescence is present, prune out and burn the affected fronds, leaf bases, and flower stalks and paint all cuts with a disinfectant such as Bordeaux paste.

CARE OF WOUNDS

When removing offshoots be careful not to gouge into the trunk of the mother-palm. If a wound occurs smooth the ragged edges and cover the wound with a disinfectant. If infection occurs remove diseased tissue, dry surface, and treat again.

TREATMENT OF OFFSHOOTS

As a precaution against loss of offshoots by heart rot, Diplodia disease, or other parasites, the bases of offshoots may be dipped in a barrel of 4-4-50 Bordeaux mixture, or the fungicide may be applied as a spray before planting.

CULTURAL METHODS

Fertilizing, cultivating, and irrigating to promote vigor in the palms greatly increase their resistance to heart rot. Remove healthy leaves only as they mature and dry progressively from the tips of the pinnae, allowing the palms to carry a full crown of leaves. In case palms are heavily pruned or defoliated for any reason, reduce irrigation to the requirements of the trees.

SUMMARY

1. A heretofore undescribed rot of the trunk and roots of the date palm and other palms has been found in Arizona and California.

2. The fungus *Thielaviopsis paradoxa* (DeSeynes) von Höhn. has been found constantly associated with the disease; has been repeatedly isolated from the diseased tissues and found pathogenic by inoculation.

3. The disease is much more prevalent on the Deglet Noor variety, although it has been found on a number of other varieties.

4. The disease attacks not only the date palm *(Phoenix dactylifera)*, but the Canary palm *(P. canariensis)*, the fan palm *(Washingtonia filifera)* and Guadaloupe palm *(Erythea edulis)*. Many other palms are probably susceptible.

5. There is abundant evidence that the causal organism is not an aggressive parasite, but attacks palms whose vitality is lowered.

6. The disease most frequently occurs where the normal crown of leaves has been removed or greatly reduced when the water supplied to the roots has not been correspondingly reduced.

7. The fungus usually gains entrance through the roots by entering the trunk near the soil line or through unprotected wounds resulting from mechanical injuries or faulty cuts made in removing offshoots.

8. In devitalized palms the progress of the disease from the time it becomes evident is rapid and the palm may die within a few days.

9. In vigorous or resistant palms the infection may progress a short distance and then stop, leaving a cavity or lesion filled with dead tissues.

10. The same fungus also causes other injuries on the date which were at first believed to be separate diseases. Black scorch, a dwarfing of the young leaves; fool's disease, a twisting of the growing point; and a decay of the inflorescence are all caused by *T. paradoxa*.

11. The fungus appears to be worldwide in distribution in semi-tropical and tropical climates and causes mild to serious losses from a stem-bleeding disease of coconut and other palms, a cane rot ("pineapple disease") of sugar cane, and a fruit rot of pineapple, and various infections of other crops.

12. Control is largely a matter of prevention and sanitation. The destruction of all diseased palms which will harbor infectious material is necessary. Burying the heavy, moisture-laden trunks is often easier than burning because they resist drying for months.

13. Avoid defoliation or close pruning of palms in ditch banks where water supply cannot be regulated. Avoid deep wounds which penetrate into the softer tissues of the trunk.

14. A condition of the trunk tissues characterized by a pallid discoloration and "sour sap" apparently not directly associated with the heart-rot disease has been observed. This may be correlated with defoliation or severe pruning accompanied by abundant water supply.

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