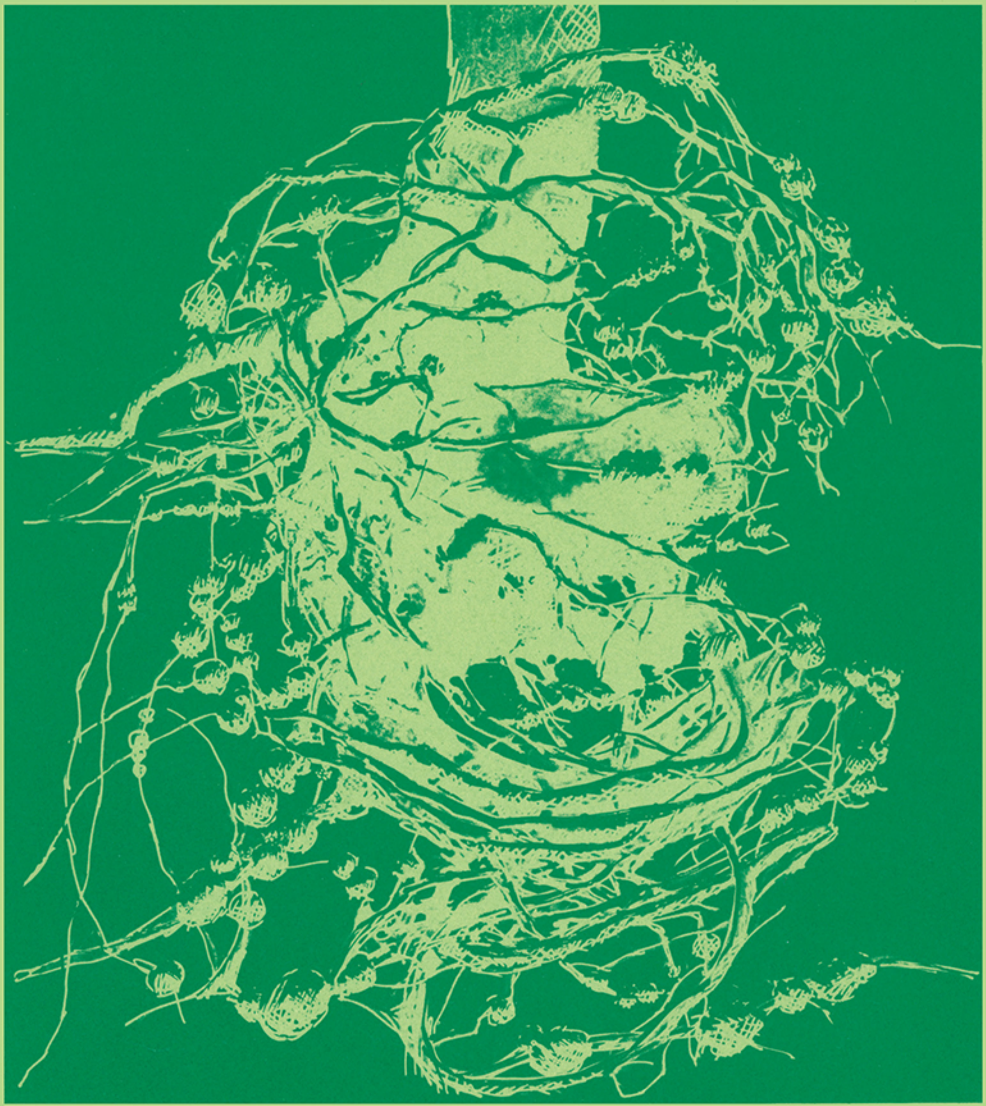
A Field and Laboratory Manual Emphasizing the Most Practical Methods for Rapid Identification

THE DIAGNOSIS OF PLANT DISEASES



Dr. Rubert B. Streets, Sr.

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A Field and Laboratory Manual Emphasizing the Most Practical Methods for Rapid Identification

Dr. Rubert B. Streets, Sr.

Line drawings, from pencil sketches by the author, by Paul Douglas Streets, who also made most of the photographs and prints.

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About the Author . . .

DR. RUBERT B. STREETS, SR., was distinguished for research in many areas of his field, and in particular for his widely acclaimed, authoritative book *Diseases of the Cultivated Plants of the Southwest* (University of Arizona Press, 1969). He is best known for his researches on the control of Texas root rot in field crops, tree crops, and ornamentals; diseases of dates, citrus and guar, brown rot of stone fruits, and roses; and his selection of flax resistant to wilt; the serology of citrus viruses; and the use of antibiotics for the control of crown gall and fire blight.

As a capable, understandable and well-liked teacher, for 43 years plant pathologist and for eight years head of the department of Plant Pathology at the University of Arizona, Dr. Streets taught all plant pathology courses from bachelor of science to doctorate level. In his courses, Dr. Streets strove to have his students identify the diseases, evaluate the situation, and recommend practical and effective control measures.

His multifaceted career resulted in his having received many awards, including two national awards: The Citation for Outstanding Service to Horticulture from the American Horticultural Society in 1965, and the John Chapman ("Johnny Appleseed") award of the Men's Garden Clubs of America in 1967.

A native of Montana, and holder of an M.S. and Ph.D. from the University of Wisconsin, he became a member of the University of Arizona faculty in 1924.

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DIAGNOSIS OF PLANT DISEASES

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P R E F A C E

Rapid and accurate diagnosis of plant disease is necessary before timely and proper measures can be suggested for control or prevention. Because of the scarcity of local, professional practitioners, plant pathologists at universities are often requested to assist in diagnostic work. Usually, extension plant pathologists are most competent to make diagnosis because of their training and experience.

Other university and industry plant pathologists engaged in research or resident instruction are qualified by training to diagnose plant diseases. However, because of other duties, they participate very little. Many other people who assist with plant, crop, or forest "problems" have a limited knowledge of plant diseases. Others with no formal training in plant pathology are seriously handicapped in doing plant-disease work even though their occupation makes it desirable or necessary.

The diverse groups of individuals who may find this manual useful are as follows:

1. State Extension Plant Pathologists.

2. Instructors of plant pathology in Universities and Land-Grant Institutions.

3. Research personnel dealing with practical applications of their investigations.

4. County agricultural extension agents in search of quick and accurate diagnosis of growers problems.

5. Leaders of 4-H projects and Teachers of Vocational Agriculture.

6. Personnel of State and Federal quarantine and regulatory agencies.

7. Personnel of Agricultural Chemical industries who recommend and sell fungicides and nematocides.

8. Personnel in charge of large farm operations who need information on identity of plant diseases and safe and effective means of combatting them.

9. People who are entering the diagnostic field perhaps in conjunction with beautification and recreational programs. Many of these have little or no plant-pathology training.

10. Personnel in charge of parks and recreational areas, botanical gardens, and national monuments.

11. Professional gardeners, advanced amateurs, or hobbyists who prefer to take part in solving their own problems.

12. Nurserymen, growers and sellers of plants.

13. Pest-control operators expanding operations into plant-disease control.

14. Others involved in various Plant Health programs.

While it is difficult to prepare a manual for diverse groups, the need is urgent. The author has had such a project in mind for years, but time has been preempted by research, teaching, and administrative duties. When the preparation of such a manual was suggested by a representative of the U. S. Department of Agriculture, at the time of my approaching retirement, the opportune time seemed to have arrived.

Diagnosis of plant ailments is an art. Improvement results from practice. It is similar to improvement in playing golf or the violin, assuming one has the aptitude. Much time and effort is necessary to develop skill. There is no substitute for experience. However, use of this manual will help guide you to better plant-disease work and shorten your time spent in learning diagnostic procedures.

WE NEED BETTER METHODS OF DIAGNOSIS

"None of the methods given here are to be considered as 'standardized.' To think of them in such a way would put an end to efforts for improvement. They are useful only until better procedures can be developed." Riker and Riker in preface to Introduction to Research in Plant Diseases. 1936.

Preoccupation with research and teaching has diverted the attention of most plant pathologists from participating in diagnosis. As a consequence the development of quicker and simpler methods of diagnosis has been neglected. This area needs development by those concerned, and advances in discovering new methods and improving older ones, would prove of great value to all concerned with the diagnosis of diseases--the necessary prelude to the application of effective control measures.

A C K N O W L E D G M E N T S

I am indebted to Dr. Harlan E. Smith, Principal Extension Plant Pathologist, A.R.S., and Dr. George A. Gries, former Head, Department of Plant Pathology, University of Arizona, for encouragement and making possible the publication of this volume. Also, I am indebted to my colleagues on the staff of the Plant Pathology Department for suggestions, information and for reviewing portions of the manuscript. I wish to thank especially R. M. Allen (Department editor) and Alice M. Boyle, Arlen Davison, E. L. Nigh Jr., H. B. Reynolds (A.R.S.), M. R. Nelson; also R. L. Gilbertson and W. G. Solheim (University of Wyoming) for assistance with sections on identification of fungi. R. B. Hine, R. L. Caldwell, and S. M. Alcorn have submitted suggestions for the second edition.

P R E F A C E T O S E C O N D E D I T I O N

The exhaustion of the two printings of the first edition in seventeen months suggested that arrangement should be made to keep the book in print. The University of Arizona Press stepped forward to provide this service. With this aim and with a change in publishers it seemed desirable to revise the text, and to include additional techniques, illustrations, and references. Important added topics are mycoplasma diseases, aerial infrared photography, injury to plants by air pollutants, how to get meaningful pictures, and more differential media for isolation of pathogens.

I N T R O D U C T I O N

The common conception of the Plant Disease Diagnostic Service is that it operates like a vending machine ("coke machine")--you put in your problem and pull a lever. Immediately you receive the diagnosis and complete recommendations for prevention and control.

In the case of a very common disease this is actually possible providing the pathologist has sufficient local experience. Your "image" as an expert diagnostician depends upon the degree to which you can fulfill the public's expectation for prompt and accurate identification and recommendations.

THE "BEDSIDE MANNER"

Of equal importance is use of the medical profession's "bedside manner." The patient is aware of the doctor's interest in his illness. There is a feeling of optimism that successful treatment is available to effect a cure.

The dedicated plant pathologist is always genuinely interested in the plant problem. This feeling should be evident to the client. Most important, the pathologist regards each problem as a personal challenge. He is an observer of symptoms - and a questioner. The pathologist gets from the grower of the ailing plants additional information concerning the many factors of environment such as soil, climate, irrigation, applications of fertilizers and chemicals. All these might have a bearing on the problem.

It is usually very helpful to chat with the person concerned about the problem. Gain the confidence of your clientele. Ask proper questions and listen very closely for clues dropped which may solve the problem, or indicate that the first tentative conclusion was in error. Often when either the samples submitted or the accompanying information is inadequate, it is necessary to become a "detective," searching for and evaluating clues. You may have to reject some too obvious ones in order to finally arrive at a correct solution.

The writer has had 44 years of post-doctoral experience in this field, and the feeling of challenge is still there. Surprisingly, disease situations not previously encountered still arise at fairly frequent intervals.

KEEP LOOKING, KEEP LISTENING, KEEP THE CLIENT TALKING!

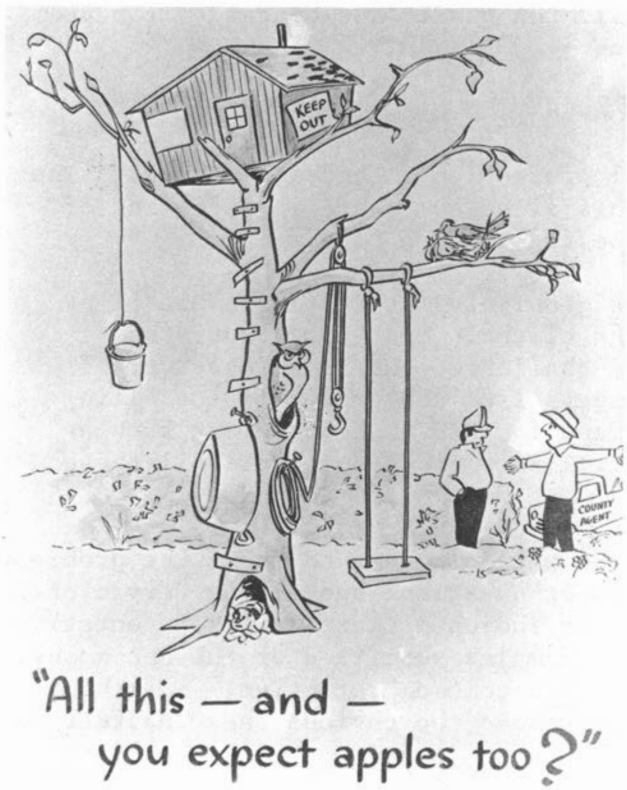
"S I G H T U N S E E N"

Local and long distance telephone calls requesting instant diagnosis and assistance on disease problems (often important!) are a challenge to be handled with caution. Unless you have just returned from a field trip in the area in question, you are dependent upon the caller's description, often very inaccurate and inadequate. You should not make more than a <u>tentative</u> diagnosis, "It sounds like ____________," and suggest that specimens be brought or sent to the clinic immediately, giving directions for proper sampling and shipping. Many above ground symptoms are due to causes acting below the soil surface, so be sure to suggest root samples also. Likewise suggest a check of the base of trunk for injury to bark. A letter with all information the client can give should be ATTACHED TO THE PACKAGE.

In sampling roots, remember that trees and large shrubs have far-ranging roots and may be found in the root zone of the diseased plants. The roots of some trees and shrubs are of distinctive color and texture, and you will learn to recognize roots of citrus, mulberry, tamarisk, and others.

HOPELESS CASES

Frequently the grower has not been alert to the early stages of the disease. It may be a disease that progresses rapidly under favorable conditions. The affected plants or crop cannot be saved at times.



In this case, it is well to say very early in the examination that, "the disease has progressed too far. It is doubtful that the plants can be saved. I will do everything possible to help you effect a cure or check the spread of the infection through the whole crop."

If you have predicted failure, you will not be blamed; if perhaps your recommendations save the plants or check the spread of infection, you will get the credit. At least you can diagnose the disease and give information on the prevention or treatment of the disease in the future.

PREVENTION IS BEST

In annual crops the value of an individual plant is usually small. The pathologist is more interested in protecting the healthy plants than saving the sick annuals. Plant Pathology is more concerned with the PREVENTION of disease than curing it after the hosts are attacked. The situation is somewhat different in case of parasites attacking valuable woody perennials (fruit or nut trees, or ornamental trees or shrubs, etc.) where treatment is possible.

In case it is too late to apply effective control measures, the grower should be informed how to prevent or minimize future damage by the same disease, or what crops or plants can be grown on infested land. Spray applications are futile after the foliage is heavily infected--but, "better luck next time." Infections probably will appear the following year if the weather conditions are favorable. The grower should be prepared to spray or dust prior to or at first appearance of the infection.

There are two kinds of people who will come to you with their problems who are difficult to help because of their lack of basic knowledge of plant needs.

"Do you have to spray it or feed it or prune it or anything?"

N O N G A R D E N E R S

People who in most cases have lived in city apartments and have never grown plants, or who have never tried to care for plants, often fail to realize that plants need fresh air, sunshine, and a well-watered and aerated soil with an adequate supply of essential plant foods. Some are eager to learn and will soon be raising plants and puzzling over their ills; -- the new plastic flowers and fruits are for the others.

T R A N S P L A N T E D G A R D E N E R S

Many gardeners (and some farmers) have moved from the climate in which they learned to grow crops and ornamentals to regions of quite different temperatures, humidity, rainfall, soils, diseases, and pests -- and find their knowledge inadequate for the new climate. Attempts to grow their favorite plants from "back home" in the new environment will fail if plants are moved outside the range of their adaptation. Colorado blue spruce, common lilac, lily-of-the-valley, and other cool-climate species have failed in the hot, dry desert. Citrus, bougainvillea, and hibiscus fail where winter temperatures go below 20 degrees F.

The transplanted gardeners either adjust and learn the new cultural methods, or they take up golf or some other activity. Those who seek local information and read articles <u>written for the local climate</u> soon become competent growers. Those who attempt to apply the planting dates, cultural methods, etc., to an entirely different climate and to plants not adapted encounter many frustrating difficulties.

Those who have lived where 40 or more inches of rainfall supplied adequate moisture for all plants, have to adjust to the necessity of regular irrigation in regions of less rainfall. Compared to a humid climate, the drier regions have relatively few foliage diseases. But they do have different disease problems such as those caused by parasites causing root rots, nematodes, and crown gall which attack many plants.

DON'T BLUFF

When you engage in making diagnoses of plant diseases, you imply that you are qualified to make accurate identifications. In order to maintain a good reputation you better be RIGHT most of the time.

In case your knowledge and experience is not adequate, or the nature of the specimen submitted makes it impossible to make an accurate diagnosis--DON'T BLUFF. Tell the inquirer that you will have to study the material further in the laboratory or that you need better material. Laboratory study or consulting with more experienced co-workers may not produce a definite answer. Admit that you are, for the time being, unable to solve the problem. If possible, look at the problem in the field or garden where you have a chance to observe all the environmental conditions and collect your own samples.

The first year I was in Arizona (as a one-man "department") a prominent citrus grower was losing many recently planted young trees. He sent in samples. My diagnosis was "dry root rot." A simple treatment was suggested for all trees including those apparently healthy. It checked the disease. I learned soon afterwards that the grower also sent specimens to Dr. Fawcett, the veteran citrus pathologist at Riverside, California. Dr. Fawcett made the same diagnosis and recommendation to the grower. A rumor got around, "I guess the new kid is all right." This helped public relations.

Whenever a real crisis arises and growers are faced with the possibility of substantial losses, they typically contact everyone they can think of who might possibly help solve the problem. You must, of course, make every effort to meet any situation.

Some disease problems are not immediately solvable, especially when due to nonparasitic causes. Sometimes each "expert" has a different tentative opinion, which is baffling to the growers. Also, when material is sent to inexperienced persons, the diagnosis given may be wrong. If you are sure of your diagnosis, stand your ground.

"D O U B L E   C H E C K"

One useful practice is to check the diagnosis you have just made with an experienced staff member for an independent opinion. Be sure to say, "These pear twigs came from Oak Creek. What do you think they have?" and not, "I think this is fire blight. What do you think?" If two independent diagnosis agree, further verification is perhaps not necessary and much time is saved. If they disagree, a brief discussion usually indicates which diagnosis is right.

REMEMBER, YOU ARE A GUEST

You may visit a grower's property at his request to make diagnosis of disease problems. In the interest of good public relations behave like a well mannered guest. Such advice should not be necessary, but the writer has observed many violations of good conduct.

Ask the owner's permission to dig up plants to examine the roots, especially if dealing with fruit or shade trees, shrubs, or other large plants. It is often not necessary to remove completely the tree or shrub, and this should be avoided unless the specimen is apparently doomed anyway.

If it appears to be possible to save the tree or shrub, dig down on the most affected side about two or more feet from the trunk (or close to the trunk if crown gall is suspected) and examine the roots.

Examine the bark just above and just below the soil line before digging. Death of trees and shrubs by girdling of the trunk frequently occurs.

Refill any holes dug before you leave.

Ask permission to remove medium to large diseased branches. Make cuts parallel to trunk or large branch according to best pruning practices so wounds will heal properly. Also ask permission to chisel cavities in trunks, etc., in exploring sap rots and heart rots.

When working around trees bearing ripe fruits or nuts, or in vegetable gardens, do not pick and eat fruit, etc., unless invited to do so by the owner.

O B S E R V A T I O N

(H O W M U C H D O Y O U M I S S?)

How much do you miss?

The most rewarding phase of your training in diagnosis is the development of your ability to observe accurately all symptoms and the growing conditions which might contribute to the problem in question -- and the ability to draw valid conclusions from these observations.

This should, with practice, become automatic. Your skill will improve with years of experience and you are never too old to improve further. Going over a set of specimens submitted a second or third time may reveal much you overlooked the first time.

Don't overlook the possibility of several diseases occurring together as a complex. On this account do not make snap judgments without completing a careful examination of the specimens. I impressed this on my classes by giving them fresh field specimens of cotton (whole plants) attacked by both Verticillium wilt and Phymatotrichum root rot. Verticillium causes slow drying and shedding of the leaves, brown streaks throughout the length of stem and branches, and little damage to cortex of root until late in season. Phymatotrichum causes rapid dying of the plant, dead leaves clinging for a while, vascular tissue of stem is not discolored more than four inches above soil line, but the entire root is killed and surface bears strands of fungus. Yet the overall effect is--a dead plant.

You also find crown gall AND root-knot nematodes; brown rot AND Rhizopus rot in post-harvest peaches; downy mildew AND Sclerotinia rot, AND big-vein, AND lettuce mosaic in the same lettuce field (fortunately rarely); curly top AND cucumber mosaic AND root-knot nematodes in the same cantaloup or watermelon vines--to name just a few.

When the grower or person submitting the problem fills out the question sheet, scan it at the time and try to bring out, by your questions, information pertinent to the problem that has been omitted. Perhaps the grower does not know or has not observed accurately, but get all the information possible.

W H A T E L S E S H O U L D Y O U K N O W?

Knowledge of related fields

When you engage in diagnosis of plant diseases -- what, in addition to plant pathology, should you know? You are in the position of the (now) old-fashioned family doctor who had to diagnose all manner of human ills: measles, broken bones, influenza, sprains and bruises, poisons, arthritis, and stomach ailments or improper diet. If you stay with it long enough you will encounter as great a variety of plant problems.

1. A sound basic knowledge of plant growth and physiology, plant nutrition, and ecology such as you would acquire in good courses in botany and agriculture will furnish a good background for understanding both the normal and the diseased plant, and its reaction to adverse conditions.

2. Each species or variety of plant is adapted to a certain ecological condition. For example, it will do best in a certain temperature range (optimum temperature) and grow progressively poorer as the temperatures become too hot or too cold. Beyond a certain point, its growth becomes unsatisfactory or it will not grow at all. The same is true for moisture (rainfall or irrigation), humidity, soil type and pH, length of day, length of season, fertility, and competition with other plants. Does the plant or crop have the necessary environment for successful growth? Certain stresses make plants more susceptible to some diseases.

3. Those who have had a basic course in Entomology plus a course in Economic Entomology are very fortunate. Insects spread plant virus diseases, bacterial and fungus diseases. Often, in case of such diseases, control must be directed against the insect vector.

4. It is well to be able to recognize crop plants (fruits, vegetables, and field crops) and all common ornamentals, and common weeds by a few leaves or shoots. It helps your professional "image."

S O L V E T H E P R O B L E M!

Those who bring you their plant problems (diseases and what have you) do so in the expectation of receiving a prompt and accurate diagnosis of the problem--plus, of course, directions for treating it or at least avoiding it in the future.

The solving of any and all the plant disease problems brought to the extension plant pathologist (or his non-university counterpart) is challenging indeed, and calls for a considerable amount of dedication on the part of the pathologist.

There is, however, a great deal of satisfaction in being able to diagnose the problems and to specify what control measures are applicable to the particular conditions at hand. In a good many cases there is a crop of considerable value at stake, and prompt action is necessary to save it. This is the major reason for emphasizing rapid methods of diagnosis.

With experience, your ability to observe symptoms and select those that are diagnostic should constantly improve and you also will become familiar with the diseases and other problems common in your vicinity. Also your ability to get clues from talking to persons bringing in the specimens will enable you to ask questions that often throw light on the problem, particularly when non-parasitic maladies are concerned. Sometimes this is the only method of discovering what has caused the plant problem.

<u>The challenge has been made -- can you meet it</u>?

D O N ' T   T A K E   S I D E S

A plant pathologist may be requested to determine whether crop plants show injury from air pollutants (sulfur dioxide, fluorides, smog, PAN, etc.) or other chemicals (herbicides, insecticides, fungicides). In many cases the grower is seeking evidence for a suit for damages, and industrial plant or dealers selling the chemicals are skeptical of the presence or severity of the injury. Each side has an equal right to a candid answer--but it better be the same answer!

The writer has had to deal with these problems for some 47 years, and has tried to maintain the position of a neutral observer. In the interest of accurate diagnosis and maintaining public good will, the person submitting the sample gets an impartial diagnosis and the other party gets a signed carbon copy of the report. In many cases the two parties are able to arrive at a satisfactory agreement.

Since making estimates of the amount of damage (percent loss to grower) is very time-consuming and must be done in the field, and the results are at best controversial, this should be avoided.

When the evidence of injury is insufficient to justify a positive answer, ask for a better sample.

Circumstantial evidence is not reliable. For example: Following summer showers, sulfur dioxide odor was evident on a farm. In a few days the foliage in a field of watermelons collapsed and the melons developed sunken salmon-pink spots on the underside--due to anthracnose caused by Colletotrichum lagenarium. Plants sensitive to sulfur dioxide were not marked, but the grower was never quite convinced that the damage was not due to sulfur dioxide.

C A N   Y O U   R E C O G N I Z E   S I G N S   O F   I N S E C T   I N F E S T A T I O N?

You should be able to recognize cases where insects are the primary cause of the trouble. Then you can refer the problem of exact identification and recommendations for control to an entomologist. This will get you "off the hook" and is the safest procedure.

As insects spread many diseases, including virus diseases, their presence cannot be ignored as part of the disease picture. (See Section on Viruses)

SIGNS OF INSECT INFESTATION IN ADDITION TO VISIBLE PRESENCE OF THE INSECTS, MITES, ETC.

(1) HONEYDEW: Often visible as a wet appearance of foliage from a distance of 10 to 50 feet when abundant, as seen on pines, arbor vitaes, pecan, Pittosporum, etc. Due to aphids (different species on each host).

(2) SCOTY MOLD: Black deposit covering leaves, stems, twigs, etc., as seen on alfalfa, citrus, and ornamentals, especially in humid areas or greenhouses. Due to saprophytic fungi feeding on honeydew excreted by aphids.

(3) STIPPLE OR BLEACHING: Few to numerous tiny spots bleached, or severe--whole leaf area bleached from spots so numerous they coalesce and involve whole leaf. Due to feeding of leaf-hoppers or other sucking insects or mites.

(4) GALLS: Various sizes, shapes and colors, and surface texture (smooth, hairy, or warty) which usually contain larvae or pupae or show exit holes of adult insect--mostly caused by small wasps. Also some scabby spots caused by blister mites.

(5) LEAVES CURLED OR DISTORTED: Leaves curling downward, sometimes much dwarfed and distorted. Caused by some species of aphids, often gone but with cast skins evident inside the curled area.

(6) CORTEX OF ROOTS GONE: Not dead--gone, leaving girdled roots and producing symptoms of root rot. Caused by white grubs and other subsurface-feeding insects or gophers.

(7) BARK OF TWIGS AND SMALL BRANCHES GONE: Leaves all eaten first. Caused by swarms of grasshoppers, blister beetles, Mormon crickets, etc.

(8) HOLES IN FOLIAGE, FRUIT, ETC.: Usually due to feeding of chewing insects, but don't confuse with "shot hole" due to dropping out of leaf spot areas. Tunnels in fruits or vegetables are often caused by the larvae of insects; surface pits by feeding of adults. LEAF MINERS feed between leaf surfaces--occasionally beneath epidermis of fruits. LEAF SKELETONIZERS devour all but the upper epidermis and the larger vascular elements.

(9) SCALES: Pinhead size to 1/8 inch or larger sucking insects living under a protective shell, white, which may be rust colored or dark, many sizes and shapes, on bark, leaves, fruit.

(10) SOFT WHITE COVERINGS hide cottony cushion scales and mealy bugs. FROTH on stems, etc., hides spittle insects.

(11) WILTING OF FOLIAGE may be caused by squash bugs and some other insects.

THE PLANT CLINIC

Most departments of Plant Pathology at State Land-Grant Universities maintain a diagnostic service called "The Plant Clinic" or "The Plant Disease Diagnostic Laboratory." It is manned by an Extension Plant Pathologist who devotes a major portion of his time to educational work throughout the State. Other plant pathologists or graduate students (interns) work in the clinic. These individuals quickly become familiar with the common diseases, so they can devote their attention to the less common ones as they appear.

In some cases the disease is one that can be readily identified by merely examining a plant or making a routine microscopic study of the diseased tissues. Following the diagnosis the information can be given to the person bringing in the sample or mailed to him the same day.

For specimens that require special laboratory cultures, or careful study for the identification of fungi or parasitic nematodes, the report may take several days. If inoculations of host plants are necessary, a week or two often is necessary. In either case the sender is informed that the specimen arrived (see form on page 2.8) and that the diagnosis will be sent as soon as available.

COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
U. S. DEPARTMENT OF AGRICULTURE AND STATE LAND-GRANT COLLEGES COOPERATING

PC #__________

We are in receipt of a ______________ plant specimen submitted to the Plant Disease Clinic ______________.

The specimen arrived at the Clinic in (excellent, fair, poor) condition.

☐ It is necessary for us to (culture, isolate, identify the pathogen) from the submitted specimen.

☐ Diagnostic results will be forthcoming in approximately ______________ weeks.

☐ Please submit another specimen. Include the roots ☐, leaves ☐, stems ☐, soil ☐.

Yours truly,

Extension Assistant
in Plant Pathology

The rapid diagnosis of a plant disease is often very important, especially in instances where a grower can take some immediate steps to control or correct a disease situation. Telephone calls may be made in cases where large economic loss is involved. Also, "difficult to diagnose" specimens often can be referred by the Clinic to the staff pathologist who is in the best position to know or find out the cause of the disease.

Each clinic has its own information form which the person submitting the sample fills out. The questions, if accurately answered, are a great help in diagnosis of the problem. Some institutions make a small charge for this service (to discourage trivial inquiries), others do not. (See sample form on next page.)

Scan the form if filled out in your presence, and ask the person submitting it for omitted information or other pertinent details.

Clinics have hours and diagnosticians have other duties. A sign at the clinic door, and a table and supply of information forms, enable those bringing samples to leave them for examination.

The clinics or laboratories help support extension, research, resident instruction, and regulatory programs in Plant Pathology. They assist growers in obtaining prompt accurate plant-disease information.

PLANT DISEASE IDENTIFICATION FORM

Submit specimens to: EXTENSION PLANT PATHOLOGY
DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

☐ CA ☐ C ☐ GA
☐ N ☐ HG ☐

Date collected__________
P.C. #__________

HOW TO COLLECT AND SHIP PLANT SPECIMENS FOR DISEASE DIAGNOSIS

The accurate diagnosis of a plant disease depends on receiving a fresh sample. All specimens should be fresh when collected, placed in a plastic sack and shipped immediately in a mailing tube or strong cardboard carton to prevent crushing enroute. When specimens arrive unidentified, wilted, crushed or in advanced stages of decay, diagnosis is often impossible. If the sample is in good condition, the disease can be diagnosed more rapidly. Most specimens will be diagnosed and acknowledged within a few days. Proper completion of this form will aid in prompt, accurate service.

GENERAL INFORMATION: Telephone Number__________

Owner or grower__________ Address__________

Collector__________ Address__________ Zip Code__________

Plant (or crop) attacked__________ Variety__________ Acreage__________

Plant part injured: Roots_____; stem or branch_____; leaves_____; flower_____; fruit_____

General appearance: Wilted_____; dead areas_____; yellowed_____; stunted_____; abnormal growth_____; leaf spot or blight_____; leaf mottle_____; other__________

Distribution of diseases: Scattered plants_____; groups of plants_____; most of field_____; on slopes_____; low areas_____; upland areas_____

When were symptoms first noticed?__________

Weather conditions of previous week:__________

Cropping history:__________

Chemicals applied, rates and date:__________

Fertilizer
Fungicide
Herbicide
Insecticide
Other

Location in relation to buildings:__________

ADDITIONAL INFORMATION FOR SPECIAL CROPS AND ORNAMENTALS:

Trees and Shrubs

Year established__________ Approximate age and size__________

Location: street or terrace__________; landscape__________; flower bed__________

Depth to caliche layer:__________

Shaded area__________; relation of injury to wind and sun__________

What is the watering schedule?__________

DIAGNOSIS AND PREVENTION:

Date reply:__________ L:_____ OC:_____ T_____ By__________

PLANT CLINIC FORM

The form is made up in triplicate with: (1) The carbon "built into" the sheets so that filling in the original white page makes three copies; (2) the reply is typed in the space under "Diagnosis and Prevention"; (3) the white copy is kept for office records, the other copies are mailed to the County Agent or person other than the grower who submitted the specimen. The County Agent, etc., notes the yellow copy and files it, and forwards the pink copy to the grower; (4) six boxes at the upper left permit classifying the type of grower or agent submitting sample: CA - Commercial Agriculture; C - County Agent; GA - Government Agent; N - Nurseryman; HG - Home Gardener; and one blank box for staff and others.

Directions on "How to Collect and Ship Plant Disease Specimens" are given a prominent place at the top of the sheet. The importance of good specimens is emphasized.

D I A G N O S I S   C L I N I C   E Q U I P M E N T

The plant-disease clinic manned by a full-time or part-time plant pathologist or intern should have the following basic equipment in addition to the usual office and laboratory furniture and supplies: (Others engaged in diagnosis should select from the list the most needed items as their budget will permit.)

1. Binocular microscope (zoom type preferred). With 20X oculars you can dial any magnification between 14X and 60X. Built-in light available, prefocused on stage from above, intensity controlled by rheostat. (About $600)

2. Compound microscope, binocular body, with quadruple nosepiece and 5X, 10X, 43X and 95X (oil-immersion) objectives, and 20X oculars (10X, 15X, etc., optional), with built-in substage light and rheostat. (About $1,200)

3. Incubator for cultures, electric. (About $250)

4. Refrigerator, household 7 to 12 cubic feet, for storage of specimens, cultures, media, etc. (About $250)

5. Solu-Bridge Soil Tester. (About $85)

6. "Hardware" - Bunsen burner, dissecting instruments, clamps, ring stand, etc.

7. Glassware - Test tubes, Erlenmeyer flasks for media, petri plates, pipettes, funnels, beakers, micro slides and cover slips, 1 doz. 30 ml. dropping bottles for reagents, stains, and mounting media.

Disposable plastic petri plates and pipettes, etc., are convenient as they are sterile and ready for use.

8. Clinic should have use of the Plant Pathology Department's facilities: (1) Autoclaves for sterilizing media; (2) Ovens for sterilizing glassware, etc.; and (3) Stock of chemicals, stains, and materials for making media.

LESS DELUXE EQUIPMENT WILL DO

Readily available and inexpensive equipment will suffice for sterilization:

9. A medium sized domestic pressure cooker is a very efficient autoclave if a "hot" gas burner or electric plate is available to furnish adequate heat.

10. The oven of a kitchen range with a thermostat is quite adequate as a dry sterilizer for glassware, etc.

SUPPLIES FOR PLANT DISEASE CLINIC

Chemicals and supplies needed for a well-equipped clinic. The amounts suggested for expendable items should be sufficient for at least a year.

GLASSWARE:

1 gross	18 x 150 Pyrex test tubes, no lip.
1 gross	metal test tube closures (optional)
1 gross	18 x 100 Pyrex petri plates and covers
or 3 gross	18 x 100 disposable plastic petri plates (sterile)
or 3 gross	15 x 60 disposable plastic petri plates (sterile)
or 1 gross	6 oz. prescription bottles (for media, can be autoclaved)
and 1 gross	12 oz. prescription bottles
and 1 gross	32 oz. prescription bottles
1 each	500 ml., 1000 ml. and 1,500 ml. porcelain pitchers (for media, more durable than glassware)
or 1 each	1 qt. and 2 qt. stainless steel beakers, or saucepans (for media, etc.)
6	55mm Buechner Funnels
2	500 ml. filter flasks
3	Boxes (100 sh.) No. 2 filter paper
6	1500 ml. Erlenmeyer flasks (for making media)
12	250 ml. Erlenmeyer flasks (for bulk storage of media)
3 gross	1 x 3 microscope slides, non-corrosive
6 oz.	Micro. cover glasses, 2 oz. each 15 and 18 mm. circles, 2 oz. 18 mm. square
1 doz.	Dropping Bottles, Barnes with rubber bulb, 30 ml.
1 doz.	Dropping Bottles, with screw cap and rubber bulb, 30 ml.
6	Dropping Bottles, with interchangeable pipettes, 30 ml.

2	6 inch porcelain or plastic funnels (for tubing media)
6	6 inch glass funnels (for extracting nematodes)
	HARDWARE:
1	Small bunsen burner, for type of gas available
4	Scalpels, 2 small, 2 medium
3	Forceps, straight tip; fine, medium and coarse
3	Forceps, curved tip; fine, medium and coarse
1 doz.	Dissecting needles in wooden handles
4 doz.	Safety razor blades (Gem type with heavy back) Stainless steel if available
2 pair	Scissors, surgical, small and medium
4	Pinch cocks for rubber tubing
1	Small laboratory balance weighing to 1/10 gm. (Photo scale)
1	Water pump or vacuum pump for suction
	CHEMICALS:
1 gal.	95% ethyl alcohol (tax free to educational institutions)
1 qt.	Xylol (Xylene) Alcohol can be denatured with a few drops of Xylol and marked with a few drops of dye (safranin, et al.).
4 oz.	Chloral hydrate
1 gal.	Sodium hypochlorite, 5.75% (Chlorox, etc.) at grocery stores
1 gal.	Formalin (40% formaldehyde)
2 qts.	Acetic acid, glacial
1 qt.	Lactic acid
1 qt.	Glycerin
1 qt.	Hydrogen peroxide
1 lb.	Acetone
1 lb.	Phenol crystals
1 lb.	Copper acetate
1 lb.	Paraffin

8 oz.	Mercuric chloride
4 oz.	Vaseline
4 oz.	Unflavored gelatin
5 gal.	Distilled water (available in gallon bottles at groceries, etc.)
4 oz.	Chromic acid
1 gm.	Osmic acid
3 lbs.	Absorbent cotton (1 lb. rolls) at drugstores, etc.
	STAINS: Amount suggested may be sufficient for several years or more
5 gm.	Orseillin BB
10 gm.	Safranin O
10 gm.	Gentian Violet (Crystal violet)
10 gm.	Cotton Blue (Methyl blue)
5 gm.	Basic Fuchsin
5 gm.	Acid Fuchsin

S E L E C T E D   F O R M U L A S

The following formulas and methods are the most useful in diagnostic work. The writer prefers Rada's solution for routine work.

1. STERILANT SOLUTIONS: To eliminate or lessen surface contamination before attempting isolation of plant pathogens.

<u>95% ethyl alcohol</u>: Dip for 3 seconds - for thin leaves, etc. Mild.

<u>Mercuric bichloride</u> 1-1,000: 15 to 45 sec. for bacterial leaf spots. Rinse in 3 changes of sterile water, 30 sec. each.

<u>Rada's Solution</u>: Mercuric chloride in 50% alcohol. Stronger and more effective in wetting surfaces. Excellent for surface sterilization in isolating Verticillium and other slow growing pathogens.

<u>Sodium hypochlorite</u> 5.75% (Chlorox, etc.): Dilute 1:9 to wipe down surfaces of table or culture hood before making isolations. Also very good to remove surface contaminations before making isolations.

<u>Hydrogen peroxide</u> diluted to 50%: 15 seconds to 5 minutes depending on tissues and distribution of pathogen.

<u>Formalin</u> diluted to 1:250: 15 seconds to 5 minutes as above.

2. STERILIZATION BY HEAT:

Glassware, etc.: Heat to 150-160 Deg. C. (303-403 Deg. F.) in hot air oven with thermostat for one hour or more. A kitchen range can be used. Wrap glass petri plates in paper to protect against contamination if they are stored in laboratory or store in closed containers (coffee cans will do). Allow glassware to cool slowly in oven to avoid danger of cracking the glass.

Culture Media: Use laboratory autoclave or domestic pressure cooker. Open petcock until air is displaced by steam. Either cotton plugs or metal closures can be used in test tubes and flasks. Culture media, 10 ml. per test tube, should be sterilized 20 minutes after pressure has reached 15 lbs. Media in flasks should be melted, then sterilized for 30 minutes or more (up to 500 ml.) at 15 lbs. Allow pressure to reduce slowly to avoid wetting plugs--do not open petcock.

3. CHEMICAL STERILIZATION OF GLASSWARE AND/OR INSTRUMENTS: Glassware may be sterilized by one minute or more in strong (bichromate) cleaning solution; 1:100 mercuric chloride; 5% formalin; or 95% ethyl alcohol followed in each case by three changes of sterile distilled water. Metal instruments (scalpels, inoculating needles, etc.) may be dipped in 95% ethyl alcohol and passed through a Bunsen burner flame. Repeated heating will spoil temper of cutting edges.

4. CULTURE MEDIA: Much time can be saved in the preparation of media by the use of prepared media now available dehydrated and ready to dissolve in water and sterilize. ("Difco" has an extensive list of different media.) Only 3 or 4 media are necessary for routine diagnostic cultures. Most fungi grow well on a medium rich in carbohydrates and with a pH around 5.0. Bacteria generally thrive on a medium rich in proteins and with a pH around 7.0. The media we have found most useful are:

Potato Dextrose Agar: Most (but not all) fungi grow well on this medium and it is used in most isolations.

Beef-extract Agar and Potato Dextrose Peptone Agar: Preferable for isolating bacterial plant pathogens.

Water Agar: 15 gm. agar per liter is useful to separate bacteria from Pythium and Fusarium. Glucose Agar is also low in proteins.

Lactic Acid: 1 or 2 drops of a 25% solution added to 10 ml. melted agar before pouring the plate will inhibit growth of pathogenic and saprophytic bacteria.

Sodium Polypectate Medium:* For 1 liter mix in the following order:

4.5 ml. of 1N NaOH
6.0 ml. of a fresh 10% $CaCl_2 \cdot 2\ H_2O$
1 ml. of 1.6% alcoholic Brom thymol blue solution.

Place half of this solution in a Waring blender and add 15 gm. sodium polypectate and mix rapidly (like crazy). Do the same to the other half.

*While not truly an easy and rapid method, it is cited here because of its usefulness for soft rot bacteria.

Place each portion in a 1,000 ml. flask. Do not plug. Instead autoclave foil for caps C media. Autoclave 15 min. at 15 pounds per square inch. Pour immediately into plates. It will lump even while hot if you wait.

Corn Meal PPP Medium: For isolation of *Phytophthora* and *Pythium* from plant roots.

Difco corn meal agar - - - -	17 g per liter	
Pimaricin Na-salt	100 ppm	= 10 ml/liter of .1 g/liter stock sol.
Penicillin G Na-salt	50 ppm	= 5 " .1 "
Polymyxin	50 ppm	= 5 " .1 "

Keep antibiotics in a sterile water solution in the dark, and add the antibiotics to partially cooled sterilized agar just before pouring petri plates. Only penicillin is heat sensitive.

V-8 Juice Agar: For obtaining production of oospores by *Phytophthoras*.

V-8 Juice - - - - - - - - - -	200 ml.
Calcium carbonate	2 g
Agar	15 g

Citrus leaf bait: Species of *Phytophthora* parasitizing citrus roots can be isolated from infested soil (well moistened) in petri plates. Freshly cut pieces of citrus leaves inserted edgewise in soil will be invaded by *Phytophthora*.

Isolating *Pythium* free from Bacteria: Use following agar medium:

Dextrose	10 g
Ammonium acid phosphate	2 g
Potassium nitrate	1 g
Magnesium sulphate	1 g
Agar	25 g
Water, distilled	1000 ml

Pour melted agar, 5mm thick, in petri plates. When solidified divide into 4 equal quarters with sterile spatula. Place bit of nonsurface-sterilized inoculum in center of each quarter. With a broad sterile spatula lift each quarter and invert in center of sterile petri plate so agar block makes a seal. *Pythium*, if present, will grow through the agar block within 24 hours.

5. PRESERVATIVES: Perishable material for reference or further study (but not for making isolations) is best preserved in liquid. Select material carefully and cut away all unnecessary parts.

Alcohol-Formalin-Acetic Acid: This is an excellent fixative, and material fixed and stored in it can be used for embedding, sectioning and staining. Material fixed in it also has a very good consistency for hand-sectioning. There are two formulas:

	No. 1	No. 2
50% Alcohol - - - - - - - - - - -	100 ml.	100 ml.
Formalin - - - - - - - - - - - - -	6.5 ml.	10 ml.
Acetic acid, glacial - - - - - -	2.5 ml.	10 ml.

No. 1 is preferred for host tissues with invading mycelium.

No. 2 is preferred for fungi not within tissues.

70% Alcohol: Useful for storage of succulent tissues. It often has a bleaching action.

5% Formalin: A low-cost solution for storage of specimens in liquid.

6. PRESERVING GREEN COLOR: Make a stock solution by adding copper acetate crystals to a 50% solution of acetic acid until saturated. Dilute 1 part of stock solution with 4 parts of water and immerse specimens and heat to boiling. The green color will change to a yellowish-green and then the copper salt will restore the green color. Time of treatment will vary with nature and thickness of material; from 3 minutes for thin leaves of grains, etc., to 15 minutes or more for thick or waxy leaves, stems, etc. Rinse and store in 5% formalin. We have some specimens unchanged after over 40 years of storage.

7. BLEACHING SOLUTIONS:

Chloral Hydrate-Phenol: Overwintering stages of fungi in fallen leaves may be observed by treating selected pieces placed in the following liquid for 20 minutes (or more if necessary to clear): Mix equal parts of chloral hydrate crystals and phenol crystals. Heat slowly until dissolved. If mycelium is hyaline, try a very dilute counter stain. For a permanent slide, wash in xylol and mount in balsam. This is much quicker than standard methods.

Lactic Acid: To decolorize tissues, immerse in 75% lactic acid for several days. Colored mycelium, etc., will then show distinctly; if mycelium is hyaline, stain lightly with cotton blue or gentian violet.

Hydrogen Peroxide: Bleach tissues in solution of hydrogen peroxide and 95% alcohol, 1:1.

8. STAINS: Certain stains, usually well-diluted, are useful in bringing out details in hyaline mycelium, spore bodies and spores.

Orseillin BB: A rose-pink dye used in Satory's solution for temporary or semipermanent mounts. This also is used for contrast to crystal violet in staining mycorrhizal fungi. Orseillin is likewise a bacterial stain.

Orseillin BB, .25% in 3% acetic acid: Is a good stain for mycelium, etc. Stain 1 to 4 minutes and remove excess stain with 3% acetic acid. For semipermanent mounts, add a drop of Satory's modified solution and ring.

Phloxine B: Acid. 2% solution in water is an excellent stain for hyaline fungus mycelium and spores for temporary mounts--one drop on a slide.

Safranin O: Red dye staining cutinized, suberized and lignified tissues and spore walls. Use very dilute for temporary mounts. This is used as bacterial stain in contrast with gentian violet in Gram technique.

Gentian Violet (Crystal Violet): Purplish dye, a general histological stain. Use very dilute for temporary mounts.

Cotton Blue (Methyl Blue): Blue dye staining contents of mycelium and spores, contrasting cell walls and cross walls. Also a tissue stain.

Basic Fuchsin: A red dye; a very powerful bacterial stain, either in tissues or smears. Use dilute in temporary mounts.

Acid Fuchsin: For cortex, pith, cellulose walls, etc., in vascular plants and fungus mycelium (Pianeze IIIB).

Fast Green FCF: Used for plant tissues and as a bacterial stain.

Gram Stain: Useful in testing bacterial cultures. Only a few plant parasitic species are Gram positive.

Prepared Stains and Reagents: Some of the larger dealers in botanical supplies now offer prepared stains and reagents for those who prefer the convenience of purchasing prepared formulas ready to use.

9. MOUNTING MEDIA (SOME WITH STAINS): For semipermanent mounts, place material in a drop of one of these solutions and seal. Medium must not extend beyond cover glass.

Lacto-Phenol (modified): Made by combining 1 part each of lactic acid, phenol crystals and water, with 2 parts glycerin.

Satory's Solution: Combine 10 gm. phenol crystals, 20 gm. lactic acid, 40 gm. glycerin, and 20 gm. water.

Satory's Solution (modified): Keener (Arizona) used 9 parts of Satory's solution to 1 part Orseillin BB stain (see stains) as a mounting medium for temporary slide mounts.

Cotton Blue-Lacto-Phenol: This stain is very good for delicate material and very rapid: phenol crystals 10 gm., glycerin 10 ml., lactic acid 10 ml., distilled water 10 ml., Cotton Blue .02 to .05 gm. (If precision balance is not available, make a stock solution of cotton blue ten times above strength (.2 or .5 gm. in 10 ml. water) and add 1 ml. with a pipette.)

(1) Fix material in A. F. A. No. 2 before or after free-hand sectioning; 48 hours if before, 20 minutes, if after.

(2) Wash in water 20 minutes.

(3) Stain 10 to 15 minutes and mount in drop of stain.

(4) Seal with thick xylol-balsam or vas-par.

Glycerin Jelly: This material is used by melting a drop-sized piece (a 2 mm. cube) on a slide and adding specimen and cover glass before it re-hardens.

Much used years ago; not much used now.

High quality gelatin	7 gm.
Distilled water	42 ml.
Glycerin	50 ml.
Phenol crystals	1 gm.

Dissolve gelatin in water (soak 2 hours or longer); add glycerin. Add phenol crystals, warm and stir constantly until clear; filter through 3 layers of cheesecloth into widemouthed bottle. Solidifies on cooling. Melt 2 mm. cubes on slide, add specimen and cover.

Karo: The blue label clear grade is an excellent substitute for glycerin jelly and more convenient. When hard, Karo is a firm as Balsam and cover-slips need not be ringed.

10. SEALERS: To make slides even semipermanent they should be sealed against evaporation with one of the following. Much neater seals can be made by using a slide turntable (about $12) and circular cover glasses. Center cover glass and apply sealer with a brush as table turns. Mounts should last several months. Some of ours have lasted over three years.

Canada Balsam: This should be rather thick for sealing and applied with a glass rod or stiff pointed brush.

Vas-Par: Made by mixing together equal parts of vaseline and melted paraffin. Apply with a warm rod or a brush.

Commercial Sealers: Several compounds, either black or clear, are sold for sealing slides; apply with a brush.

Commercial Auto Lacquers: Available in many colors in small bottles. They are fast drying and form a good seal.

Collodion: (A solution of pyroxylin in alcohol-ether--inflammable!)* Very good for separating fresh powdery and downy mildews and other superficial fungi from host for examination on slide. Flood mildewed area with several drops of solution and allow to dry. Put material on 4" hotplate (lowest heat) to hasten drying. Strip the dried film which has "embedded" the fungus from the leaf and mount on slide, either dry or in water or temporary mounting medium. For permanent mounts, mount directly in Balsam. (F. L. Steven's method, quoted by W. G. Solheim)

*(Commercial preparation "New Skin" is similar.)

Reference on methods.

Altman, Jack, Phytopathological Techniques, Laboratory Manual. 1966, Pruet Press, Boulder, Colo., 259 pp. Formulas of media, stains and preparations used in the plant pathology laboratory, and details used in isolation, inoculation, and identification are described.

S H O R T E R,   S I M P L E R   M E T H O D S

The causal organism for each of our known plant diseases has been verified by following Koch's Postulates, which are briefly: (1) A certain organism must be consistently associated with the disease. (2) An organism must be isolated in pure culture from the diseased tissues. (3) The pure culture must be used to inoculate healthy plants of the susceptible species and produce the typical disease symptoms. (4) The organism must be reisolated from the inoculated plant and the culture compared with the original isolation. Only then, can the organism be considered as being proven the cause of the disease. For research purposes this process must frequently be repeated.

This procedure may take weeks or months and require more training and laboratory facilities than are available to most individuals who need to diagnose diseases. Most of this manual is devoted to explaining the use of relatively quick, simple methods which are adequate for diagnosis in most cases. In some cases, the use of cultural methods, and in relatively few cases the full gamit of Koch's Postulates, are necessary.

FIELD EQUIPMENT

MINIMUM: The absolute minimum of field equipment (See Fig. 1) is a folding 10-X (10-power) hand lens of good quality (will cost $5 to $15) attached to a stout nylon cord firmly knotted, and a sturdy, sharp pocketknife (a folding linoleum knife is sturdier and better). A small plant press and a dozen 1-quart or 2-quart polyethylene bags are very convenient. In the field, the lens is carried in the shirt pocket and the cord around the wearer's neck for insurance against loss. A lens dropped in a heavy stand of grass, alfalfa or cotton can rarely be recovered. (I have lost several!) Painting the outside of the lens mount with fluorescent orange-red traffic paint greatly facilitates finding a lens that has been dropped.

STANDARD EQUIPMENT: A quite complete field kit (See Fig. 2) can be carried in a small, sturdy, fibre suitcase about 12" x 18" to 21" x 5". The most useful cutting tools are a hand pruning shears, folding grape saw, a small Swedish bow saw (23") (if it will fit). A good (not cheap) trowel will dig out small plants. Polyethylene bags, sizes 1-pint, 2-quart and a few "turkey" size will keep specimens separate and prevent them from drying out. Very thin polyethylene sandwich bags ("baggies" are excellent) are fine for small samples. Shell vials, 1 x 4 inches, with molded screw tops and filled with a preservative solution (F. A. A.--see Appendix) will kill and fix plant tissues, etc., permanently. (As the organisms are killed, these pieces cannot be used for incubation or pure cultures.)

A "pocket-size" plant press made from herbarium driers cut in four pieces (4 1/2" x 12") with corrugated ventilators and 1/4-inch plywood ends with heavy rubber bands or a light adjustable strap will preserve leaves and other thin material as well as a standard press. Lacking this any pulp magazine or paperback book with cheap newsprint type of absorbent paper will serve as an emergency press.

A camera equipped with extension tubes or bellows attachment to take photos close up, even full size, will be most useful. Color film is best.

A good supply of labels, string tags, rubber bands, and data sheets is most convenient.

Fig. 1. Minimum Field Equipment: Lower row: 10-X hand lens, Stout (linoleum) pocket knife, small plant press. Upper row: Exposure meter, 5 and 10 mm. lens extensions for close photography, camera, polyethylene bags for specimens.

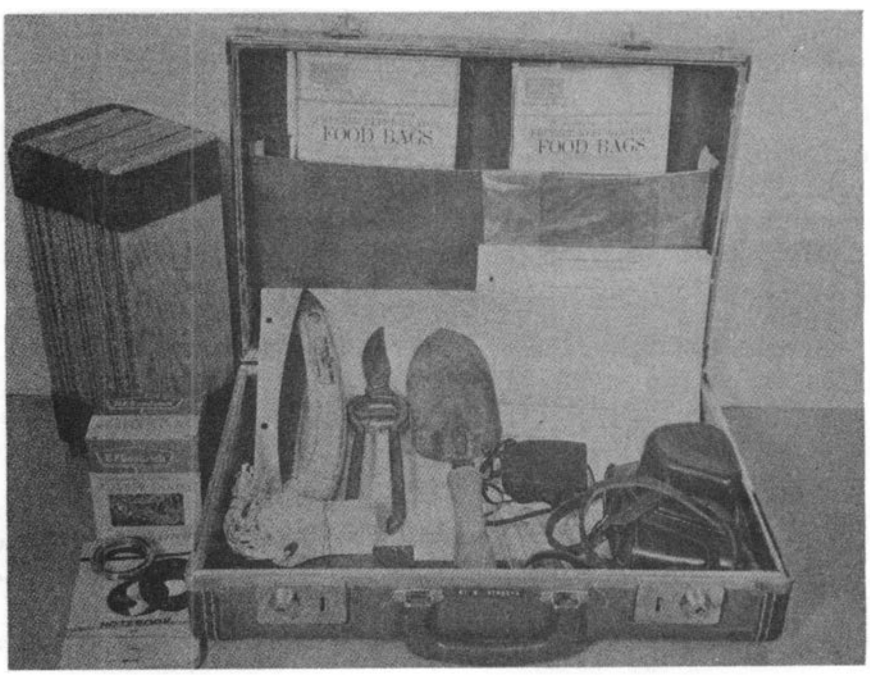


Fig. 2. Compact Field Kit: In carrying case, 5" x 12" x 18", -- 1 qt., 2 qt., and "turkey size" plastic bags for specimens. Folding saw, hand clippers, sturdy trowel, 1 x 4" screw top vials of F. A. A. String tags, plant clinic report blanks, camera, exposure meter. At left, small plant press, notebook, lens extension rings.

FOR AUTOMOBILE TRIPS: The kit described above can be carried on a bus or plane. In addition to this kit, bulky equipment that has proven most useful on auto trips is:

(1) Cold box. The large size, all-plastic picnic boxes have efficient insulation properties and are very inexpensive, but will not stand rough handling. When iced, they will keep plant specimens "salad fresh" for three or four days in hot weather cooled by a 25 lb. piece of block ice. Drain morning and evening.

(2) A standard plant press, with driers 12" x 16", will preserve specimens permanently if driers are changed after 12 hours, 24 hours, and 48 hours. Specimens should be fully labeled.

(3) A full-sized shovel with a short, D-handle or full-length handle is really needed to check for root-rots, crown galls, nematodes, etc., on orchard and shade trees. Hatchets and axes are relatively inefficient in getting specimens in good condition. (See Fig. 3)

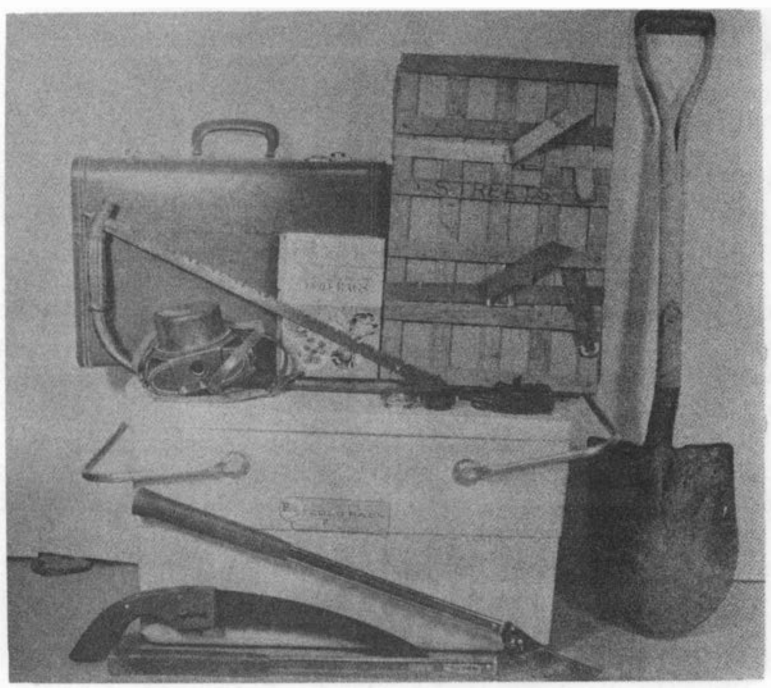


Fig. 3 FIELD KIT FOR AUTO TRIPS: Includes everything shown in previous picture packed in carrying case. Also bow saw, crescent saw, sturdy lopper, strong D-handle shovel, plant press, and extra large (44-qt.) molded plastic cold box. 25-lb. block of ice will keep this box cold three or four days.

WHAT IS AN ADEQUATE SAMPLE?

Adequate samples

While about half of the samples brought in or mailed in for diagnosis might be termed USABLE, most of them are not OPTIMUM -- that is, excellent and well chosen. This is, of course, due to lack of knowledge of the person collecting the sample of how to choose the characteristic symptoms, what parts to select from, and how to protect the sample against deterioration. In case of too small a sample, there is considerable probability that the sample submitted may not show symptoms of the major disease involved and may lead to an error in diagnosis. However, in the case of a spore-bearing fungus, positive identification is possible from even a very small piece of plant material. Nevertheless, an adequate sample is MUCH MORE DESIRABLE.

WHEN POSSIBLE, COLLECT YOUR OWN SAMPLES and make your own field notes. Under these conditions you have a much better opportunity to get adequate samples. It is preferable that the person taking the sample(s) bring them to the clinic, as he can fill out the information sheet if he has not already done so and answer questions and give additional information.

THE OPTIMUM SAMPLE:

(1) As many stages of the disease as are showing.

(2) Sample the REAL SITE of the plant disease. Many times leaf symptoms, etc., are due to damage to the root system or other parts of the plant. Check roots, trunk, and branches for lesions, galls, etc.

(3) Sample protected from deterioration due to exposure to heat and drying, by using polyethylene bags and storage in a styrofoam cold box. Samples of succulent vegetation tossed in the back of an automobile and exposed to heat and drying for even a few hours are usually worthless for diagnoses.

(4) Sample should be submitted as quickly as possible and not shipped so it will lie in the post office over the weekend before being delivered.

(5) Samples arriving at clinic in absence of pathologist or technician should be promptly stored in a refrigerator or cold room to prevent deterioration.

With some practice, you can improve greatly on the quality of specimens collected. People who submit samples to the clinic frequently should be encouraged to use care in selecting, handling, and shipping specimens.

NOTES AND PERMANENT RECORDS

Records and photographs

In addition to field and laboratory notes made in connection with diagnoses of plant-disease specimens as they are encountered and identified, it is desirable to keep a permanent record of the diseases in your area. I have found that 5 x 8 in. punch cards (Form Y9, Unisort Analysis Card, Burroughs Corporation) are very satisfactory. This card is large enough, by using both sides, to accommodate almost as much typing as a letter-sized page single spaced. There are 91 numbered holes in the edge, so that many categories can be separated by one operation of the sorting needle. Using the six extra unnumbered holes permits a preliminary sorting into seven major categories of 91 divisions each (or 7 x 91 or 637 classes using the sorting needle twice). Thus the records can be cross-indexed by host, parasite, location, etc., as desired.

The only equipment needed to set up this "poor man's I.B.M. system" is a supply of 5 x 8-inch punched cards which are inexpensive, a punch, a sorting needle, and a 5 x 8-inch filing drawer. Less than 300 cards need not be filed in order.

PHOTO RECORDS

COLOR PHOTOS: While leaf specimens and other material can be preserved for reference by drying between blotters, much of the material encountered is too bulky or too perishable to be preserved in this manner. The best and most useful method of recording such specimens is by use of 35 mm. color film. This method is the only one by which the fresh appearance of fruits and vegetables, and fleshy fungi can be accurately recorded. It is likewise valuable in recording specimens too bulky or perishable to keep -- such as large limb and trunk cankers, galls, root rots, wood rots, blights, etc.

A 35 mm. camera with interchangeable lens of good quality and a set of extension tubes for close-up work to make pictures on any scale down to natural size is adequate for the purpose. Recently available, several plastic slide viewers that can be used in ordinary room lighting and permit rapid change of a series of slides by moving a lever back and forth, greatly facilitate a study of colored slides, as the image is brilliant and large enough to reveal details satisfactorily.

HOW TO GET MEANINGFUL PHOTOGRAPHS

A GOOD photograph is better than a long description for conveying your ideas to others, or to make an accurate permanent record of plant disease symptoms. Most photos are not as good as they might be, and the following suggestions are offered to enable you to secure the best possible photos for your purpose.

1. AVOID POOR SUBJECTS. Most photos are cluttered with a lot of distracting detail to the point of having little value. General black and white photographs of plots, fields, orchards, and gardens are not capable of showing infections of smuts, rusts, leaf spots, mildews, fruit spots or rots, or blossom blights and should be avoided. Even in color, the details are so small such photographs fail to record field conditions.

<u>Exceptions</u>: Subjects with a simple pattern and strong contrast such as solid areas of dead trees or plants do make good photos in black and white or color.

2. FILL THE PICTURE AREA with the important part of the subject matter (emphasizing details of lesion, fruit or vegetable rot, blight or leaf spot of foliage, etc.) and eliminate all parts of subject not necessary.

3. PROVIDE UNIFORM, CONTRASTING BACKGROUNDS.

<u>Black backgrounds</u>: Use a dull black cloth as a nonreflecting background for both black and white and color photos. Black emphasizes the subject and eliminates all distracting background shadows. You should have two such cloths, one 3' x 3' and the other 3' x 6'.

White backgrounds by transmitted light: White fabrics or paper used as backgrounds usually appear somewhat gray in photographs. Often symptoms such as mosaic mottling or young bacterial lesions on thin leaves show much greater contrast when viewed toward a strong light. Photos of such subjects are best taken with transmitted light. A light box with a milky-white opal glass is most convenient. (See Figure 91, lettuce mosaic; Figure 72, bact. blight of bean; Figure 71, discolored veins in leaf of cabbage with black rot.) The lighted backgrounds also eliminate distracting background shadows.

4. EVALUATING PHOTOS: Use two L-shaped pieces of cardboard to mask out unnecessary parts of a picture. Often an enlargement of the useful part is much superior to a print of the full negative. Most pictures that are published have been trimmed. When taking pictures, try to eliminate as much unnecessary detail before making the exposure.

5. COLOR PROCESSES: There are three common color processes: One produces color positive transparencies usually mounted as 2" x 2" slides. Duplicate transparencies or enlarged color prints may be ordered. Roll or sheet film for larger sizes are available from some suppliers.

The second process produces 35mm negatives from which 3" x 3" color prints are made by the processor.

The third process produces either black and white or color photos which are delivered from the camera itself on the scene. Additional prints can be ordered. In processes 1 and 3, submit the original in ordering duplicates.

Good color requires fairly accurate exposure time, so use a meter. Also color films come in a variety of speeds, use the ASA rating in using the meter.

6. COLOR SLIDES OR PRINTS FOR REFERENCE AND DEMONSTRATION: Most people are visual minded and learn more from looking at a good color picture than they would from even a good oral or written description, and this is an important aid in diagnosis. Slides can be shown to one or two people in daylight using a small slide viewer, or shown to larger groups in a darkened room using a slide-projector. The large projected color pictures are impressive.

7. LIGHTING: Daylight is quite constant on clear days. When the sky is full of fast-moving small clouds, you have problems--use a light meter--and shoot before the light can change. Light has warmer coloring, and is less intense, in early morning and late afternoon than at noon. Use a meter.

Side lighting for stereo effect: Black and white photos give better modeling of roundness of stems, fruits and other solid objects when the main light source is 45 degrees to the right or left of camera axis. Color is recorded accurately when the sun or light is directly above the camera, but prints are somewhat flat. Lighting at a 45-degree angle will correct this but if shadows are dense use an aluminum reflector to lighten them. Some detail should be visible even in the shadows.

Artificial lighting: Photoflood bulbs in 12-inch clamp-on reflectors give a well-diffused light and should be used at a 45-degree angle with reflectors to lighten shadows as needed. The blue glass bulbs are balanced for color film.

Flash bulbs and Strobe: These are useful in obtaining well-lighted photos in otherwise impossible situations such as under trees, in dense shade, or dark interiors or where sunlight through foliage gives a "camouflage" pattern obscuring detail. If the light unit is on a cord so it can be moved to one side, flat lighting such as occurs when flash unit is attached to the camera can be avoided.

8. TAKE IT NOW: When you are sent good specimens, or when you find them in the field--Photograph them IMMEDIATELY--while they are available and in good condition. A good collection of color slides has many uses. You will need one!

9. PHOTOGRAPHING DETAILS: This book emphasizes the fact that for most diseases there are certain characteristics that are distinctive and diagnostic. They can usually be shown best by close-up photographs.

It is generally best to photograph symptoms at three magnifications: (1) one or more photos of general symptoms characteristic of the disease; (2) one or more photos of details of spots, cankers, etc., about natural size; and, (3) one or more photos giving a "hand lens view" of such items as fruiting bodies or fungus growth at 5X to 12X magnification.

Equipment for obtaining "natural size" photos: The lens of camera must be removable so that a set of extension tubes or an extension bellows attachment may be placed between the camera and the lens. The distance from the lens to the film must be twice the focal length of the lens (that is, 4 inches for a 2-inch lens--normal for a 35mm camera) and this will equal the distance from the lens to the object being photographed. Focus carefully as the depth of field is slight at this setting. Stopping down the lens and using longer exposure will increase the depth of field.

Equipment for 10X photos: The best equipment is a compound microscope and light with a mount which will accept your 35mm camera (less lens). The ocular of the microscope is also removed. To determine correct exposure make a series of test exposures each about twice as long as the preceding (example 1/100, 1/50, 1/25, 1/10, 1/5, and 1/2 second). Record correct exposure for your film. Special lenses with diaphragm for photomicrographs are available in focal lengths of 16, 32, and 48mm. Focus critically, depth of focus is very slight.

10. PHOTOGRAPHING SECTIONS: Characteristic symptoms in fruits and fleshy tubers and roots are often best shown in cross section (See Figure 73, Potato ring rot; Figure 49, Alternaria rot of orange; Figure 65, Cold injury of citrus fruit; and Figure 95, Phloem necrosis of sugar beet).

Likewise the characteristic symptoms of vascular discoloration in woody stems or roots are best shown by photos of longitudinal sections taken life-size or larger. (See Figure 25, Vert. wilt of cotton; Figure 27, Oak wilt.)

Section photos should be accompanied by surface views where surface lesions are evident.

FIELD SAMPLING TECHNIQUES

QUALITATIVE: When you are in the field taking your own samples, if you wish to determine what diseases (if any) are present and their approximate severity, sampling is relatively simple. For field or vegetable crops, walking between the rows for 50 to 100 feet and noting disease prevalence and severity is usually sufficient. If the field is large, sampling the opposite corners (e.g., NE and SW) or opposite ends is advisable. In case of irrigated fields, always check the low end where water accumulates -- diseases are more prevalent there.

If root infections are suspected, dig a few plants with a trowel or shovel. If dirt clings to the roots, soak roots in water in order to check for nematode galls or lesions on roots. Note whether infections (aerial or underground) are uniformly distributed or localized in one or more spots. Many root rots due to parasites persisting in the soil follow this pattern. New infections introduced in or on infested seed may appear in spots.

Collect your samples as outlined under "The Optimum Sample."

QUANTITATIVE: While it is possible to sample a field thoroughly and estimate the extent of infection or probably loss in yield, it is best to avoid this as it is very tedious and time consuming and the results are controversial. The most valid measure of the loss is the decrease in yield of the crop determined at harvest time, compared with normal yield, or preferably with a comparable non-infected field nearby.

One should know, however, how estimates are made. In case of field or vegetable crops, walking the diagonal of the field and making disease counts on at least 20 plants at intervals of 100 or more feet, the average of not less than 10 counts gives a fairly accurate estimate of disease prevalence.

AERIAL COLOR PHOTOS: In case of diseases causing death or conspicuous color changes in field, vegetable, tree or bush crops, aerial photos in color give better permanent records of distribution and severity of the disease(s) present than any map that can be made from ground data. Color photos made with a 35 mm. camera are surprisingly good, showing great detail (even bare spots caused by harvester ants, and skips in the row in cotton fields). Areas affected by root rots, severe chlorosis, flooding, and defoliating diseases are conspicuous.

INFRARED AERIAL PHOTOGRAPHS

A new method of detection of plant diseases from color changes in diseased plants seen in aerial photographs made with infrared color film has made possible early detection of some plant diseases (41). Rapid surveys of large areas (thousands of acres) affected by disease have been made.

This work was reported in 1966 by Colwell et al. (42) in California, and Norman and Fritz (43) in 1965 in surveys of Florida citrus groves.

Ektachrome Infrared Aero Film 8443 is available in 35mm and 4" x 5" sizes and is used with a Wratten No. 12 filter. In infrared photos with No. 12 filters healthy foliage was a reddish hue, diseased foliage was purplish, green, blue or yellow, and the color was often specific for a particular specific host and disease.

COURSE IN DIAGNOSIS OF PLANT DISEASES

In the past ten years there has been a definite swing away from the practical and applied approach to plant pathology which had dominated the experimental and instructional field. The preoccupation in recent years with basic research in laboratory and greenhouse on biochemical, physiological, and visual aspects of plant pathology financed by grant money (abundant at this time) has resulted in the dropping of most of the courses in which graduate students were trained in applied plant pathology.

This, the writer feels, is a long step backwards, and many well-known plant pathologists agree. In the meantime, courses in research methods proliferate, and we are training for research only, rather than a balanced program including training for teaching and extension work. At one time, about a year ago, of the 12 plant-pathology job openings, 9 were for part-time or full-time extension work, and we are not filling this need.

The writer taught a new course in "Diagnosis of Plant Diseases," two units, six laboratory hours per week, for two semesters to a class of 15. The course attempted to simulate the plant-clinic approach, in that the students were given "unknowns" -- mostly actual specimens received by the clinic, plus the information (adequate or not) accompanying the specimens. They also were given specimens collected by the instructor with more adequate information.

In order to guide the students through an orderly examination of the specimens a two-page work sheet was used for each specimen to enable the student to follow the proper sequence and record his findings with the minimum of writing. Following the complete outline was rarely necessary. As soon as the disease was identified, the student skipped to the bottom of page two and gave recommendations for control. This approach, plus field trips, we feel, was the closest approach to actual experience possible in the classroom, and the students appreciated the practical approach.

Incidentally, the following pages form a usable outline for a "do-it-yourself" course in diagnosis. It would, of course, be of great value to have a qualified person check your identifications and recommendations.

(See "diagnosis work sheets" on next two pages.)

Specimen No._______ Student________________________________ Grade_______________

1. Host Plant_______________________________ submitted by _____________________

2. Where grown____

3. FIELD SYMPTOMS: Your own notes, if collected in the field. Otherwise, data from person bringing in sample.

   FIND OUT: a. General symptoms; b. No. of plants affected; c. Sudden or long-standing; d. Susceptible plants near sick ones.

4. CULTURAL CONDITIONS under which host plant was growing:

   Depth and nature of soil____

   Irrigation practice: How much, how long?____________________________________

   Fertilizer used: What and how much?_______________________________________

   Fungicides or insecticides used____

   Weedicides, soil sterilants, termite treatment_______________________________

5. SYMPTOMS: in detail: a. Foliage and twigs; b. Trunk, stem, branches; c. flowers and/or fruit (if any); d. Taproot, main roots, feeding roots.

6. LOW POWER: seen under hand lens and/or binocular:

   Details of lesion____

   Evidence of spores or fruiting bodies____

   Exudate (color, consistency)____

   Evidence of insects or mites____

   Evidence of mechanical or chemical injury___________________________________

Specimen No.________ Student____
HIGH POWER: Scrapings or sections in temporary mount seen under compound microscope.

<u>Diagram</u> of
fruiting body.

<u>Accurate drawing</u> of
spores and conidiophores.

8. ISOLATIONS: Cultures made to isolate causal organism. (Advancing margin of lesion is best place to get pure culture of most organisms.)

Tissues cultured____

Method and culture media____

Appearance of colony: Size, shape, color, consistency______________________________

____

Fruiting bodies and spores____

9. INOCULATIONS: into host plants to prove pathogenicity:

Method____

Results: symptoms, how long?____

____

10. DIAGNOSIS: common name of disease____

Name of causal organism or agent____

11. RECOMMENDATIONS TO GROWER: After each recommendation give reasons why it was chosen as the most practical and effective method for this situation.

____

____

____

____

____

____

12. REFERENCES USED:

____

____

____

R.B. Streets, Instructor

Grade________________

STEPS IN DIAGNOSIS

Following the worksheet: Item 1: IDENTIFY THE (DISEASED) HOST PLANT: Does the sample provide adequate material for recognition of the host? If it is a crop plant or commonly cultivated ornamental, identification should not be difficult. Usually the plant is named by the person submitting it. If the host plant is uncommon or bears no distinctive flower or fruit parts, the problem is more difficult.

Those who have had a course in Taxonomy of Flowering Plants should be able to identify the plant by running it through the keys, or perhaps they can approximate the plant group and proceed from there. As a last resort, appeal to the instructor or taxonomist of the institution as you will need to know the host in order to look up control measures after you have identified the disease-inducing organism or agent.

2. Whether the host was grown in the field, garden, orchard, or yard will affect the control measures applicable. Record name and address of person submitting the specimen for use in replying with recommendations.

3. FIELD SYMPTOMS: Use your own notes if possible; otherwise, data from person submitting the sample. Follow suggestions in worksheet.

4. CULTURAL CONDITIONS: These six items are concerned with the cultural factors that are often a major factor, especially in the case of nonparasitic diseases. They are very important -- do not slight them.

Observation and Interpretation

From this point on, your success will depend upon keenness of observation and accuracy of interpretation of what you see:

5. SYMPTOMS: Close observation of the symptoms as viewed without magnification should indicate the general type of disease: leaf spot, twig blight, blossom infection, fruit spot or rot, limb canker, trunk infection, root rot, etc. Record all symptoms briefly.

6. LOW-POWER EXAMINATION: Close examination under a 10X hand lens of the surface of lesions, bark or dead tissues often will show evidence of spore-bearing bodies of fungi, bacterial exudates, or clear gum. Often only a few of the lesions show this evidence. Lesions showing no evidence of these types of surface growths could be young lesions which may develop spore bodies, etc., or they may be the result of conditions causing non-parasitic diseases.

Inducing spore formation: Young active lesions will usually form spores if incubated in a moist chamber for 24 to 72 hours. The most convenient forms of chamber are plastic bags, a large widemouth jar with cover, or a regular or large sized petri plate with a sheet of filter paper moistened with sterile distilled water or boiled tapwater. Place a few selected lesions bearing leaves or twigs, etc., in the petri plate and label for identification. Examine for growth at least every 24 hours. If kept too long or too wet, secondary fungi or bacteria may overrun the leaves.

Evidence of spore formation: (1) Leaves showing medium to large areas of paler green or yellow-green may develop on the underside only a thin weft of pale violet to whitish branched conidiophores and conidia. Make scraping or sections to examine spores and conidiophores. (This is typical of downy mildews.)

(2) Either surface of leaves or stems or flower parts showing white powdery areas. Surface mycelium is visible under 10X lens. Make scraping, use wet needle, or section. (Spores barrel-shaped in chains are powdery mildews.)

(3) Surface of lesion bearing tiny tufts (light or dark) over area or only in center. (If scraping does not yield conidiophores as well as spores, make sections.) Often imperfect fungi of order Moniliales. Spore-bearing lesions may be composed of living or more often dead cells.

(4) Lesions are more or less sunken, usually on fleshy fruits or stems, sometimes on leaves, cells dead. In the center of lesion areas, slightly raised, are cushions or tufts of spores. Pick up spores on a wet needle, or section lesion. (Anthrac-nose types, belonging to order Melanconiales.)

(5) Lesions of various sizes; cells usually dead, small black dots appear on lower or both surfaces, slightly raised like pimples. These usually are black and are protruding necks of flask-shaped fruiting bodies which may produce sexual spores (Pycnidia of fungi in the order Sphaeropsidales) or perithecia of the order Sphaeriales in the class Ascomycetes. (Sometimes these can be dug out of the tissue and mounted whole in KOH solution and crushed, or they can be sectioned in place in the leaf.)

THE REST OF THE ANSWER

Having correctly diagnosed the plant disease problem, the next questions from the client are WHAT DO I DO ABOUT IT? and WHAT IS THE CONTROL?

Specifying the best control of each disease is outside the scope of this book. The answers are to be found in the selected list of text and reference books in the appendix.

For the benefit of users of this book whose background in plant pathology is limited, the following may help the understanding of the relation of the pathologist to the public.

The list of control measures in the manuals usually attempts to cover all variations in growing conditions, climate, etc., and the selection of specific remedies to recommend is so important to the control of the local problem--and to your personal (and department) image--that a few suggestions are in order.

(Trade names used in this publication are for identification only and do not imply endorsement of products named or criticism of similar products not mentioned.)

Some questions you should ask yourself are:

1. Can anything be done now? Most growers would rather try something than feel that nothing can be done. Often that something must be applied to the next crop.

2. Is the injury enough to warrant a control program? A few plants in a home garden may not justify treatment--unless owner wishes.

3. Leafspots, mildews, etc., can best be treated (by spraying or dusting) in early stages. Is spraying when foliage is heavily infected worthwhile?

4. Could injury have been avoided by planting resistant varieties? Examples: Fusarium wilts of watermelon, tomato, cotton, soybean, flax; Verticillium wilts of tomato, strawberry, cotton; rusts of small grains, snapdragon.

5. Does grower have equipment necessary for control, such as sprayers for fruit trees, row crops, etc., or equipment for injecting nematocides?

6. Is infection systemic, as in viruses so that plants cannot be saved?

7. Does the pathogen persist many years in the soil (e.g., wilts of watermelon, tomato, and pepper)? Would it be possible to rotate into noninfested soil?

8. Are the root-knot nematodes the major problem? So many host plants are susceptible that either soil treatment with a nematocide, or moving the planting to noninfested soil are the only practical solutions.

9. Will the disease reoccur? Most diseases once introduced will tend to reoccur each year, but in varying amounts depending on weather and other conditions. The grower should be expecting the reoccurrence and be prepared to treat on first appearance of symptoms when control measures will do the most good. (E.g., fire-blight of apple and pear, bacterial blight of stone fruits, apple scab, cherry leaf spot, brown rot of stone fruits, to name a few.)

10. What diseases require immediate treatment? The damping-off of seedlings of vegetables, flowers, cotton and other row crops must be given a soil drench of fungicide immediately to save the seedlings as the disease spreads very rapidly.

S P E C I A L   M E T H O D S

(Methods are explained in the most appropriate places. See page numbers.)

(In many other cases, young, active lesions are so distinctive that inoculation for verification is unnecessary.)

DIAGNOSING LEAF SPOTS

Diagnosing leafspots

Inducing sporulation: In case of leaf spots showing no signs of spores or only immature fruiting bodies, incubate selected leaves in a moist chamber (a plastic bag, standard petri plate, large petri plate, or plastic-covered dish). Filter paper moistened with sterile, distilled, or boiled water and applied to inside of the chamber top and bottom will furnish the necessary humidity. Incubate at room temperature for 24 to 72 hours. Examine daily, as saprophytes may overgrow the lesions if leaves are left in chamber too long.

If no growth from possible parasites is observed after incubation in a moist chamber, the malady may be due to a virus or nonparasitic cause.

TEMPORARY MOUNTS: Temporary mounts for examination under the compound microscope are quickly made from fresh material by placing a drop of water on a 1 x 3 inch microscope slide, putting a tiny bit of material in the water and covering with a thin glass coverslip.

(1) When aerial growth of conidiophores and conidia is present, a small amount picked up on the tip of a wet dissecting needle, dissecting spear, or corner of a

razor blade usually will give a good view of the conidiophores and conidia. Powdery mildews and other imperfect fungi, downy mildews, smuts, and rusts can be mounted this way.

(2) When pinhead sized or smaller cushions bearing spores occur in the center of lesions, a wet needle, etc., will pick up spores but few conidiophores. Temporary sections of such lesions are necessary to observe the structure of the fruiting body.

(3) When small, usually black dots appear on the lesion, they usually are the neck and opening (ostiole) of flask-shaped spore bodies (pycnidia producing conidia of fungi of the order Sphaeropsidales of Fungi Imperfecti) or perithecia producing ascospores (usually 8 in a transparent sac) of fungi of the order Sphaeriales and other orders of the Ascomycetes. Often these can be dug out of the leaf tissue with the point of a needle, etc., and mounted whole in a drop of water and crushed by gentle pressure on the cover glass to reveal the contents (conidia, asci, ascospores). The lesions also may be sectioned freehand (See page 4.3) to reveal the fruiting bodies in position, and possibly some good vertical sections of them.

<u>Reviving collapsed spores and tissues</u>: Thin-walled spores and mycelium (e.g., of powdery or downy mildews, etc.) when dried are collapsed and distorted and difficult to examine. Mounting them in a drop of 1% KOH (potassium hydroxide) will cause immediate restoration to the original size and appearance. <u>CAUTION</u>: KOH in contact with microscope lenses causes an irreparable etching of the glass resulting in a fogged image. Use only <u>one</u> small drop of KOH and see that <u>NO</u> KOH extends beyond the edges of the cover glass. Absorb KOH beyond cover slip with a strip of filter paper. Should KOH get on front lens, wash immediately in water. It is the drying concentrated KOH that causes severe etching.

SOLHEIM METHOD: An alternate method used by Dr. W.G. Solheim, for many years Mycologist of the University of Wyoming, can be used to make either temporary or permanent mounts from dried material. It also should be superior in softening thicker and firmer material such as pods, roots, stems, and twigs, so that better free-hand sections can be cut.

About four spots with fruiting structures should be cut out and boiled for ten minutes in a 10% solution of KOH. The KOH is then poured off and replaced with distilled water and the material again boiled for ten minutes to remove most of the KOH. The procedure is best performed by means of a waterbath and a small hot plate.

The material is then emptied into a dish and floated onto a glass slide. One spot is placed on the slide with the top leaf surface up, another with the lower leaf surface up. At times it is preferable to cut a single spot in two, reversing the position of one of the pieces. The material is then covered with a coverslip and examined under the compound microscope. Extra pieces may later be used for teasing apart with dissecting needles to reveal details of spores and fruiting bodies.

This procedure clears the leaf tissue and swells dried fungus structures back to normal. It permits the examination of the material to determine the relations of the parasite to the host tissue and also makes possible easy measurements of many structures.

In a few cases, instead of clearing, the leaf turns dark (from presence of tanning, etc.). This happens with oak and walnut leaves and some others of similar nature.

SEMI-PERMANENT MOUNTS: If mounts of spores or sections are wanted for use or comparison for some weeks or months, mount as follows:

(1) Satory's Solution: (See Appendix for formula) This is a nondrying acid solution containing a preservative and a red stain. It is best used directly on fresh fragments or sections. Use small drops. Slides may be sealed if Satory's Solution does not extend beyond edge of cover glass. If used after KOH, many bubbles will form from reaction of alkali with acid.

(2) Glycerine Jelly: (See Appendix for formula) A very old formula containing phenol as a preservative. This is a firm jelly at room temperature. Place a small piece (a 2 mm. cube) on slide and heat gently until jelly melts. Orient material and apply cover glass. It can be ringed for greater permanence.

F R E E H A N D   S E C T I O N I N G

The following method of direct sectioning of fresh or dried specimens was taught to many generations of Graduate Students at the University of Wisconsin by Dr. J.J. Davis, Mycologist and Curator of the Herbarium. I was his student in 1921-23. The method is not as well known as it should be. It is a rapid and satisfactory substitute for the long and laborious classical method of preparing permanent stained sections (killing, fixing, infiltrating, embedding, sectioning, staining, and mounting) where permanent slides are not needed. Permanent slides ARE needed for detailed anatomical and cytological studies.

(1) Fresh material is sectioned dry without treatment.

(2) Material dried (from recently pressed to herbarium specimens decades old) is too brittle to section and must be softened JUST ENOUGH TO PERMIT SECTIONING, but not enough so tissues will collapse under the knife.

Selected leaves (with apparent sporulating lesions) are placed on a soft pine or redwood board well saturated with water. The spore-bearing side (if only one) should be up. The leaf is pressed lightly into contact with the wet surface, care being taken to keep the top surface dry to prevent premature exudation of spores. In from 10 to 30 minutes, the leaf should be flexible and ready to section. The time necessary depends upon the thickness and texture of the leaf.

(3) Select an area about 1/4 by 1/2 inch bearing promising lesions (from either fresh or softened leaf) and cut it out with the point of a razor blade. Place with the spore-bearing side UP on a dry piece of soft pine (a 1 x 6 inch pot label is very good) and cover all but 1/8 inch of the long dimension with a 1 x 3 microscope slide. Press down lightly with the thumb or middle finger of left hand and using a new sharp single-edge razor blade with a stiffened back (Gem type) cut sections as thin as possible using a forward sliding motion of 2 to 5 mm. The thickness of the section is regulated by the pressure of the razor blade against the thumb nail of the left hand.

PRACTICE IS NECESSARY: The first sections made will no doubt be much too thick, but the technique is easily learned and surprisingly good sections 20 to 40 microns thick can be obtained by this seemingly crude method. Sections secured will vary greatly in thickness but will improve rapidly with practice. The success of the method depends upon making a dozen or more sections. Then pick them up with the corner of a razor blade and transfer directly to one small drop of KOH on a slide. Section with a dry blade, pick up sections with only corner of blade. Mount 3 or 4 of the best (usually the thinnest) sections on slide in KOH or dilute stain and add coverslip.

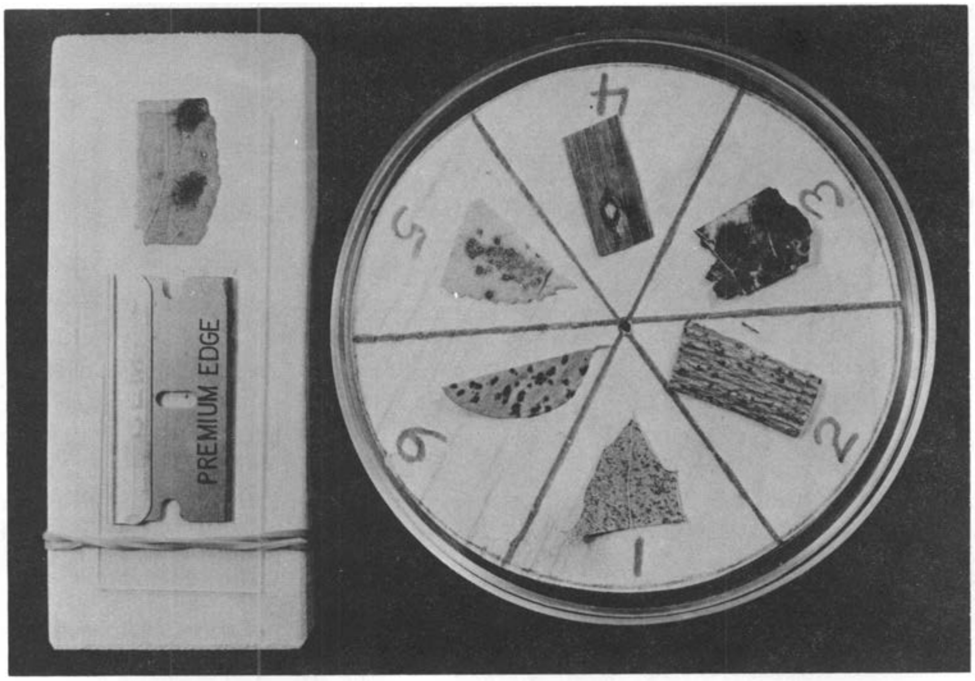


Fig. 4. Freehand sectioning. Cutting block with softened leaf section under slide ready for sectioning. Petri plate with disc of soft pine marked to identify specimens being conditioned on the moist wood. Petri dish cover prevents too rapid drying.

Fig. 5. Quick method of making sections of plant disease material for temporary mounts. All necessary material is shown.

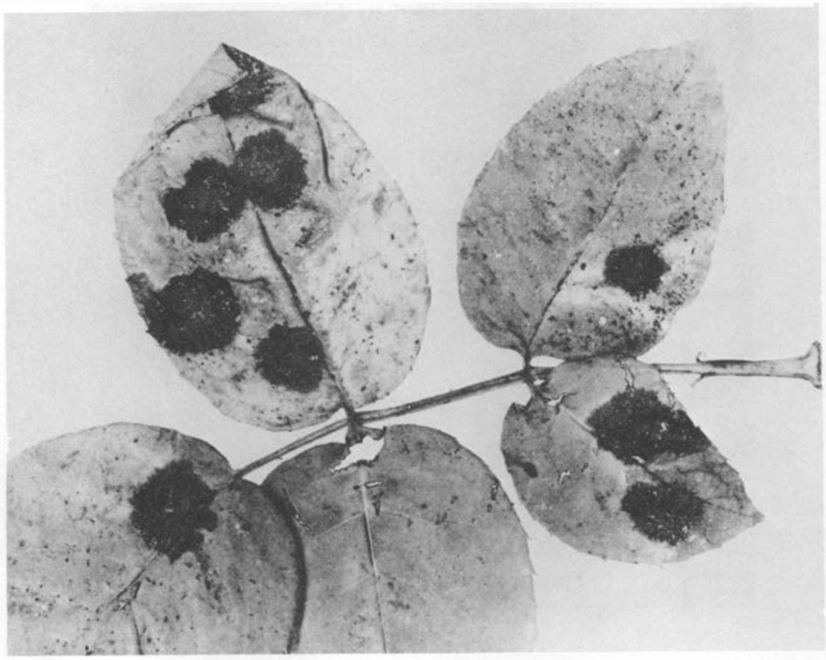


Fig. 6. Black spot of rose. Causes yellowing and shedding of leaves.

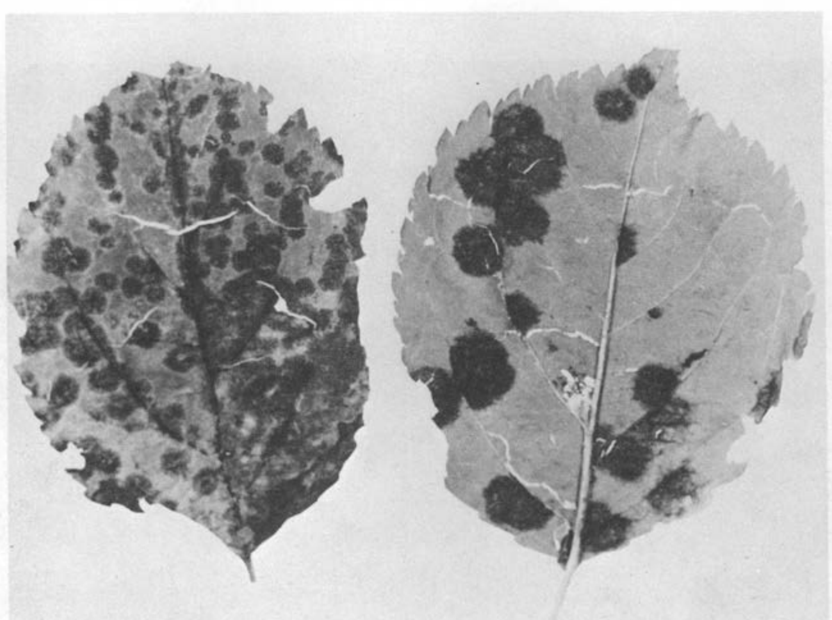


Fig. 7. Dark olive-green lesions of apple scab on leaves.

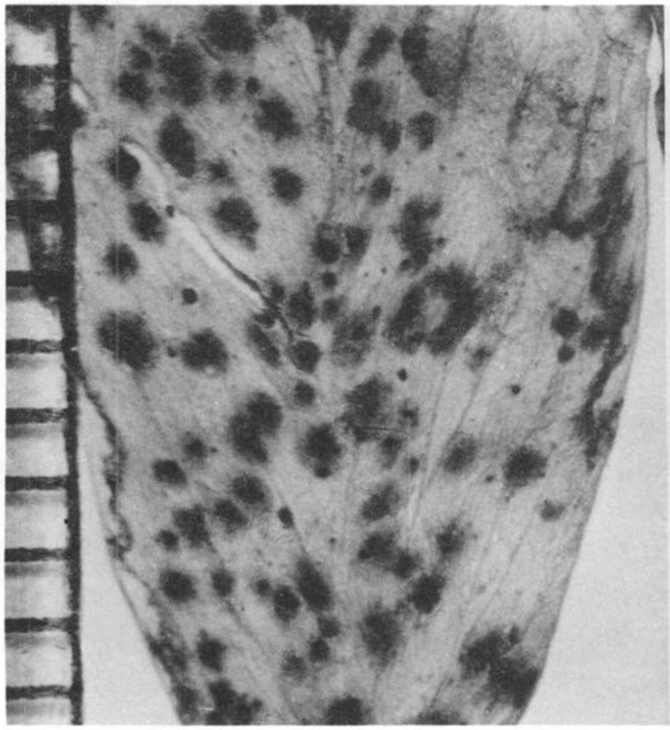


Fig. 8. Common (Pseudopeziza) leaf spot of alfalfa. X 10.

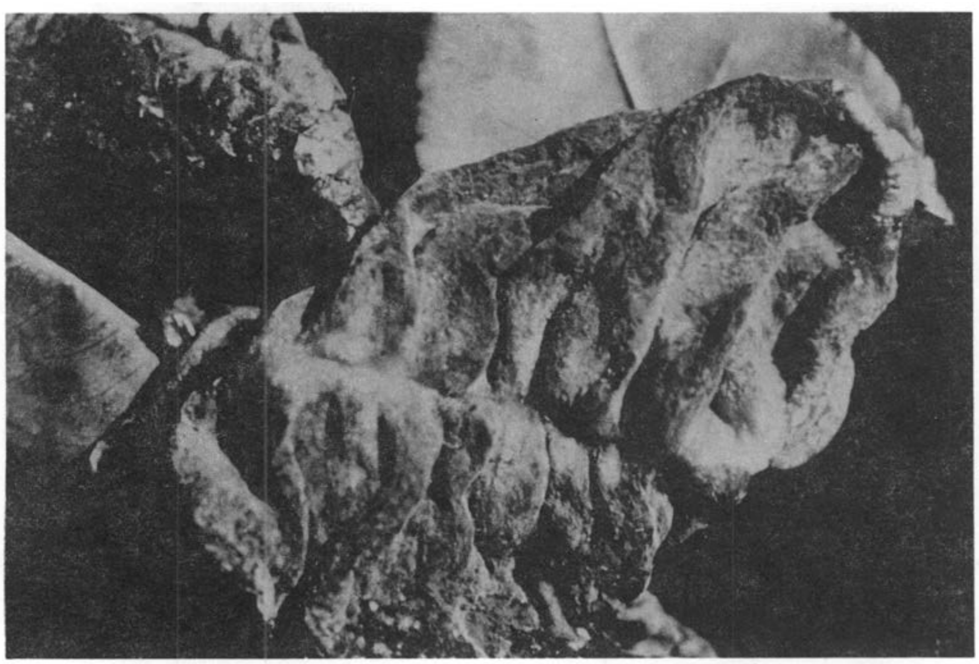


Fig. 9. Leaf curl of peach. The distorted areas bear a surface "pallisade layer" of asci. X 4.

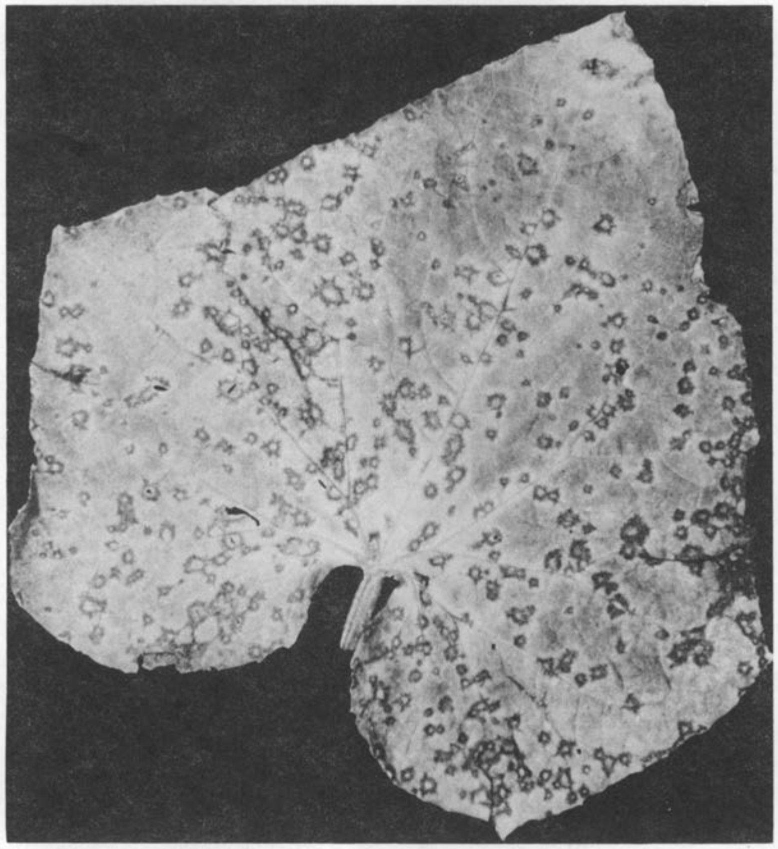


Fig. 10. Anthracnose leaf spot on cucumber. X 1.

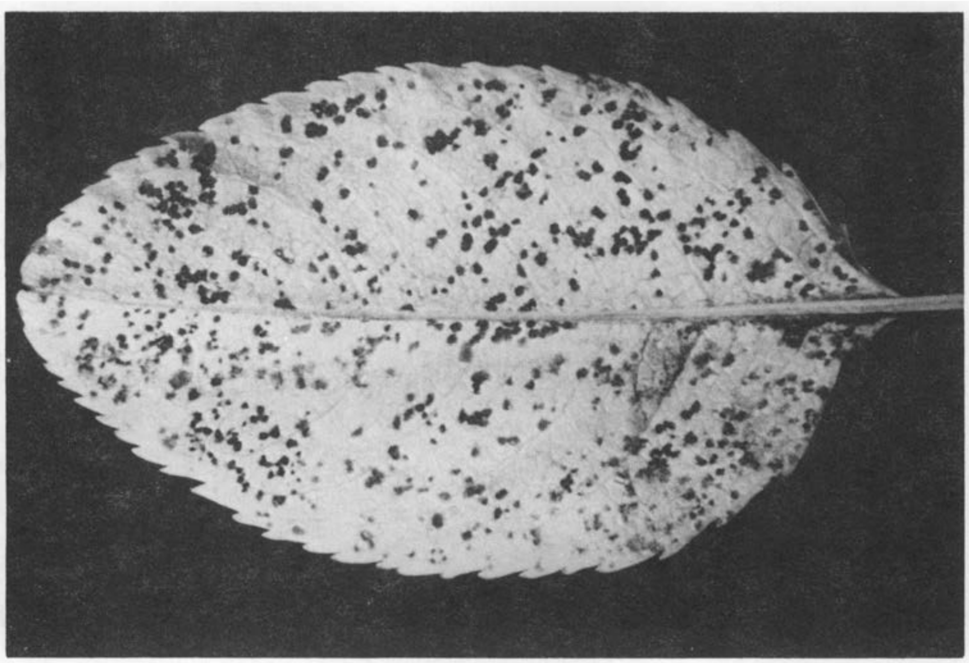


Fig. 11. Late season symptoms of stone fruit rust. Yellowed leaf contrasts with dark brown teliosori. X 2.

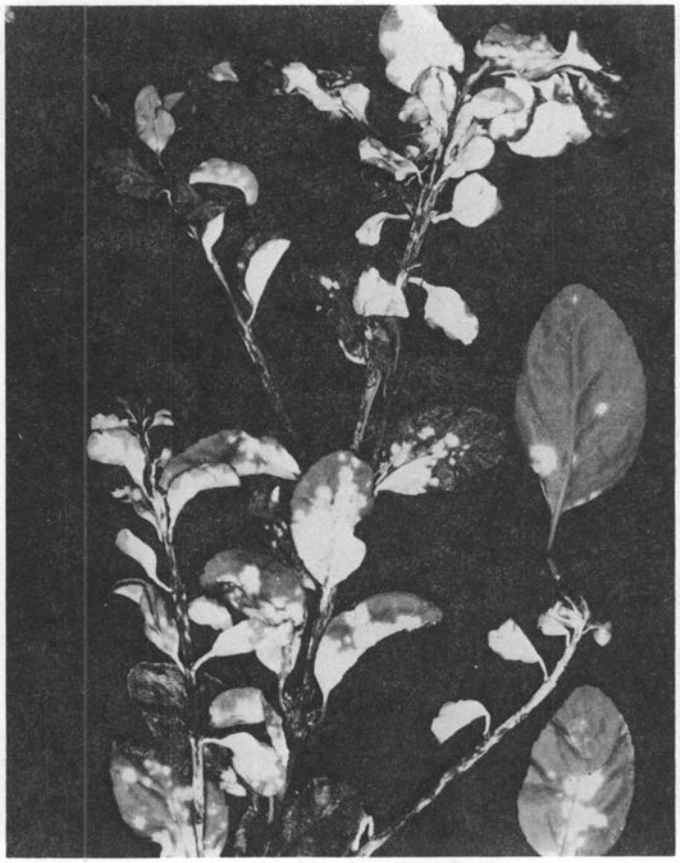


Fig. 12. Powdery mildew on Japanese euonymous. Infection is severe on plants in shade.

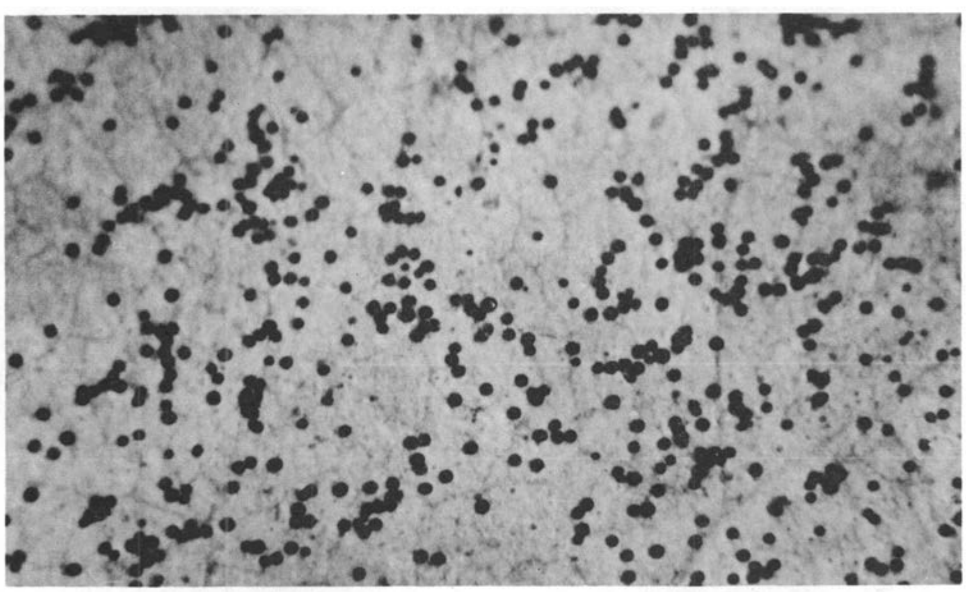


Fig. 13. Powdery mildew: Cleistothecia (dark) and white mycelium and conidia. X 10.

Fig. 14. Lesion of downy mildew of lettuce enlarged 5 times to show conidiophores and conidia.

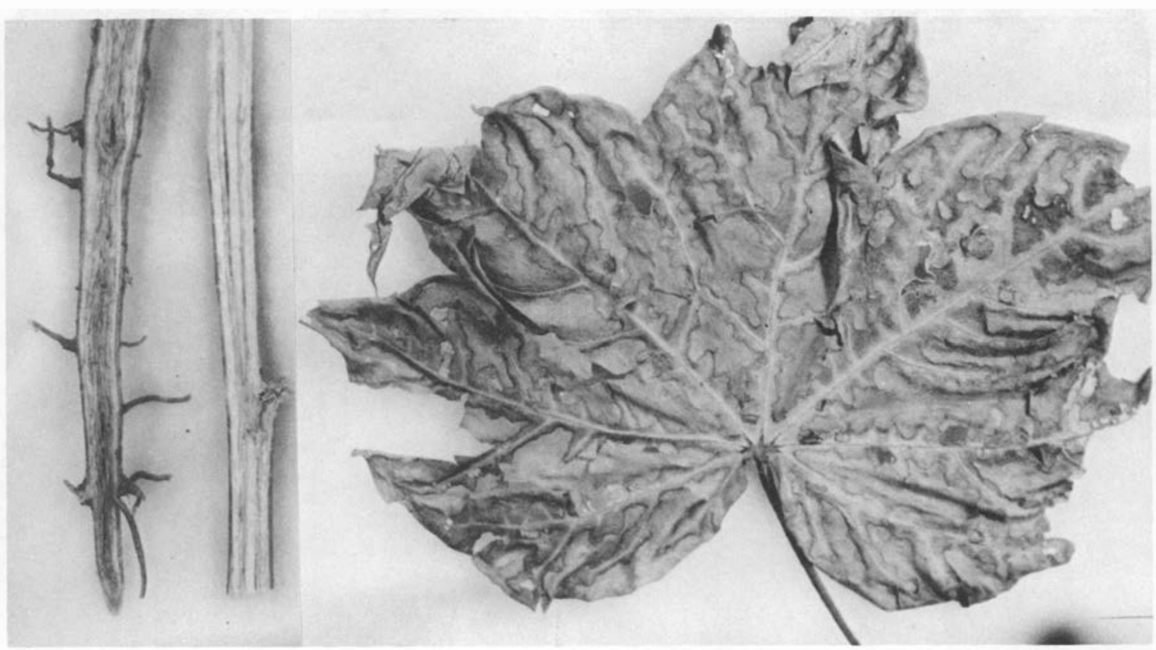


Fig. 15. Example of a nonfruiting leaf spot--Verticillium wilt of cotton. The chlorotic midseason spots become dry in late summer and the leaves are shed. The Verticillium fungus can be isolated from the brown streaks in root or preferably in the stem.

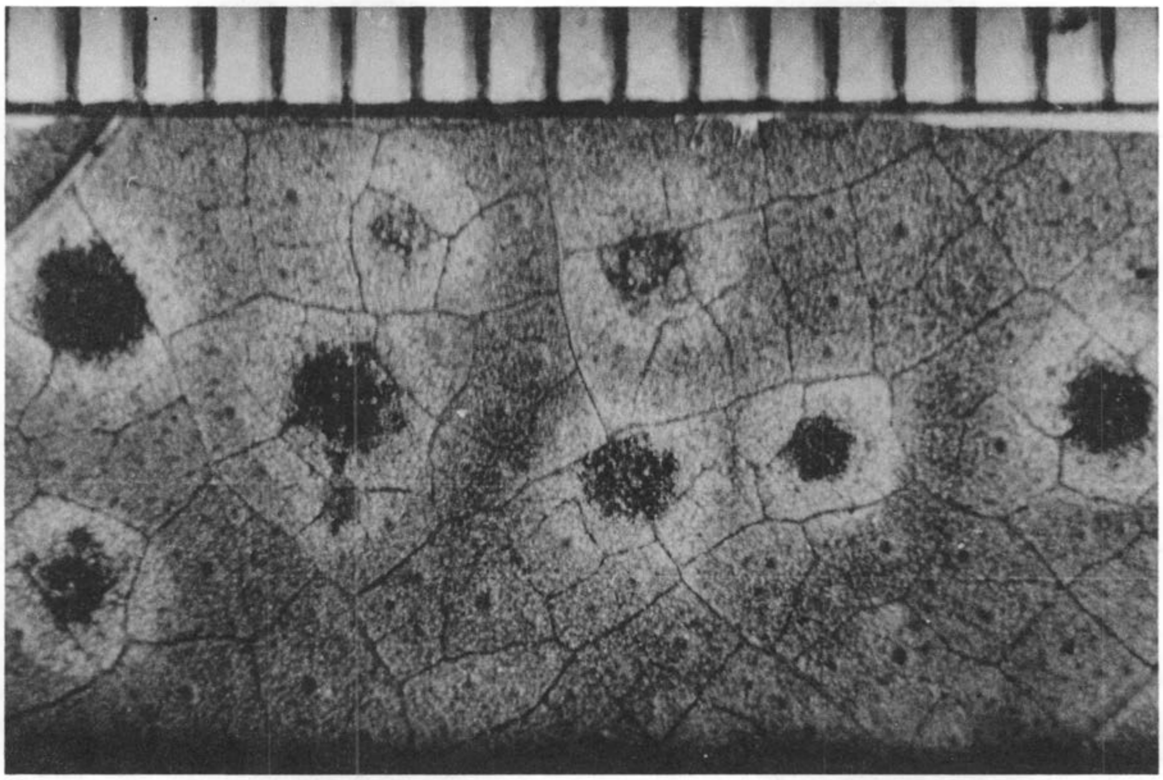


Fig. 16. Southwestern cotton rust: Orange pycnia (about 10 days from infection) with yellow halo. X 10.

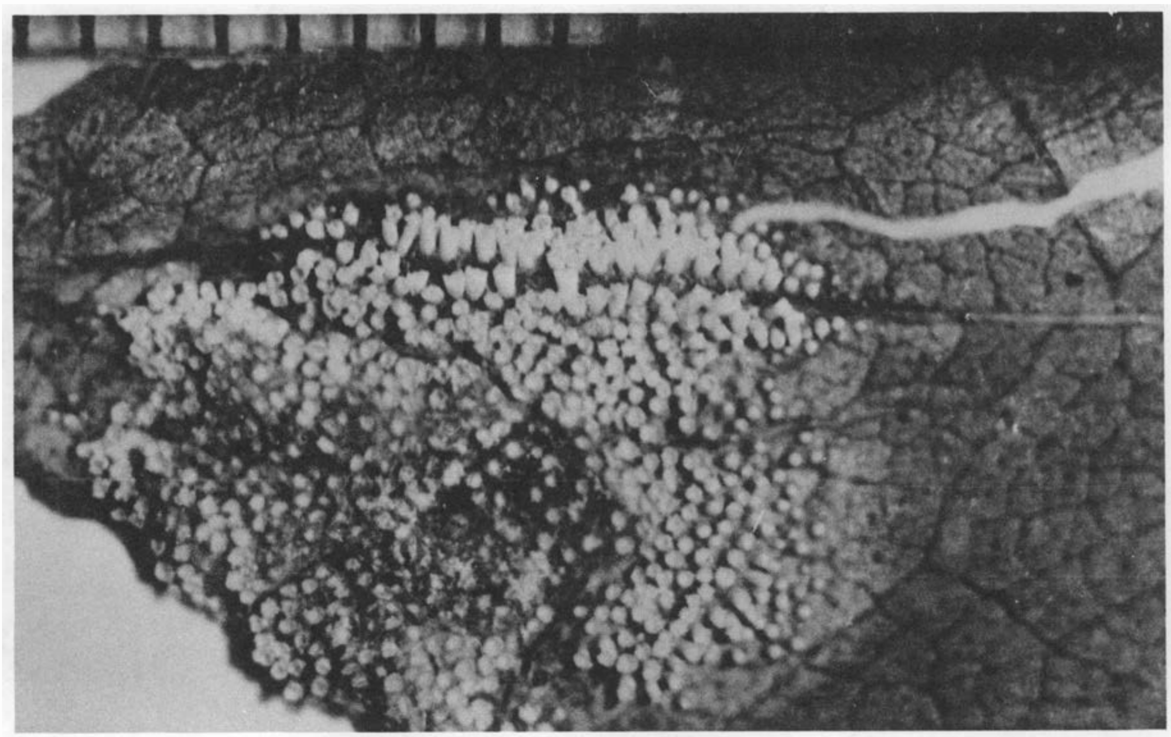


Fig. 17. Southwestern cotton rust: Old aecium on cotton leaf with band of new aecial cups on margin. X 10.

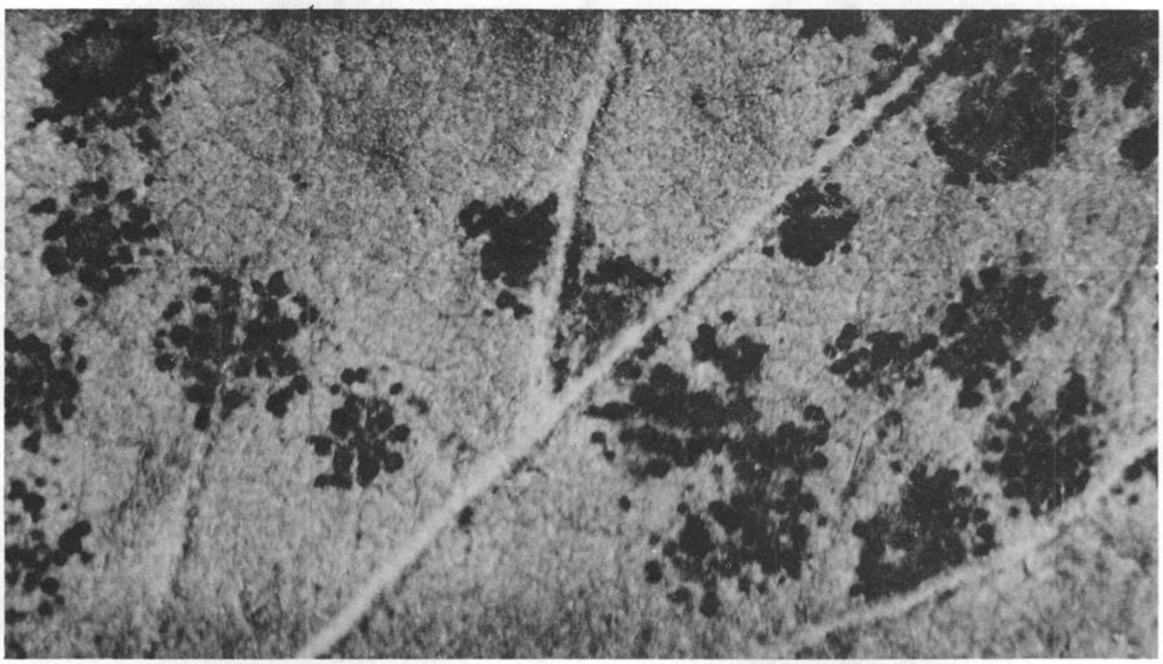


Fig. 18. Sphaeralcea rust: Telial sori in clusters on leaf. X 10.

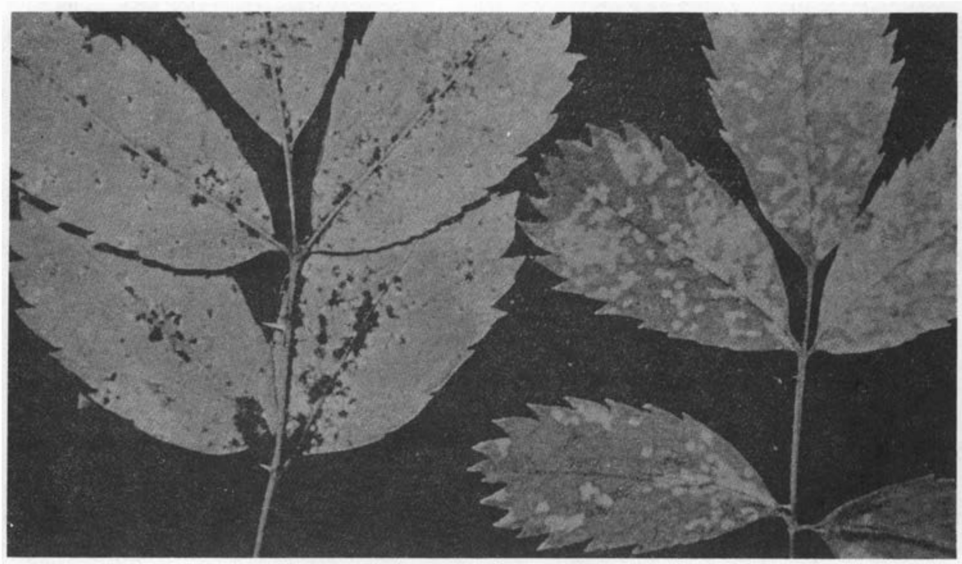


Fig. 19. Rust on wild rose: Yellow uredo sori and black teliospores (left) and yellow uredo sori (right). X 2.

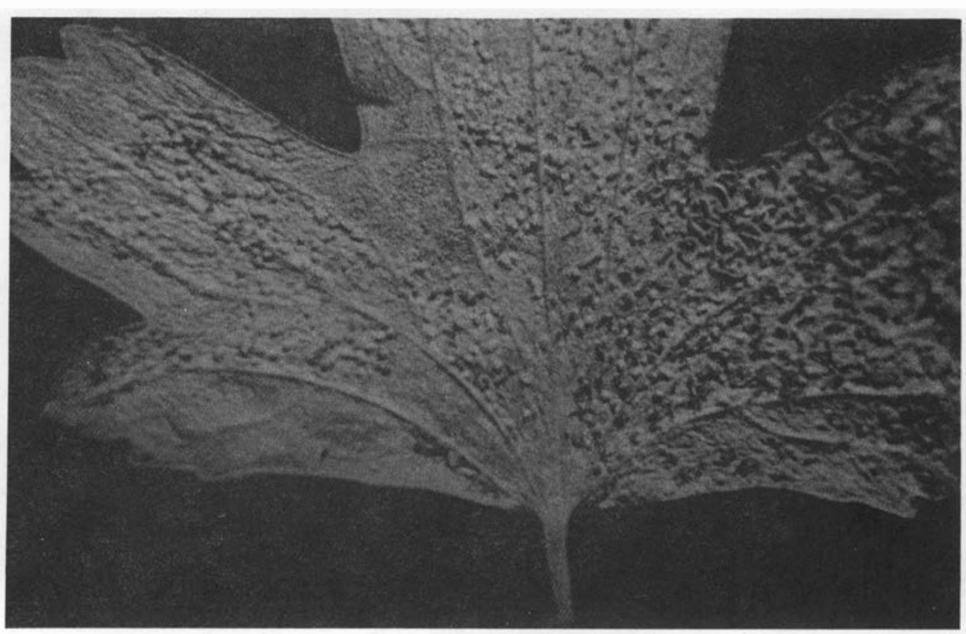


Fig. 20. White pine blister rust on under surface of currant leaf.

To be usable, the sections must be thinner than the leaf so it will come to rest exposing the cross sections of the leaf. The best thickness depends upon the material to be shown. Wedge-shaped sections, which are very common, will often show details at the thin end that are not visible in thicker sections. A drop of dilute stain (Orseillin BB, or Phloxine B) often will clarify structural details of host or parasite

No spore-bearing sections will usually be found until sections are well inside the margin of the lesions. Cut off 1 mm. of margin and start sectioning.

A Dry Climate Modification: Softened specimens dried too fast in the warm, dry air of the Southwest, so I devised a method of controlling this drying. Discs of soft pine, 1/4 inch thick and 3 1/4 inches in diameter were divided by ruling lines with waterproof ink into 6 equal pie-shaped sectors. The sectors were numbered 1 to 6; 7 to 12; 13 to 18; etc., so that each specimen could be identified by number, which corresponded to a number on the original specimen or collection. The dry discs were placed in the bottom of glass or plastic petri plates, flooded with water for five minutes, then drained. The small amount of water in the bottom of the dish kept the discs from drying. When the specimens were in place, covers were put on.

If desired to keep specimens for further examination, remove covers and let specimens dry. If kept moist they will deteriorate. Replace covers when disc is well dried out and store in refrigerator.

THE $64 QUESTION - - WHAT IS IT?

The classification of fungi is based on the characters of the asexual and sexual spore bearing bodies. Now that you have on the slide the spores and evidence of where they were borne, identification becomes a problem of elementary mycology.

WHY STOP AT THE GENUS IN DIAGNOSIS?

Having determined the genus from spore characters and the structures on which the spores are borne, why not continue and determine the species as well?

Species determination from strictly mycological characters is a time-consuming and difficult task in most genera, and requires much more training and experience than possessed by the average reader of this manual. If you are capable of determining species of fungi--you don't need this book!

Species usually are named and described by the person first discovering or first making a study of them. Later some specialists on the group, after a long and careful study of all available specimens, publish a monograph in which species will be accepted, combined with others, or rejected. The monograph, if well done, is accepted as the authority for the group. Frequently specimens are sent to a specialist for identification or verification.

For our purposes in diagnosis, we can take the genus name (*Phoma*, *Alternaria*, *Sclerotinia*, or *Puccinia*) and by referring to text and reference books (11, et al.) find what species have been recorded and described on the host plant in question. A species name should not be accepted, even tentatively, without carefully comparing symptoms, spore, and fruiting-body characters as given. If several species have been described on your host plant, even more care is necessary to distinguish between them. However, if they all cause similar leaf spots, controlled by similar spray schedules, it is not essential that an exact identification be made at the time. For permanent records, however, exact identification should be made later.

EXAMINING TWIGS, SMALL AND MEDIUM SIZED (TO 3 INCH) BRANCHES:

Such tissues are subject to:

- Bacterial cankers, with or without exudation.
- Fungus cankers, with variable development of spore bodies.
- Non-parasitic gummosis.
- Low-temperature damage.
- Slime fluxes.
- Heart rots.

INDUCING SPORULATION BY MOST FAVORABLE MOISTURE LEVEL

If examination of cortical surfaces shows no evidence of spore bodies, exposure to conditions favorable to spore development often produces them. A whole series of moisture conditions, from saturation to dryness, can be induced in the tissues by placing the branch or twigs to be tested in a tall glass cylinder with 1 or 2 inches of water in the bottom, and sealing the top with foil. It is generally best to dip the entire specimen in water briefly at the start. Specimens should be at least 10 inches long and the cylinders 12 inches deep.

Observe the specimens daily: Cytospora cankers will produce a band of extruding spore tendrils at the most favorable moisture level. Other canker-forming fungi (Endothia spp., Nectria spp.) usually will do likewise. Bacterial cankers often will produce slender tendrils or drops of exudate on the infected areas.

Observe cross sections carefully to see whether the parasite initially destroys the bark (cortex), sapwood, or heartwood, as this aids in determining the parasite.

Non-parasitic or physiological gummosis is common in citrus fruits and stone fruits, arising (usually) from small gum pockets in the cambium region. If a year or more old, there may be one or two annual rings of wood over the pockets.

For two simple, rapid methods of producing an abundance of sporangia in cultures of Phytophthora citrophthora see Phytopath. 58: 550, 1968.

EXAMINING MAIN BRANCHES OR TREE TRUNKS

These parts of the tree are subject to the same types of diseases as the smaller branches, but you usually find:

More sunburn and bark cankers due to bacteria and fungi.
More cortical rots and rots of sapwood (living outer layer).
More heart rots of trunks and large branches.
A girdle of dead bark just above or just below the soil line.
Rots extending into root system or arising in root system--BUTT ROTS.
Copious masses of clear gum on trunk of stone fruits. (Check root system for crown gall.)

The method of placing the base of branches in water to stimulate production of spores or exudate can be used on young trees with smooth bark. It sometimes works with the thicker bark of older trees.

There are two small portable saws that are very efficient in both collecting and dissecting specimens of branches and trunks. The first is a thin-bladed bow-saw with a triangular frame and the second is a folding crescent-shaped pruning saw. Both cut rapidly if kept sharp.

EXAMINING ROOTS OF WOODY PLANTS

Roots are subject to many important diseases. Among them:

Cotton or Texas root rot, which is so prevalent and important in the Semiarid Southwest that it is treated in a special section following.

Fig. 21. Peach limb showing a profusion of gum extruded from the bark. Youngest drops of gum are colorless. Drops enlarge and darken to a dark translucent amber. Cord at upper left embedded one-quarter inch deep girdling limb, but not related to gum flow. Gummosis may be due to parasitic or nonparasitic causes.

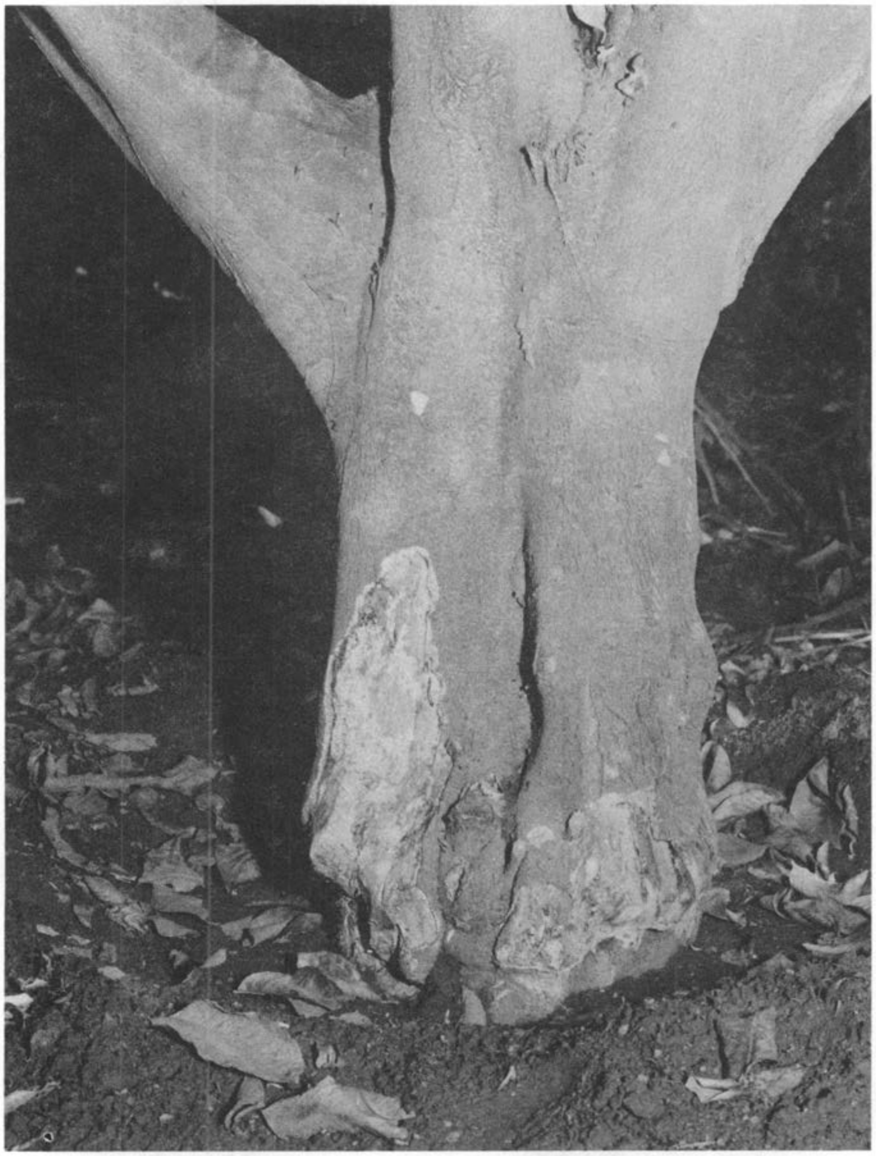


Fig. 22. Phytophthora foot rot on trunk of grapefruit on sour orange root. Diseased bark removed. Photo by Ivan Shields.

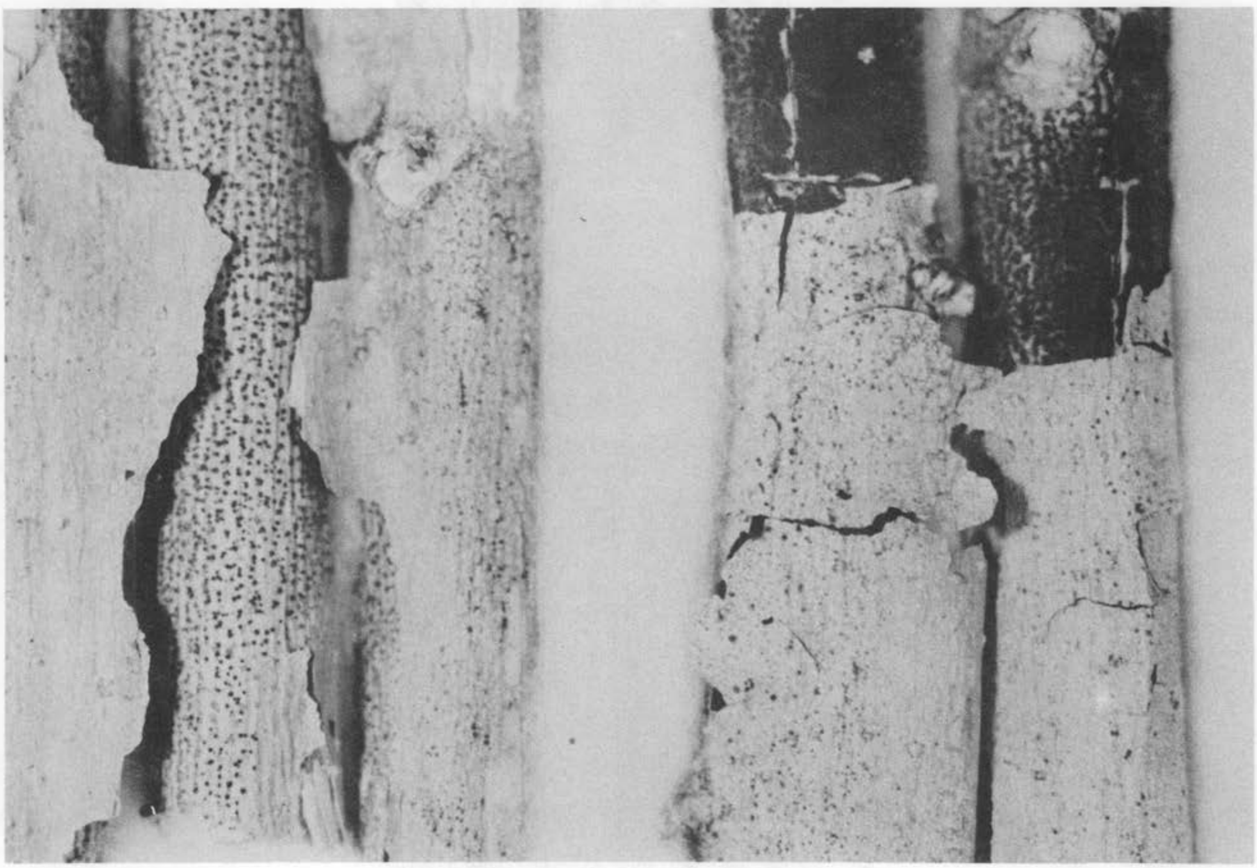


Fig. 23. Sooty Canker on one-inch branches of Mulberry. The smooth outer bark peels revealing black fungus growth (left) which later becomes a sooty layer (right).

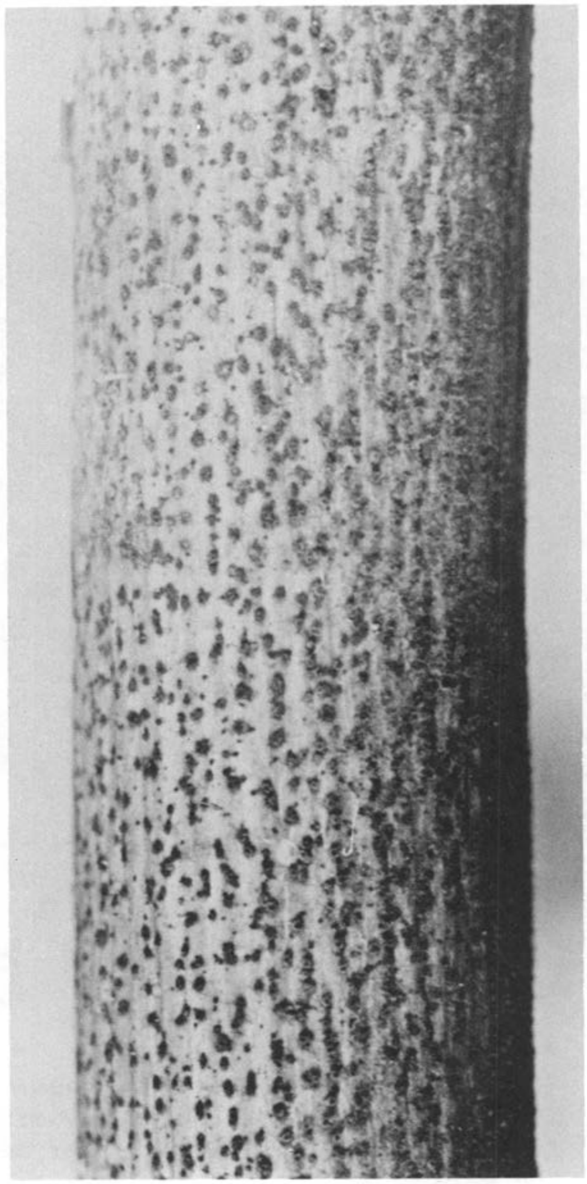


Fig. 24. Trunk of young Cottonwood killed by Cytospora canker. Dark bodies are orange-red dried masses of spores extruded from pycnidia in the bark. X 1/2.

Fig. 25. Verticillium wilt in cotton. Cotton stems split to show discontinuous brown steaks in wood. Healthy stem at right. X 2.

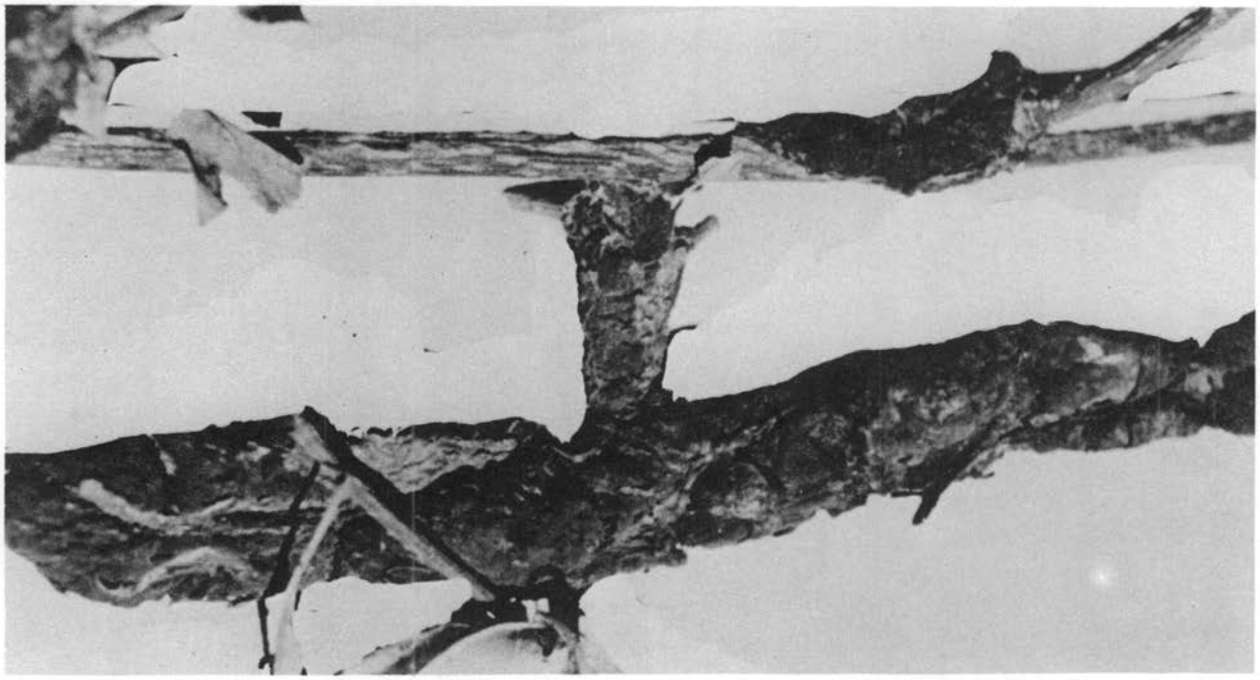


Fig. 26. Black knot of plum, uncommon but damaging when it occurs. X 1/2.

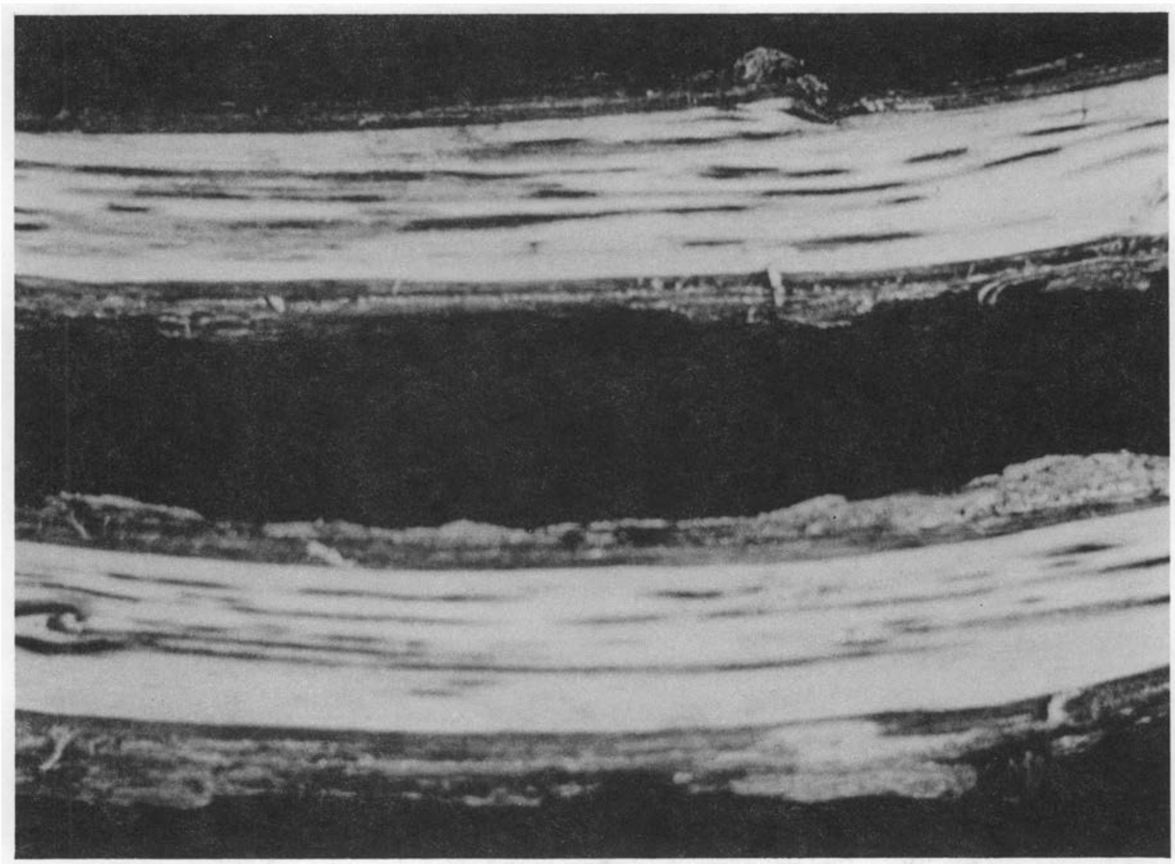


Fig. 27. Dark streaks in wood of oak-infected with oak-wilt fungus. X 2.

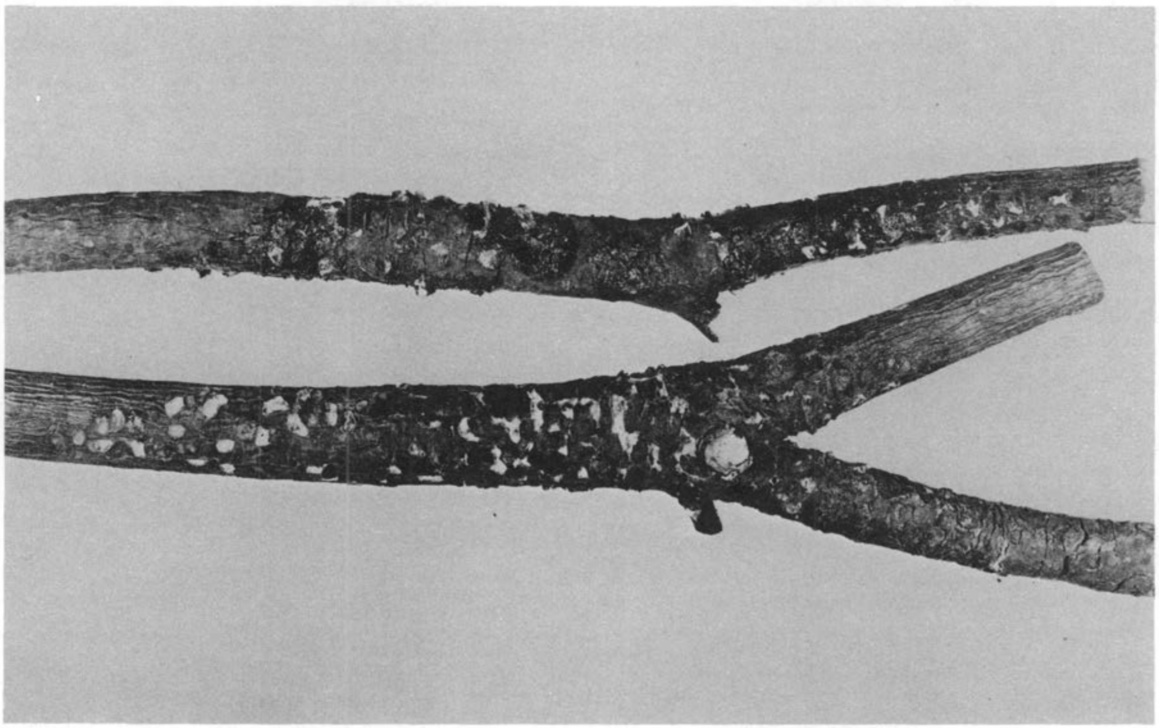


Fig. 28. White pine blister-rust fungus sporulating on trunks of small white pines. X 1/2.

Fig. 29. Oak-root fungus (Armillaria mellea) on Citrus. A. Healthy root. B. Sclerotial growth (black when wet) in cracks in bark of infected root. C. White mycelial fans on wood and bark in cambial region of infected root. X 1. (White not a problem at present, this major root rot may occur in the future.)

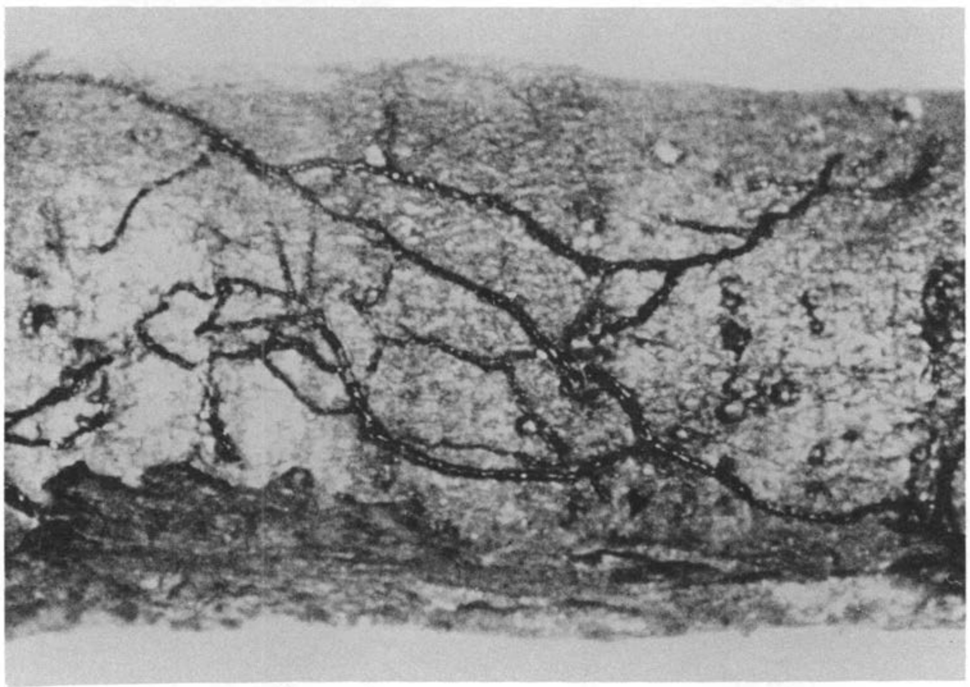


Fig. 30. Rhizomorphs of Armillaria mellea on surface of root. X 2.

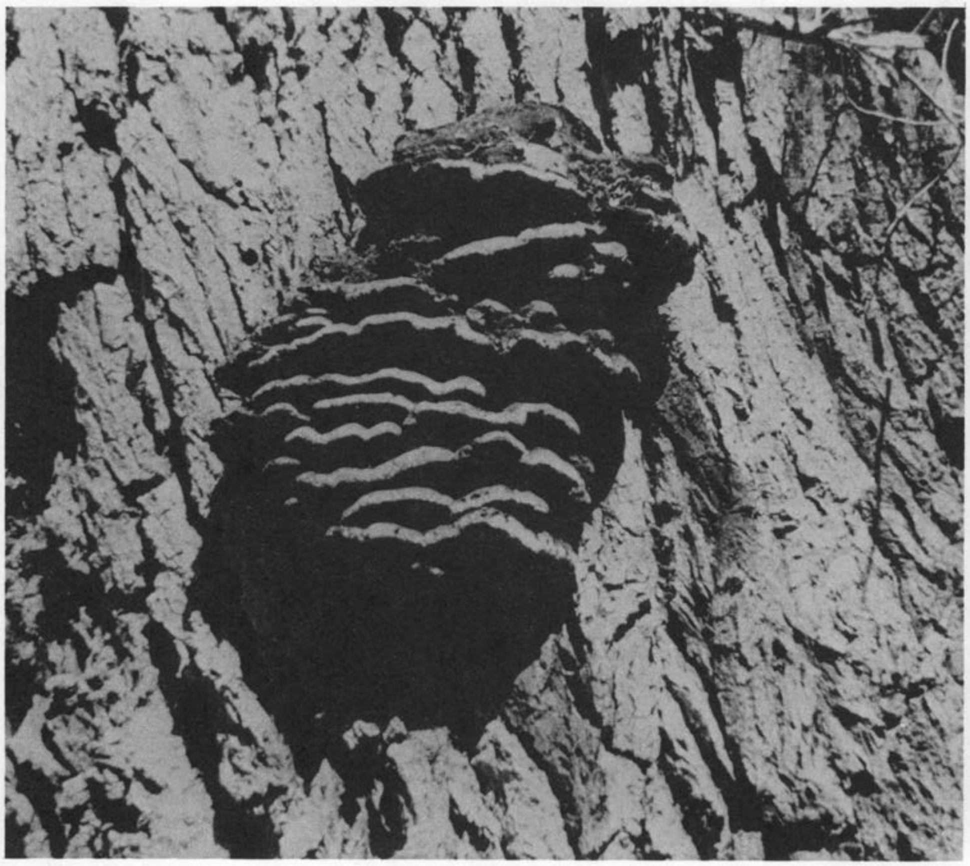


Fig. 31. Chocolate brown fruiting bodies of Polyporus farlowii, the fungus causing heart rot of the Pepper Tree.

Fig. 32. Spore mats of root rot fungus in alfalfa field. The outer younger zone is pure white and cottony, while the inner zone, a few days older, has become a powdery mass of buff spores. X 1/3.

Mushroom root rots, caused by Armillaria, Clitocybe, etc.
Phytophthora root rots on citrus, avocado, etc.
Crown gall.
Root-knots and lesions caused by nematodes.
Root rot caused by excess water.
Root rot caused by chemicals, fertilizers, weed-killers, gas, etc.

Roots usually die from the tips back. An experienced pathologist realizes that root samples are often inadequate, not representative, and misleading. He often wishes he could see the WHOLE root system, as crown galls below the surface may escape detection, or only the deeper roots may be diseased.

ARE THE ROOTS HEALTHY OR DISEASED?

There is a rapid and simple test to determine if medium to very small roots are healthy or diseased. If there is soil or mud adhering to the roots, immerse them in water until the soil "melts" away. Then scratch the surface of the bark with your fingernail to remove the thin brown surface layer. In healthy roots the inner bark is light colored; if diseased the inner bark is darkened. This works with roots as small as 1 mm in diameter.

COTTON (OR TEXAS) ROOT ROT -- A SPECIAL CASE

If trees, shrubs, vines, fruit trees, vegetables, crop plants, or ornamentals in the semi-arid Southwest die suddenly during the hot summer months, suspect the fungus, _Phymatotrichum_ _omnivorum_. This fungus attacks practically all tap-rooted plants but not monocots, and has by far the largest known host list of any plant parasite--over 2,000 species.

In spite of having no functional spores, the fungus has truly unique vegetative characters by which it can be positively identified--the acicular hyphae on the fungous strands and the so-called "spore mats."

COLLECTING SAMPLES: Select pieces of recently killed roots with the cortex intact. Preferably the soil should not be too wet as soil will cling to the roots. Choose 3 to 6 pieces of root the length of a pencil and protect from drying with a polyethylene bag.

EXAMINATION: Do not attempt to remove dirt from the roots. Even the softest brush will remove most of the delicate fungus strands. If soil particles obscure the cortex, immerse roots in a dish of water and let stand for several hours. Even the heaviest clay will melt away and sink to the bottom.

The distinctive strands are exactly the color of most roots and slender enough to be hard to detect. They look like very thin fuzzy threads. They are plainly visible to the experienced eye under a 10X hand lens. They are abundant for several weeks about the time the roots are killed, but often disappear later--probably parasitized by other soil organisms. However, the practiced eye can usually find small fragments of strands in crevices in the bark. A very favorable location to find strands is in the crotch of roots where they escape abrasion when roots are removed from the soil.

The acicular hyphae are unique in the true sense of the word. A single "cross" under the high power (400X) is a certain verification of the presence of the root-rot fungus. Multiple infections such as Verticillium wilt and Texas root rot on the same cotton plant are not uncommon in Arizona. Brown streaking of the woody cylinder extending high on the stems is almost certain to indicate Verticillium wilt -- but Fusarium wilt causes very similar symptoms. So it does not pay to make snap judgments.

EXAMINING ROOTS OF HERBACEOUS PLANTS

Most of our cultivated crops and ornamental plants suffer in varying degrees from cortical root rots -- most often due to species of Fusarium, Phytophthora, or Rhizoctonia, although many other fungi cause important root rots. The general symptom of these root rots is a watersoaked condition of the tap root and smaller roots, but this gives little clue of the causal organism.

Our soils are full of spores of saprophytic Fusaria and teem with other saprophytic fungi so isolation of parasitic fungi in culture poses problems.

LONG WASHING: Roots especially are always contaminated with a large variety of soil-dwelling organisms, many of which grow readily on culture media. Washing selected pieces of root in running water for several hours often greatly reduces the population of contaminants so that the primary parasite can be isolated by petri plate cultures.

Fusarium species come up fast in the cultures, but some slow-growing fungi like Verticillium are often masked by rapidly-growing parasites or saprophytes. This is ONE case in which inoculation of healthy host plants is necessary to verify diagnosis.

Phytophthora root rots also are prevalent, especially in warm climates. Coarse mycelium lacking cross-walls is characteristic of this group of fungi. They develop rapidly at warm temperatures (70 to 90 degrees F.). In moist situations, a filmy white mycelium develops, but production of sporangia is sometimes scant. Isolation of the causal organism as outlined above is indicated. Apple fruit may be used as a "test plant." Surface sterilize the fruit with Rada's Solution, inoculate small cuts with mycelium from cultures, or use chips of infected tissues. Phytophthora cactorum will invade healthy apple tissues; most saprophytes will not.

I S O L A T I O N O F P A T H O G E N S

It is assumed that research workers have access to all equipment (sterilizers, binoculars, microscopes, etc.), chemicals and supplies used in making isolations and cultures of microorganisms. Lists of equipment, chemicals including media, stains, formulas, etc., found most useful are given in the Diagnosis Manual.

It is assumed also that you are familiar with the methods of isolating pathogens from plant tissues by removing aseptically small bits of the advancing margin of the infection and placing them on agar plates, using flamed scalpels, forceps, or needles to prevent contamination.

If separate culture rooms are not available, any reasonably clean room free from drafts and dust can be used. Wet mop the floor to minimize dust particles. Also wet your arms. A towel or cloth, wet with water or preferably a 1% chlorine bleach solution, spread on the work table will greatly reduce contamination from organisms on dust particles. Evaporative coolers or air-conditioners should be turned off to minimize air movement.

MAKING ISOLATIONS FROM FLESHY ROOTS, TUBERS, FRUITS, OR VEGETABLES

Surface lesions where penetration is slight should be washed free from adhering soil; surface sterilized with Rada's solution as described in next paragraph and small pieces placed on agar in petri plates.

Fig. 33. Taproots of two-year old alfalfa plants with numerous deep pits in cortex caused by Rhizoctonia solani.

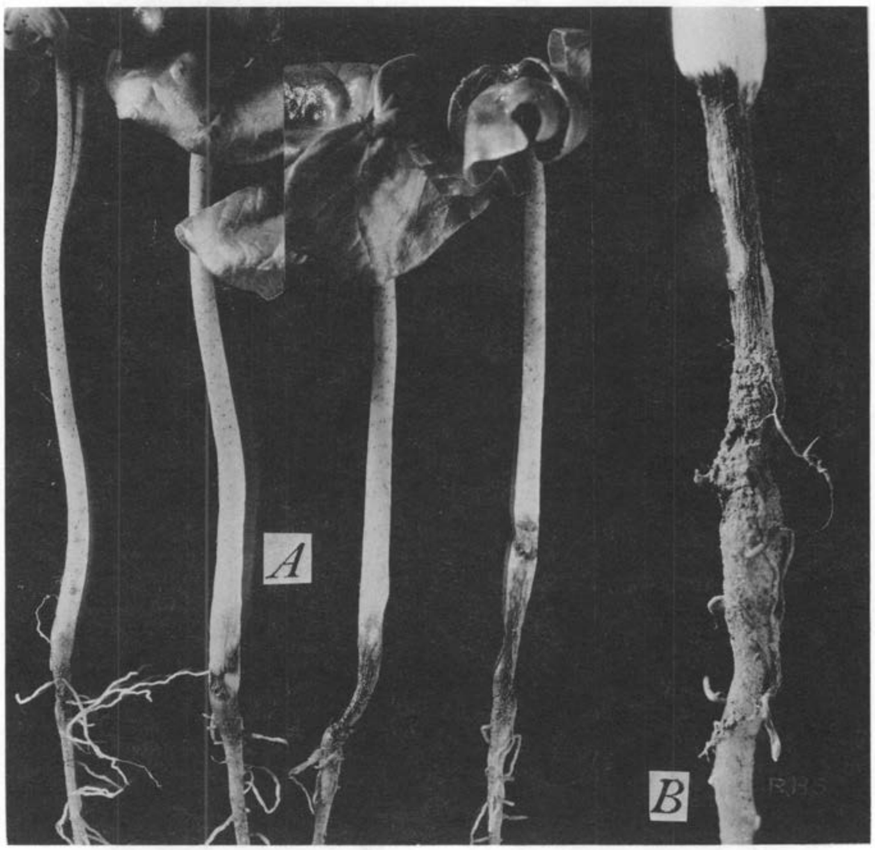


Fig. 34. Sore-shin of cotton (damping-off): A. Seedlings showing 4 stages of severity of lesions at or below soil line. B. Infected area. X 3.0.

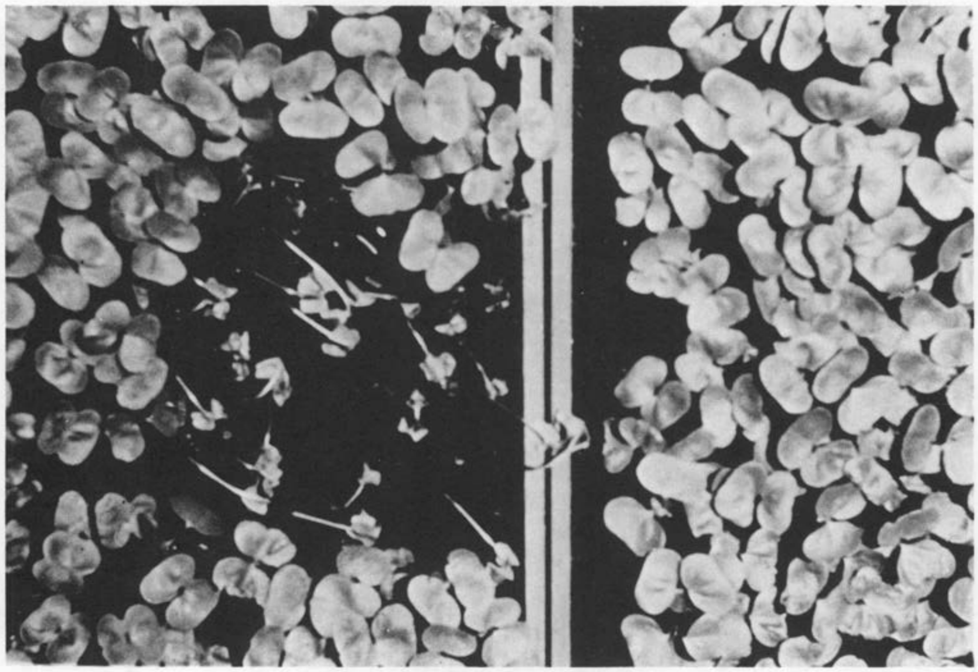


Fig. 35. Damping-off killing cotton seedlings in flat of untreated soil. No disease in same soil which has been sterilized. Rhizoctonia is major cause of damping-off in the West; Phythium in the East.

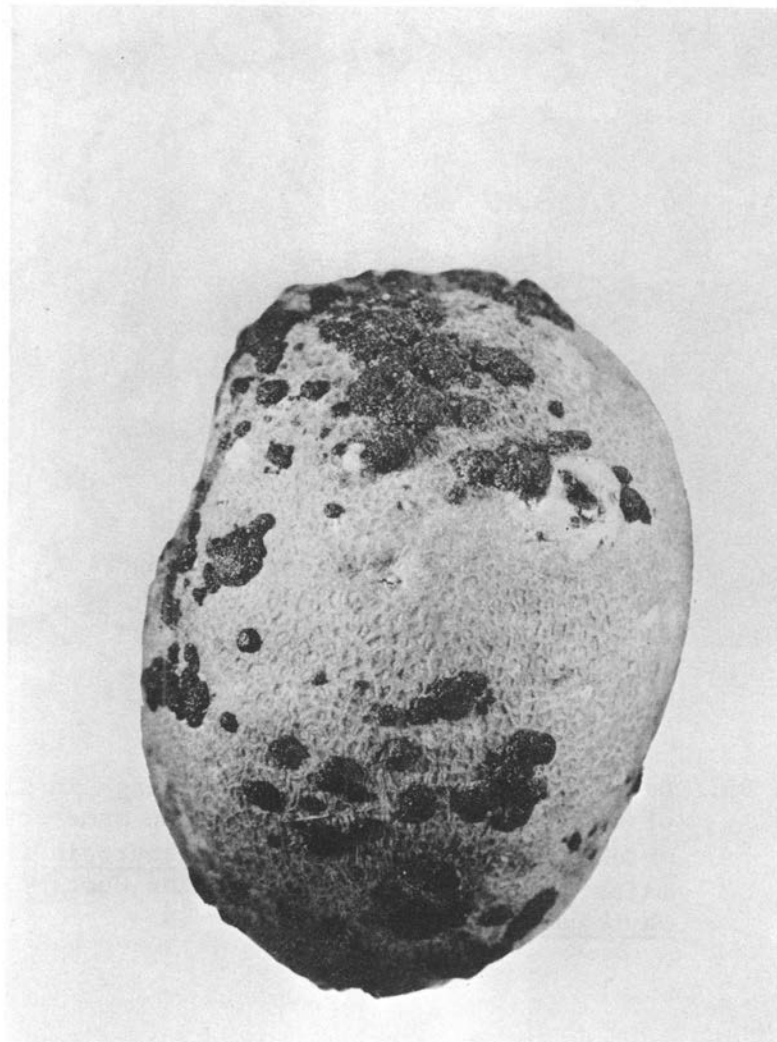


Fig. 36. Sclerotia of Rhizoctonia on potato tuber.

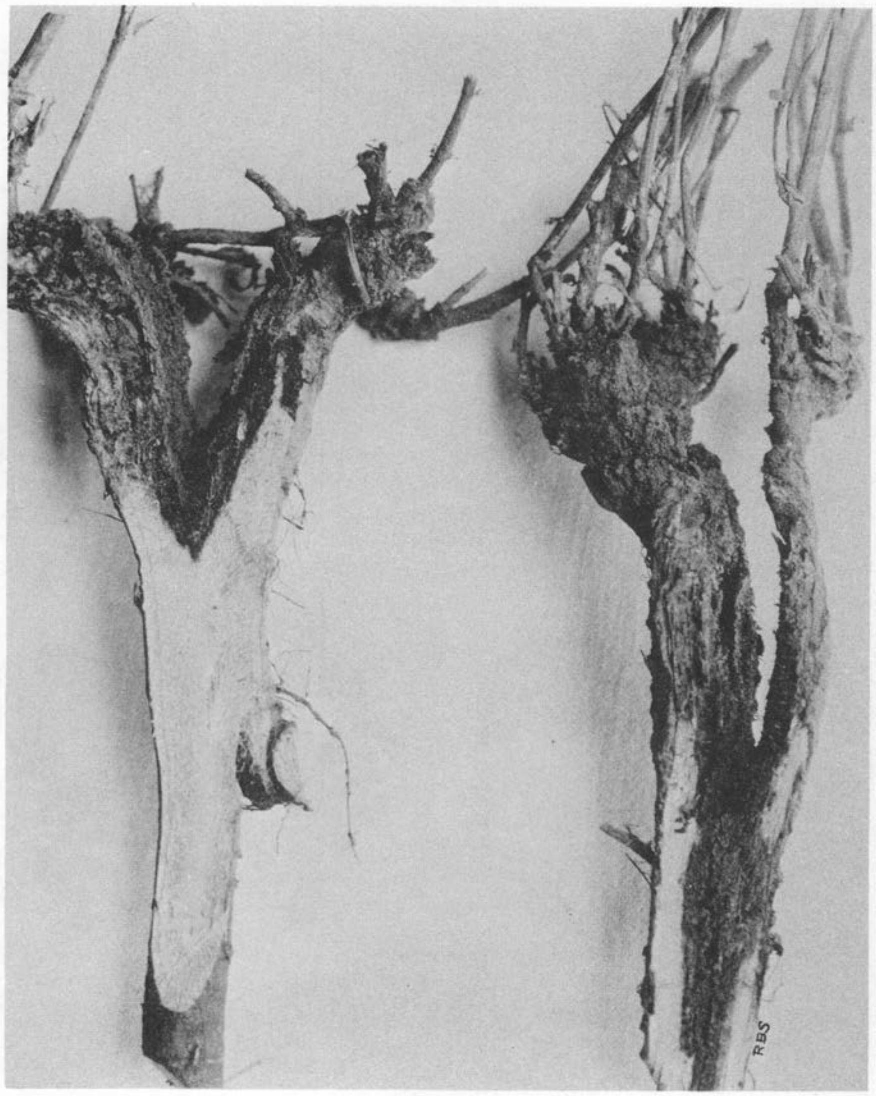


Fig. 37. Alfalfa plants almost dead from crown rot complex. Often follows splitting of crown from various causes.

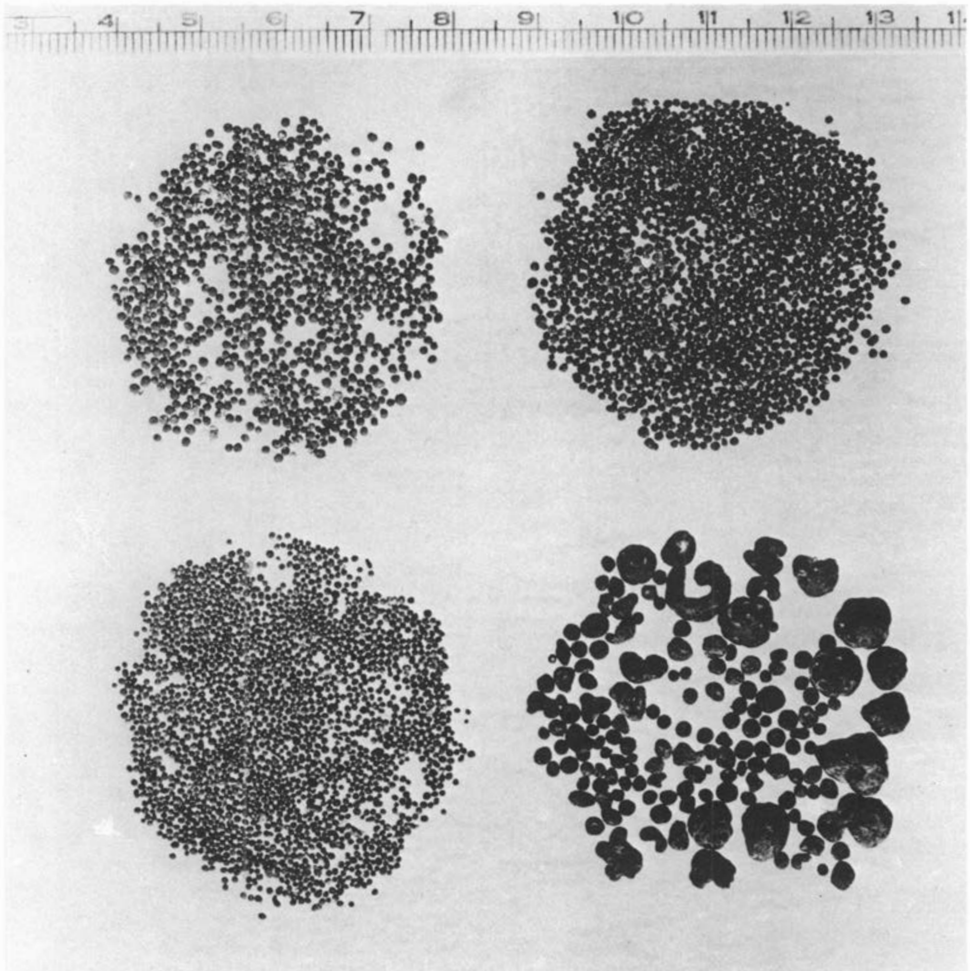


Fig. 38. Sclerotia from three strains of <u>Sclerotium rolfsii</u> and larger sclerotia of S. delphinii. X 1.

Organisms penetrating deeper are best isolated by taking bits of tissue from the advancing margin of the affected area. Breaking the specimens (potato tubers; beet, carrot, sweet potato, or other fleshy roots; fruits or vegetables) by scoring the opposite side with a flamed knife and breaking by hand exposes tissue not touched by hand or knife, so not contaminated. Bits of tissue can be cut from the advancing margin of the rot by a flamed scalpel. These pieces can be plated on agar or inoculated directly into susceptible host tissue by placing them in cuts in surface-sterilized tissue.

SPECIAL METHOD FOR ISOLATION OF SLOW-GROWING PARASITES

In attempting to isolate Verticillium albo-atrum, other vascular parasites and slow-growing pathogens, cultures are usually overrun by fast-growing saprophytes. Dr. Alice Boyle in our laboratory found that by using a more active surface sterilant for five to six different periods, pure cultures of Verticillium, etc., could be obtained.

Host material without visible contamination was selected and surface sterilized and cut into 25 to 30 pieces not over 5 mm. long and immersed in Rada's Solution (1:1000 mercuric chloride in 50% alcohol) for one minute. Then pieces were picked from the solution with sterile forceps one by one, after a rinse in sterile distilled water, on agar medium (five per petri plate) until all had been removed from the Rada's Solution. This gave a long series of sterilizing times and somewhere in the series between insufficient and over-sterilization the parasite would grow from the tissues in pure culture.

EXAMINING VEGETABLES WITH FRUIT ROTS -- (SOFT ROTS)

WATERMELON: Phytophthora cactorum causes an important fruit rot of watermelons in the field. The rot is light tan in color, usually starting on the lower surface of the melon in contact with moist soil and quickly rotting entire large melons. Scant to moderate mycelial growth occurs on surfaces in contact with moist soils in the field. A more dense growth can be induced in a moist chamber and is quicker than making isolation cultures. The advancing margin of the rot on the top of the melon probably will be free from secondary invaders.

CANTALOUPS AND OTHER MELONS AND SQUASHES: These also have similar rots and the same Phytophthora cactorum is believed to be the most common parasite. Melons subject to summer rains during their ripening period (or in contact with moist soil under irrigation) often develop a soft rot with a white mycelial growth and salmon-pink spores (often Fusarium). Melons are predisposed to infection by injury or cracking of the rind in contact with moist soil. Anthracnose caused by Colletotrichum lagenarium appears as sunken lesions mostly on lower surface of all common types of melons and watermelons. The tiny cushions of spores are salmon pink. The vines often are defoliated by leaf and stem lesions. A number of other fungi cause infection under similar conditions, so care is necessary in making diagnosis.

TOMATO: A tan rot, usually with darker zone-lines, is called "Buckeye Rot." It is attributed to Phytophthora parasitica, but is also due to P. cactorum in part. Use a moist chamber to induce mycelial growth and sporulation. A darker, firmer rot is induced by Rhizoctonia. In case the tissues of the fruit become liquid and the fruit becomes a tear-drop shaped bag of watery fluid, the cause usually is the vegetable soft-rot bacterium *Erwinia carotovora*. Infection in most cases is from contact of the fruit with moist soil or through wounds. A rapid spreading soft rot of green and ripening tomatoes is caused by the fungus, *Geotrichum candidum*, which produces a wet pasty film of white spores, and a sour odor.

PEPPERS: A soft rot of pepper fruits, either green or ripening, occurs through contact with the moist soil or through injuries (mechanical or insect) and a soft tan rot of the fruit due to *Phytophthora* species is common. The fruit may become a dry "mummy" on the plant. The other rots of pepper also occur.

DIRECT INOCULATION TO ELIMINATE CONTAMINATION AND PROVE PATHOGENICITY

Rather than isolate organisms which should be tested for pathogenicity, infected tissue suspected of containing some of our common and important plant pathogens can be placed directly in very susceptible plants or tissues. The parasite usually will outgrow the saprophytes present and bits of tissue from the advancing margin of infection transferred to culture media usually will give pure cultures. This procedure is quicker in the following cases:

Crown gall: Bits of tissue just beneath the surface of a live, preferably young, gall inoculated into growing tissue of Bryophyllum will give galls in seven to fourteen days.

Phytophthora rots: Bits of tissue from advancing margin of root or fruit rots inoculated into apple fruit will cause a typical rot in a week or less. Surface sterilize an apple with Rada's Solution; cut a plug 3/8 to 1/2 inch deep with a flamed sharp cork borer; place a bit of suspected tissue in bottom of hole and replace plug; seal with a square of scotch tape. Incubate about five days in a moist chamber; culture from advancing margin of rot, or examine under microscope. Ten plugs can be made in a large apple. Label with grease pencil.

Phytophthora brown rot of citrus: Bits of tissue from interior of fruit, or advancing lesions of root, or trunk lesions placed in one-half inch of sterile water in a petri-plate or beaker will infect unwounded lemon fruits placed in the suspension.

Pythium: Bits of tissue inoculated into fruit of cucumbers or summer squash will give a wet, soft rot in a few days.

Sclerotium and Sclerotinia: The abundant white mycelium of either of these fungi usually will produce sclerotia in a moist chamber in a few days, so inoculation usually is unnecessary. But carrots, lettuce, celery, cabbage, and soybeans are susceptible to *Sclerotinia* and beets are susceptible to *Sclerotium*. If pure cultures are desired, place surface-sterilized sclerotia on agar.

EXAMINING FRUIT WITH LESIONS OR ROTS

The following diseases are most commonly encountered on fruit in the orchard or as post-harvest rots, etc., on fruit in transit, storage, or on the market. Some incipient infections occurring in the orchard become very important under post-harvest conditions. Some important post-harvest rots are absent or unimportant in the orchard.

Fig. 39. Phytophthora cactorum, conidial stage on watermelon. Note water-soaked margin of lesions.

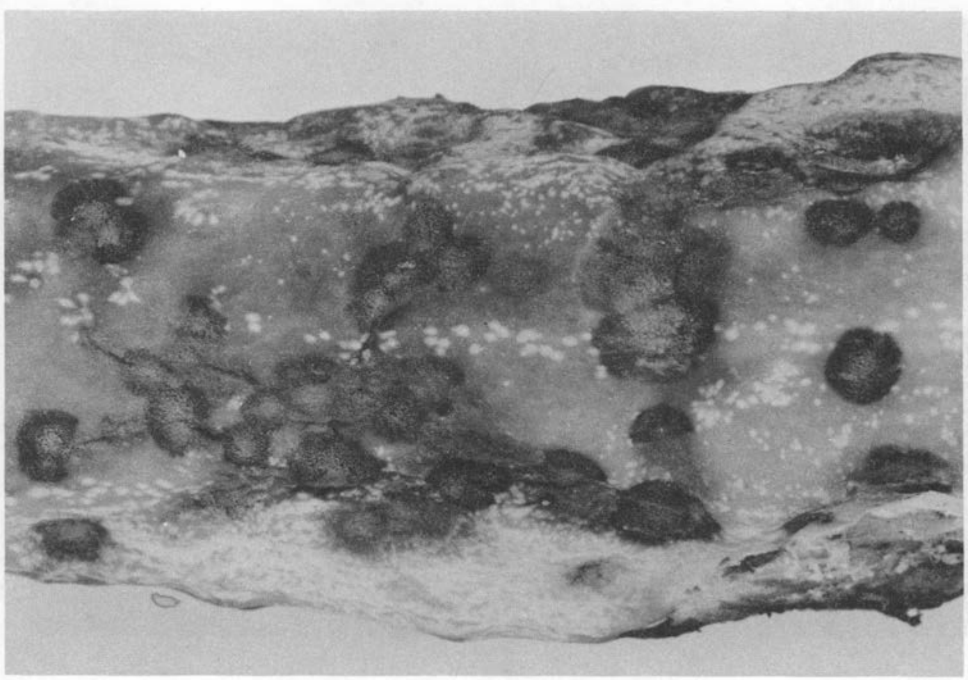


Fig. 40. Cucumber anthracnose. The sunken lesions show small moist tufts of pale salmon-colored spores. Symptoms on other cucurbits are similar. Photo by M. J. Goode.

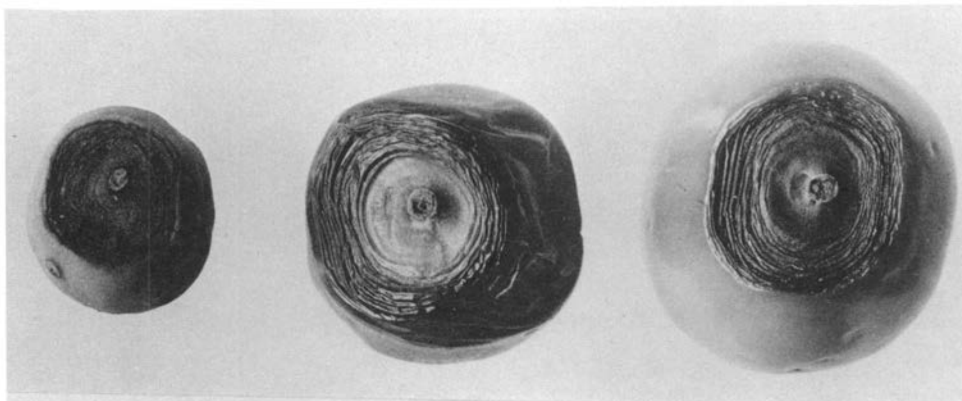


Fig. 41. Phoma rot of tomatoes. Lesions are very dark and sunken. Concentric lines often inconspicuous.

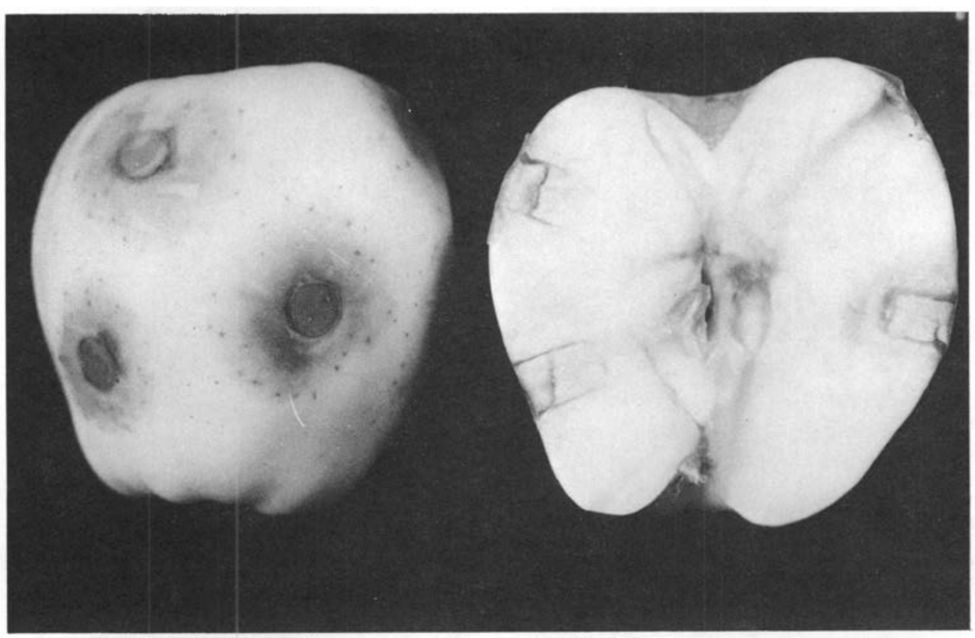


Fig. 42. Yellow apple seven days after inoculation with culture of Phytophthora cactorum in holes made by cork borer and sealed with Scotch tape. A quick test for this fungus. Can be read in three days.

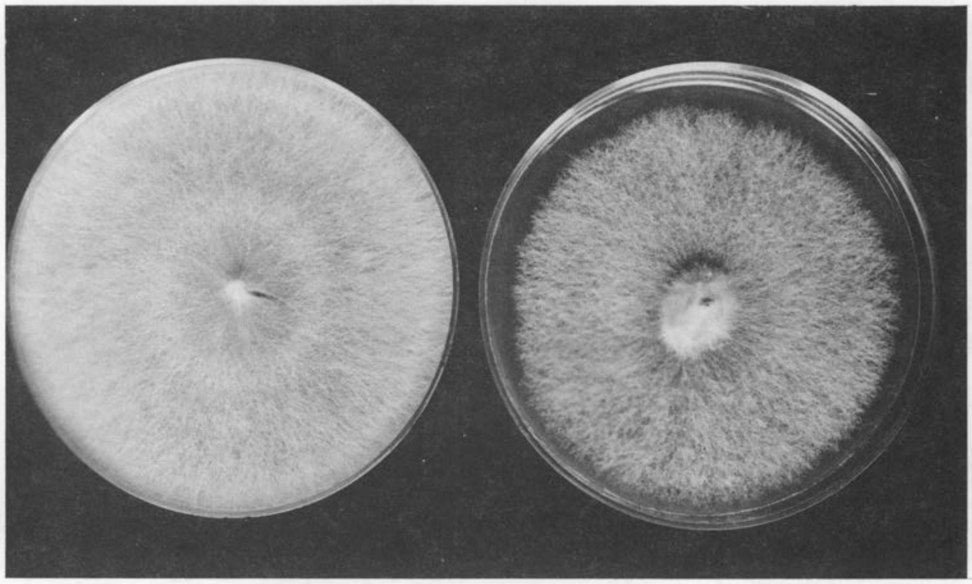


Fig. 43. Petri plate isolations of two fungi, apparently in pure culture. Cultures may or may not sporulate readily.

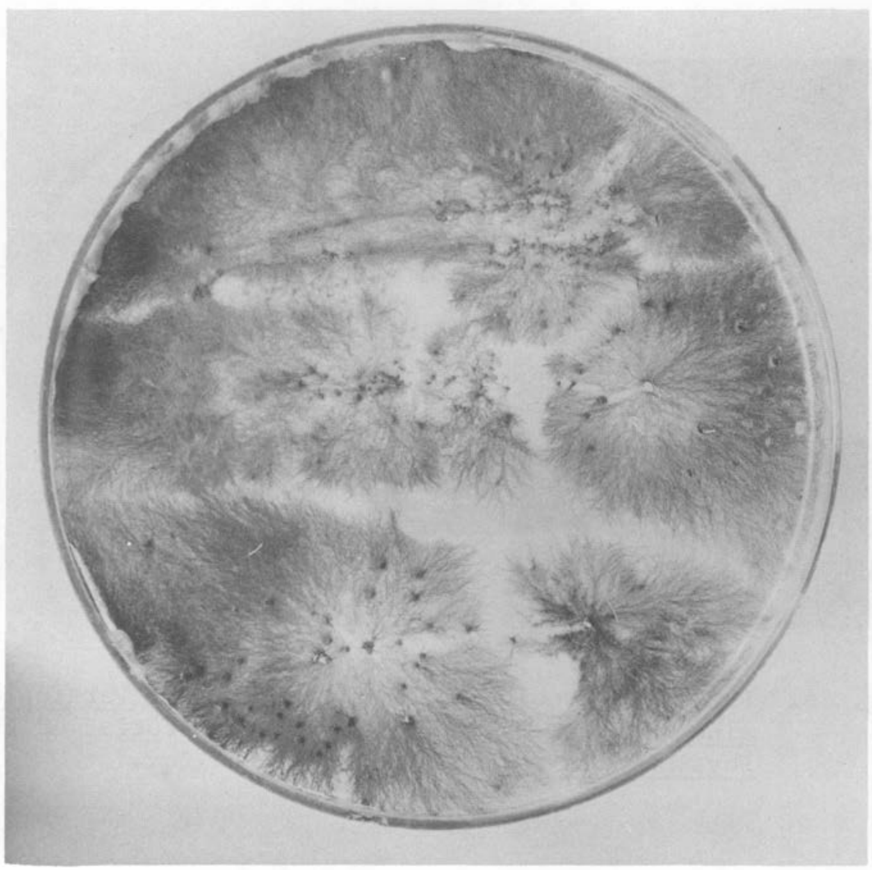


Fig. 44. Diplodia sp. with pycnidia on mycelium growing from pieces of stem plated on agar. X 1.

Fig. 45. Dense white mycelium and dark brown sclerotia of Sclerotium rolfsii isolated from kernels of peanut. X 9.

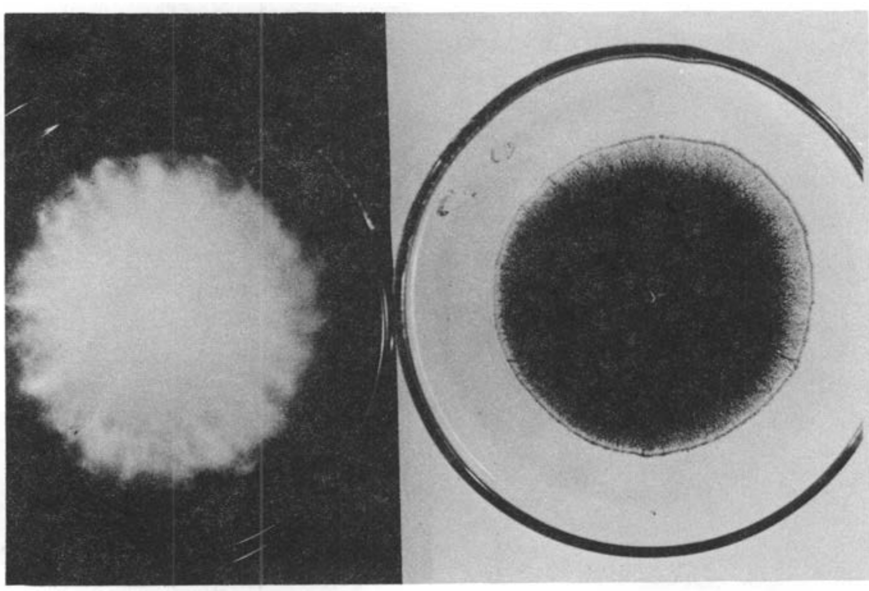


Fig. 46. Petri plate cultures of fungi: Left: Verticillium albo atrum with numerous microsclerotia. Right: Phytophthora sp. with cottony mycelium.

Fig. 47. White mycelium and black sclerotia of Sclerotinia sclerotium. Symptoms are similar on lettuce, celery, and other vegetables.

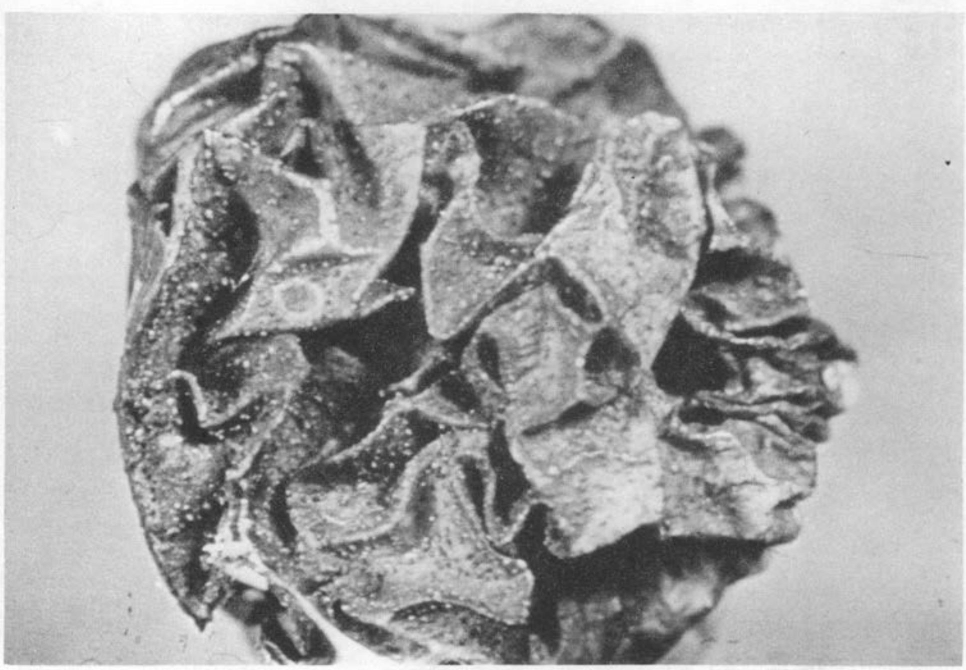


Fig. 48. The black rot (Sphaeropsis malorum) of apple progresses, involving the whole fruit which dries out to a wrinkled mummy, covered with small imbedded pycnidia full of spores. Grapes infected by Guignardia form similar, much smaller mummified berries.

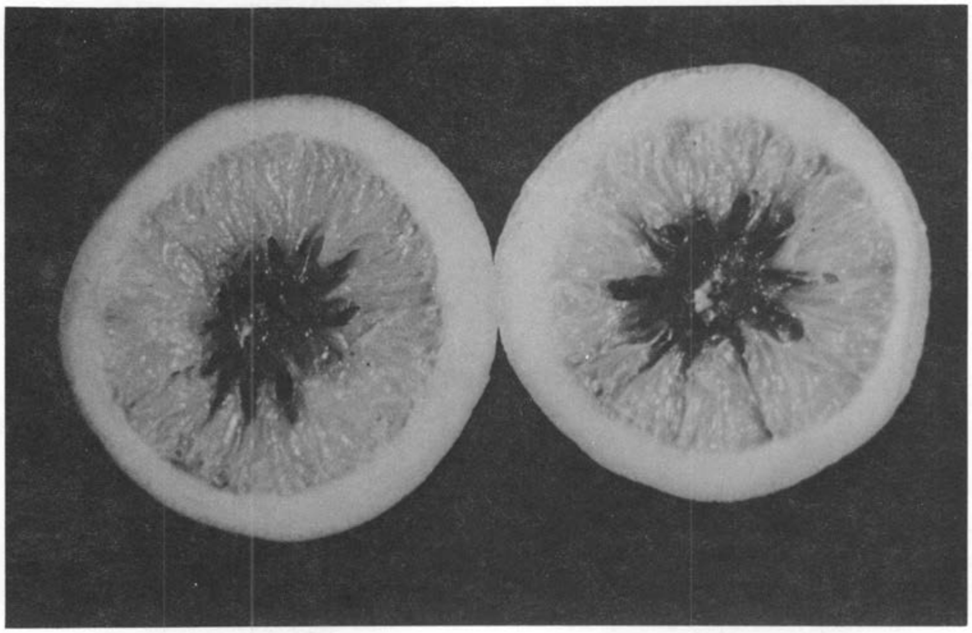


Fig. 49. Internal rot of orange caused by Alternaria citri.

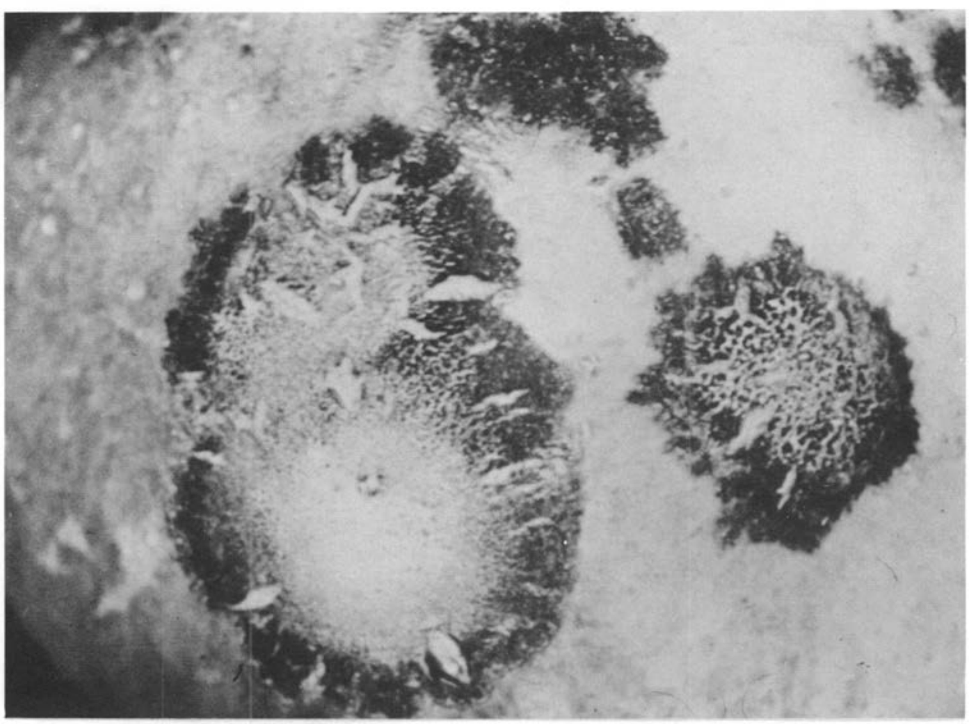


Fig. 50. Apple scab. Old lesions on fruit from early season infection. X 4.

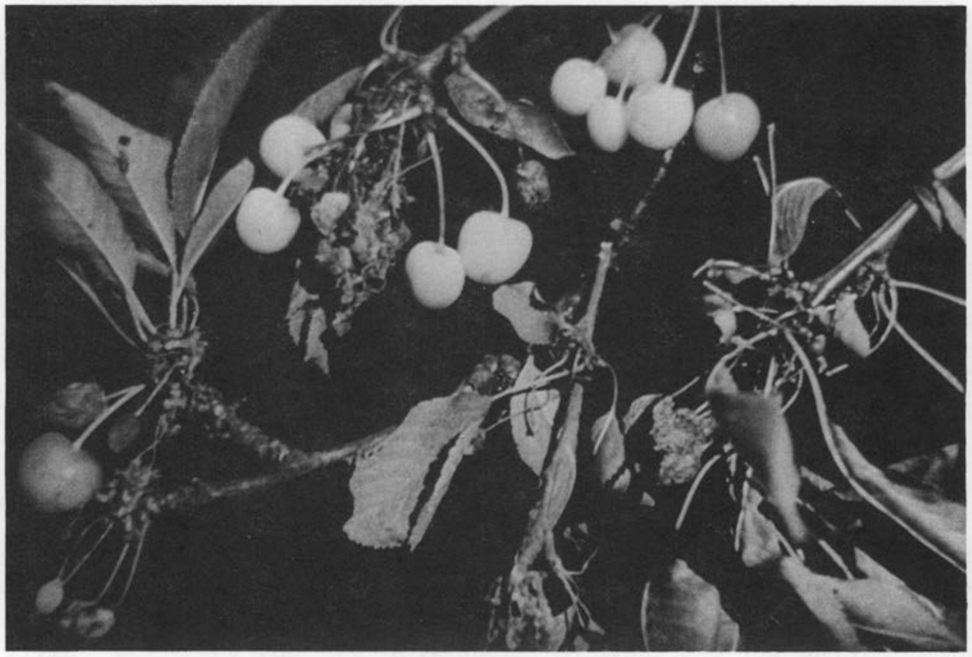


Fig. 51. Brown rot in Cherry, showing all stages from infection of blossoms, very young fruit, leaves, and ripening fruit.

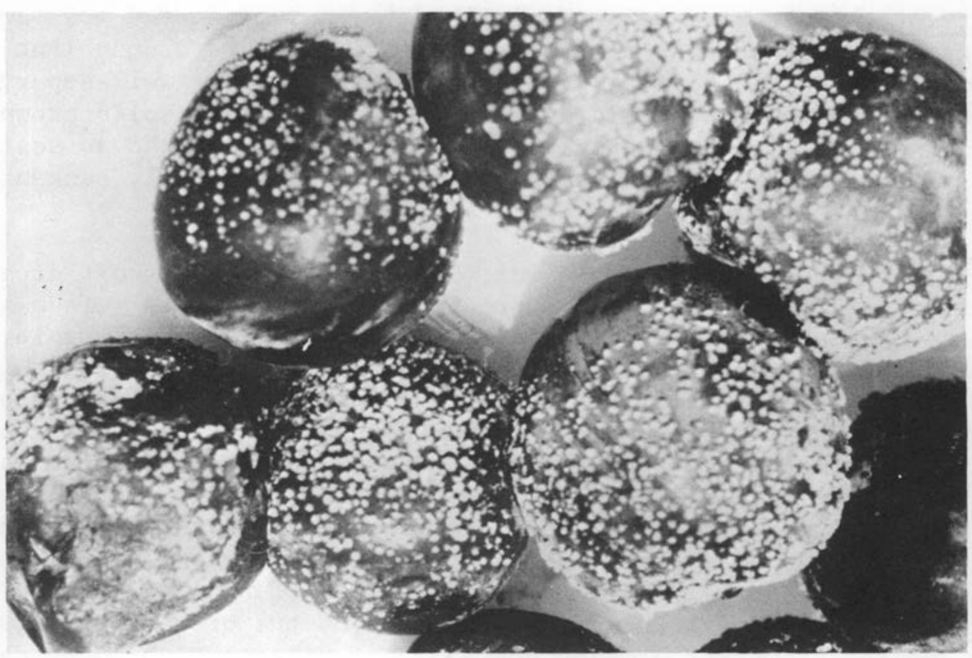


Fig. 52. Conidial stage of the brown rot fungus (Monolinia fructicola) on fruit of plum. X 1.

CITRUS FRUITS - In orchard: In Florida and the Gulf States, "tearstain" occurs as a superficial surface blemish of tiny flyspeck spots on the rind, especially on grapefruit. Less common, scab occurs as corky raised spots on rind, especially on lemons, tangelos, and other hybrids. Diplodia causes a brown, firm rot of the stem end, especially on oranges and lemons. In all districts (but not common in semi-arid sections) Phytophthora causes a semifirm, tan to brown, rot of low-hanging fruit. Anthracnose causing sunken half-inch lesions on fruit is usually not common. Alternaria citri causes a minor early-season end-rot of navel oranges.

Post-harvest: Phytophthora brown rot can be a serious storage rot when fruit with incipient infection is placed in storage. Green mold and Blue contact mold caused by Penicillium spp., are the major post-harvest rots nearly everywhere, although Diplodia end-rot can be equally important in Florida at some seasons. Alternaria citri causes a dark-brown rot of the center axis in lemons and grapefruit, entering through the button. Geotrichum, less common, can cause a soft, watery rot with a sour odor involving the whole fruit; white mycelium is usually abundant.

APPLE, PEAR, QUINCE - In orchard: A firm rot of the fruit and fruit spurs of apple (brown) or pear (black) is due to the fire-blight bacterium. Scab occurs as olive-green spore-bearing round spots on skin of apple or pear. Fruit infected while small often cracks open as it grows. Black rot, Sphaeropsis, infections involve entire fruit which develops a firm, dark-brown rot, and progresses into a shriveled mummy bearing numerous pycnidia showing as tiny pimples. Bitter pit (physiological) affects fruit approaching maturity, causing slightly sunken water-soaked spots, color depending upon the apple-skin color. In storage, skin may turn brown. In section, a small cone of brown, dry tissue penetrates flesh about one-fourth inch. Jonathan spot is similar but the spots are smaller with a sharp circular margin, brown in color (dead tissue) and only a few cells deep. Both diseases develop in storage.

Post-harvest: Apple blue mold (Penicillium expansum) is the most common fruit rot and causes the greatest loss of fruit. Infection occurs around lenticels or through wounds. The rot is soft and the wrinkled fruit shows well-separated clusters of leaden-blue spores. Common scald develops as a diffuse to solid brown discoloration of the skin which, in more severe cases, loosens and sloughs as scald becomes more severe. Soft scald occurs as definitely localized, slightly sunken areas on the fruit. (See Photographs)

STONE FRUITS - In orchard: Brown rot (Monilinia) attacks fruit of all sizes from blossoms to maturity reducing immature fruit to dry mummies (often in clusters) clinging to the branches. Rot progresses very rapidly as ripening fruit softens. Rot is soft and the tan spores are produced in separate tufts in firm-skinned plums and cherries; in a diffused layer in soft skinned peaches. Scab occurs as numerous small, scurfy spots on skin of peaches and apricots. Stone fruit rust occurs as yellow aecial cups on a raised spot. It is rare but occurs in California. Leaf curl (Taphrina) appears as large blister-like areas on fruit, often tinted pinkish to reddish. Plum pocket appears as oversized bladders, spongy in texture replacing normal fruit. Bumpy fruit is caused by the peach mosaic or the peach wart viruses.

Post-harvest: Fruit with incipient infection by the brown-rot fungus breaks down rapidly, making brown rot a major post-harvest disease. Rhizopus causes a major rot of stone fruits, especially peaches, and progresses even at the usual refrigeration temperatures. The rot is soft, leaks juice, and produces abundant course mycelium and dark spore bodies. Blue mold (Penicillium) and Black mold (Aspergillus) are also frequently seen on fruit held too long.

GRAPES: In vineyard: Black rot, Guignardia, appears as a firm, dark rot of immature berries or loss of entire bunch. Mature berries become wrinkled mummies with numerous pimples showing the necks of spore bodies. The downy mildew fungus Plasmopara viticola destroys blossom clusters and very young bunches. Older berries are rotted. Powdery mildew caused by Uncinula necator produces white mildewed areas on leaves, young canes, and skin of green berries and is readily recognized. Geotrichum occasionally causes a sour, wet rot of the interior of bunches following showers.

Post-harvest: Grey mold (Botrytis) infects berries causing the skin to slip. Spores are produced in five to seven days. Blue mold (Penicillium) rot advances slowly. Geotrichum, a wet rot, is more rapid in development, but not common.

STRAWBERRIES - In field: Leather rot caused by Phytophthora cactorum appears as firm, tan rot of the berries. The infected area is not easily separated from the healthy tissue. Rhizoctonia causes a hard, black rot of berries in contact with the soil.

Post-harvest: Strawberries are very perishable and lose quality after several days storage even in absence of rots. Rhizopus causes a soft, wet rot which "leaks" juice. The berries are promptly covered by spore bodies, "whiskers." It is cosmopolitan and the major post-harvest rot. Botrytis causes a soft, gray mold rot which advances rapidly. Field infections may progress in storage.

MYCORRHIZAS

You should be aware that fungi frequently occur on the root systems of certain groups of plants in a relationship that has been interpreted as either symbiotic (benefiting both host and fungus), nonparasitic, or weakly parasitic. Two forms occur: Ectotrophic, such as those occurring on pecan, pines and forest trees in which the fungus forms a loose mantle on the surface of the feeding root tips; and Endotrophic as in the orchids and Ericaceae (Rhododendrons, etc.) in which the fungus occurs in certain layers of root cells. The absence of the fungus may be more harmful than its presence. Mycorrhizal roots are often short and swollen.

BACTERIAL NODULES

Small unbranched or branched lateral nodules usually occur in abundance on the roots of leguminous crops, shrubs, and trees. These are due to Rhizobium spp. bacteria which fix nitrogen and are beneficial, and should not be confused with galls due to root-knot nematodes.

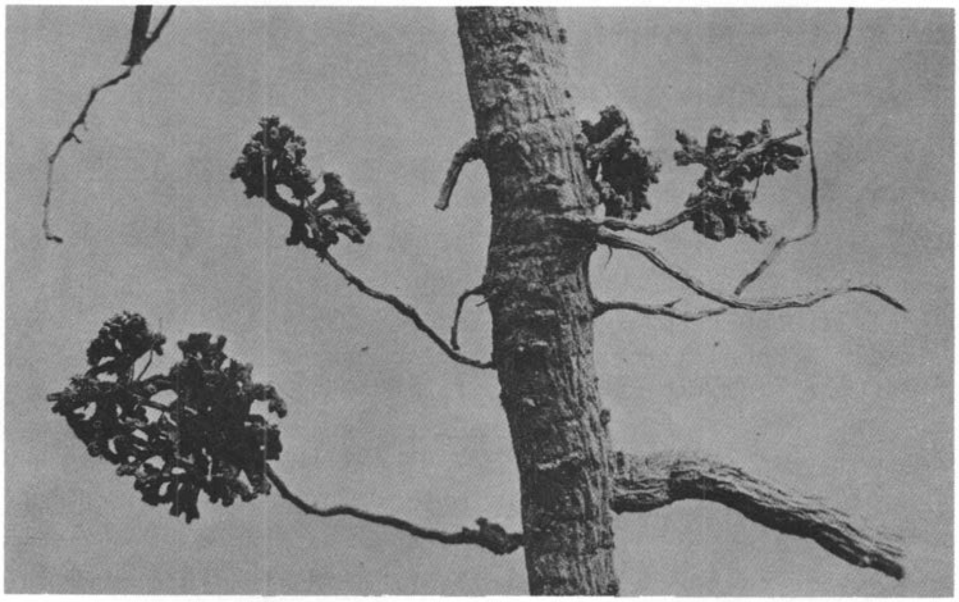


Fig. 53. Mycorrhiza on roots of Eleagnus. The stubby, much-branched rootlets are caused by fungi. These should not be confused with bacterial nodules or root-knot nematode galls. X 1.

DIAGNOSIS OF NONPARASITIC DISEASES

In semiarid regions, where moisture conditions are not favorable for infection of above ground tissues, over half the plant disease problems encountered are due to causes other than parasitic fungi, bacteria, viruses, nematodes or flower plants. To cope with these adequately, close observation of symptoms and growing conditions are required as there are no structures of an organism that can be used in identification. Nonparasitic diseases are also prevalent in regions of moderate to heavy rainfall. Some of the maladies that occur in more arid regions are present, but nutrient and micronutrient deficiencies are more prevalent.

Frequently dead plant tissues are quickly overrun by secondary organisms thus compounding the difficulty of determining the true cause. Plant roots killed by any adverse condition, whether it be excess water or alkali salts, gas or chemicals (herbicides, fertilizers, insecticides or fungicides) are quickly invaded by the soil flora. Species of Fusarium, Rhizoctonia or bacteria are almost universally present on and in dead roots. Also, above ground dead tissues occurring in blossom-end rot of tomato and watermelon are often overrun by Aspergillus, Alternaria, etc.

DEFICIENCY OF NITROGEN: Since it is readily leached, nitrogen is the major element most frequently deficient. Retarded growth and a uniform pale green color are the most common symptoms, but may be due to other causes. In case of doubt, add quick-acting nitrogen to a few plants.

MICRONUTRIENT DEFICIENCIES

IRON DEFICIENCY: - CHLOROSIS: In regions of alkaline, calcareous soils, a yellowing of the interveinal areas of the new growth due to lack of iron in a form <u>available</u> to the plant is both prevalent and important. The <u>symptoms</u> range from mild to severe and are easy to recognize:

(1) <u>Mild chlorosis</u>: New leaves are pale green or yellowish-green between the veins which are normal green. (2) <u>Moderate chlorosis</u>: New leaves have areas between the veins quite yellow, but veins, even the smaller ones, are normal green. (3) <u>Severe chlorosis</u>: New leaves are pale yellow to straw-color, midribs may or may not be green. Brown spots may occur in hot weather, or all or part of leaves may dry. Leaves may be shed.

In the field, look for evidence of excess moisture and calcareous soils which predispose plants to chlorosis.

ZINC DEFICIENCY: There are several major symptoms of zinc deficiency on a variety of host plants. It is most important on woody plants.

<u>Little leaf</u>: Small, narrow, more or less deformed leaves, chlorotic at tips of new growth, forming terminal rosettes on almond, apricot, apple, grape, peach and plum. Defoliation is progressive from base to tip.

<u>Rosette</u>: In spring leaflets are yellowish and rough to the touch. Later growth is reduced to small deformed leaves with short internodes on twigs forming rosettes. In midsummer dead spots appear on leaflets of pecan and walnuts. Severe drying of leaves occurs in advanced cases. Trees rarely die.

<u>Mottle leaf</u>: Citrus, especially navel orange, shows small, narrow, upright leaves with yellow areas between the veins and bushy growth of trees.

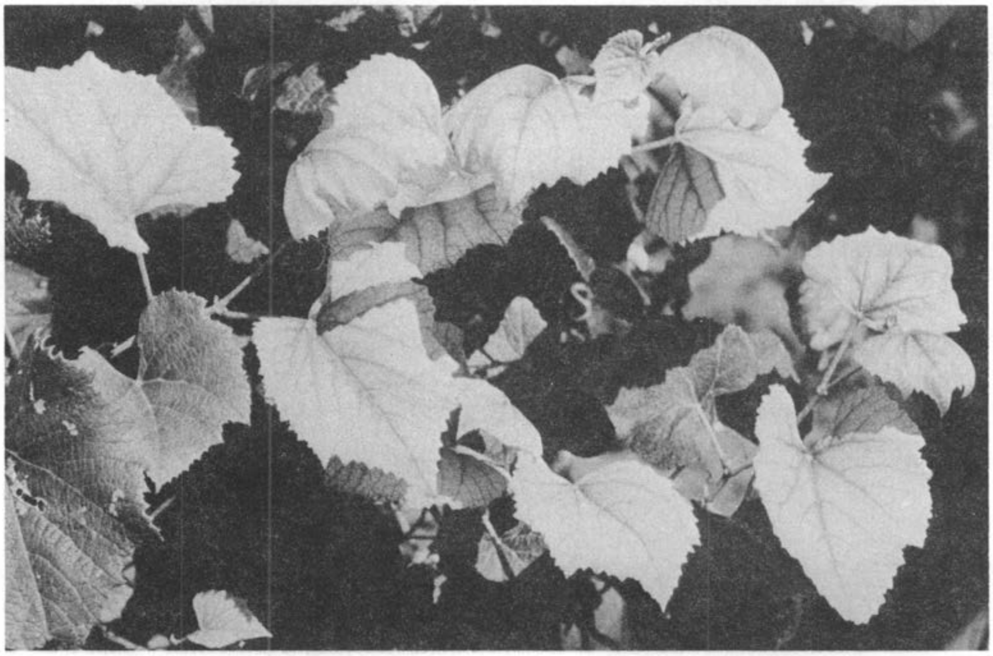


Fig. 54. Chlorosis of grape leaves due to deficiency of available iron.

MANGANESE DEFICIENCY: Resembles iron deficiency but green color is retained in tiniest veinlets, and there is some green color alongside these veins. Most prevalent in citrus, peach and bean. Usually mild.

MAGNESIUM DEFICIENCY: Prevalent in vegetable crops in the Atlantic and Gulf Coast states. Symptoms vary greatly with host plants. A chlorosis resembling iron induced chlorosis but with more green along the veins occurs in some vegetables. On Citrus a striking dark green V at base of leaflet with part or all of remaining leaf yellow is readily recognizable, but rare and usually mild.

COPPER DEFICIENCY: Causes dieback in citrus, apple, pear, apricot, prune, olive, etc., and failure of vegetable crops in muck soils. Occurrence in fruits is widespread in Florida and common in California. Symptoms on citrus are striking: at first very large dark green leaves, later brown stained twigs, and dieback, stunted, brown stained fruit with gum pockets in angle of segments.

BORON DEFICIENCY: Only a minute amount of boron is required by most plants, but its absence causes very definite symptoms varying with the host plants.

Root crops: Turnips, beets, rutabagas and cauliflower, lacking boron are stunted with dark spots or cavities in the fleshy roots. Lettuce and spinach have deformed or blackened terminals.

Fruit trees: Apples show internal and external corky spots, dieback and rosette; pears show dieback and blossom blight; peaches show stunting, excessive branching and internal necrosis.

Cracked stem: Petioles of celery and rhubarb develop cracks and brown streaks, and leaflets of celery have brown spots.

Many ornamentals are susceptible to injury from lack of boron.

DIAGNOSIS OF CHEMICAL EXCESSES

FERTILIZERS: Excessive use of fertilizers is most likely to be encountered in commercial fruit and vegetables grown on a large scale where fertilizer is used to secure maximum yield and in home plantings where proper dosage is hard to estimate. Most of injuries are due to nitrogen which is very soluble and may not be properly diluted by rain or irrigation water before it comes in contact with the tender feeding roots.

Nitrogen: Poor distribution rather than excessive amounts per acre is the usual cause of injury to roots or foliage. If nitrogen is broadcast on wet foliage, each particle will produce a small dead spot. If the fertilizer is spread by hand, branches above spots where fertilizer is concentrated will often die. Fertilizer for vegetables is frequently applied in bands (by planting machinery) either below or at the side of plant rows, or later "side-dressed" near the rows. If band is too close to roots or application too heavy, injury to lateral and top root may occur and may be attributed to root-rot fungi.

PHOSPHORUS: A considerable excess of phosphate fertilizer may interfere with absorption of nitrogen.

Potassium: Injury from luxury use of potassium has not been encountered.

EXCESS OF TOTAL SOLUBLE SALTS IN SOIL OR WATER OR BOTH

In regions with 25 or more inches of annual rainfall, the alkali salts are leached below the root zone. In regions of 20 inches or less annual rainfall alkali salts often remain in the root zone in injurious amounts. Irrigation waters from surface flow from mountain areas are relatively low in soluble salts. Well waters vary widely in salt content, and continued use of any well water fairly high in soluble salts will sooner or later cause an accumulation injurious to crops. When an irrigation water containing 5 tons of salts per acre foot is used at the usual rate of 3 to 5 acre feet per year, 15 to 25 tons of salts are applied each year.

COMPOSITION: White alkali is principally chlorides and sulphates of sodium and other bases. It may appear as a whitish surface incrustation in winter or after dry periods.

Black alkali is principally carbonates of sodium which are capable of dissolving organic matter and the dark brown to black surface accumulation gives the name black alkali. It is not too common, usually occurs in heavier soils which do not take water readily.

SYMPTOMS: (1) Seed germination may be retarded or prevented. (2) Slender or sickly growth of seedlings may be followed by chlorosis and early death. (3) Retarded growth and chlorosis of larger plants occurs, often with burning of foliage as the season advances. The effect is very similar to drought injury. (4) Shade or orchard trees may make good growth until the salts accumulate. Then retarded growth and chlorosis are evident. Scant growth, weak shoots, brilliant yellow foliage and small leaves are common symptoms. Leaf burn and premature shedding are late season symptoms. (5) Premature death of the older leaves has been observed on date and other palms.

SALT TOLERANCE: For data on specific crops see "Salt Tolerance of Crops in Desert Soils." Ariz. Agr. Ext. Mimeo. (7 pages) Mar. 1968.

A QUICK METHOD FOR MEASURING TOTAL SOLUBLE SALTS
(For regions where salts in soil or water are a problem)

In diagnosing nonparasitic diseases we often wish to know whether the soil contains an excess of soluble salts. A quick laboratory method of determining T. S. S. (Total Soluble Salts) is to take a reading of the soil extract by means of a Sol-U Bridge (see list of equipment on page 2.10-2.11). The procedure consists of three simple steps: (1) Find the saturation point of the soil (about 100 gms.) by wetting with distilled water and stir until it forms a paste with a slight shiny film of water on top. Allow it to stand one hour, covered. If surface becomes dull, add a very little water; if too wet add a little more soil. (2) Pack soil paste in a 55 mm. funnel on a No. 2, 55 mm. filter paper, and apply suction with a water pump or vacuum pump, until 3 ml. of clear soil extract are extracted. (3) Rinse the electrodes by drawing water in and out by pressing bulb. Then draw soil extract into electrode avoiding air bubbles, and adjust dial until dark wedge at top of electric eye has sharp edges. Reading on outer circle multiplied by 700 gives PPM total soluble salts. Examples -- .8 x 700 gives 560 P. P. M. indicating a small amount of salts; 3.2 x 700 gives 2,240, indicating high salt content.

(Use photo of flask, filter, Sol-U Bridge.)

Fig. 55. Late season symptoms of zinc deficiency (Rosette) in Pecan. Left: Two stunted leaves with blunt tips. Center: Three small rosettes. Lower right: Part of normal leaf. X 1/3.

Fig. 56. Mottle leaf, a zinc deficiency of navel orange, more prevalent on fall flush of growth. X 1/2.

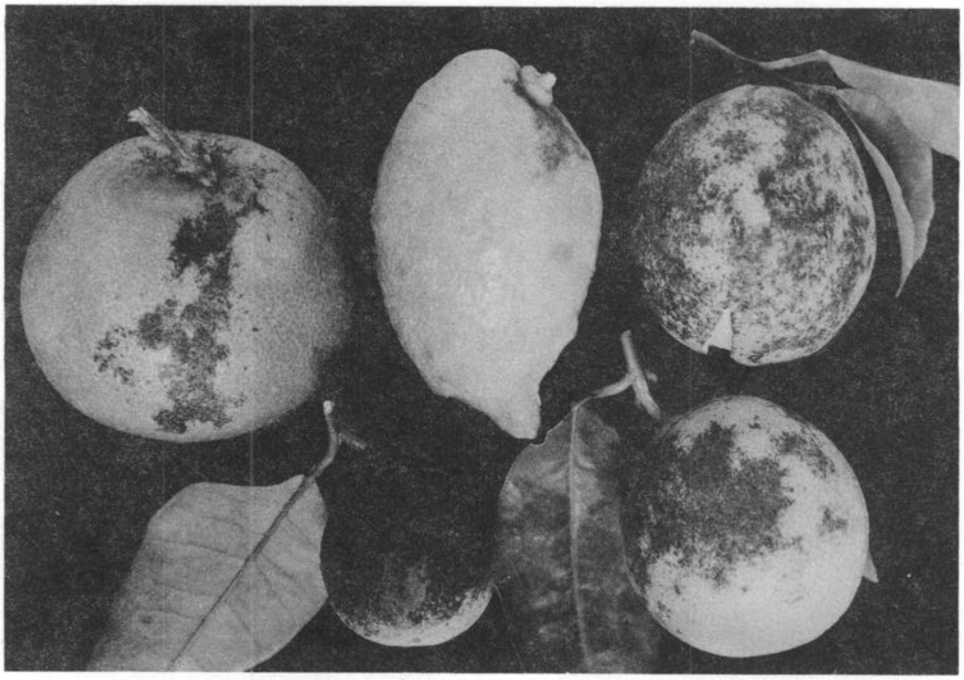


Fig. 57. Exanthema (copper deficiency) of citrus fruits. Upper row: grapefruit, lemon (note off-center axis of fruit), orange, split. Lower row: undersized heavily stained oranges.

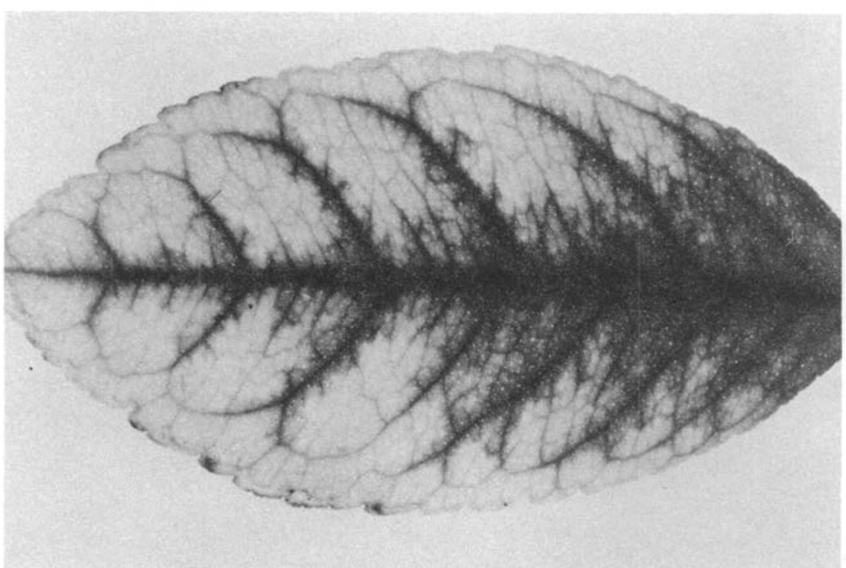


Fig. 58. Typical marginal chlorosis on lemon leaf due to excess boron in irrigation water.

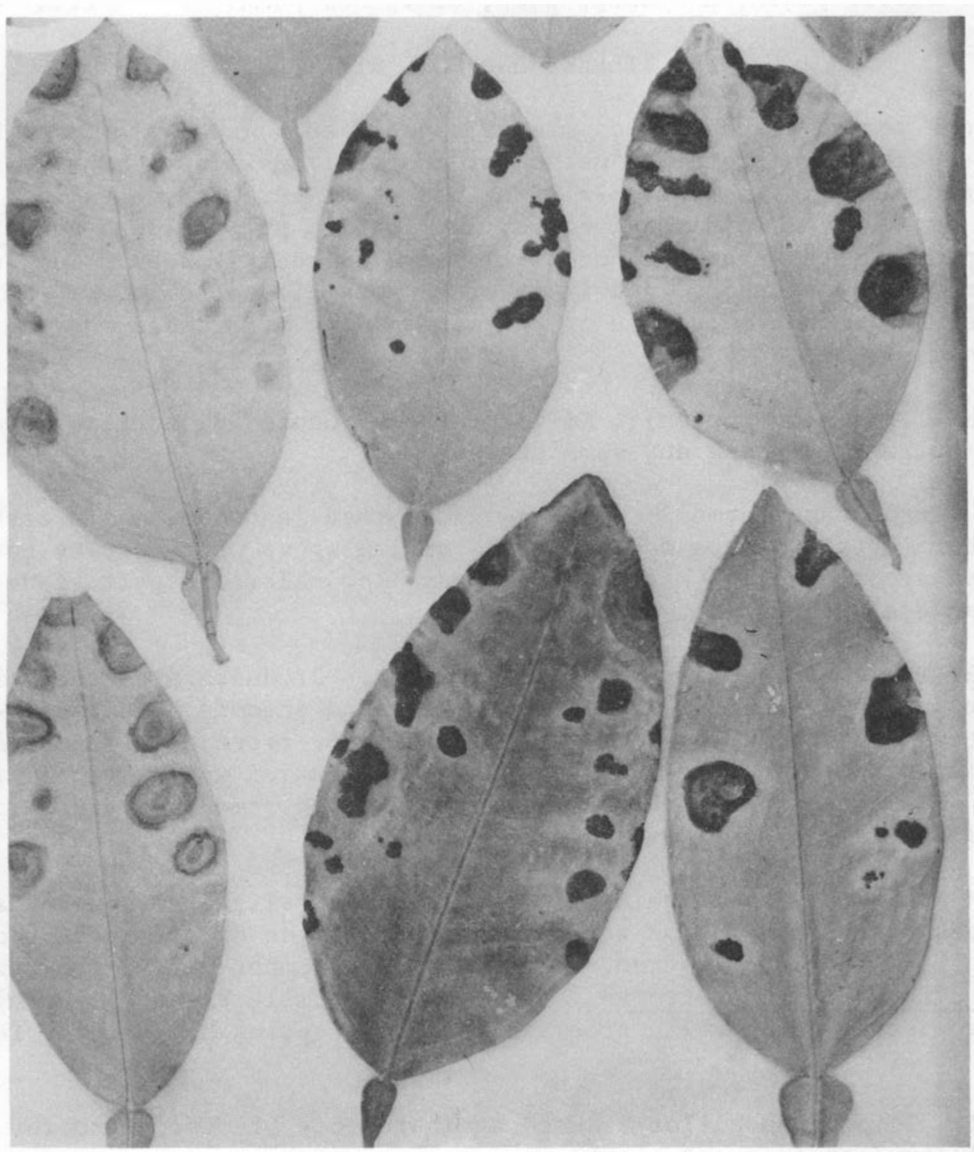


Fig. 59. Spotting of mature citrus leaves from white alkali salts in soil.

See list of Equipment: pages 2.10 - 2.11

Sol-U Bridge Soil Tester - - - - - - - - - - - - - - - - - - - About $85.00

6 55 mm. Buechner Funnels, 55 mm., No. 2 Filter paper,
500 cc. Filter flask, and water pump, or vacuum pump. - - - Est. $15.00

WEED KILLERS AND SOIL STERILANTS

Weed killers

In recent years, the use of chemicals applied as a spray or drench has been hailed as a relatively effortless method of controlling weeds. Most of these chemicals are selective in action--killing the weeds but not the "good plants." But this is true ONLY when directions for application are followed exactly. However, many plants with strange abnormalities are frequently seen. Each material produces distinctive symptoms, and it is often possible to tell from the plant what material has been used. Some of the more common herbicides and their characteristic symptoms are:

DALAPON (Trade name Dowpon): Kills grasses. Causes distortion, browning, and shedding of foliage on roses and some trees.

DIURON (Trade name Karmex): Used against broad-leaved weeds in cotton at "lay-by time." Cotton leaves develop solid yellow spots where wet by spray. New leaves formed after spraying have a striking yellow chlorotic pattern between veins. If severe, leaves are shed.

UREOBOR (Trade name): A general weed killer. Produces a severe yellowing of tips and margins of leaves of citrus, and drying and shedding of leaves--all from spraying weeds under the trees. On mulberry, ureobor produced a severe stunting and chlorosis and drying of new leaves following treatment of weeds even 30 feet away from trunk. Mulberry trees injured one summer, showed some injury the following year but had no visible symptoms the second year.

2,4-D: Frequently used against lawn weeds, with slight to severe damage to adjacent trees and shrubs. Most striking symptom is the drastic reduction of the blade area of the leaves of cotton, umbrella tree, trumpet vine, grape, zinnia, etc. 2,4-D affects only new growth. Lawn under umbrella trees was sprayed in the fall; the new leaves on umbrella tree the following spring had slender fern-like leaves.

2,4,5-T: This brush killer is used against woody plants. Stronger than 2,4-D and more injurious to adjacent plants.

Herbicide injury can be confused with that caused by excess chlorides, sodium or boron, but the salts first affect the older leaves while DALAPON and SIMAZINE affect young leaves also, and the SIMAZINE injury shows first as a narrow yellow band around the leaf margin.

Soil Sterilants

SOIL STERILANTS

Soil sterilants have two characteristics: (1) They persist for several years in the soil and (2) they will, when applied at recommended rates, kill all plant roots in the soil. Tree roots range widely and will be killed in areas treated by sterilants. Absence of ALL vegetation is the best field clue to the use of

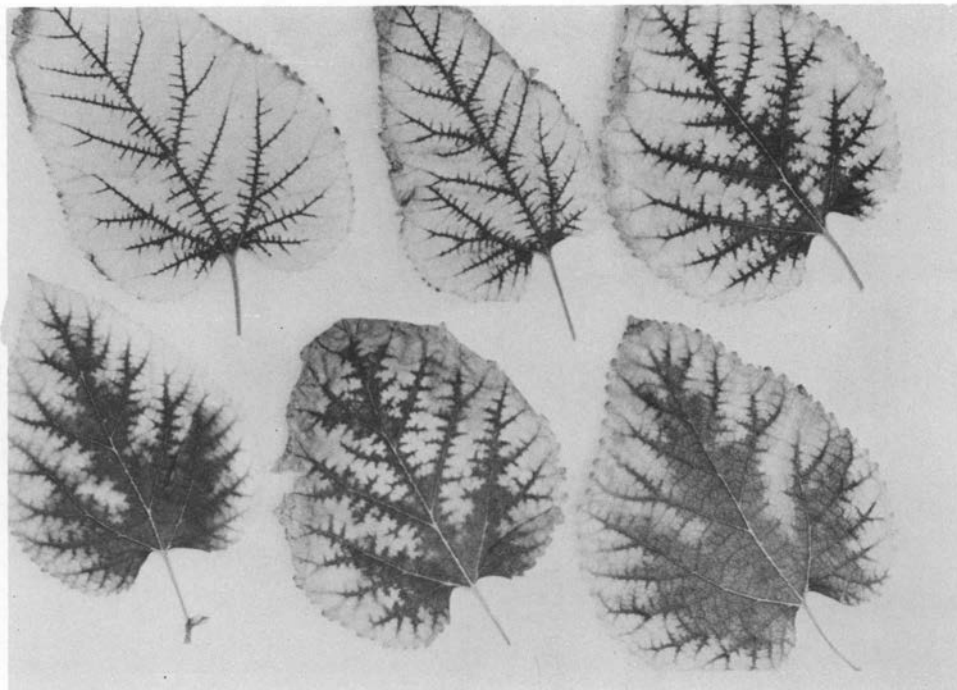


Fig. 60. Chlorosis of mulberry leaves from herbicide (Ureobor) applied to weeds 20 feet from tree. More severe injury results in drying of leaves.

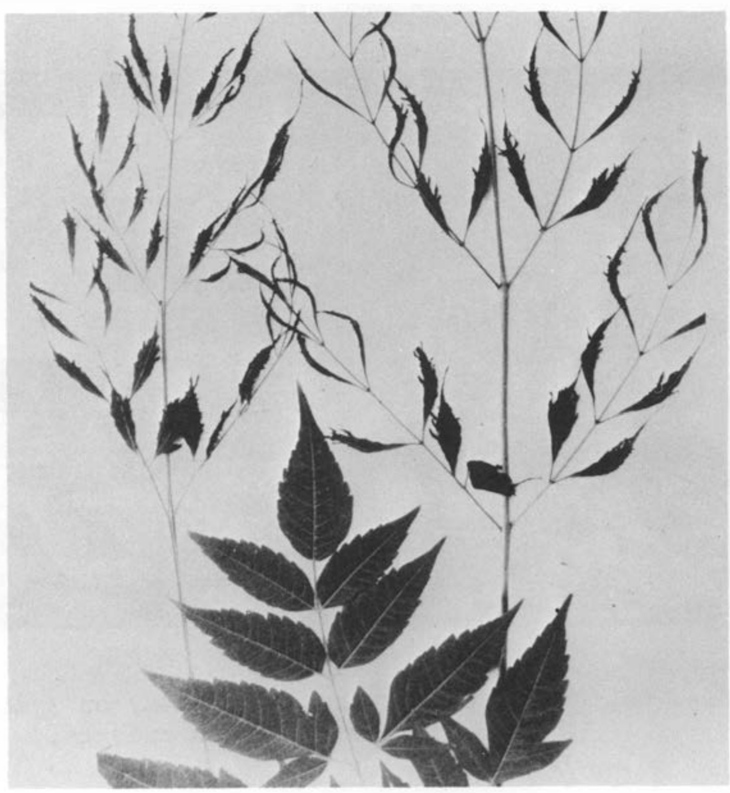


Fig. 61. 2,4-D injury on leaves of umbrella tree--a result of weed spray the preceding fall. Normal leaflets at bottom.

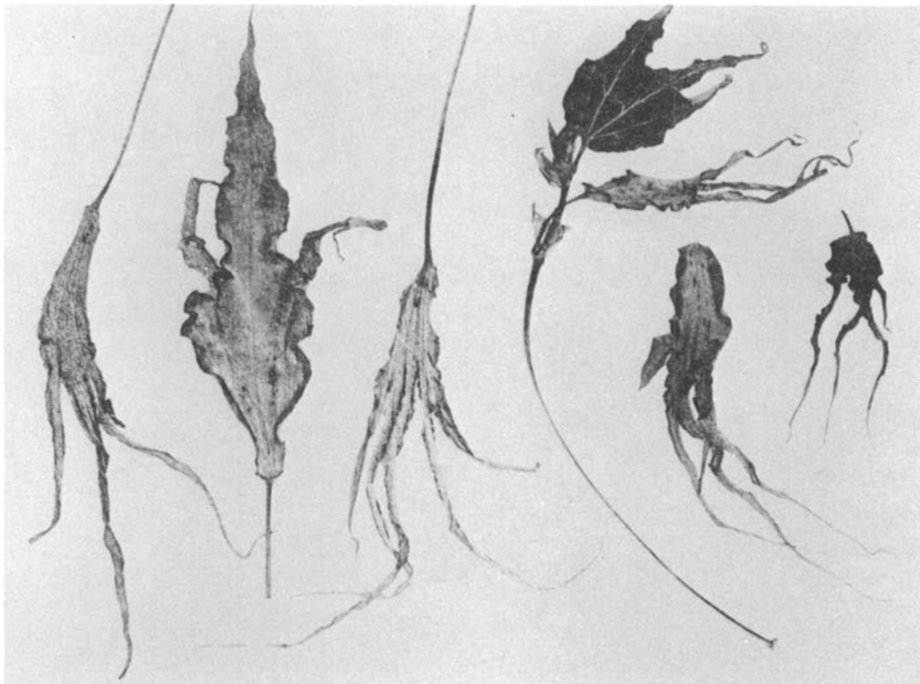


Fig. 62. 2,4-D injury on cotton leaves. Volatile herbicide was air borne. Cotton was not sprayed. X 1/2.

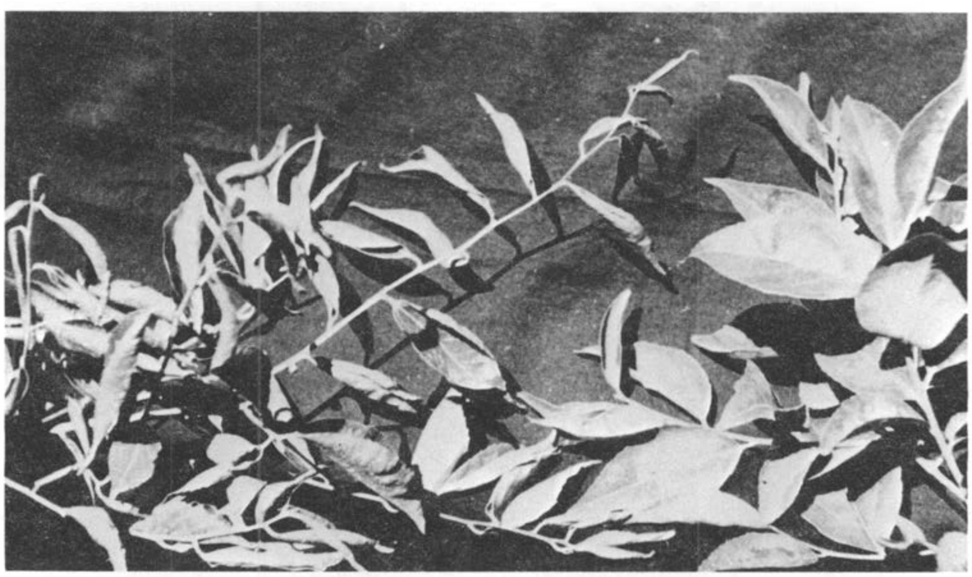


Fig. 63. 2,4-D injury (rolled leaves) on Xylosma. Similar injury occurs on privets.

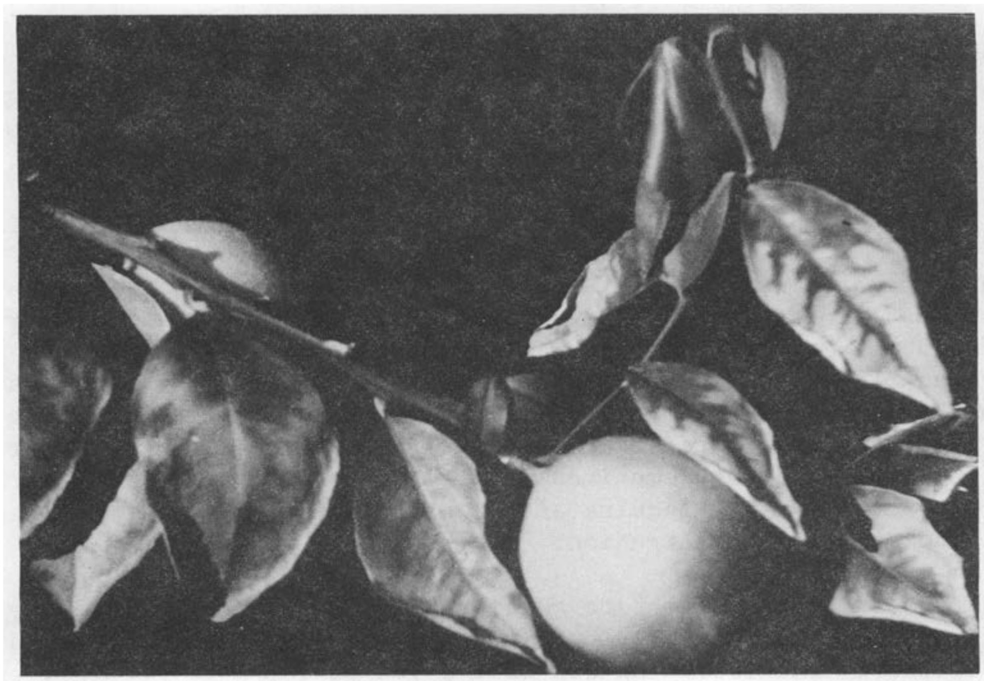


Fig. 64. Ureobor injury (orange-yellow chlorosis) on Meyer lemon.

sterilants. Growers and home-owners are sometimes reluctant to admit the use of sterilants and weed killers.

In urban and some suburban areas where lots are small, the chemicals may have been applied on adjoining property to soil which harbors roots of your trees and shrubs.

SODIUM CHLORATE: Formerly used more than at present. Persists in the soil for several years. No distinctive symptoms.

SODIUM ARSENITE: A soil sterilant, also formerly used to treat soil under houses against termites. Roots of foundation shrubs and trees penetrating the treated area may pick up enough arsenic to kill the plants. The leaves turn brown and dry, and the wood of the trunk and branches is strongly stained brown.

INJURY FROM FUNGICIDES, NEMATOCIDES, AND INSECTICIDES

Fungicides, nematocides, and insecticides if carefully prepared and applied at the concentrations and combinations recommended, rarely cause plant injury. The injuries produced are mostly necrotic areas, chlorosis or russetting, but are so variable they cannot be satisfactorily described. The number of these pesticides is rapidly increasing and many of them will, under conditions predisposing plants to injury--high temperatures, overdosage, sensitivity of certain crops or varieties--cause injury; usually mild but sometimes severe. In case of puzzling necrotic, chlorotic, or russetted areas, inquire as to what sprays or dusts have been applied, how recently, and at what concentration.

It is not practical to attempt to catalog all the materials which may be phytotoxic or describe the symptoms, but in diagnosing injuries you should be aware of the possibilities. The following are just a few of the more commonly encountered examples of phytotoxicity:

NEMATOCIDES: With the exception of DBCP (trade names Nemagon, Fumazone) which can be used as a soil drench around living plants (at the recommended rates) nematocides will kill all roots in the treated zone. Ethylene dibromide, Methyl bromide, D.D. mixture, and Chloropicrin are all toxic to plant roots, and should not be used to treat soil within 20 feet of trees and shrubs.

SULPHUR DUST OR SOLUBLE SULPHUR SPRAYS: Sulphur compounds will often cause leaf or fruit burns if applied in hot weather (above 85 degrees F.). Cantaloups and some other melons are very sensitive to sulphur under these conditions.

ACTIDIONE and KARATHANE may cause some injury to roses in hot weather.

BORDEAUX MIXTURE causes a slow-developing russetting of young apple fruit and leaves.

MERCURIC CHLORIDE: A 1-1000 p.p.m. solution applied as a drench to control damping-off of seedlings will cause death of leaves and stems if allowed to dry on the foliage. Other soil drenches may cause similar injury.

CAPTAN as a soil drench may be phytotoxic under some conditions.

TOXAPHENE, an insecticide, applied to cotton in hot weather often causes slight to moderate leaf burn.

MALATHION under some conditions causes foliage injury.

INSECT BARRIERS AND REPELLANTS

It is unsafe to apply materials with a grease or oil base to green bark or smooth young bark on trunks of young fruit (and other) trees as practiced to prevent harvester ants, etc., from gaining access to the foliage. In our experience, a 3-inch band of tree tanglefoot killed the bark of young citrus trees, and the whole planting was lost. Also a petroleum jelly mixed with chlorodane girdled the trunks of one and two-year-old peach trees and they died. If necessary to use such compounds, a light, grease-proof paper or plastic wrap should be applied to the trunk before the grease-base compound is applied.

GAS INJURY

Many puzzling cases of decline in trees and shrubs with indefinite symptoms have turned out to be due to gas leakage. There are no diagnostic symptoms which are reliable. A sample of the root system will show many dead roots, but by that time deterioration of the top is evident--dieback, shedding or drying of leaves, and poor growth. Frequently a "gassy" odor can be detected in recently exposed soil--but chronically water-logged soil gives off a similar odor.

The natural gas now widely used is much less toxic than the manufactured gas formerly used, but continued exposure to gas leaking from aging pipes causes anything from a slow decline to sudden death. Large leaks cause wilting, browning of foliage and quick death; slow leaks may cause a gradual decline over a year or even several years but eventually kills the tree.

When definite clues are lacking in urban areas, suspect gas leaking from service pipes. When the location of gas line is not known, dig by the meter to determine direction and probable location of the gas pipe.

In case of suspected gas leaks, the gas company will test the area with a sensitive probe which registers the concentration of gas in the soil, and will replace leaking pipes--if the leaks are on <u>their</u> side of the meter.

INJURY DUE TO AIR POLLUTANTS

The present concern with ecology has drawn attention to air pollution and its effect on man and his environment. In many areas of the United States damage to vegetation by air pollution poses a significant economic problem. In addition to the obvious visible symptoms of air pollution damage, there may be an invisible effect: the plant appears healthy but growth and production are reduced, in some cases by 50 percent or more.

We, as diagnosticians, are concerned only with the <u>visible</u> symptoms of injury to plants caused by air pollutants; to measure possible invisible injury would take a growing season, and the data are difficult to assess and evaluate, and the results often are controversial.

It should be noted that some injuries are localized near the sources releasing considerable amounts of contaminants; in other instances the injuries may be quite widespread. Usually the chemicals remain in toxic form from one to several days only.

The following is an outline of the injury to plants by common air pollutants:

Indicator plants: Certain crop plants and weeds are very sensitive to each pollutant and if these are found unmarked in the field other plants which are more resistant will also be unmarked. The most useful of these will be noted under each pollutant.

SULFUR DIOXIDE gas is released from the stacks of smelters and power plants. Normally injury to vegetation is seen within 35 miles of the source. Concentrations of 0.5 ppm for a few minutes will mark sensitive (indicator) plants like alfalfa, cotton, squash (melon family in general), okra, weeping willow, zinnia, cocklebur, or pigweed (Amaranthus). Mild injury, called the chlorotic phase, produces a yellowing of leaf tissues between the veins, whereas in the acute or cecrotic phase tissues are dead and either bleached or brown depending upon the host. The gas is converted into sulfate in about one day.

Predisposing conditions: Three conditions are necessary for plant injury: (1) high humidity, (2) sunlight, and (3) an injurious concentration of sulfur dioxide at ground level. No injury occurs in long rainless periods, or when humidity is low.

Tissues affected: The four or five recently matured leaves are most susceptible to injury by sulfur dioxide. Young immature leaves, old leaves, stems and blossoms escape injury except from massive doses of the pollutant.

Injury from sulfur dioxide may result in a slightly watersoaked appearance of leaf blades within an hour and other symptoms develop fully in three days. Normally no further spread of symptoms occurs. Acutely injured leaves may be shed later.

FLUORIDE INJURY may result from fluorine fumes emitted from industrial plants producing aluminum, steel, ceramics, and phosphorus chemicals and fertilizers. Fluorine gas enters through the leaves and is concentrated in the tips and margins which are killed and become bleached or brown. Fluorine is the only pollutant concentrated in this manner. Indicator plants are gladiolus, corn, pine (reddish-brown bands on needles), apricot, and European grape. The effects may be due to long exposure to low concentrations of fluoride.

The two other principal types of injury are due to the components of visible smog resulting from emissions from automobiles, trucks, planes, other forms of transportation, and industrial plants. The nitrogen oxides participate in photochemical reactions which produce ozone and peroxyacyl nitrates (PAN), two highly phytotoxic oxidants.

OZONE: Small stippled chlorotic or bronzed spots appear on the upper surface of leaves; and acute interveinal necrosis and bleaching may occur (e.g., in petunia). Indicator plants are spinach, bean, alfalfa, oats, apple and sycamore.

NITROGEN OXIDES: Concentrations are normally too low to produce visible symptoms, but experimentally produce stippling and necrotic areas on the upper leaf surface like those from ozone. Good indicator plants for nitrogen oxides are tobacco, lettuce and bean.

PAN (PEROXYACYL NITRATES): PAN causes a bronzing and glazing of the lower surface of leaves of beans, romaine and petunia. Stronger concentrations cause necrotic areas. The above-named plants and Swiss chard and oats are good indicators.

ARE YOU AN EXPERT? Now if you are sufficiently confused, there is one way to clarify a very difficult subject. A 1970 pictorial atlas, "Recognition of Air Pollution Injury to Vegetation," contains a concise and accurate text giving sources of pollutants, symptoms on plants, and tables of plant susceptibility for each pollutant. It also contains color photos of markings often confused with each type of air pollutant injury. The book is available from the publisher, Air Pollution Control Assn., Pittsburgh, Pa., for $15.00

WHAT TO DO ABOUT IT: Even with the book, you really do not know the diagnostic symptoms until you have seen the malady in the field. Many specimens submitted show injury due to disease or insect damage or some other nonparasitic cause and these must always be considered. Maybe more than one is present. Which is doing the damage?

Correct diagnosis of air-pollutant damage to plants is extremely difficult. Many other influences such as herbicide injury, insect damage, plant pathogens, nutritional imbalances and weather effects cause similar symptoms. It is advisable to rule out these possibilities before strongly considering air pollution as the causative factor of a particular problem.

The whole subject is a sensitive area, and perhaps should be left to the experts. It would be prudent to maintain your amateur standing, for if you become an "expert" you may be called to testify in court against well-qualified experts.

INJURY FROM LOW TEMPERATURES

The immediate effects of freezing temperatures on plants are usually easily recognized, but some of the delayed effects are not so well-known. The kind of cold injury depends upon the season when it occurs:

(1) FROST INJURY IN FALL: Early frost will catch plants and crops growing and succulent, and more easily injured by cold, especially if the fall weather has been unusually warm and has stimulated continued growth.

(2) MIDWINTER FREEZES: Citrus and tender subtropicals are injured when temperatures drop below 27 degrees F. for more than a short time. Deciduous fruit and shade trees when dormant will stand zero temperatures, but may have twigs and limbs injured by low, subzero temperatures. Pome and stone fruits may show delayed injury, the twigs or limbs dying in midsummer. Sections of the limbs show a "black heart" condition of the wood.

In our northern states where the soil freezes in winter, drying winds may dehydrate the needles of conifers and leaves of evergreens causing injury or death.

(3) SPRING FROSTS: Freezing temperatures, after new growth has started in the spring, may do moderate to severe damage to crops and ornamentals. Late frosts may kill the blooms and leaves of citrus, new shoots of grapes, and blooms of deciduous fruits, causing loss of all or part of the year's crop. Very light frosts may cause "frost bands" on pome and stone fruits--russet bands at blossom end or around middle of fruit with deformed growth and distorted leaves.

Freezing temperatures after a warm spell has started flow may cause the death of bark on the southwest side of the trunk of deciduous fruit and shade trees.

Very late frost, after deciduous fruits are the size of a golf ball or larger, may cause ice crystals to form in the outer layers of fruit. Numerous short cracks in the surface may follow frost injury. (Fig. 66) Deep penetration of frost will cause fruit to drop.

H E A T I N J U R Y

Heat injury is more prevalent in, but not limited to, the semiarid Southwest. Lack of adequate water predisposes to heat injury, as cooling of tissues by transpiration is minimized. Plant tissues may be injured when they are exposed to the afternoon sun with air temperatures of 100 to 110 degrees F. or above. The most heat is absorbed when the sun's rays are perpendicular to the plant surface being heated.

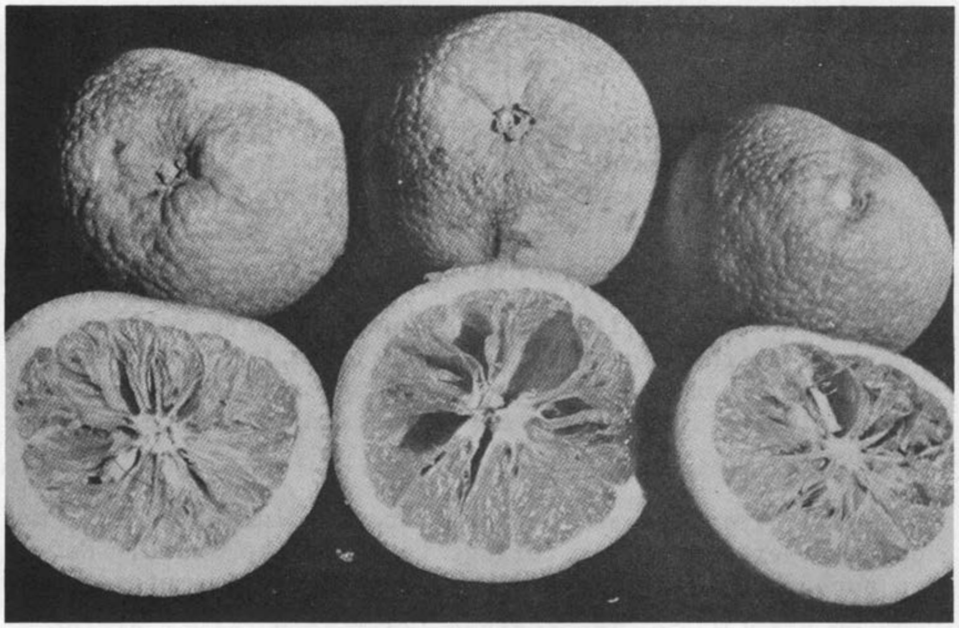


Fig. 65. Oranges picked from tree one month after freeze. Broken juice sacs have dried out. Note flattening of end fruits accompanying dehydration.

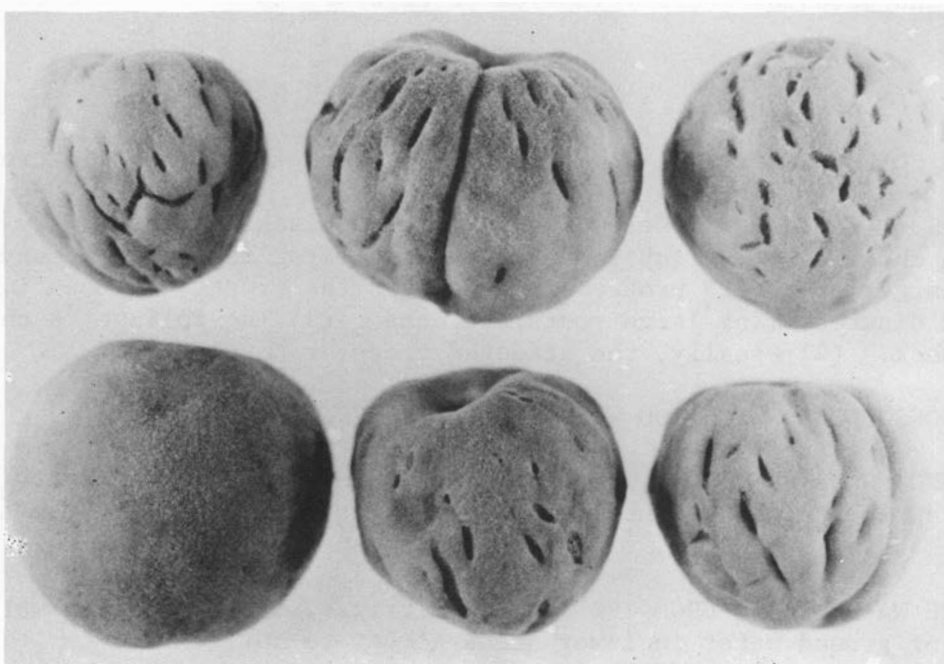


Fig. 66. Peaches stunted and with numerous surface cracks resulting from a very late frost when they were the size of golf balls. Edible but not marketable.

The following types of heat injury occur, depending upon the tissues affected:

SUNSCALD OF BARK: Smooth bark on the southwest side of trunk or branches may be injured or killed. The bark of young trees, tree roses, etc., especially if just planted, is very subject to injury. Old bark which has not been exposed to sunlight is also very subject to severe sunburn. Old plants of Japanese pittosporum and olive "hatracked" (defoliated) in midsummer lost all bark on the southwest side of each limb. The trees and shrubs were years recovering and not all of them lived.

Removal of trees may expose those left to sunscald.

SUNBURN OF FOLIAGE: In its milder form, sunburn causes yellow to orange spots with indefinite margins on the southwest side of citrus trees and many other plants. A more severe sunburn will cause drying and shedding of foliage. Trees or shrubs grown under lath and planted in full sun may show mild to severe drying of the foliage during the hot months.

SUNSCALD OF FRUIT: Tomatoes and peppers maturing in hot weather may suffer severe sunburn unless there is enough foliage to shade the fruit. Navel oranges (fruit) are often sunburned while quite young, but show no symptoms until the sunburned sides turn yellow just before normal coloring takes place.

HEAT CANKER OF SEEDLINGS: The surface (half inch) layer of the soil may reach 140 to 150 degrees F. which will kill tender plant tissues. Seedling flax, small nursery trees, and small plants of many kinds develop "heat canker," a zone of dead tissue at the soil surface which usually kills the plant. This may be confused with damping-off.

HEAT CHLOROSIS: Certain plants adapted to cooler climates, like geraniums, hydrangeas, and petunias, turn yellow under exposure to summer heat of 100 degrees F. or over.

E X C E S S   W A T E R

Excess water

TOO WET SOILS account for some puzzling cases of root rots in trees and shrubs.

SYMPTOMS: (1) The soil below the surface is black and has a gassy odor when the condition is chronic. (2) Tiny feeder roots die first from lack of oxygen; then larger and larger roots die progressively toward the trunk. By the time the tree shows marked distress many large roots are dead. (3) The foliage is thin with more or less dieback. (4) Finally, the affected trees or shrubs die.

CONDITIONS UNDER WHICH TOO WET SOILS HAVE BEEN FOUND:

(1) "HANGING WATER TABLE" where caliche, hardpan, or other impervious layers occur and drainage holes have not been dug and tested before planting trees or shrubs.

(2) HIGH WATER TABLE FROM IRRIGATION: Irrigation over shallow water table causes rise of ground water in lower areas almost to surface.

(3) HIGH WATER TABLE FROM RAINFALL OR STREAM-FLOW: Low spots become waterlogged from poor surface drainage.

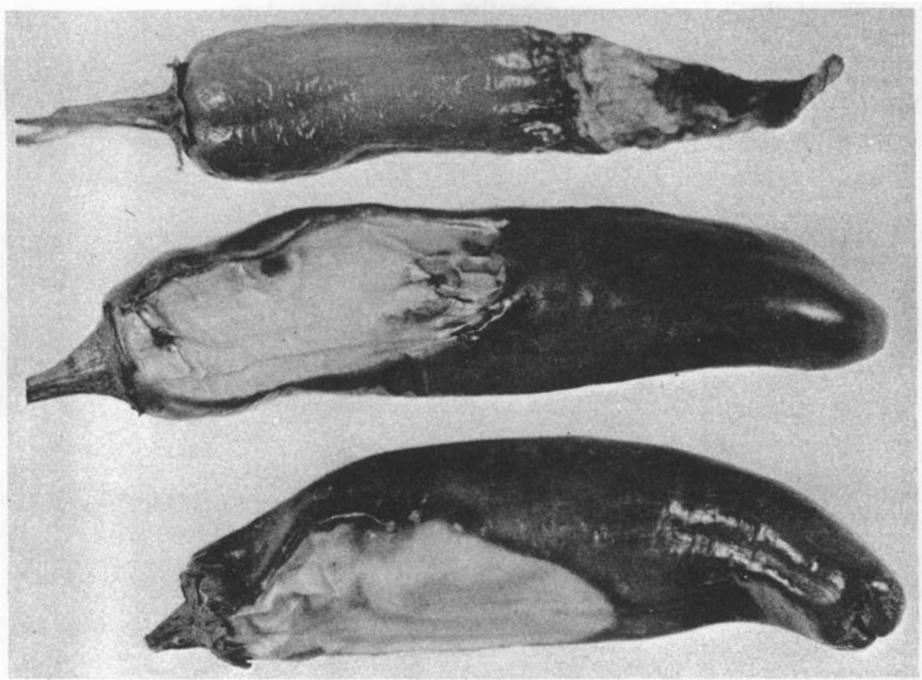


Fig. 67. Sunburn of chili pepper fruit. Tip rot of fruit at right caused by Rhizoctonia solani. Commonly occurs when fruit is in contact with moist soil.

(4) TOO LONG RUNS OF IRRIGATION WATER: May cause waterlogging of soil in tree holes with good drainage.

(5) DRAINAGE HOLE IN CONTAINERS CLOGGED: Plants were growing well in large clay pots, tubs, or other planters. The roots growing through drainage holes effectively sealed them, waterlogging the soil, and the plants died.

(6) COOLER DRAINAGE: Drainage hoses from evaporative coolers left in one spot for months, so overwatered trees and shrubs that they died.

Overly moist but not waterlogged soils, predispose roots to infection by Phytophthora spp., Verticillium or other moisture-loving organisms.

YELLOW LEAVES

Following the spring flush of new growth, many broadleafed evergreens (trees, shrubs, vines) usually show a few too many yellow leaves (some with reddish shadings). Note that the leaves affected are the older ones. Leaf shedding in citrus is conspicuous. Oleander, gardenia, camellia, azalea, Raphiolepsis and Cocculus are among those which develop yellow leaves which are slowly shed. Evergreens must eventually lose the older leaves, because of natural senescence so this is normal aging, not disease.

Heavily pruned deciduous trees, such as umbrella tree (Melia), cottonwood, and mulberry produce 4 to 8 feet of new growth during the summer, and the oldest leaves will turn yellow and are shed starting in late summer.

DROUGHT INJURY

Lush growth produced by heavy fertilization and irrigation suffers more severely from drought than plants grown with ordinary amounts of water.

SYMPTOMS: Lawns: Drought is easy to recognize in lawns, as grass in dry areas turns blue and the leaves roll. Clover and dichondra wilt badly when dry.

Vegetables: Symptoms may be indefinite. When water shortage is chronic, poor growth and color are evident. Plantings temporarily dry will wilt badly on hot afternoons - but root-knot nematodes and vascular wilts also cause wilting.

Shrubs: Small, pale leaves occur when water shortage is chronic. Afternoon wilting appears. Leaves of privets and some other shrubs turn bluish. If severe or prolonged, drought predisposes to sunburn and marginal drying. (Also caused by alkaline waters.) Drying or shedding of leaves indicates severe or prolonged drought or root rot.

Roses: All the above symptoms may occur. In chronic drought, poor growth and small leaves with irregular brown spots (not true black spot) occur on leaves.

Citrus: Leaves of tangerines, mandarins, and rough lemon roll upward when the soil is even slightly dry. In case of chronic water shortage, growth is poor, leaves small and pale, and fruit is small, sparse, and of poor quality. The trunks of stressed trees sunburn badly if exposed to the afternoon sun. Citrus trees, unwatered for months and looking very poorly, usually respond to a deep irrigation.

Pecan: Leaves of pecan are unique in that they dry out under severe drought without a preliminary wilt. Leaves of recently planted pecan trees often dry at the edges until the root system becomes established.

Shade Trees: The leaves of deciduous trees, especially box elder, European sycamore, and other trees adapted to a cool, more humid climate, show marginal drying or irregular dry areas in midsummer when grown in a hot, dry climate. If drought is prolonged, leaves dry and are shed.

L I G H T N I N G I N J U R Y

The suddenness of appearance of injury following an electrical storm distinguishes lightning injury.

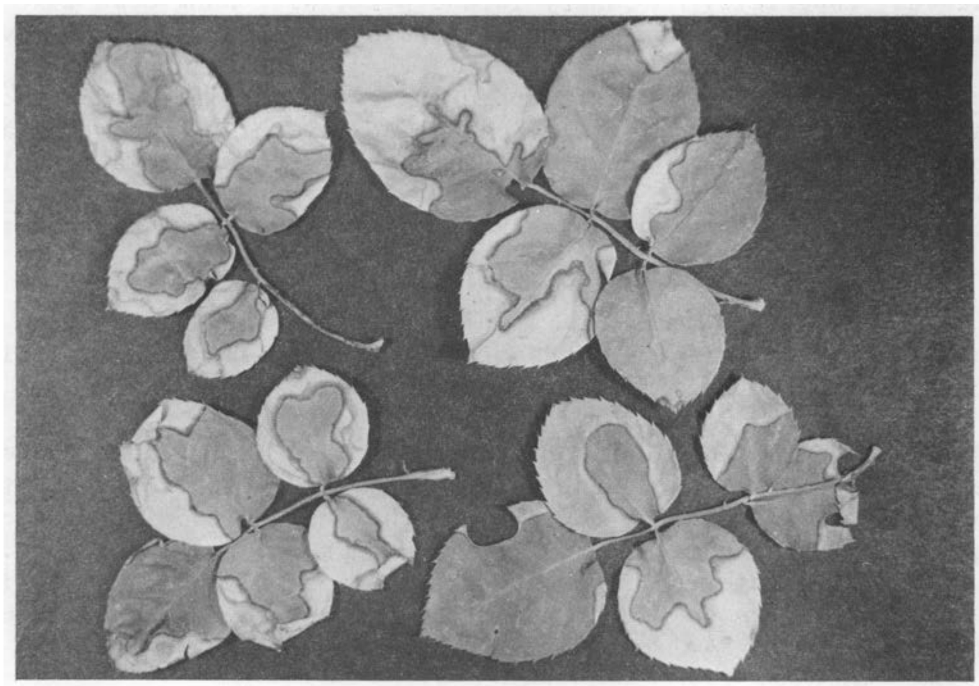


Fig. 68. Drought injury on rose leaves. Some herbicides produce similar symptoms.

Trees: Any tall or exposed forest or shade tree may be struck. Some are killed, others have a third to two-thirds of the top shattered; most show a streak down the side (often a deep groove) where the heat of the stroke turned the sap to steam and the wood exploded; many show scars but survive with little apparent injury.

Palms: Collapse of the crown foliage of large palms overnight following severe thundershowers is often due to lightning striking the palm, killing the terminal bud. Washington fan palms and Canary Island palms are most often struck. Following the stroke, the leaves, especially on Canary Island palm, will hang down like a partially closed umbrella. No disease of palms produces this flat-top appearance overnight.

Field Crops: Spots of dead plants appearing overnight in fields of cotton, potatoes, beans, or other field crops may be due to lightning. The tops and sometimes the roots of plants in the center of the spot are blackened and killed. Damage decreases toward the edges of the spot, especially on the roots. Surviving cotton plants may continue growth, but show streaks of dead tissue in the woody stems.

UNFAVORABLE SITES

Often when a planting fails, a study of the location shows that conditions are unfavorable to healthy growth. A few of the most common are:

(1) AREAS OF POOR SOIL IN FIELDS, ORCHARDS, LAWNS, ETC.: These are evident as spots or streaks varying from shorter plants and poorer yields to areas of bare ground. These are conspicuous from the air or other high viewpoint, and color photographs give the most accurate method of mapping such areas in detail. Most spots are sand and gravel areas and their fertility and water-holding capacity is inadequate. Some other soils are so "tight" that they do not take water and they resist root penetration.

(2) INADEQUATE GROWING SPACE FOR ROOT SYSTEMS: Root space is especially important in the case of large trees. Large fan palms making scant growth on the University of Arizona campus were moved in realigning a driveway. When excavated for moving, the root systems were confined to the original tree holes, 4' x 4' x 4', in solid caliche.* These large palms were reset in new holes, 8' x 8' x 6' and have made very good growth ever since (40 years).

Some citrus orchards have been planted on shallow soil, 18 to 24 inches to caliche, or in holes blasted in caliche at the 6 to 12 inch level. Those observed made poor growth and were abandoned.

Pecans are native to river bottom where soil is many feet deep and do not thrive in small holes in poor soil. They grow best in deep valley soils.

The following conditions are found mostly in ornamental plantings:

ROOT SYSTEMS SEALED AGAINST WATER AND AIR: Paving, sidewalks, curbs, or other material impervious to water and air inevitably cause decline of trees or shrubs whose root systems are covered. Large trees so treated will use all available water in the covered area and quickly or slowly decline and die.

*Caliche is a cemented layer high in calcium carbonate (limestone) of highly variable depth and texture which greatly restricts root penetration.

COMPACTION OF SOIL: Closely related to the paving, etc., over root areas is the compaction of surface soil frequently encountered on lawn areas or even unpaved paths where heavy traffic, especially on moist soil, has pounded the surface into a "pavement" impervious to water and air. This has become a real problem around schools and public buildings, in parks, playgrounds, and National Parks and Monuments.

GIRDLING ROOTS: Trees, shrubs, and houseplants started in small containers will develop some of the larger roots growing in a circle if held too long in the container. If these roots are not cut or freed when the tree, etc., is set in its permanent position, the circling root may girdle the trunk and later cause poor growth or even breakage of the taproot during a wind storm.

GIRDLING BY WIRES: Strong wires left in place on taproot or trunk will later become embedded in the trunk and cause poor growth or breakage of trunk in the wind.

LACK OF GROWING SPACE: Plants do not thrive if so crowded that both roots and tops lack room for healthy growth.

TOO MUCH SUN AND HEAT: Direct and reflected heat on the south or west walls of buildings will injure all but the most drought resistant plants.

CONSTRUCTION HAZARDS

PHYSICAL HAZARDS: When houses, apartments, schools, or commercial buildings are constructed on property where it is desired to save existing trees or shrubs, sturdy barriers are necessary to protect the trees, etc., from injury by trucks, piles of soil, or building material. Very often plants will be run over or buried under material or soil.

PHYSIOLOGICAL HAZARDS: Most prevalent is the partial--yes, often total--lack of water for the months of construction. Trees may survive where rainfall is adequate so they need not be watered, but in arid regions, palms and shade trees, especially pines, may become permanently stunted or die from lack of regular irrigation. Have someone (not the contractor) water them regularly.

CHANGE OF GRADE: When <u>cuts</u> of several feet are made in lowering the grade, trees may be left on a small mound, having suffered moderate to severe root pruning. Unless a retaining wall is built to restore a basin, it will not be possible to irrigate the trees adequately.

When <u>fills</u> of several feet are made and soil piled around the trunk without provision for aeration and water penetration into the root zone, trees may decline or die. A layer of coarse crushed rock or gravel spread on the surface and a wall around the trunk before adding the fill soil will usually protect the tree from bad effects of the additional soil. Tree wells of brick or cement block will admit water and air to the root system.

TRENCHES: Trenches dug for utility lines will cause severe root pruning if dug too close to large trees. Tunneling under, rather than severing, major lateral roots will avoid damage to trees and prevent windfall.

DRASTIC PRUNING: This often predisposes trees, etc., to poor growth, breakage by wind and infections by canker diseases and wood rots, in addition to spoiling the beauty of the tree.

Fig. 69. Root system of a young tree badly distorted by being grown too long in a small pot.

"Are you sure he knows about pruning?"

"Hatracking" or "dehorning" predesposes trees to wind-breakage and wood rots which spoil their beauty.

SYMPTOMS OF BACTERIAL DISEASE

Each branch of knowledge has its own vocabulary, and in the case of Plant Pathology an understanding of the terms used to describe the symptoms of plant diseases is very desirable as it makes unnecessary the use of lengthy popular or technical descriptions.

A few bacteria stimulate the host to form Bacterial Galls, usually on the crown or roots of woody plants. The classical example is the Crown Gall of pome and stone fruits which also attacks some 200 other species of woody plants including many ornamentals. The bacteria may be cultured from the outer layers of new and growing galls and their pathogenicity checked by inoculating into tender growing stems of tomato or leaves of a succulent (Kalanchoë) which form galls quickly. Other gall forms cause bacterial galls on olive, oleander, ash, and forest trees.

Other bacteria invade primarily the vascular tissues causing the Vascular Bacterial wilts. These bacteria are usually specialized as to the hosts they invade--melon family, tomato, potato, bean, corn, etc. Some others start in the vascular tissues but soon cause a rot of the adjoining tissues.

Bacteria also cause a Bacterial Slime-flux or Wetwood of elms and other trees. The causal organism *Erwinia nimi-pressuralis* is a gas former and the invaded heartwood developes a liquid under pressure that may be released and flow down the trunk. Other bacteria and yeasts develop in the flux and cause an offensive odor, but are not the cause. See paragraph discussing the Bacterial soft-rots as a group on page 6-7.

Firm Rots resembling both leaf spots and cankers or blights: the bacteria in this case cause limited areas of dead tissues on leaves, stems, fruits, corms, bulbs, etc. Lesions are watersoaked when young, but often dry and harden later.

Bacterial blighting of blossoms, fruit spurs, and new twigs commonly occur at and following the season of blossoming and rapid spring growth. The infected tissues die and become light to very dark brown depending on the host plant. The infection usually is checked by midsummer and there is a sharp line between the living and dead tissues. Fire Blight is best known on pear and apple but occurs on many other members of the rose family including stone fruits and ornamentals such as loquat, cotoneaster, pyracantha, and Photinia.

The more damaging phase of Fire Blight is the invasion of the cambium region of small to large branches and the trunk of the tree. The bacteria usually enter the branch or trunk from twigs, fruit spurs, or water sprouts and the invaded cambium becomes a light brown. Following death of the cambium cells the bark dries and hardens and shrinks with often a definite crack at the edge of the dead bark. Branches whose cambium is girdled quickly dry out and are very conspicuous. A girdle of the trunk kills the top of the tree. The bacteria often overwinter in the cambium of the cankered branches and may produce a bacterial exudate in the spring, which is spread to the blossoms, etc., by moisture and insects.

Similarly Bacterial Leaf spots have certain characteristics in common. They are at first translucent, becoming dark and opaque with age. Under high humidity the organism may exude droplets of a bacterial slime which may dry to tiny droplets if undisturbed, or be spread by moisture and dry down as an extremely thin whitish membrane. The spots on leaf blades often are angular, being limited by small veins. On stems or fruits, spots may be small or large--at first translucent, then darker, but usually round or elongated, not angular. (Fig. 72)

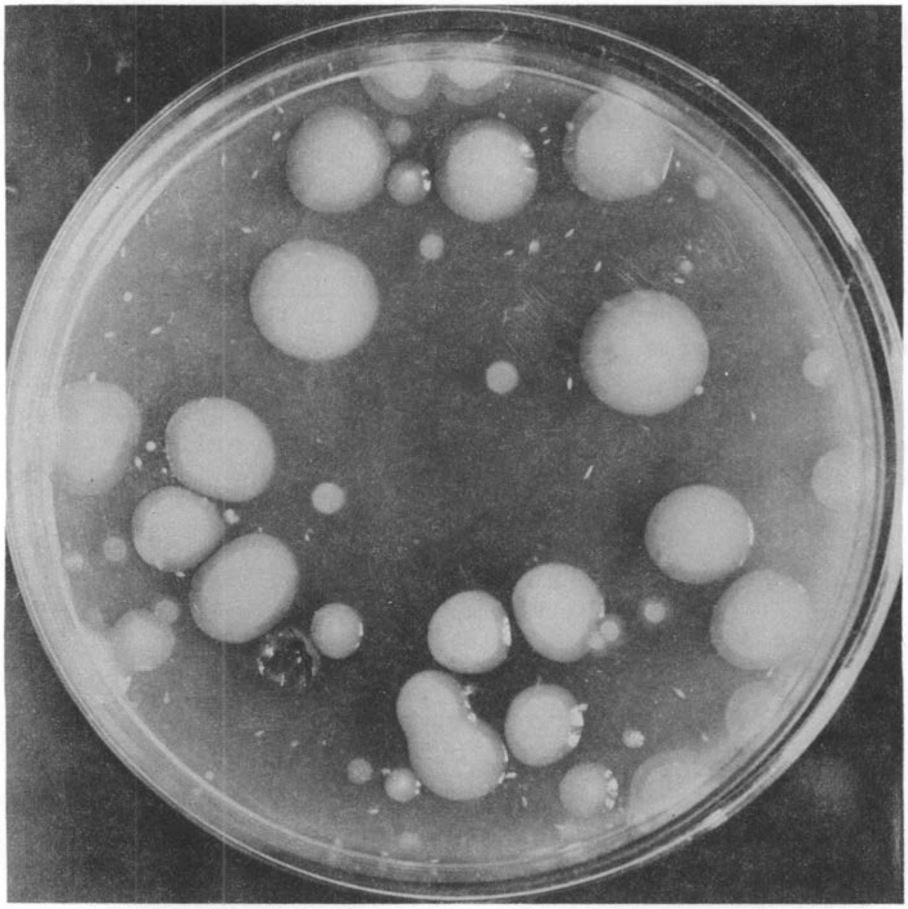


Fig. 70. Bacterial colonies on agar medium in Petri plate. Isolated from diseased plant. X 1.2.

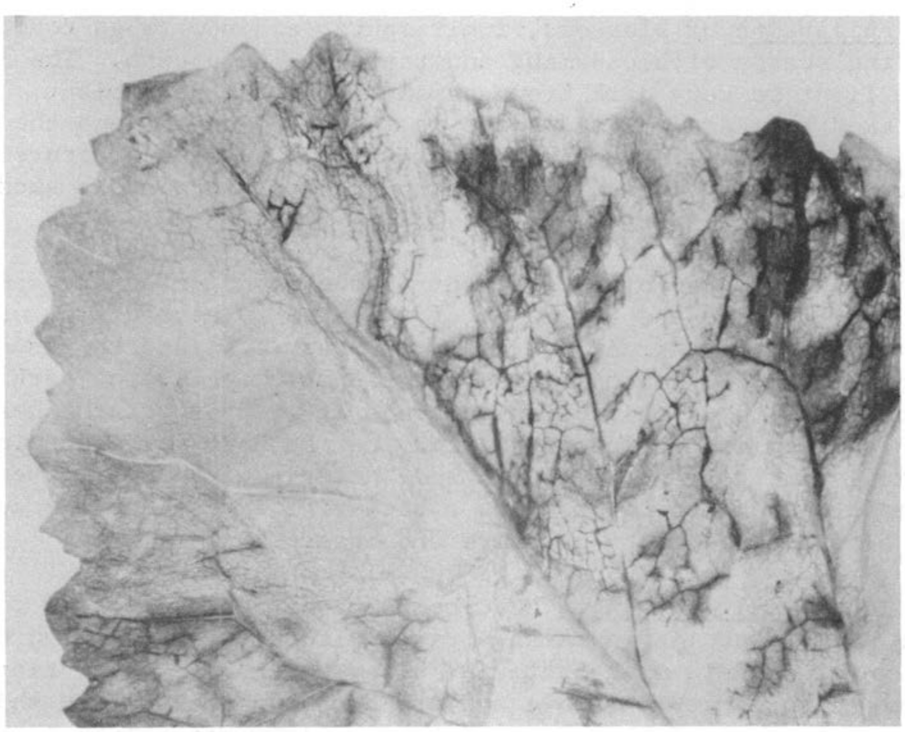


Fig. 71. Veins of cabbage leaf infected through water pores on margin of leaf and blackening veins as infection spreads into vascular bundles of main stem. X 1/2.

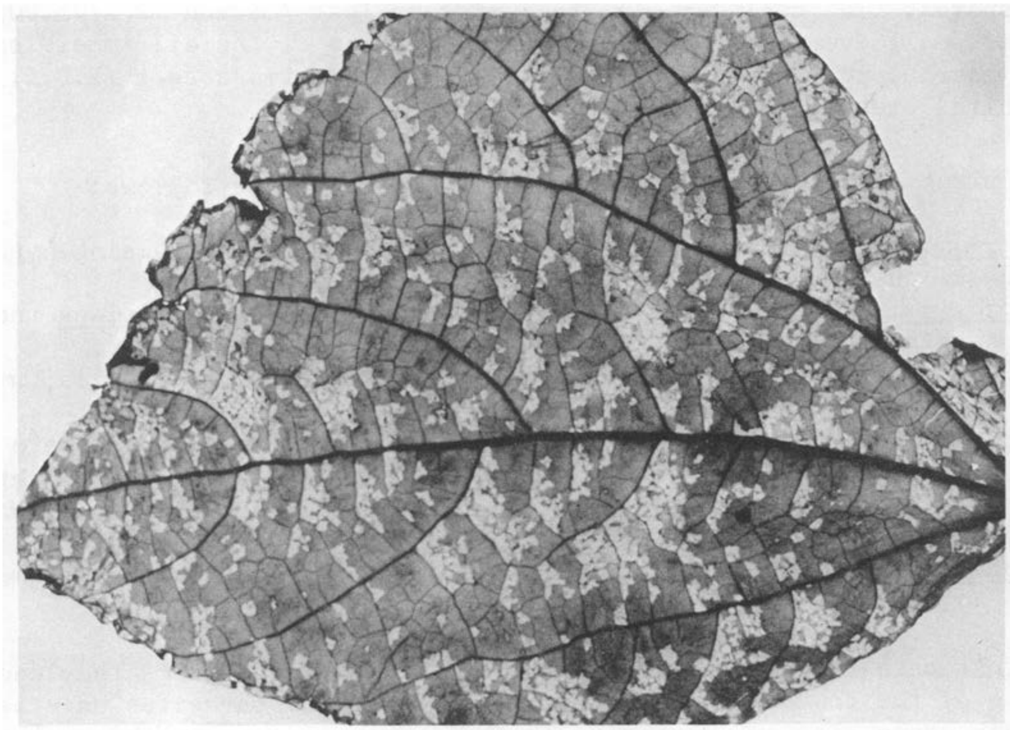


Fig. 72. Bean leaflet photographed against the light to show numerous small, angular, translucent "windows" typical of very young bacterial infections. X 3.

An interesting variation is the Bacterial Pustules which form tiny (1 to 2 mm.), corky raised spots on the under surface of leaves and on fruits of tomato, pepper, soybean, etc. Heavily infected leaves yellow and are prematurely shed. (Fig. 73)

BACTERIAL DISEASES

There are some 200 described species of bacteria parasitic on plants, many of them on host plants of minor importance. They are rod-shaped, many of them motile by polar or peritrichous flagella (occurring on sides as well as ends of cells) and form no spores. The cells are 1.5 to 3 microns long (micron is 1/25,000 of an inch) and appear small even under the 1000X magnification of the oil-immersion lens of a compound microscope. They grow readily on potato dextrose agar (P.D.A.), forming round, white, cream or yellow colonies.

Plant parasitic genera

The plant parasitic species are all in six genera as follows:

Agrobacterium: short rods, motile, peritrichiate flagella, causing hypertrophies or galls on roots or stems of plants.
Corynebacterium: slender rods, non-motile (except C. flaccumfaciens and C. poinsettiae). Producing a variety of symptoms, mostly wilts.
Erwinia: Motile rods (peritrichiate); producing dry necroses, galls, wilts, and soft rots.
Pseudomonas: rods, motile with polar flagella. Many species produce a greenish, water-soluble pigment in culture. They cause leaf spots and blights.
Xanthomonas: small rods, motile, single-polar flagellum. Slimy yellow colonies. They cause necroses (leaf spots and blights).
Streptomyces: the mycelium is very fine (2/3 micron), and spiral filaments segment into cylindrical spores of bacterial size (1 to 2 microns).

In most cases identification can be made from the symptoms they cause on plants. Fifty-five of the common and important bacterial plant parasites have been listed below under seven classes, depending on the major symptoms on the host plants.

I. PRIMARY SYMPTOMS GALLS OR FASCIATIONS

Gall formers

A few bacteria stimulate the host to form Bacterial Galls, usually on the crown or roots of woody plants. The classical example is the Crown Gall of pome and stone fruits which also attacks some 200 other species of woody plants including many ornamentals. The bacteria may be cultured from the outer layers of new and growing galls and their pathogenicity checked by inoculating into tender growing stems of tomato or leaves of a succulent (Kalanchoë) which form galls quickly (in 1 to 2 weeks in growing tissues). Other gall formers cause bacterial galls on olive, oleander, ash, nut, and forest trees.

Agrobacterium tumefaciens: CROWN GALL. Galls on roots, trunks, or stems.

Agrobacterium rhizogenes: HAIRY ROOT. Proliferation of roots with or without some gall tissue.

Agrobacterium rubi: CANE GALL. Galls on fruiting canes of blackberries and raspberries.

Pseudomonas tonelliana: OLEANDER GALL. Galls on canes, leaves, and flowers of oleander.

Pseudomonas savastanoi: OLIVE KNOT. Galls on roots of olive and ash, and on twigs of olive.

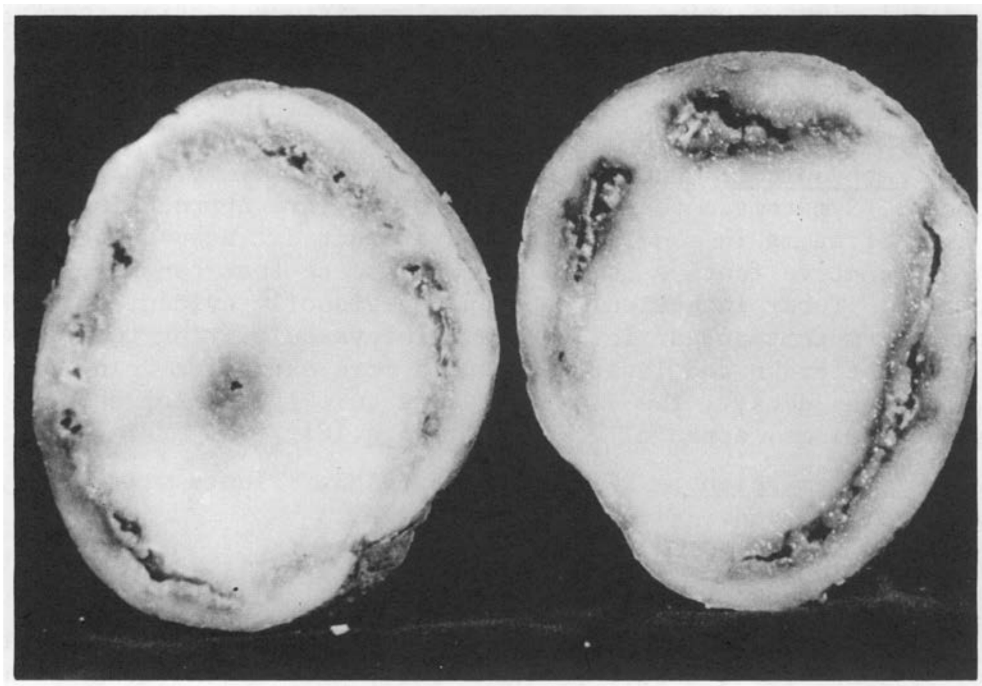


Fig. 73. "Cheesy rot" typical of advanced stage of potato ring rot (C. sepedonicum). X 1.

Corynebacterium faciens: FASCIATION. On stems of sweet peas, chrysanthemums, and other flowers.

Xanthomonas beticola: BACTERIAL POCKET. Galls with bacterial pockets on crown of beet and sugarbeet roots.

II. PRIMARY INVASION IN VASCULAR SYSTEM, PRODUCES WILTS

Other bacteria invade primarily the vascular tissues causing the Vascular Bacterial wilts. These bacteria are usually specialized as to the hosts they invade--melon family, tomato, potato, bean, corn, etc. Some others start in the vascular tissues but soon cause a rot of the adjoining tissues (ring rot).

Vascular wilts

Corynebacterium sepedonicum: BACT. RING ROT OF POTATO. Very destructive in field and storage. Symptoms appear late, when plants are approaching maturity. One or more of stems in a hill wilt or are stunted. Base of stem shows soft rot. A distinctive feature is the creamy exudate that can be pressed from the cut stem. Tuber infection is often not visually evident at first, but distinctive symptoms appear in storage. The vascular ring turns creamy yellow to light brown and later develops a more extensive "ring" of a cheesy, odorless decay. The decayed tubers quickly develop a bad odor from secondary organisms, especially E. carotovora. (Fig. 74)

Corynebacterium flaccumfaciens: BACT. WILT OF BEANS. Plants wilt at any stage. Bacteria on or in seed. Plants often stunted.

Corynebacterium michiganense: BACT. WILT OF TOMATO. Seedlings remain stunted. Margins of lower leaflets wilt and dry. Small bird's eye lesions on fruit.

Pseudomonas caryophylli: BACT. WILT OF CARNATIONS. Mostly in greenhouses. Plants wilt and dry, and roots decay. Foliage first gray-green, soon turns yellow and dies. Yellow streaks in vascular tissue of stem.

Pseudomonas solanacearum: SOUTHERN BACTERIAL WILT. Causing wilt disease in many vegetables and ornamentals. Major symptoms: dwarfing or sudden wilting, brown vascular bundles and streaks in stem. Sometimes a soft brown rot in stems of potatoes and tomatoes and brown ring and rot in tubers.

Corynebacterium insidiosum: BACT. WILT OF ALFALFA. Causes yellowing and stunting of top; when bark of taproot is pealed, wood shows in early stages brown streaks, later merging to solid yellow-brown in woody cylinder.

Erwinia tracheiphila: BACT. WILT OF CUCURBITS. Vascular wound disease spread by cucumber beetles. Sudden wilting and dying of vines. (Not on watermelon.)

Xanthomonas campestris: BLACK ROT OF CRUCIFERS. Bacteria invade leaves through water pores or wounds and spread through vascular bundles. Cross section of stem shows black vascular ring. Cross section of petiole shows black plugged xylem bundles. Causes death or defoliation. (Fig. 70, Fig. 71)

Xanthomonas incanae: BACT. BLIGHT OF STOCKS. Seedlings suddenly wilt, may die. Dark stem lesions on older plants, entire vascular system often discolored.

Xanthomonas stewartii: BACT. WILT OF CORN. Plants dwarfed, nodes browned, long, pale-green streaks on leaves. Yellow slime in vascular bundles.

III. PRIMARY SYMPTOM BLEEDING (SLIME FLUX)

Bacteria also cause a Bacterial Slime-flux or Wetwood of elms and other trees. The causal organism *Erwinia nimi-pressuralis* is a gas former and the invaded heartwood developes a liquid under pressure that may be released and flow down the trunk. Other bacteria and yeasts develop in the flux and cause an offensive odor, but are not the cause of the disease.

Bleeding

Erwinia nimi-pressuralis: WETWOOD OF ELM, ETC. Heartwood of many trees, including elm, mulberry, maple, oak, poplar, and willow, becomes dark and watersoaked with chronic or intermittent bleeding at wounds or crotches. Bacteria cause abnormal sap pressure. Secondary bacteria and yeasts in slime flux on the surface cause a bad odor.

IV. PRIMARY SYMPTOM SOFT ROT

When we understand that Bacterial soft-rot describes a TYPE of disease in which a bacterial organism dissolves the "cement" which holds the cells together and the tissues collapse into a watery slime, we need no further description. Also from a knowledge of the classical type of bacterial soft rot caused by *Erwinia carotovora* we know the type of control measures effective for other soft rots. Soft rots occur on most succulent vegetables, iris rhizomes, giant cactus, and many other plants. The organism may not be *E. carotovora*, but the syndrome is the same.

Soft rots

Erwinia carotovora: SOFT ROT OF VEGETABLES: The most common of a group of very similar soft rots, occurring on many vegetables in the field, in storage and in transit, and on a great variety of ornamentals including foliage plants. Infection is through wounds causing a rapid wet rot with an offensive odor. Bacterial enzymes dissolve the layer cementing the plant cells together causing a fluid, mushy rot.

QUICK TEST: Streak on freshly poured petri plates of sodium polypectate medium. *E. carotovora* will liquefy medium in 24 to 48 hours.

Erwinia aroideae: SOFT ROT OF CALLA. Also causes a soft rot of many vegetables and ornamentals, including bulbs, cucurbits, and cacti. Typical soft rot.

Erwinia dissolvens: BACT. STALK ROT OF CORN. Most destructive as a soft rot of basal nodes of stalk, resulting in breakage and death of stalk.

Erwinia atroseptica: POTATO BLACKLEG. Lower leaves yellow, growth upright. Stem below ground blackened and rotted, tubers infected through stem end.

Erwinia phytopthora (--*atroseptica*): BLACK LEG OF DELPHINIUM. Soft black discoloration at base of stem with bacterial oozing from cracks. Elliott includes this under *E. atroseptica*.

Erwinia carnegiana: BACT. NECROSIS OF GIANT CACTUS. Lesions at first small, circular, or oval, blackening the watermelon-like tissues of the cactus. Extensive rotted areas exude a coffee-brown liquid. At this stage the host cannot be saved as decay is too extensive.

(It is not essential to identify the specific bacterial soft rot present in order to suggest control measures--except ring rot of potato where drastic control measures are necessary.)

V. PRIMARY SYMPTOM FIRM ROTS

Firm Rots resembling both leaf spots and cankers or blights: The bacteria in this case cause limited areas of dead tissues on leaves, stems, fruits, corms, bulbs, etc. Lesions are watersoaked when young, but often dry and harden later.

Firm rots

Erwinia cypripedii: BROWN ROT OF ORCHIDS. Small, watersoaked, greasy light brown spots, becoming dark brown and sunken. Affected crown shrivel and leaves drop.

Pseudomonas cattleyae: BROWN SPOT OF ORCHIDS. Dark green, circular, watersoaked spots becoming brown to black.

Pseudomonas syringae: BLACK PITS OF CITRUS. CITRUS BLAST. Dark, sunken spots on rind of citrus, chiefly lemon; no decay.

Pseudomonas marginalis: GLADIOLUS SCAB. Tiny, raised reddish leaf spots near base of leaves enlarge to dark coalescing lesions of firm or soft rot. Young lesions on corms are watersoaked, pale yellow. On mature corms lesions are dark brown, sunken with a raised edge.

Xanthomonas citri: CITRUS CANKER. Forms medium brown corky spots on leaves and fruit. This serious disease was eradicated in Florida and the Gulf States. You will not see it in the U.S. unless reintroduced.

Xanthomonas hyacinthi: HYACINTH YELLOWS. Badly affected bulbs produce no flowers and have yellow to brown streaks on leaves. Cross section of bulb reveals slimy yellow ooze.

Xanthomonas vesicatoria: BACTERIAL SPOT OF TOMATO AND PEPPER. BACT. PUSTULE. Tiny, slightly raised angular spots on leaves, often with yellow halo cause leaves to shed. Similar small spots may occur on fruit.

VI. PRIMARY SYMPTOMS BLIGHTS AND CANKERS

(Typically necroses of various parts: leaves, twigs, branches, flowers, fruit.)

Blights and cankers

Symptoms of the well-known FIRE BLIGHT caused by Erwinia amylovora are typical of this group.

Bacterial blighting of blossoms, fruit spurs, and new twigs commonly occurs at and following the season of blossoming and rapid spring growth. The infected tissues die and become light to very dark brown depending on the host plant. The infection usually is checked by midsummer and there is a sharp line between the living and dead tissues. FIRE BLIGHT is best known on pear and apple but occurs on many other members of the rose family including stone fruits and ornamentals such as loquat, cotoneaster, pyracantha, and Photinia.

The more damaging phase of FIRE BLIGHT is the invasion of the cambium region of small to large branches and the trunk of the tree. The bacteria usually enter the branch or trunk from twigs, fruit spurs, or water sprouts and the invaded cambium becomes a light brown. Following death of the cambium cells, the bark dries and hardens and shrinks, often with a definite crack at the edge of the dead bark. Branches whose cambium is girdled quickly dry out and are very conspicuous. A girdle of the trunk kills the top of the tree. The bacteria often overwinter in the cambium of the cankered branches and may produce a bacterial exudate in the spring, which is spread to the blossoms, etc., by moisture and insects. Lesions on leaves, stems or fruits of herbaceous plants often exude droplets of exudate. When spread by moisture it forms a very thin film.

ON WOODY PLANTS

Erwinia amylovora: FIRE BLIGHT. On various pome and stone fruit and ornamentals. Overwintering cankers on medium and large branches show bacterial exudate spread by water and insects to blossoms and new growth, causing blossom and twig blight (necrosis). Cambium darkened and infected in advance of death of bark.

Pseudomonas syringae: BACTERIAL CANKER OF STONE FRUITS. Similar to fire blight with two important differences: (1) Infection active during winter and early spring months, becoming quiescent during summer. (2) Usually accompanied by moderate to copious flow of gum from cankered areas.

Xanthomonas juglandis: BACT. BLIGHT OF WALNUT. Necrotic black lesions on catkins, young and full-grown nuts, blight of twigs and green shoots. English, black walnut, and butternut attacked.

Pseudomonas mori: BACT. BLIGHT OF MULBERRY. Numerous watersoaked spots coalescing and distorting leaves, becoming brown to black with yellow margin. Dark streaks with exudate on young twigs. Trees stunted.

Xanthomonas pruni: BACT. SPOT AND CANKER OF STONE FRUITS. Numerous small, reddish spots turning brown, and a tissue dropping out leaving shotholes, causing defoliation if severe. Twig lesions dark and sunken. Fruit lesions dry, sunken with gummy, yellow exudate.

ON HERBACEOUS PLANTS

Pseudomonas glycinea: BACT. BLIGHT OF SOYBEAN. Small, angular, translucent leaf spots, reddish brown to nearly black with age. Often a whitish film of dry exudate on under surface. Lesions on stems and petioles black. Pod lesions at first water-soaked, then dark, with exudate. Seeds often infected. Very common on soybean.

Pseudomonas phaseolicola: HALO BLIGHT OF BEAN. Leaf spots like the other bean blights, except that they have a wide green or yellow-green halo around the water-soaked spots, which later turn brown and dry. Pod spots are red to brown with silvery dried exudate. All snap beans are susceptible, but many dry beans are resistant.

Xanthomonas phaseoli: COMMON BACT. BEAN BLIGHT. Leaf spots are first very small, angular, watersoaked, and light green, enlarging and drying; tan with a yellow border. Stem lesions may predispose to wind breakage. Pod lesions water-soaked, dark green, becoming dry, sunken, reddish, encrusted with dried bacterial ooze. Seed lesions tan to gray. (Fig. 76)

Xanthomonas malvacearum: ANGULAR LEAF SPOT OF COTTON, BLACK ARM. Young leaf spots water-soaked, light green by transmitted light, dark green by transmitted light, becoming dark. Angular and separate, or spreading along main veins. Stem lesions becoming large and black. Boll lesions at first water-soaked and green, becoming dark. (Fig. 77, Fig. 78)

Pseudomonas pisi: BACT. BLIGHT OF PEA. Dark green, watersoaked leaf spots enlarge, becoming dry and russet brown. Stem lesions similar. Flowers and young pods blighted. Veins infected when young usually die.

Xanthomonas carotae: BACT. BLIGHT OF CARROT. Irregular brown spots on leaves and petioles. Flower heads grown for seed may be killed.

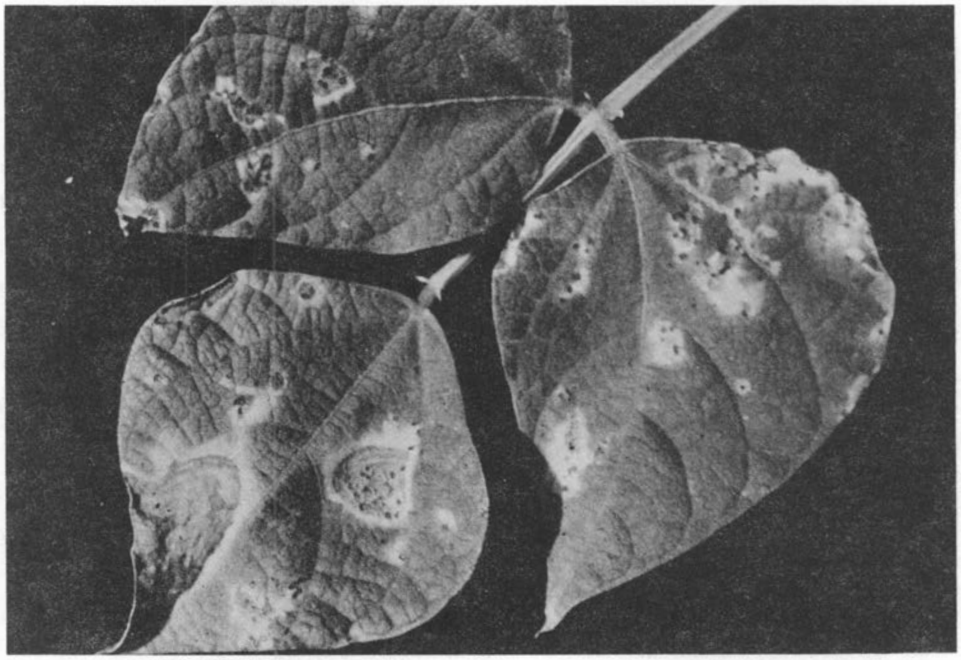


Fig. 74. Leaf of pinto bean showing yellow halos surrounding water-soaked green and dry brown lesions of bacterial halo blight.

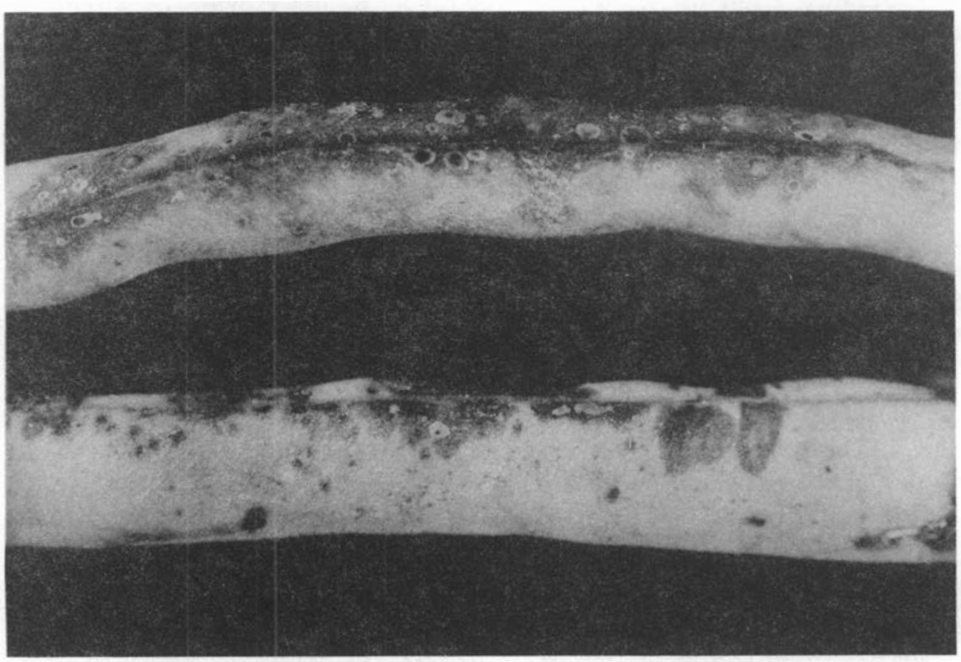


Fig. 75. Bacterial blight on pods of snap beans, showing water-soaked lesions and dried drops of bacterial exudate.

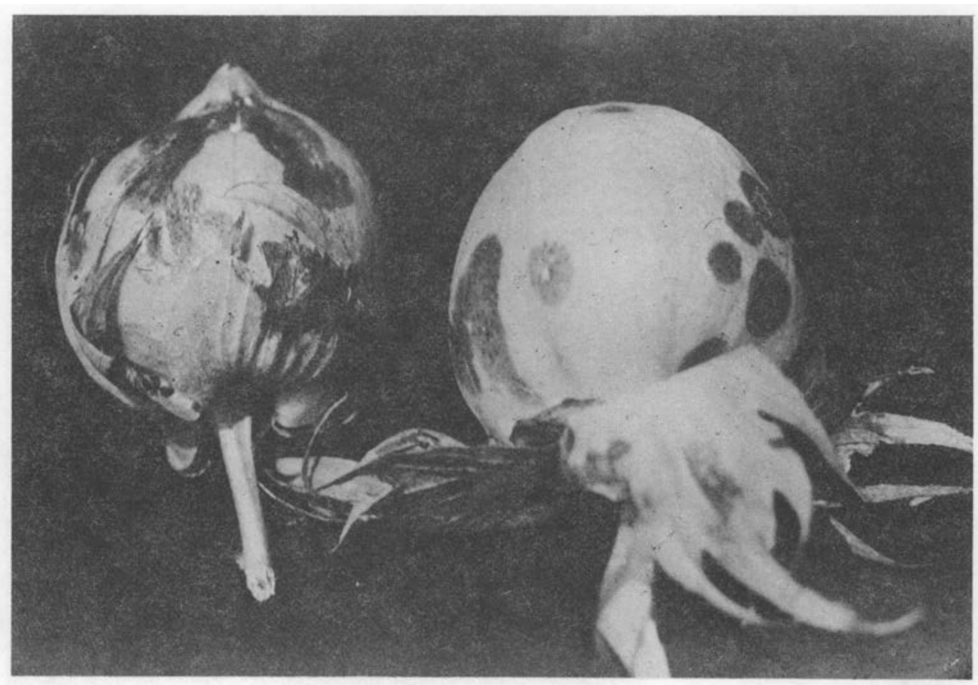


Fig. 76. Water-soaked green lesions of angular leaf spot on bracts and bolls of cotton.

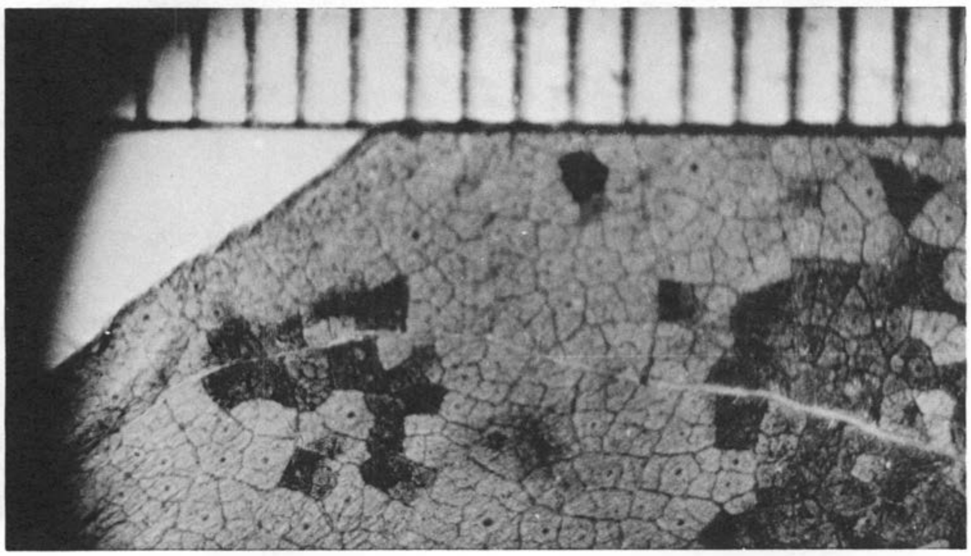


Fig. 77. Angular leaf spot of cotton. Young-water-soaked lesions (dark) and older brown necrotic lesions. X 10.

VII. PRINCIPAL SYMPTOM LEAF SPOTS

Similarly Bacterial Leaf spots have certain characteristics in common. They are at first translucent, becoming dark and opaque with age. Under high humidity the organism may exude droplets of a bacterial slime which may dry to tiny droplets if undisturbed, or be spread by moisture and dry down as an extremely thin whitish membrane. The spots on leaf blades are often angular, being limited by small veins. On stems or fruits, spots may be small or large; at first translucent, then darker, but usually round or elongated, not angular.

An interesting variation is the Bacterial Pustule which forms tiny (1 to 2 mm.), corky raised spots on the under surface of leaves and on fruits of tomato, pepper, soybean, etc. Heavily infected leaves yellow and are prematurely shed.

Pseudomonas andropogonis: BACT. STRIPE OF SORGHUM AND CORN. Red streaks and blotches on leaves and sheaths. Red crusts of dried exudate, readily washed off by rain.

Xanthomonas holcicola: BACT. STREAK OF SORGHUM AND CORN. Very similar to above.

Pseudomonas apii: BACT. BLIGHT OF CELERY. Small, irregular rusty leaf spots occasionally defoliating. Margin of lesions usually darker.

Pseudomonas delphinii: DELPHINIUM BLACK SPOT. Irregular black spots on all aerial parts. Spots frequently coalesce.

Pseudomonas lacrymans: ANGULAR LEAF SPOT OF CUCURBITS. The irregular, water-soaked, angular spots produce an exudate that dries down to a whitish film. Old lesions are gray, brittle, and shot-hole may occur. Small round, whitish spots may occur on fruit.

Pseudomonas tabaci: TOBACCO WILDFIRE. Also attacks other Solanaceae and soybeans and cowpeas. Leaf spots have tan to brown center and a yellow halo.

Pseudomonas washingtoniae: BACT. LEAFSPOT OF PALM. Numerous small translucent leaf spots, light green by transmitted light. Later become opaque.

Xanthomonas begoniae: BACT. LEAF AND STEM BLIGHT OF BEGONIA. Blister-like brown spots with yellow translucent margins on leaves; causing premature shedding of leaves. When stems are invaded, plants may die.

Xanthomonas phaseoli var. *sojense*: BACT. PUSTULE OF SOYBEAN. Principally a foliage disease. Small yellow-green spots with reddish brown centers. A small raised pustule on under surface of leaf.

VIII. PRIMARY SYMPTOM SCABS OR PITS

Order ACTINOMYCETALES Fam. Streptomycetaceae

STREPTOMYCES (*Actinomyces*): A genus with mycelium placed in a separate order of bacteria in Bergey's Manual. The mycelium is very fine (2/3 micron) and spiral filaments segment into cylindrical spores of bacterial size (1 to 2 microns long). The mycelium is difficult to see in section and difficult to isolate.

S. scabies causes COMMON SCAB of potato, beet, and other root crops. It causes corky lesions on tubers, stolons, and roots. Lesions on tubers may be shallow or deep--"pitted scab." Tuber symptoms are usually sufficient for diagnosis. Do not confuse with powdery-scab (*Spongospora*).

S. ipomoea: Causes SOIL ROT or POX of sweet potato. Leaves of infected plants are small, pale, and the stems stunted. Feeding roots are few and deformed. Deep pits up to one inch in length occur on the tubers. Diagnose by symptoms.

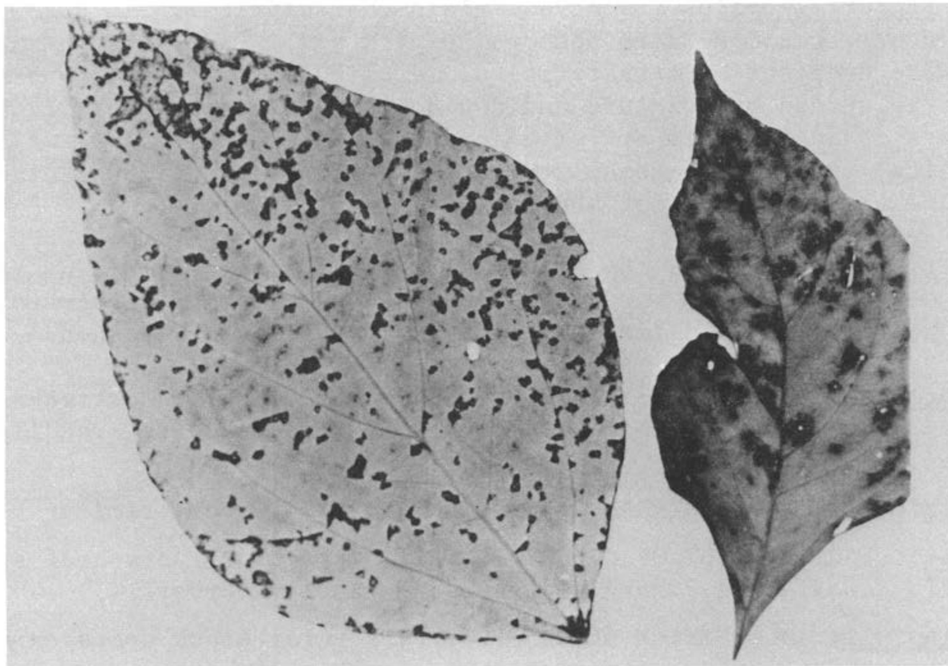


Fig. 78. Bacterial pustule of soybean and pepper, caused by different species of Xanthomonas.

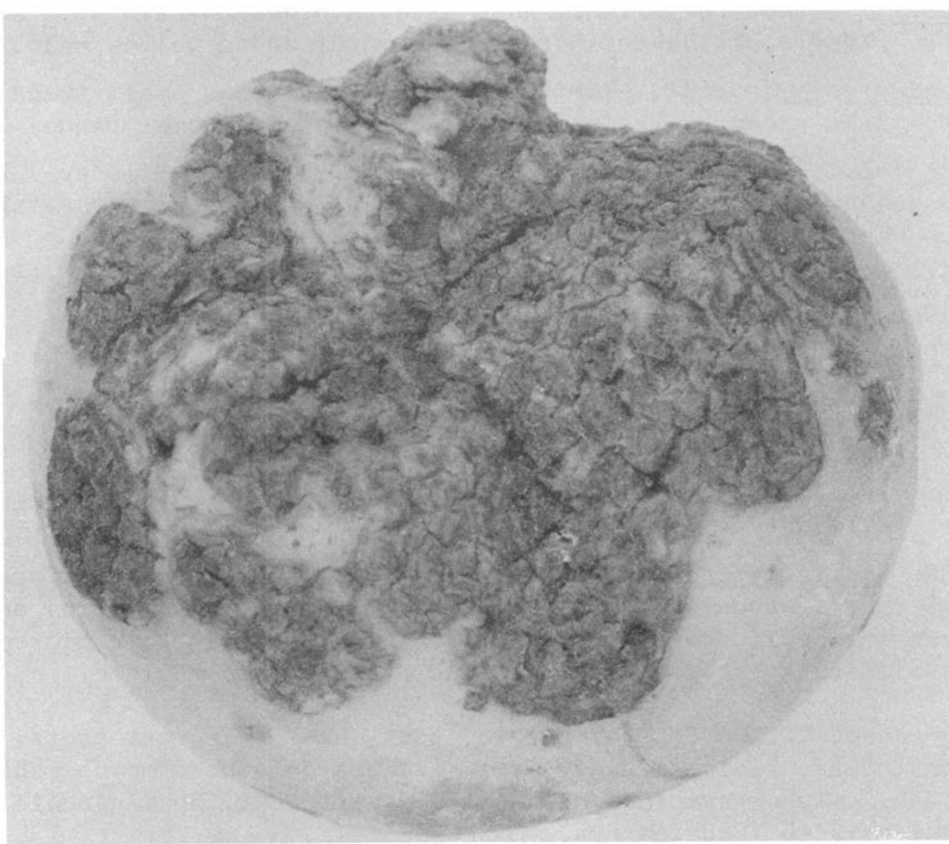


Fig. 79. Common scab on potato consists of corky slightly raised lesions on the potato tubers. X 1.

PLANT NEMATODES

The prevalence and extent of injury by plant parasitic nematodes, other than the root-knot nematodes, was not generally realized until 1950. As most of the two dozen genera which feed on plants produce no galls or conspicuous above ground symptoms, the damage they cause was not attributed to them although the host plants were retarded in growth. The principal symptoms produced by the non-gall formers are:

(1) Root lesions, pin-head size at first, may involve whole root.

(2) Root rot, by secondary organisms following nematode injury.

(3) Excessive root branching, numerous short laterals following injury.

(4) Injured root tips, stunted and swollen as in stubby root.

(5) Leaf, stem, and flower damage, distorted leaves and stems from above-ground feeders.

(6) Some nematodes attacking grains and grasses cause galls to form in place of seed.

(7) Devitalized plants, stunting, abnormal wilting, yellowing, and poor quality of produce is prevalent but often hard to evaluate and distinguish from other causes of poor growth.

Symptoms

NEMATODES

It is important that nematode infestation be accurately diagnosed as nematodes are so easily spread on plant roots, rhizomes, bulbs, and in infested soil that the owners should be alerted promptly of the danger of spreading the infestation.

DIAGNOSIS OF NEMATODE INJURY

TYPES OF ROOT-KNOT GALLS: There are several different types, depending upon the host plants attacked. (This is an artificial classification to aid in recognition.) See Fig. 82.

Types of nematode galls

Type 1: Relatively large, spherical galls - Succulent, rapid-growing crops such as tomatoes, melons, squashes, beans, gourds, and dahlias often develop roughly spherical galls (to 1/2" or more in diameter). When these galls are numerous on the tap root it becomes greatly swollen and distorted, with smaller galls on the lateral roots. These galls are succulent and soon decay and frequently teem with the tiny pearl-like females, visible to the naked eye--better seen with a hand lens. This is the most common type of root-knot gall.

Type 2: Hard, dark-colored, woody galls, large on some hosts - Very susceptible woody plants such as fig, peach, and some ornamentals (such as pepper tree) show large swellings variable in shape which might be confused with crown gall, except that they extend along the root instead of being roughly spherical, and are accompanied by many smaller galls.

Type 3: Very small spindle-shaped galls - Some plants like strawberry and ash (and other slightly susceptible species) show only very small galls which might be easily overlooked. ("Females are sometimes outside the root with no gall formation," G. Thorne, in personal communication, 1966.)

Type 4: Root-tip galls - Certain plants such as palms develop galls only as swellings of the tips of tender feeding roots. These soon decay and are apt to be lost in taking samples for examination. Decayed root tips expose a tiny white thread (the primary vascular cylinder). See Fig. 83.

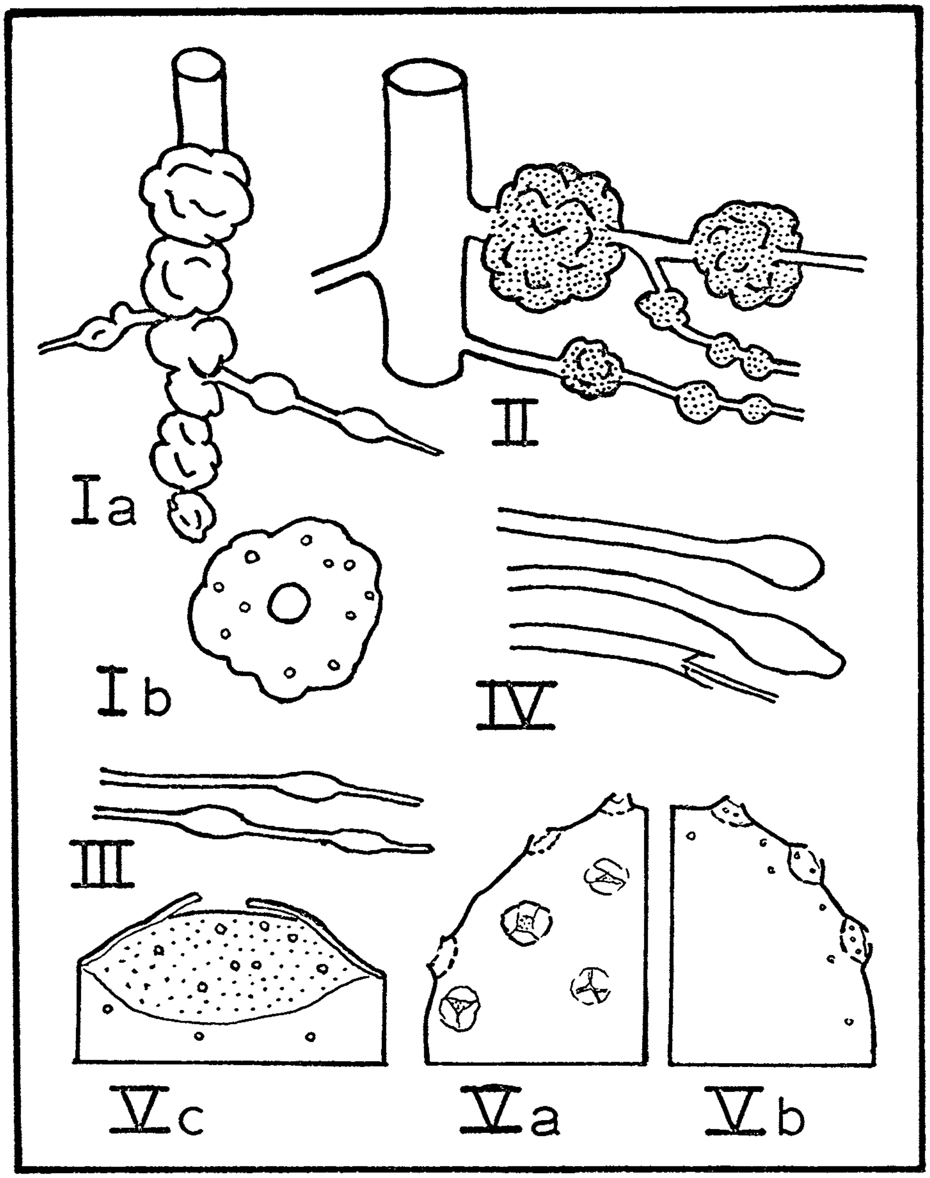


Fig. 80. Types of galls produced by root knot nematodes produced on different types of host plants as described on page 6.15.

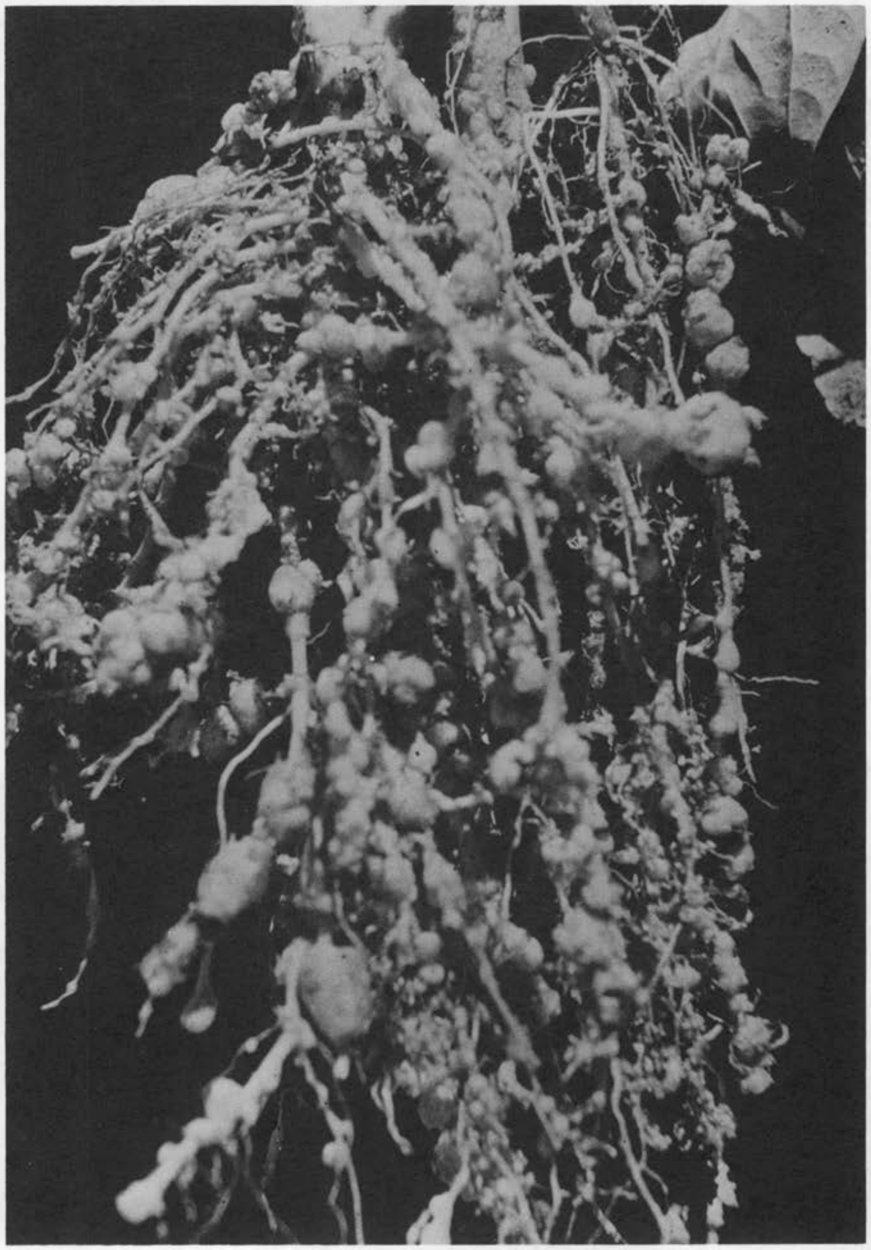


Fig. 81. Type 1: Severe infestation of root knot nematode on black-eyed beans. Note that galls tend to be spherical. These plants were dying.

Fig. 82. Tiny, bead-like galls on feeding roots, and larger galls on older roots of mulberry. Unlike galls on herbaceous annuals these galls do not decay quickly.

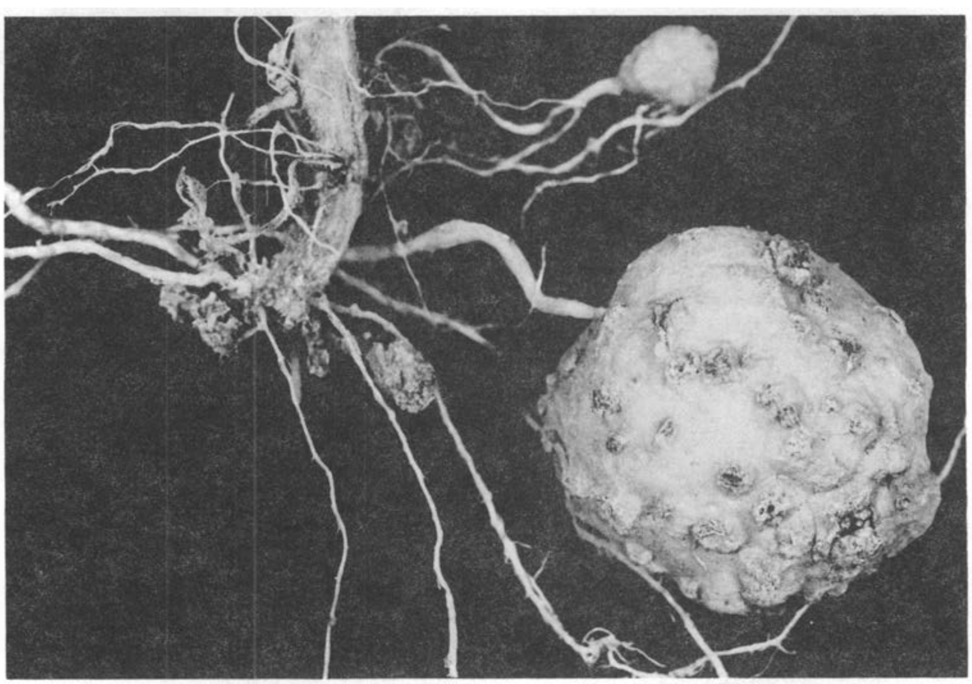


Fig. 83. Roots and tubers of potato infested by root knot nematodes. Compare with common and powdery scab of potato. X 1.5.

Type 5: Small, warty, elevated spots - Irish potato tubers show small, warty galls partially embedded in the tuber and containing small, brownish pits containing the nematodes. Iris rhizomes have similar pits, usually without surface warts.

DISTINGUISHING FEATURES: Look for: (1) NUMEROUS small, spindle-shaped to larger spherical galls on roots of all sizes. Galls are numerous even in slightly infested plants. (2) When galls are sectioned with a sharp razor blade, small brown pits containing nematodes (eggs, larvae, or adults) are visible with a hand lens, or preferably with a binocular microscope or low power of a compound microscope. Crown galls do not show these pits. (3) The cylindrical eggs often seen in mounts of tiny feeding roots are a better sign of the root-knot nematode than larvae or adults which might be other species.

Field signs. Population counts

FIELD SIGNS OF ROOT-KNOT NEMATODES: While there are some rather definite symptoms in the tops of nematode-infested plants, it is never safe to make a diagnosis without checking the root systems of the plants in question. Wilting in the afternoon, when soil moisture is adequate, is the first symptom. Death of seedlings, usually from Rhizoctonia, etc., following nematode infection, may greatly reduce the stand (as in cotton) or plants may be stunted or unproductive as a result of early infection. Very susceptible succulent annuals (vegetables and flowers) often suffer severe leaf burn or die in mid-season. When woody plants are unthrifty--CHECK THE ROOTS.

POPULATION COUNTS OF OTHER NEMATODES FROM SOIL SAMPLES: Parasitic nematodes which do not cause root galls or which are not permanently attached to the roots, can be separated from the soil and counted by a relatively simple method. The Baerman funnel technique requires only a 5 or 6 inch glass funnel, a 2 1/2" circular piece of screen, a piece of rubber tubing and a pinchcock, a stand to hold the funnel, and some cheese-cloth. (See diagram of apparatus.) Place wet-strength tissues (Scotties or Kleenex) on screen in funnel and put a 100 cc. soil sample on the tissue. With pinchcock closed, flood the soil with water and allow to stand overnight. The LIVE nematodes will migrate through tissues into the clear liquid and sink to the bottom just above the pinch-cock. Over 90% of the nematodes can be recovered by drawing off 5 ml. of water.

Unless you have had a special course in nematology, species of nematodes are very difficult to identify, but your samples can be sent to a nematologist if identification is needed.

As the above method counts only LIVE nematodes, samples must be protected against heat and drying. Also they should be taken from the 6" to 12" depth where nematodes are most abundant. The soil should be moist, and about 200 grams or one cupful should be taken for each sample and placed in a polyethylene bag, sealed and marked for identification. A composite sample--for example, a small handful of soil (including feeding roots) from four or more different sites will give a more accurate reading than a single-site sample.

Samples

SUBMITTING NEMATODES FOR IDENTIFICATION: The presence of galls pretty well identifies the root-knot nematodes. Unless you can be certain that soil-root samples will arrive without exposure to heat and dryness that will kill the nematodes, it is best to separate them from the soil by the Baerman funnel method and send a 5 ml. suspension containing nematodes with 5 ml. of (double strength 8% preservative) formalin plus 1% glycerine added as preservative and anti-drying agent. Seal vials well. PRESERVATIVE: Add one teaspoonful (5 ml.) formalin and 10 drops of glycerine to 2 oz. (60 ml.) of water. Over 4% formalin will cause shrinking and hardening of the nematodes.

TESTING SOIL FOR ROOT-KNOT NEMATODE INFESTATION: In the absence of susceptible crops of weeds, it is difficult to be certain that no parasitic nematodes are present. The best method is to take samples from a good many parts of the field and make test planting in clean containers (6 or 8-inch clay pots, gallon cans, flats, or boxes). Fast growing, very susceptible crop plants, such as watermelons, squash, beans, okra, or tomatoes, must grow not less than 1 week in warm moist soil or 2 or 3 weeks in cooler soil. The plants should then be carefully dug and the roots gently washed and examined for root-knot galls. The abundance and size of the galls will give a rough estimate of the root-knot nematode population.

THE MAJOR ECONOMIC SPECIES: The following chart lists the four types of nematodes, giving for each species: scientific name, common name, and the principal host plants. This gives the best survey now available of the plant-parasitic nematodes.

Staining nematodes in tissues: (1) Remove chlorophyll by heating 80% acetone in water in test tube to boiling (63 deg. C or 112 deg. F) in hot water bath.* Put leaf material in hot acetone and allow to cool 3 to 4 hours or until chlorophyll is removed. (2) Wash in 4 changes of water and add Flemming's Strong killing fluid, and observe in small dish under binocular until nematodes blacken. (3) Wash, dehydrate in alcohol, infiltrate and clear with clove oil. Seal for temporary mounts or replace clove oil with Canada Balsam for permanent mounts. For tissues without chlorophyll (roots, etc.) omit step (1). (See Godfrey, Phytopath. 25: 1026-1029. 1925.)

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* Inflammable. Use care!

RECOVERY OF NEMATODES FROM PLANT TISSUES*

I. Modified Baermann funnel technique: Instead of soil, place a layer of roots cut into very short pieces in funnel and proceed as described before.

II. Use of Blendor: Approximately 5 grams of roots are cut into short lengths and placed in micro-blendor cup with 80 ml. of water. Operate blendor about 20 seconds. Avoid over-maceration. The micro-cup is much more convenient than the standard cup. Examine blendorized mixture directly, or separate the nematodes from the tissues by using the Baermann funnel technique.

III. Young's Incubation Method: (See P.D.R. 38: 794-795. 1954) Roots (preferably unsuberized) up to 1/4 inch in diameter should be thoroughly washed to free them from soil and foreign organic matter and placed in a Mason jar and screw the lid on loosely. In a few hours nematodes start accumulating in the bottom of the jar in the few ml. of water drained from the wet roots. The roots can be incubated for a week or more. Water at the bottom of the jar can be poured off at intervals and examined for nematodes. At these times use a wash bottle to rewet the roots and wash nematodes from root surfaces to replace the necessary small amount of water in the jar. Young found this method to be much superior to the Baermann funnel technique for recovering *Radopholus* and *Pratylenchus* from roots of avocado.

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*Adapted from General Review of Nematology. Dept. of Nematology, University of California. Riverside and Davis. 1960.

RAPID SEPARATION OF NEMATODES FROM SOIL.

I. Jenkins' process (See P.D.R. 48: 692. 1964) recovers non-sedentary, soil-dwelling nematodes of all types in less than ten minutes. Take a 100-500 gm. portion from a thoroughly blended soil sample; place it on a 20-mesh screen and wash it through the screen with 5 quarts of water into a 10-quart pail. This step eliminates most large roots, stones and other debris. Stir soil and water in the pail and allow to settle for about 30 seconds. Decant through a 270 or 325 mesh sieve and using a wash bottle transfer the residue to a beaker. Add another 5 quarts of water to soil in pail and repeat the process saving residue on sieve. Discard the remaining soil.

Transfer the collected residue equally into two 50 ml centrifuge tubes, carefully balancing the weight of the tubes which must be equal. Place tubes in a centrifuge and spin for 4 or 5 minutes at about 1750 RPM. A hand-cranked International Clinical Centrifuge has proven very satisfactory and is inexpensive.

Now, carefully pour off supernatant liquid and add a sugar solution (1 lb. cane sugar to 1 liter of water) until tubes balance exactly. Mix sediment and sugar solution thoroughly. Centrifuge 1/2 to 1 minute. Exposure of nematodes should be as short as possible (less than 2 minutes) to avoid injury to the nematodes.

Pour supernatant liquid containing the nematodes on a 325 mesh sieve and rinse nematodes with fresh water. Nematodes are then collected in a watch glass for examination, or vial for storage.

II. Baermann Funnel Method.

See Page 6.19.

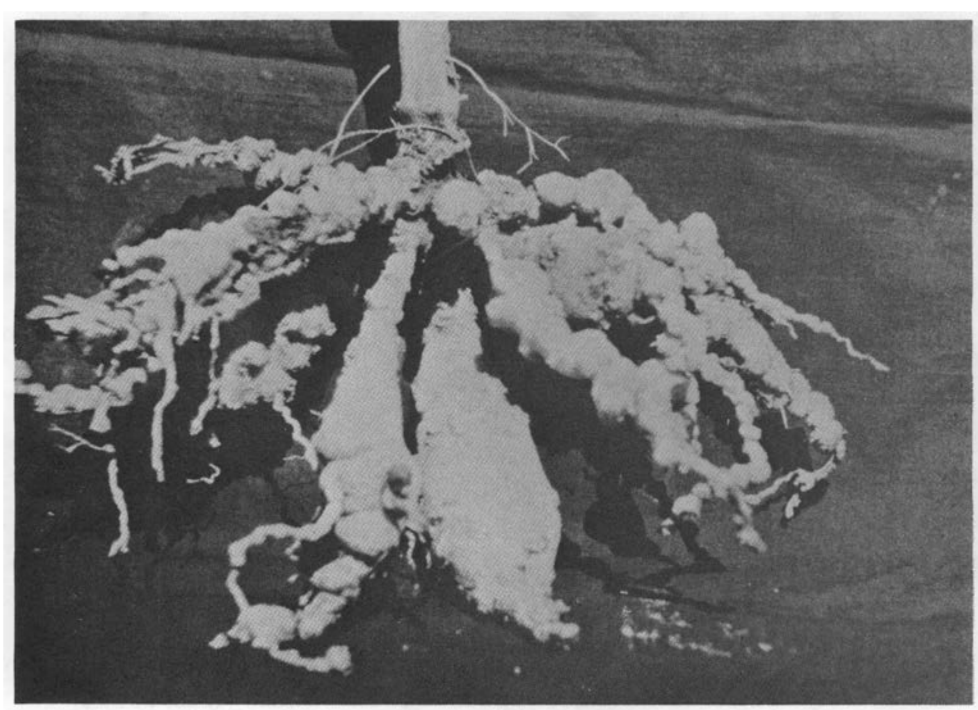

Fig. 84. Type 1: Severe root knot nematode infestation of fleshy roots of dahlia. Only one root has developed to near normal size.

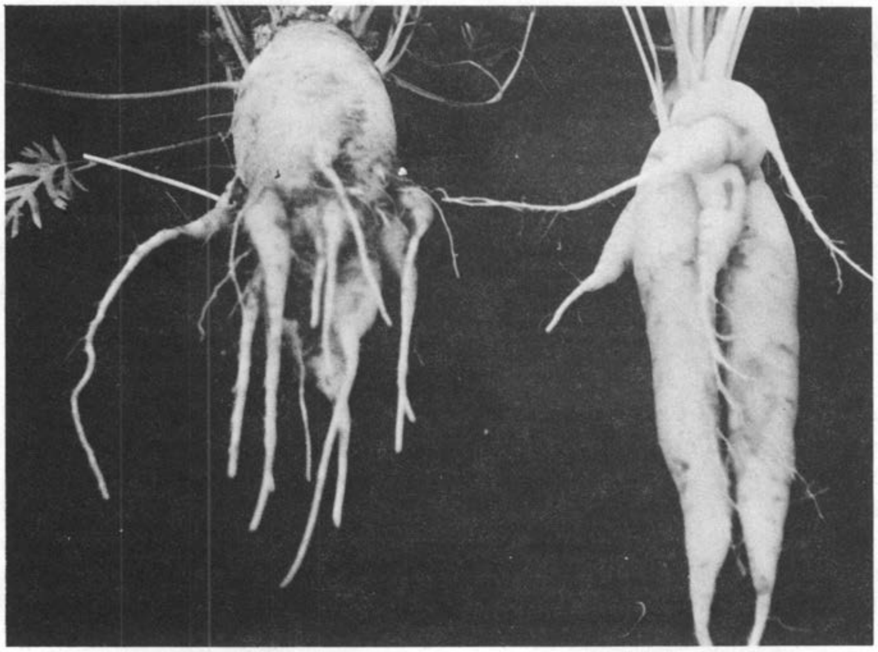

Fig. 85. Distorted carrot roots grown in root knot nematode infested soil.

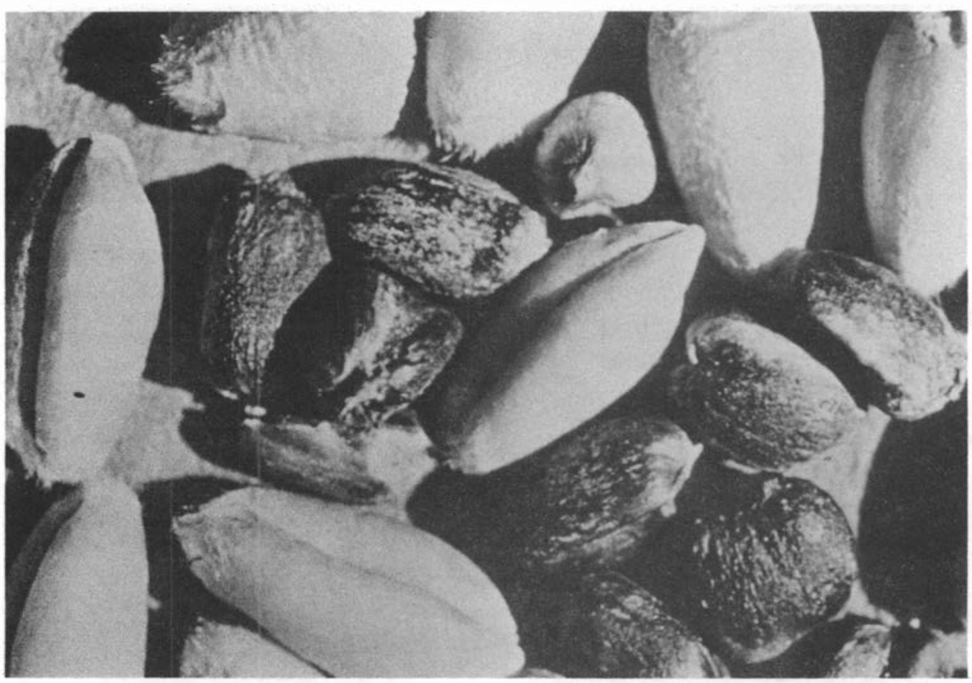

Fig. 86. Wheat enlarged showing healthy kernels and the slightly smaller galls of the wheat nematode. Nematode galls are hard and are white, not black, inside.

NEMATODE CHART

CYST FORMING NEMATODES

Nematodes that form cysts covering the eggs

SCIENTIFIC NAME	COMMON NAME	PRINCIPAL HOSTS
Heterodera	**Cyst Nematodes**	
H. avenae	Oat Nematode	Small grains, corn, grasses
H. carotae	Carrot Root Nematode	Carrot
H. cruciferae	Cabbage Root Nematode	Cabbage, other crucifers
H. glycines	Soybean Cyst Nematode	Soybean
H. gottingiana	Pea Root Nematode	Pea
H. humuli	Hop Nematode	Hop, hemp
H. punctata	Grass Cyst Nematode	Wheat, other small grains
H. rostochiensis	Golden Nematode	Irish potato, tomato, eggplant
H. schachtii	Sugar Beet Nematode	Cole crops, celery, cress, kale, weeds, radish, spinach, turnip, sugar beet
H. tabacum	Tobacco Cyst Nematode	Tobacco, tomato
H. trifolii	Clover Root Nematode	Clover, legumes
H. weissi	Knotweed Nematode	Knotweed

ENDOPARASITIC NEMATODES

Nematodes that enter the root tissue or permanently attach themselves to it

SCIENTIFIC NAME	COMMON NAME	PRINCIPAL HOSTS
Ditylenchus		
D. destructor	Potato Rot Nematode	Potato, dandelion
Meloidogyne	**Root Knot Nematodes**	
M. arenaria	Peanut Root Knot Nematode	1700 hosts, including forage, small grains, grasses, fruit, vegetables, field crops, nursery, weeds
M. arenaria var. thamesi	Thames Root Knot Nematode	
M. exigua	Coffee Root Knot Nematode	
M. hapla	Northern Root Knot Nematode	
M. incognita	Southern Root Knot Nematode	
M. incognita var. acrita	Cotton Root Knot Nematode	
M. javanica	Javanese Root Knot Nematode	
Nacobbus		
N. batatiformis		Sugar beet
Pratylenchus	**Root-lesion or Meadow Nematodes**	
P. brachyurus=(leiocephalus)	Smooth-headed Nematode	Potato, corn, peanut, cotton, pineapple, avocado, tobacco, lespedeza
P. coffeae=(musicola)	Coffee Nematode	Coffee, tea, abaca, sugar cane, banana, olive, apple
P. minyus		Wheat, tobacco, corn
P. penetrans		Nursery, grasses, forage, oats, strawberry, apple, tomato
P. pratensis		Grains, grasses, strawberry, lily, narcissus
P. scribneri	Scribner's Meadow Nematode	Potato, strawberry
P. thornei	Thorne's Meadow Nematode	Wheat, grains, grasses
P. vulnus	Lesion Nematode	Ornamentals, trees, forage, fruit, beans, walnut, grape, olive, fig, boxwood, stone fruits, citrus, raspberry, rose
P. zeae	Corn Nematode	Corn, wheat
Radopholus		
R. oryzae	Rice Nematode	Rice
R. similis	Burrowing Nematode	Citrus, ornamentals, avocado
Rotylenchulus		
R. reniformis	Kidney-shaped or Reniform Nematode	Turf, cotton, peanut, tomato, weeds, ornamentals
Tylenchulus		
T. semipenetrans	Citrus Nematode	Citrus, olive

ECTOPARASITIC NEMATODES

Nematodes that feed on the root surface and normally do not enter the root tissue

SCIENTIFIC NAME	COMMON NAME	PRINCIPAL HOSTS
Belonolaimus	**Sting Nematodes**	
B. gracilis		Turf, strawberry, corn, ornamentals, cotton, soybean, celery, vegetables, peanut, pine
Cacopaurus		
C. pestis	Walnut Nematode	Walnut
Criconema	**Pine Nematodes**	Pine trees
Criconemoides	**Ring Nematodes**	Turf, cotton, peanut, citrus, weeds, deciduous fruit
Dolichodorus		
D. heterocephalus	Awl Nematode	Celery, beans, corn, tomato, and waterchestnut
Helicotylenchus	**True Spiral Nematodes**	
H. nannus		Peanut, tobacco, tomato, clover
Hemicycliophora=(Procriconema)		Evergreens
Hoplolaimus	**Lance Nematodes**	Turf, nursery, corn, sugarcane, alfalfa, red clover
Longidorus		Grasses, Peppermint
Paratylenchus	**Pin Nematodes**	Celery, many vegetables, fig
Rotylenchus	**Spiral Nematodes**	Boxwood, ornamentals
Trichodorus	**Stubby Root Nematodes**	Turf, corn, celery, cole crops, bean, pea, tomato, cotton, cowpea, beet, pepper, weeds
Tylenchorhynchus	**Stylet Nematodes**	
T. claytoni	Tobacco Stunt Nematode	Tobacco, corn, cotton, milo, strawberry, alfalfa, peanut, bean, ornamentals
Xiphinema	**Dagger Nematodes**	Cotton, strawberry, oats, tobacco, peach, nursery

ABOVE GROUND FEEDERS

Nematodes that feed within plant tissue above ground

SCIENTIFIC NAME	COMMON NAME	PRINCIPAL HOSTS
Anguina	**Seed Gall Nematodes**	
A. agrostis	Grass Nematode	Grasses
A. tritici	Wheat Nematode	Rye, wheat
Aphelenchoides	**Foliar Nematodes**	
A. besseyi		Vanda orchid, causes white tip of rice, strawberry, African violet
A. fragariae	Bud and Leaf Nematode	Flax, mint, onions, oats, sweet potato, nursery, begonia, fern, iris, lily,
A. ritzema-bosi	Bud and Leaf Nematode	strawberry, white clover, ribes, orchid, violet, chrysanthemum
A. cocophilus	Coconut Nematode	Causes red ring disease of coconut
Ditylenchus		
D. dipsaci	Stem and Bulb, or Teasel Nematode	Alfalfa, clover, onion, garlic, sweet potato, strawberry, nursery

VIRUS DISEASES*

Viruses attacking plants have been extensively studied in the past 20 years, as many viruses are of great economic importance, some attacking a wide range of plants, others are confined to a single host. Some viruses are latent with no visible symptoms; other viruses range in severity from slight to severe and a few kill the host plant. They are spread mostly by aphids and leafhoppers and by budding or grafting or contact of infected with healthy foliage. A few are spread by thrips, mites, and white flies.

Virus symptoms are most conspicuous and severe on the new growth while the older mature foliage appears healthy, but most viruses are systemic and the sap of all parts of the plant carries the virus.

The common names of the different viruses are used here as the binomial system is more complicated and not generally accepted by virologists.

DIAGNOSIS OF VIRUS DISEASES

VIRUSES

Virus particles are so small that they can be seen only under the electron microscope which is not a practical diagnostic tool for routine identification. The presence of virus diseases in plants must be detected by plant symptoms, sometimes aided by the simplest of transmission tests.

There is a great variety of virus symptoms in plants with usually three to six symptoms commonly associated with each disease. Advanced cases of virus infections can easily be recognized as virus-caused-- but WHICH virus?

However, from the standpoint of suggestion a procedure for the grower, the answer is the same--"Virus-infected plants cannot be cured by the grower and might as well be destroyed to prevent spread of the virus to healthy plants." In large plantings this is often not practical and no effective remedy is available. A few varieties bred for resistance or tolerance to specific viruses are available; future control will be largely by use of such varieties.

Pathologists trained in virus-techniques can eliminate some viruses from propagating stocks by heat treatment or tissue culture and keep them clean by rouging.

DESCRIPTION OF VIRUS SYMPTOMS

MOSAIC SYMPTOMS:

Mosiac Symptoms

1. Vein clearing: Before mosaic or mottle develops, there is often a clearing or chlorosis of cells in or adjacent to the veins.

2. Vein banding: Consists either of a broader chlorotic band along the veins, or bands of green set off by chlorosis or necrosis in the interveinal parenchyma. (The above two symptoms may be transient or remain a major symptom of the disease.)

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*Smith, K.M., A Textbook of Plant Virus Dieseases, 2nd ed. 1957. Little Brown & Co., Boston. The most useful general reference as it gives textbook treatment of over 300 separate viruses, not counting strains.

2A. Yellow-net is a conspicuous type of vein banding with all veins yellow.

3. Ring spots: Circular chlorotic spots are called chlorotic ring spots. Necrotic rings alternating with normal green are called Necrotic ring spots. The centers of either type may eventually become necrotic.

4. Mosaic: Variations in leaf color in a wide variety of patterns.

5. Mottle describes some patterns of color variation.

NECROSIS SYMPTOMS:

Necrotic Symptoms

6. Top necrosis: Death of terminal shoots and leaves. Spotted wilt of tomato.

7. Streak: Necrotic lesions (long) in stems.

8. Phloem necrosis: Death of phloem tissue--visible in cross sections. Phloem necrosis of elm and Curly top of beets, etc.

9. Local necrosis: Small circular leaf spots of dead tissue.

Virus 2

STUNTING AND DEATH OF PLANTS:

Stunting or Death

10. Stunting: Whole plant dwarfed in all parts including roots. Dahlia stunt, alfalfa dwarf.

11. Stunting of current growth: Rosettes in peach mosaic. Spindly twigs in peach yellows.

12. Stunting and death of woody plants: Tristeza of citrus.

13. Premature leaf shedding: Cabbage mosaic, peach mosaic.

MALFORMATIONS:

Malformations

14. Rough-textured leaves: Rugose mosaic of potato.

15. *Leaf blades reduced: Fern leaf of tomato, fig mosaic.

16. Color break in petals: In sweet pea, petunia, stock, tulips.

17. Retarded growth: Pointed tips in cucumbers, spindle-tuber of potato.

18. Gum deposits in xylem of wood: Scaly bark of citrus.

19. Leaves curling upward: Curly top of beets and tomato.

20. *Leaves curling downward: Curly top on beans.

---

*Also caused by weed killers, especially 2,4-D formulas.

OVERGROWTHS:

Overgrowths

21. Enations: Soft projections on surface of leaf or stem. Curly top.

22. Proliferation of buds: Aster yellows, witches broom of potato.

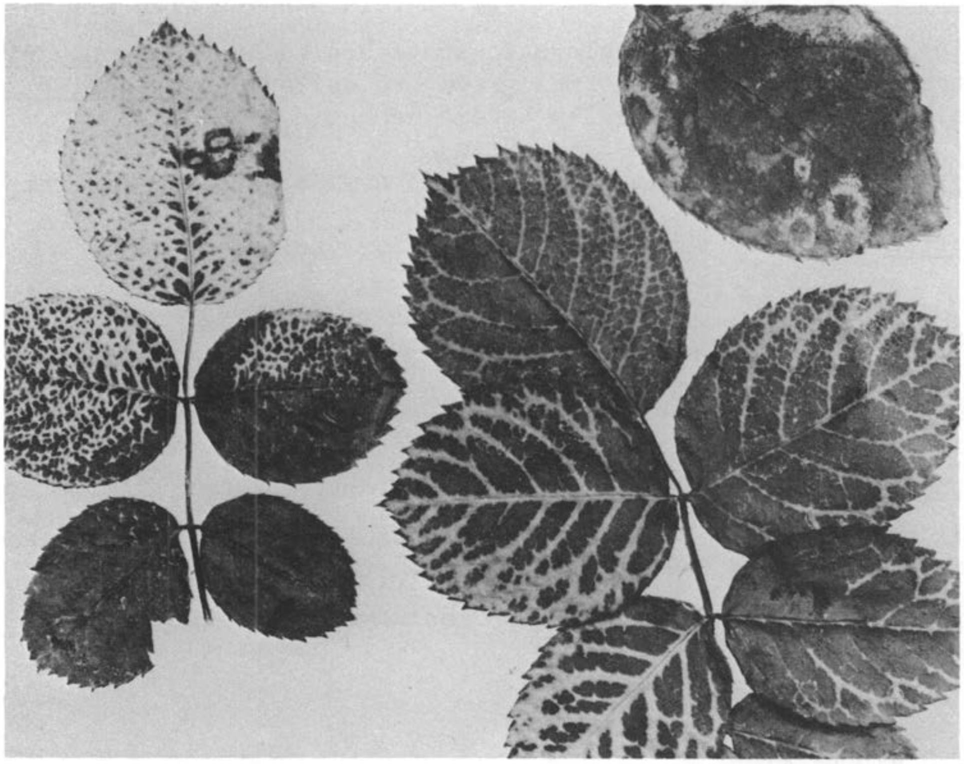


Fig. 87. Mosaic symptoms: Yellow-net(1)*, vein clearing(2) and ring spot(3). *Numbers refer to symptoms listed on pages 6.24 and 6.25.

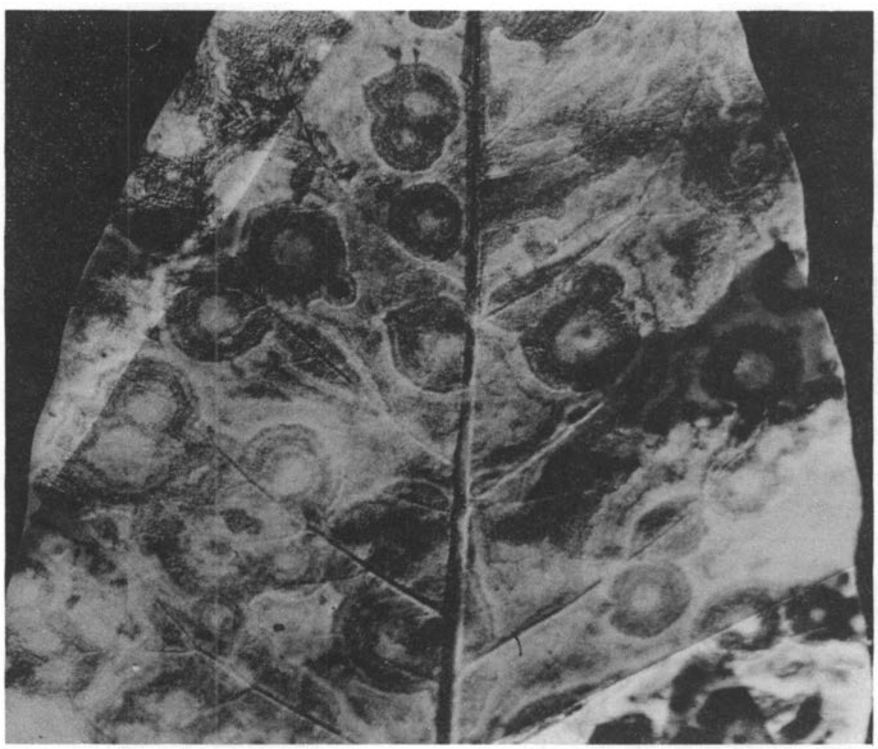


Fig. 88. Lesions of tobacco ring-spot virus(3) on Nicotiana glauca.

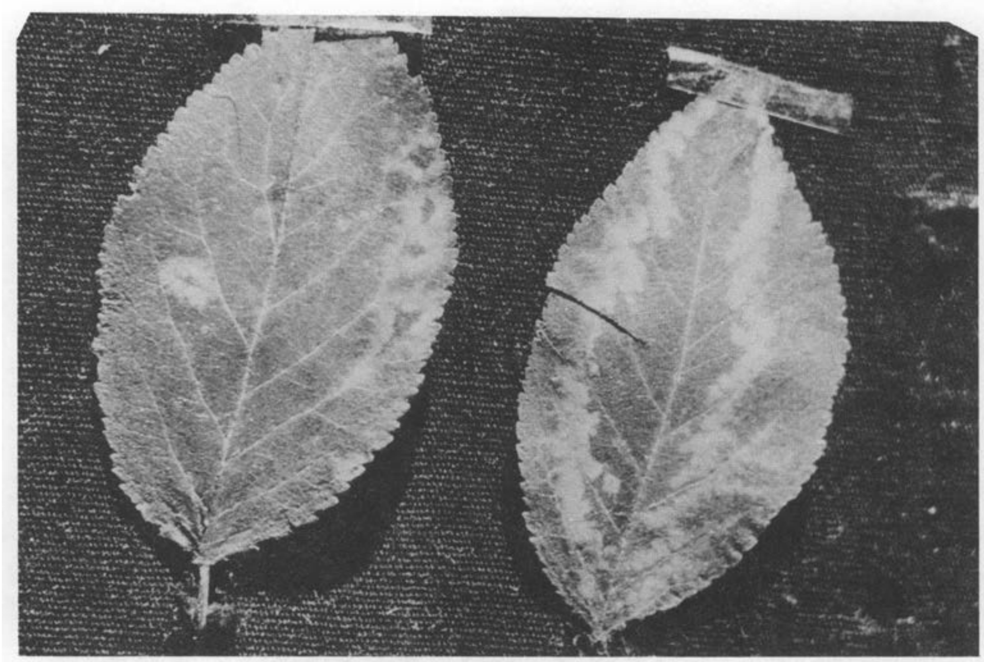


Fig. 89. Line pattern[3], a virus disease of plums.

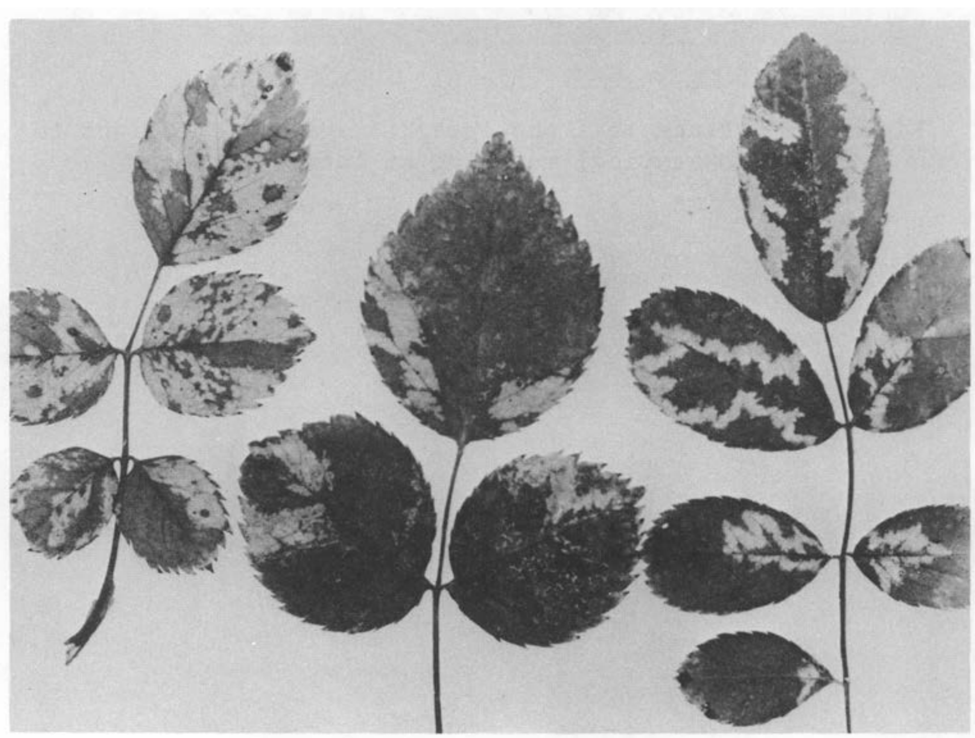


Fig. 90. Mosaic symptoms: Mosaic mottle[5] and line pattern[3] on rose.

Fig. 91. Lettuce leaf photographed against the light to show typical mottling of lettuce mosaic[4]. X 1/2.

23. Proliferation of secondary roots: Curly top, aster yellows.

24. Proliferation of tubers and aerial tubers: Potato witches broom.

25. Tumors or galls on roots or stems: Wound tumor virus.

YELLOWS SYMPTOMS:

26. Permanent uniform chlorosis of leaves, etc.: Aster yellows.

27. Greening or yellowing of petals: Aster yellows on aster & delphinium.

VIRUS SYMPTOMS ON CITRUS

28. Stem pitting on twigs and trunk: Tristeza, Xyloporosis.

29. Scaling of bark, gum pockets in bark: Psorosis, exocortis.

30. Flecking (immature leaves only) and ring spot: Tristeza, Psorosis.

31. Gum deposits in xylem. Psorosis.

MASKED SYMPTOMS ONLY FOR DURATION OF INHIBITING FACTOR. High temperature.
Potato X and Y viruses, Maise dwarf mosaic.

SYMPTOMLESS CARRIERS carry a virus but show no symptoms. They are only detected by transmission of the virus to a susceptible host.
Meyer lemon carries Tristeza virus of citrus.

SOME COMMON AND IMPORTANT VIRUSES INFECTING PLANTS

VERY WIDE HOST RANGE in different families.

Tobacco mosaic virus - - - - - vector aphids

Cucumber mosaic virus- - - - - vector aphids

Curly top virus - - - - - - - vector leafhopper (one species)

Aster yellows virus- - - - - - vector leafhoppers

Spotted wilt virus - - - - - - vector thrips

Alfalfa mosaic virus - - - - - vector aphids

WIDE HOST RANGE within a family.

Peach mosaic virus - - - - - - - - - - vector eriophid mite

Western X-disease virus- - - - - - - - vector leafhoppers

Tristeza of citrus virus - - - - - - - vector aphids

Sugar-cane mosaic virus- - - - - - - - vector not known

Cabbage black ringrot virus- - - - - - vector aphids

Bean mosaic virus- - - - - - - - - - - vector aphids (eleven species)

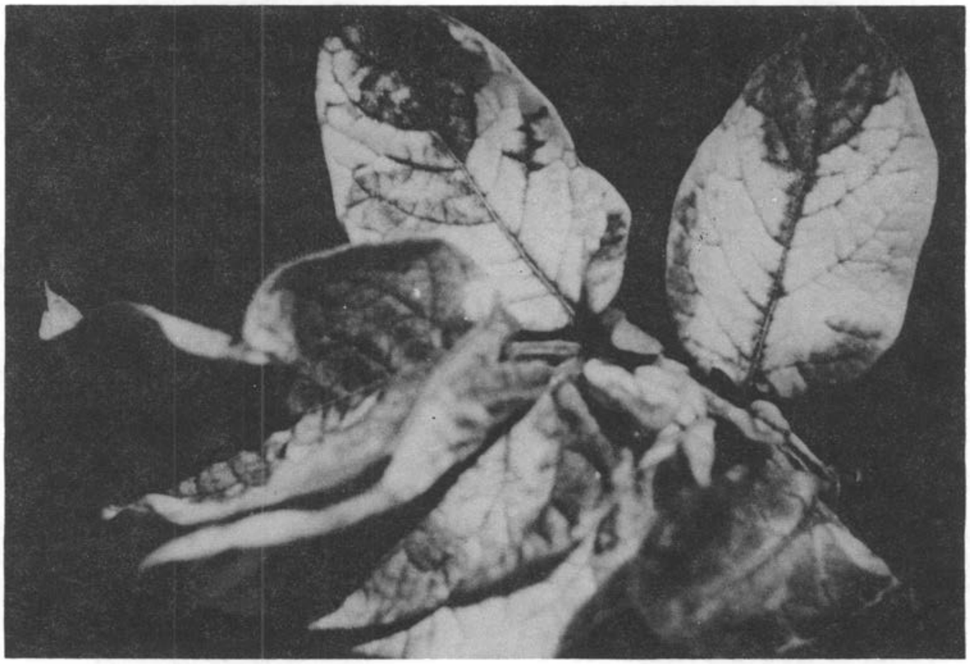


Fig. 92. Strong yellow pattern on leaflets of potato (calico) caused by the alfalfa mosaic[4].

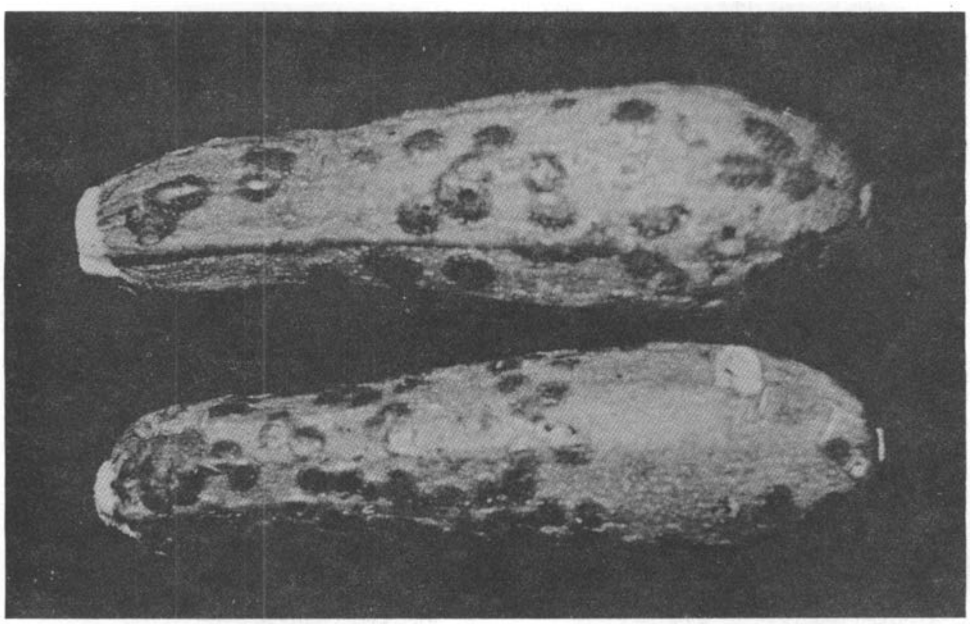


Fig. 93. Fruits of zucchini summer squash infected with squash mosaic[4]. Fruits are yellowish except for the dark green raised spots.

NARROW HOST RANGE mostly within the genus

Phloem necrosis of elm virus- - - - - - - vector bark beetles

Internal cork virus, of sweetpotato - - - vector aphids

Peach yellows virus - - - - - - - - - - - - vector aphids

Sour cherry yellows virus - - - - - - - - - vector not known

Ref: Smith, Kenneth M. A Textbook of Plant Virus Diseases. 2nd Ed. Little Brown & Co., Boston, 1957.

A very good summary of each virus disease, listed alphabetically, giving virus properties, transmission, hosts, strain, etc., and geographical distribution. Good bibliography at end. Symptoms illustrated.

MYCOPLASMA DISEASES

Quite recently (1967) it was demonstrated that a number of "yellows diseases" believed to be due to viruses were due, in fact, to a group of tiny organisms placed by size between the viruses and bacteria. These organisms, called mycoplasmas (the word means "fungus form"), have no rigid cell wall but can assume many shapes as they have a fragile membrane. They may be seen under the electron microscope as elongated branching filaments which later break up into round cells. Some are transmitted in nature by leaf hoppers.

From the standpoint of diagnosis they must be treated as virus diseases and are identified from the symptoms they cause in plants. Only a few mycoplasmas have been recognized in plants, but others will no doubt soon be found. They are completely resistant to penicillin but partially inhibited by tetracycline compounds (Aureomycin et al.).

YELLOWS (MYCOPLASMA) DISEASES:

American aster yellows: aster, chrysanthemum, petunia and others.

Corn stunt

Mulberry dwarf

Stolbur, Parastolbur: periwinkle, potatoes, tomatoes and peppers

Clover dwarf

Peach X-disease

Rice yellow dwarf

Pear decline

Symptoms: Aster yellows attacks over 150 genera of plants including many weeds, but Economic hosts are primarily ornamentals in the Compositae, such as China aster, and vegetables in the Umbelliferae, such as carrot, celery and parsley.

Symptoms include a general yellowish color, and the effect is often unilateral. There may be proliferation of small roots, stimulation of dormant buds, and "witches brooms." Flower parts are often leaf-like in shape and color, and the inflorescence may be distorted or sterile. "Purple top" a symptom of aster yellows in potato is often accompanied by aerial tubers at the stem nodes. Aster yellows can usually (but not easily) be diagnosed by the host symptoms. Reference (18) Kenaga pp. 41-49.

Diseases Caused by Mycoplasma

Suspected

Likubin (Taiwan)
Leaf Mottle Yellows (Phil. Is.)
Greening (Africa)
Stubborn (USA)
Sfarghali (Egypt)

Probably same disease

Peach yellows
Wound tumor
Clover club leaf
Western X-disease
Tomato Big-bud (US)
Legume little leaf (Aust.)
Alfalfa witches' broom
Flavescence doree (Europe)
Strawberry green petal (Europe)
Little peach, Little cherry
Cherry buckskin
Cotton virescence (Europe)
Eggplant little leaf (Europe)
Witches' broom of peanut (Java, Far East)
Sweet potato witches' broom (Jap. & Taiwan)
Witches' broom of legumes (Jap. & Taiwan)
Cryptotamia japonion witches' broom (Jap.)
Yellow wilt of sugar beet (Argentina)
Tobacco yellow dwarf (Australia)
Mal Azue (Portugal)
Peach Rosette
Alfalfa mosaic
Ash witches' broom
Yellow leaf of Areca palm

Known Associated

Corn stunt
Aster yellows
Mulberry dwarf
Potato witches' broom
Paulonia witches' broom
Crimean yellows
European clover dwarf
Blueberry stunt
Cranberry false blossom
Stolbur (Potatoes, tom, pepper)
Parastolbur (Potatoes, tom, pepper)
Peach X-disease
Clover phyllody
Rice yellow dwarf
Safflower phyllody
Sugarcane whiteleaf (Taiwan)
Sandalwood spike
Papaya bunch top (Puerto Rico)
Pear decline

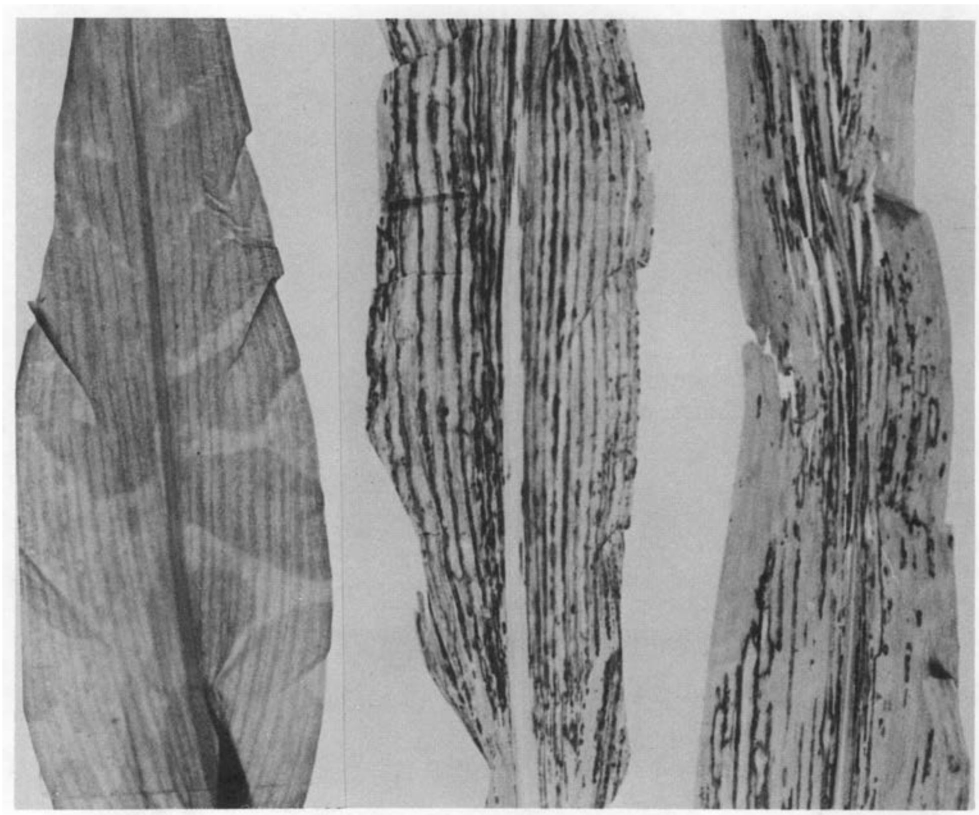


Fig. 94. Maize dwarf mosiac has become widespread in the last few years on sorghum. Translucent streaks mark the early stage. Maroon stripes with or without tan areas in center mark the late, "red-leaf" stage.

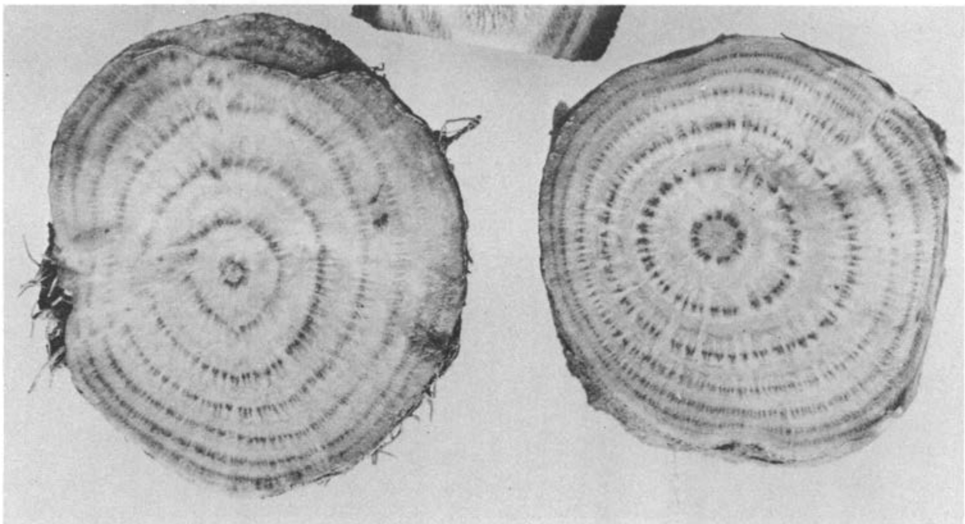


Fig. 95. Cross sections of sugar beet root showing rings of phloem cells killed by curly top virus[8]. X 2/3.

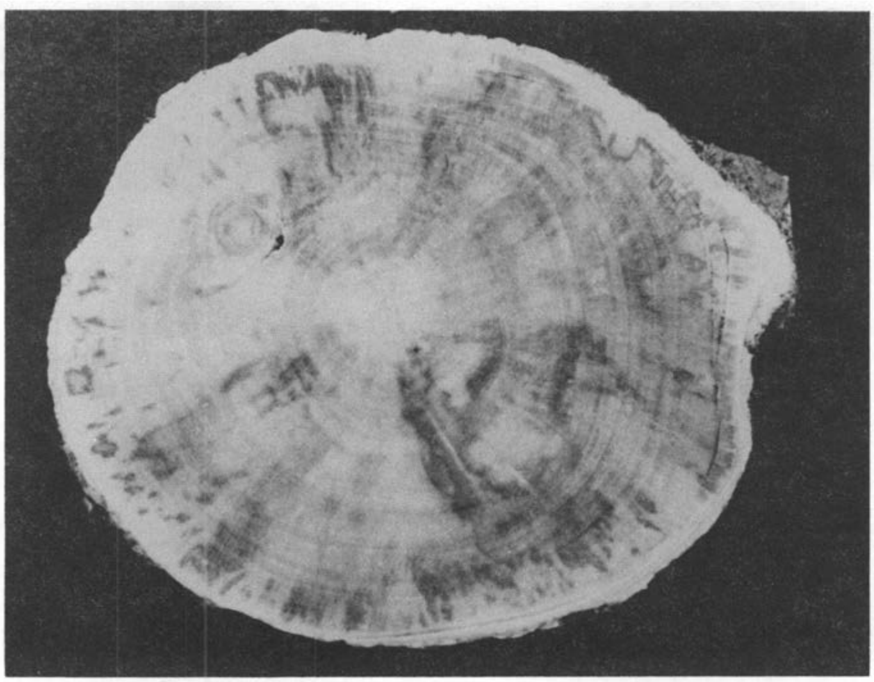


Fig. 96. Scaly bark (psorosis)[18] on grapefruit. Cross section of 3-inch limb with severe scaly bark showing brown gum deposits in wood cells.

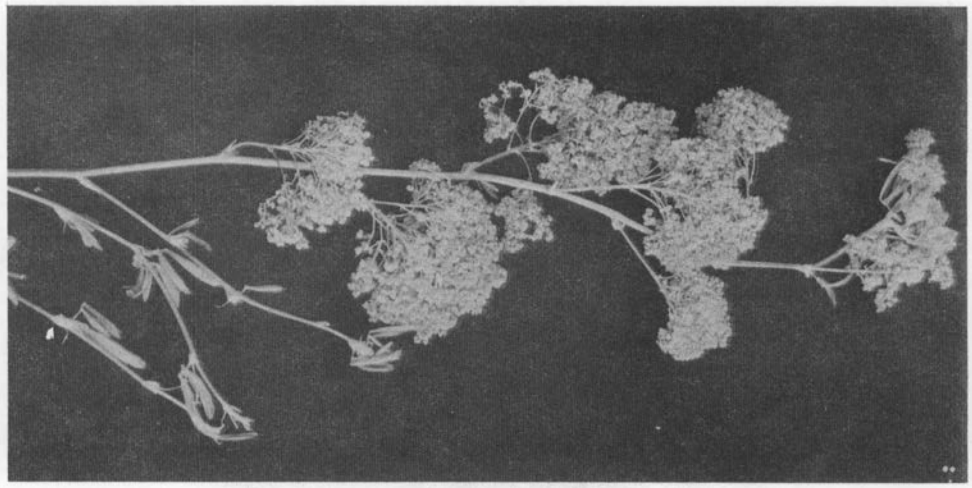


Fig. 97. Phyllody of alfalfa flowers caused by aster yellows virus[22]. Mass of leafy bracts replaces normal flower clusters.

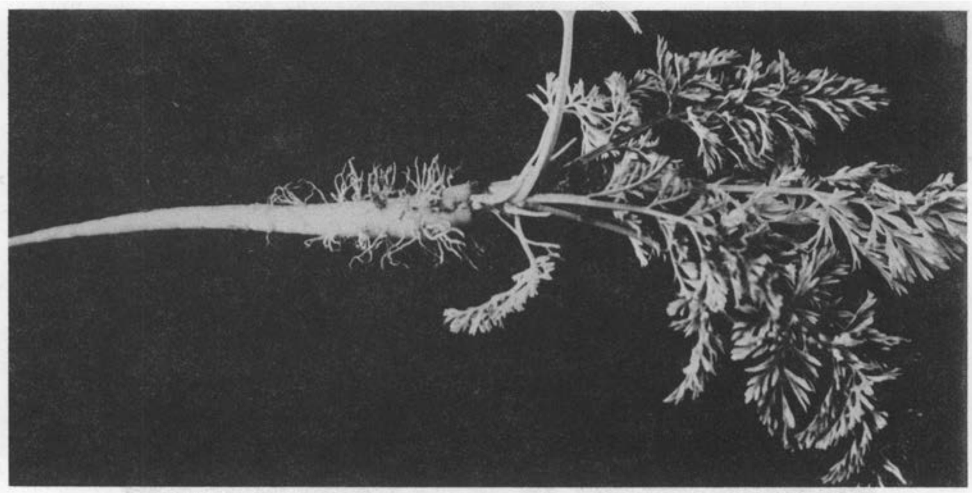


Fig. 98. Carrot plant showing yellow stunted foliage, and stunted taproot with excessive lateral roots caused by aster yellows virus[23].

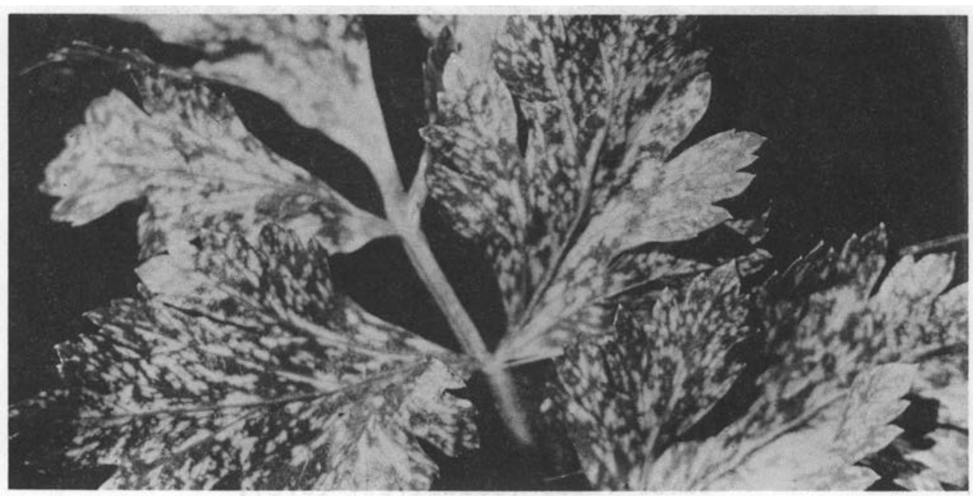


Fig. 99. Aster yellows-yellow-spot complex on leaflets of celery[26].

Fig. 100. Curly top of sugar beet, showing curling, twisting, and enations of the younger leaves. X 1/2.

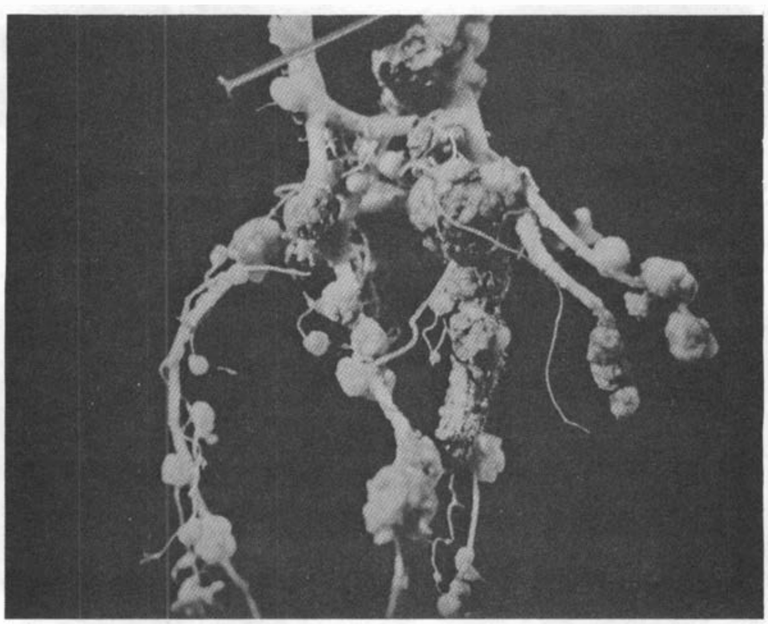


Fig. 101. Galls on crown and roots of Melilotus resulting from infection with wound tumor virus (relatively rare).

IDENTIFYING FUNGI

In most cases TWO kinds of information are needed to identify a plant disease: MACROSCOPIC, including SYMPTOMS produced on the host plant and growth of mycelium or fruiting bodies visible to the unaided eye or by hand lens; and MICROSCOPIC, to determine the distinctive features which separate the fungus under observation from all others. These details are best located by study of the lesions with a 10X hand lens, but must be studied under a magnification of 15X to 20X under a binocular; or 50X to 500X (1,000X for bacteria) under a compound microscope.

Mycelial characters are of limited value but the presence of cross walls in the mycelium is important. Only one major group, the Phycomycetes (including Chytridiales, Oomycetes, and Zygomycetes) has mycelium typically lacking cross walls. Clamp connections occur in mycelium of most Basidiomycetes, except smuts and rusts. The presence of clamp connections often will indicate that the fungus belongs to the higher Basidiomycetes when no fruiting body has been formed. These hyphal outgrowths (1 or more) occurring at cell wall connecting two adjacent cells.

Most of the classification is based on the size, shape, color, and number of cells in each asexual (conidial) or sexual (oospore, zygospore, ascospore, or basidiospore) spore produced, and the characters of the fruiting body which produces each type. This usually can be seen clearly enough in temporary or semipermanent mounts on glass slides as described in previous sections. In case fruiting bodies and spores are not present on the specimens, they can often be induced to form, as described in the sections mentioned, or produced on the fungus isolated from the diseased tissues.

Most classifications of fungi include many saprophytic forms. Perhaps less than 5 percent of the total number of fungus species (approximately 200,000) are parasitic on plants, and less than one percent are of any economic importance. The classifications in this volume are stripped down to the genera you are apt to meet and probably will include 95% or more of the parasites you will encounter in a year's time.

FUNGI IMPERFECTI

The "IMPERFECTS" are fungi with septate mycelium but lacking a perfect (sexual) stage. Except for a few genera which produce no spores (*Rhizoctonia* and *Sclerotium*) they produce conidia (often in abundance) and many of them are important plant parasites. Thousands more are saprophytes.

A great many imperfect fungi have been found to have a perfect stage, mostly in the Ascomycetes, but also some in the Basidiomycetes. The name of the perfect stage takes precedence; e.g., *Venturia inaequalis* is the perfect stage of *Fusicladium dendriticum*. The conidial stage is often the aggressive, parasitic stage of the disease and the perfect stage developes saprophytically on the infected host and acts as a resting stage. The conidia are often too fragile to survive adverse conditions. It is necessary to maintain the classification of Imperfects so the fungi can be identified from their conidial stage, as the perfect stage usually is not present on the active lesions.

The Fungi Imperfecti is the best group in which to begin the study of identification as a great many common fungus parasites have a very active conidial stage and many of them produce a new generation of conidia every two or three weeks, so spore material is usually available on the specimens collected. If not present, it usually can be induced in 1 to 3 days in a moist chamber.

NO SPORES! -- WHAT THEN? If spore formation cannot be induced, either: (1) the fungus may have been killed by heat, dryness, etc., or, (2) the lesion may be due to bacteria (and may produce an exudate in moist chamber) or a virus; or (3) the lesion may be caused by a chemical spray, or one of many causes of nonparasitic diseases. Additional samples and field observations may reveal the cause.

Having determined the inspection of temporary microscope mounts (slides) the shape, color, septation and place where the conidia are borne--either from scrapings from lesions or freehand sections--consult the following table (See pages 7.9 and 7.10) adapted from one used by Dr. J. J. Davis (of freehand section fame) to determine the genus of the fungus involved.

The classification is largely artificial and the genera are grouped in "pigeon-holes" depending upon just three characters: (1) type of conidiophores and/or fruiting body (aecervulus or pycnidium); (2) color of spores and mycelium--both listed across the top in the table; and (3) number of cells and shape of conidia listed down the side of the table. All genera agreeing in these categories are placed in the same "box." In most cases the necessary spore and fruiting body characters can be determined quickly from freehand sections or scrapings of lesion-bearing material.

Having mastered this group, the more complicated classification of the other groups will be easier to understand and use.

The most useful references are listed in the appendix: Stevens (8) for keys and genus descriptions; Barnett (4) for illustrations, and Schwartze (3) for economic species.

THE ILLUSTRATIONS

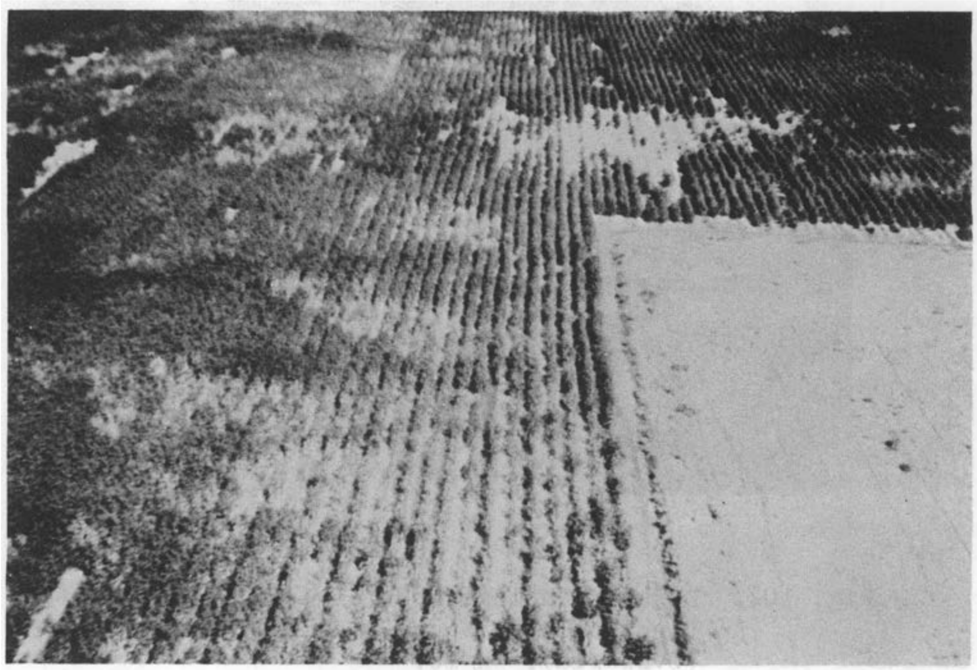
In preparing illustrations of the fungus genera included, it appeared desirable to limit the features presented to those distinctive of the genus illustrated. For example, the line drawings include: type of lesion on plants, often a 5 to 10 times enlargement of the lesion to show fruiting bodies (hand-lens view); enlarged view of fruiting structures (often sectional in pycnidia and perithecia); and spores. The drawings are semidiagramatic rather than detailed, and cell and mycelial structures are indicated rather than completely drawn. Full compliment of spores, etc., is reduced to a few to more clearly indicate how they are borne. The spores themselves are drawn in more detail. It is felt that this treatment creates a better mental image of a genus than detailed drawings.

A few of the saprophytes most commonly submitted as causing disease are included. Persons identifying plant diseases should know them, as they frequently appear on lesions, on petri plates, and in temporary mounts made for microscopic examination.

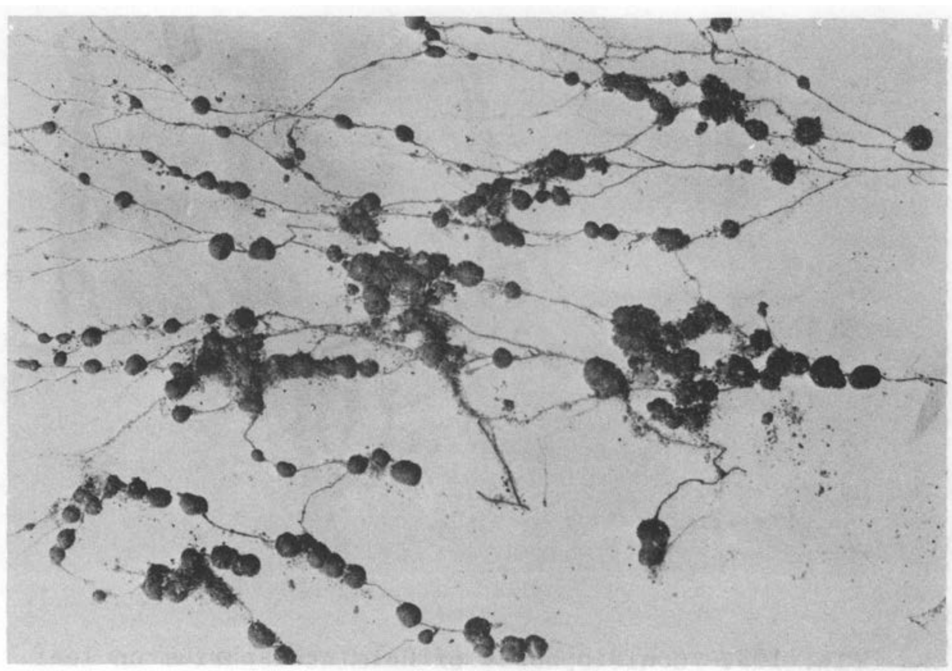
PHOTOGRAPHS OF TEMPORARY MOUNTS

Photographs of temporary microscope slide mounts of fruiting bodies and spores prepared by quick methods as suggested in this book are distributed in appropriate places near the descriptions and drawings of the genera. Each fungus has been made into a temporary mount for immediate viewing under the compound microscope. All the techniques mentioned in the text are illustrated and the method used is indicated in the legend.

Temporary mounts satisfactory for identification are easy to prepare. Much can be seen by focusing up and down under the microscope which cannot be shown in photomicrographs which must be taken with only one plane in sharp focus.



Aerial view of cotton field showing areas of plants killed by cotton root rot.



Strands of cotton root rot fungus with numerous black resting bodies (sclerotia).

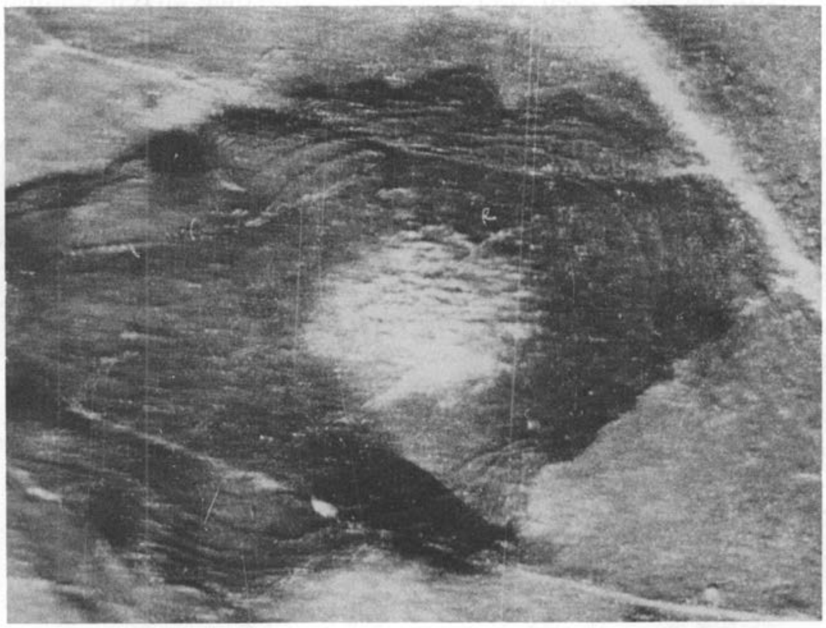


Fig. 102. Dark-brown leaf spot on leaf of Sambucus. Light-colored spore-bearing area in center (Ovularia). X 10.

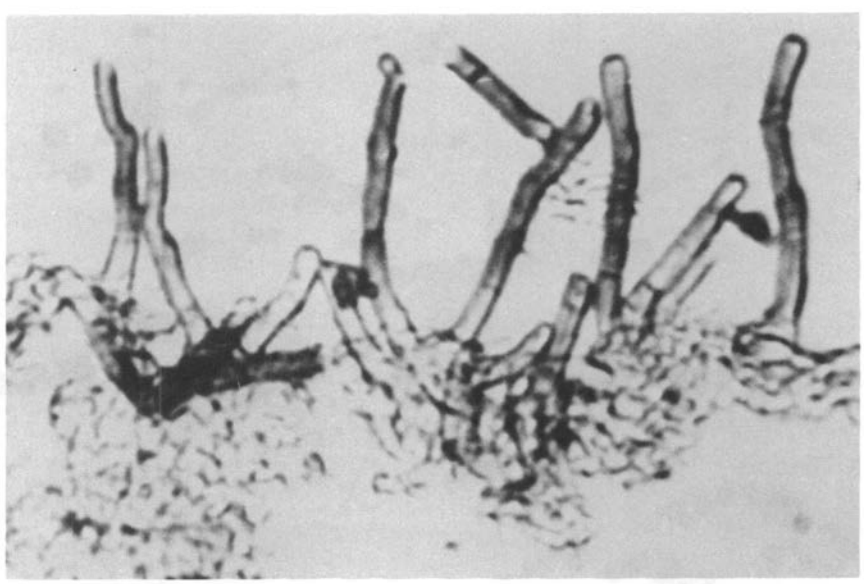


Fig. 103. Conidiophores of Helminthosporium on leaf section of barley. (Davis Method)

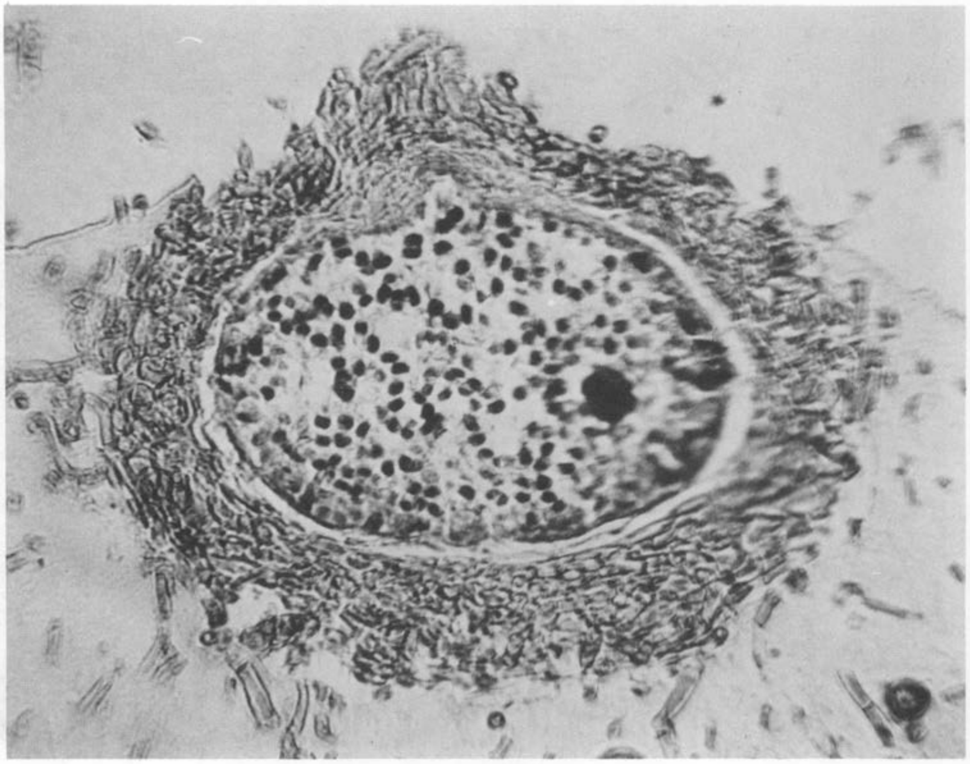


Fig. 104. Section of heavy-walled pycnidium showing conidia. Not quite median section does not show ostiole.

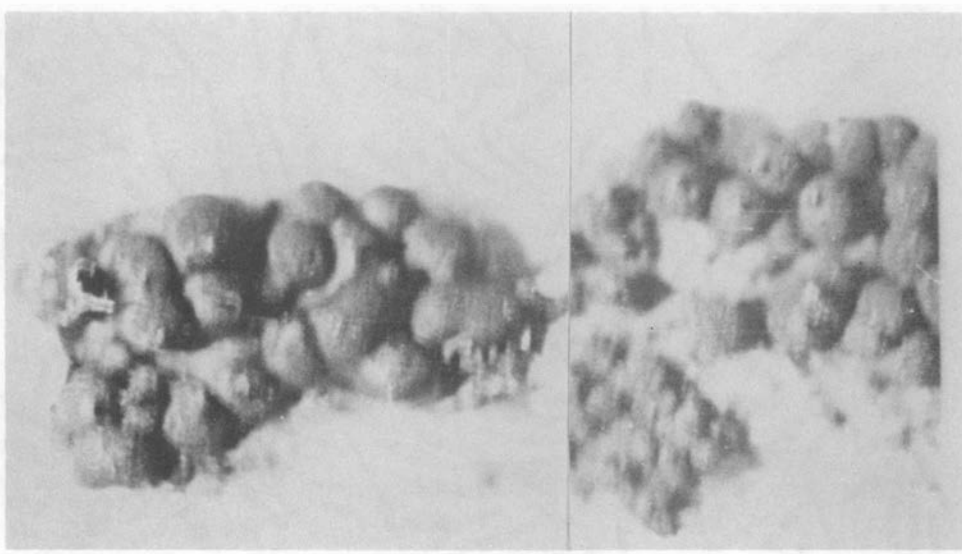


Fig. 105. Flask-shaped pycnidia or perithecia produced on surface of host plants. Crushing these bodies revealed contents to be dark, one-celled conidia of Sphaeropsis.

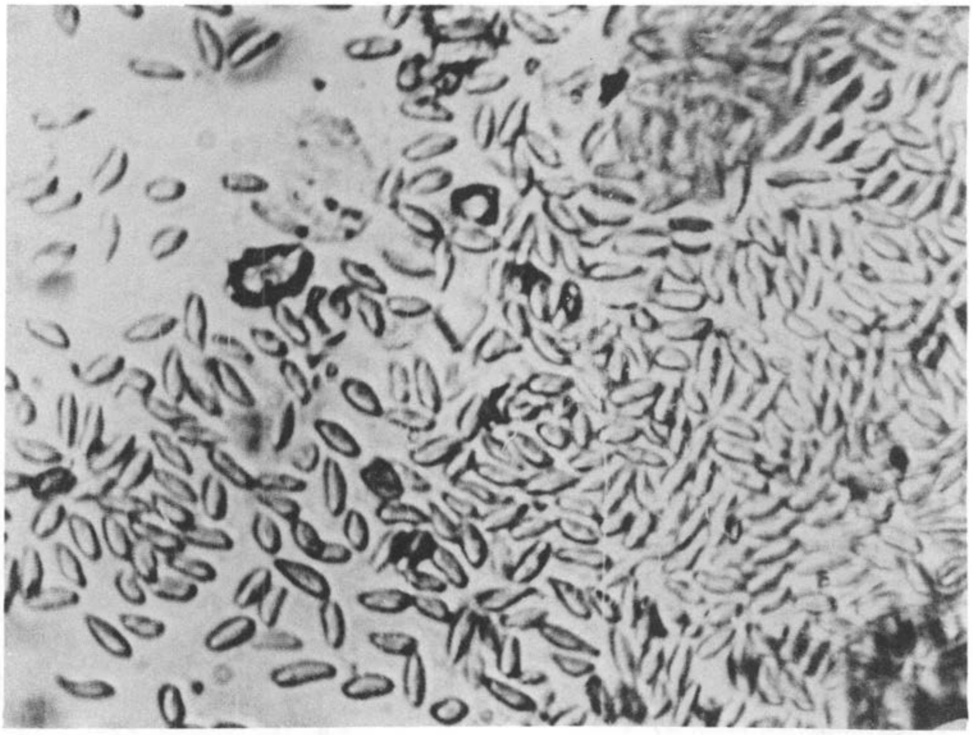


Fig. 106. Conidia exuded from pycnidium of Phoma on pod of mesquite.

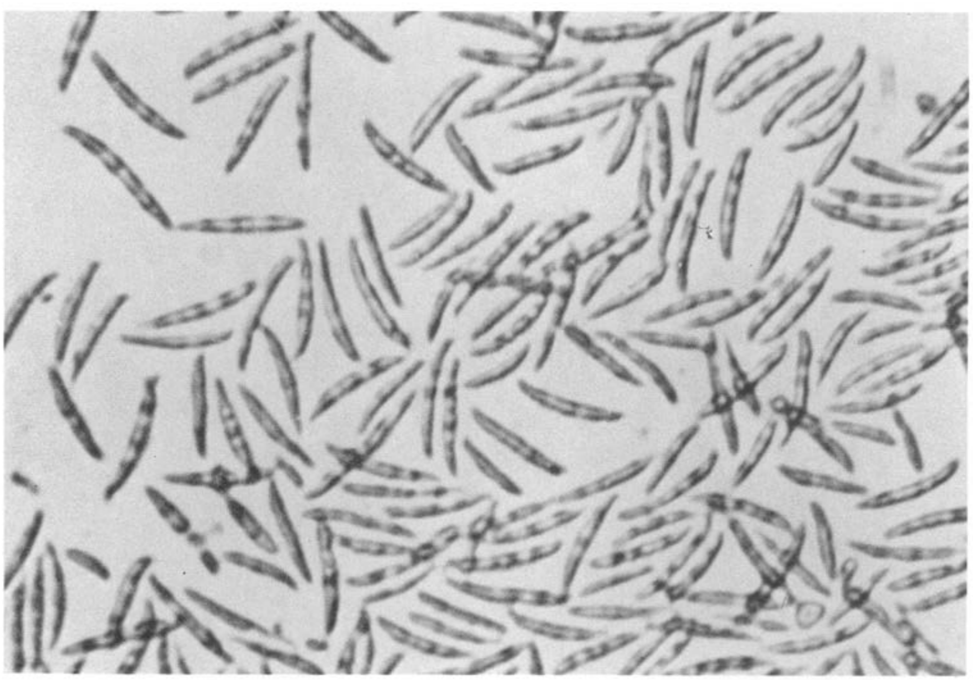


Fig. 107. Spores of Septoria from lesion on celery.

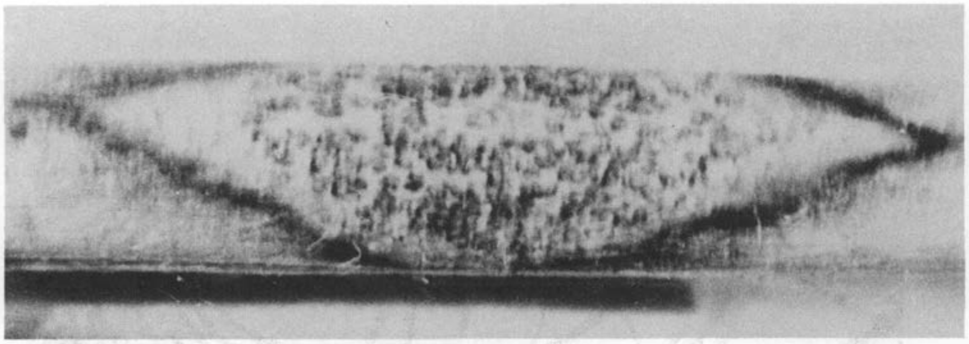


Fig. 108. Anthracnose lesion (on alfalfa stem). Light-colored acervuli made visible by the dark-colored setae.

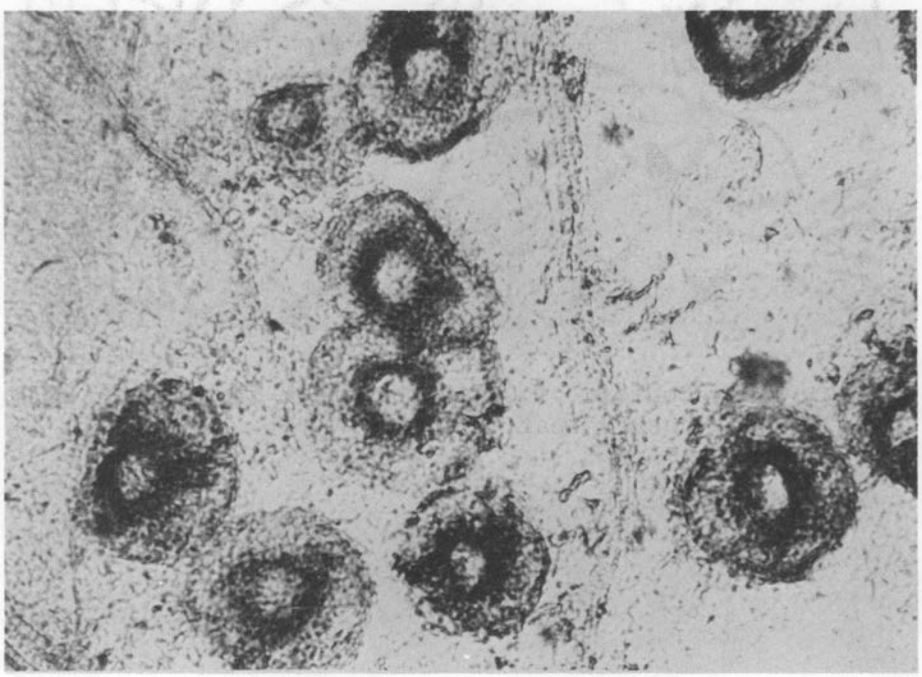


Fig. 109. Lesions of cherry leaf spot X 10. Clusters of slender, white aecervuli bear numerous slender conidia (Cylindrosporium).

Fig. 110. Conidia of Cylindrosporium from lesion on cherry leaf.

ABBREVIATED KEY TO THE PRINCIPAL GENERA OF THE FUNGI IMPERFECTI

PART I

	I. SPHAEROPSIDALES (PHOMALES) (Conidia borne in pycnidia)		II. MELANCONIALES (Conidia borne in acervuli)	
	Light	Dark	Light	Dark
1-celled	Phyllosticta Phoma Phomopsis Cytospora Dothiorella Melasmia Macrophomina Macrophoma	Sphaeropsis Coniothyrium	Colletotrichum Gleosporium Sphaceloma*	Melanconium
2-celled	Ascochyta Darluca***	Diplodia	Marssonina	
3 to many celled	Stagnospora Aschersonia****	Hendersonia* Hendersonula	Septogloeum	Coryneum Pestalotia*
Filiform 1 to many celled	Septoria		Cylindrosporium	Entomosporium*
Muriform (Cross walls on both axes)				

*Minor importance
**Saprophyte
***Parasitic on rusts
****Parasitic on scales

ABBREVIATED KEY TO THE PRINCIPAL GENERA OF THE FUNGI IMPERFECTI

PART II

	III. MONILIALES (Conidia on simple or branched conidiophores)		IV. STILBACEAE (Conidia on synnema)	V. TUBERCULARIACEAE (Conidia on sporodochium)	VI. STERILE MYCELLIA No spores
	Light	Dark			
1-celled	Oidium Monilia Ovularia Geotrichum Botrytis Phymatotrichum Verticillium Aspergillus Penicillium Trichoderma	Moniliochaetes Periconia Nigrospora Torula** Hormiscium <u>Endosporae</u> Thielaviopsis Chalara	Graphium	Tubercularia Tuberculina*** Sphacelia	Sclerotium (Pellicularia) Rhizoctonia (Pellicularia) (Helicobasidium) Ozonium (Phymatotrichum)
2-celled	Cephalothecium Rhynchosporium	Cladosporium Fusicladium Scolecotrichum* Polythrincium*			
3 to many celled	Ramularia Piricularia	Helminthosporium Curvularia Heterosporium Stigmina*		Fusarium Epicoccum** (dark)	
Filiform 1 to many celled	Cercosporella Fusarium	Cercospora			
Muriform* (Cross walls on both axes)		Alternaria Macrosporium Stemphyllium Fumago**			

*Minor importance
**Saprophyte
***Parasitic on rusts
****Parasitic on scales

<u>SPORES 1-CELLED IN PYCNIDIA: LIGHT COLORED</u>:

1. PHYLLOSTICTA: Conidia small, ovate to elongate, hyaline. Parasitic, producing spots, principally on leaves. See Phoma.

A-<u>P</u>. <u>acerina</u> on maple leaf; B-lesion enlarged; C-pycnidium; D-conidia.

2. PHOMA: Much like Phyllosticta, but parasitic principally on stems, fruits, or parts other than leaves--but often occurs on leaves also.

<u>P</u>. <u>lingam</u>. A-stem lesion on cabbage; B-pycnidium extruding spore mass; C-pycnidium; D-conidia.

2a. MACROPHOMA: A large-celled Phoma. Conidia over 15 mu long, ovate or broadly ellipsoid. Fig. 2E-conidia over 15 mu.

3. PHOMOPSIS: Conidia of two types: (1) ovate to fusoid, and (2) slender and bent or curved (stylospores). Causes spots on various plant parts. Pycnidia not deeply embedded.

<u>P</u>. <u>vexans</u> on eggplant. A-lesions on fruit; B-pycnidium; C-section of pycnidium; D-conidiophores, conidia and stylospores; E-conidia.

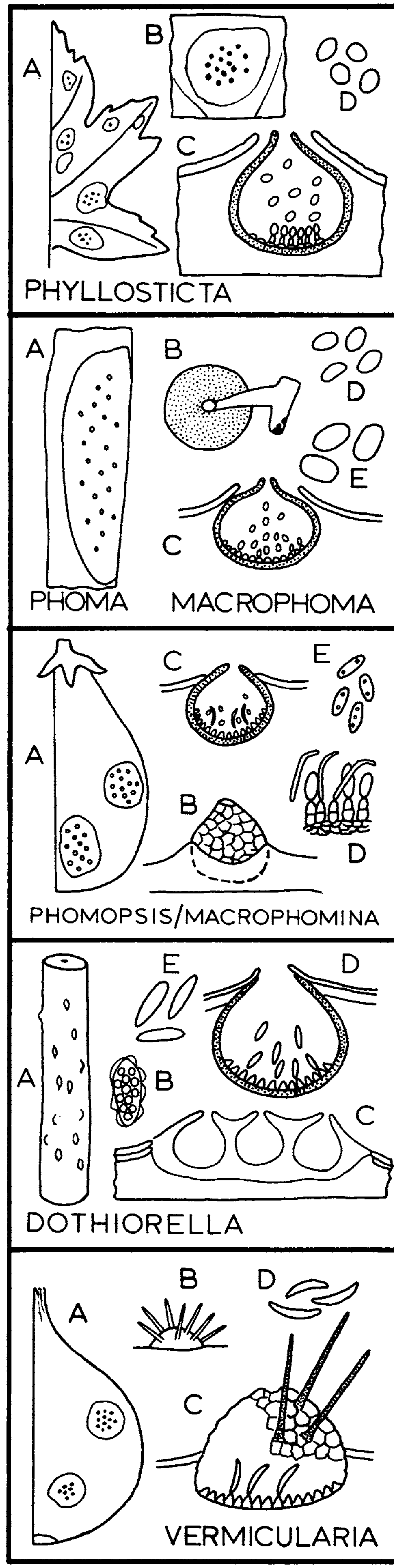
3a. MACROPHOMINA: (<u>Rhizoctonia</u> <u>bataticola</u>) <u>Minute black sclerotia</u> are found on lower stems and roots and within the tissues as conspicuous black dots. In most cases the conidial stage is not formed but occurs occasionally on the surface of dead tissues. The dark pycnidia contain 1-celled hyaline spores. Causes Charcoal rot of sorghums and corn (microsclerotia are abundant in the disintegrated pith) and Ashy stem blight on beans, soybean and many other vegetables and flowers. <u>Infected stems are weakened and break</u> above ground line. (Like Phoma, but with microsclerotia, see <u>Sclerotium</u> <u>bataticola</u>.

4. DOTHIORELLA: Pycnidia grouped in a stroma (fungus "tissue"), breaking through cortex. Parasitic on leaves, bark, fruit.

<u>D</u>. <u>mali</u> on Ribes. A-lesion on currant cane; B-lesion enlarged; C-pycnidia in stroma; D-section of pycnidium; E-conidia.

5. VERMICULARIA: Pycnidia erumpent, globose depressed, black with many dark bristles, conidia fusoid, curved.

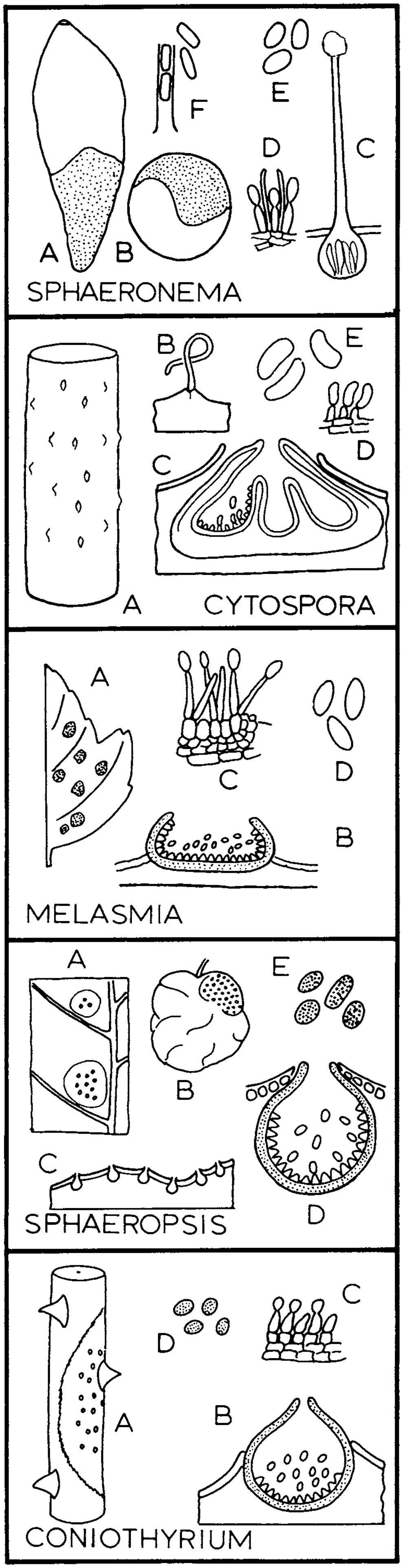
<u>V</u>. <u>circinans</u>. A-lesions on onion bulb; B-pycnidium with bristles; C-section of pycnidium; D-spores.



Phyllosticta Phoma Macrophoma Phomopsis Macrophomina Dothiorella Vermicularia

SPHAEROPSIDALES: Spores in pycnidia, 1-celled, light

FUNGI IMPERFECTI - 1



SPORES 1-CELLED IN PYCNIDIA: LIGHT COLORED:

6. SPHAERONEMA: Pycnidia immersed or superficial, pear-shaped or globose, beak long, conidia ovate or elongate.

S. fimbriatum on sweet potato. A-lesions on fleshy root; B-section showing rot; C-pycnidium with exuded spores; D-conidiophores; E-conidia; F-endospores.

7. CYTOSPORA: Pycnidia forming cavities in embedded or erumpent stroma. Conidiophores slender; conidia elongate and curved. Profuse spore threads or horns extruded after rains, en masse orange when wet, drying to a tangerine-red. Parasitic or saprophytic on bark of deciduous fruit trees, cottonwoods and willows. Mostly imperfect stages of Valsa (Ascomycete).

C. chrysosperma on Populus sp. A-twig canker; B-pycnidium exuding thread of spores; C-section of pycnidium; D-conidiophores; E-conidia.

8. MELASMIA: Pycnidia in a superficial broad, black stroma. Conidia slightly curved or fusoid. "Tar spot" on leaves, the imperfect stage of Rhytisma.

M. acerina on maple. A-"Tar spots" on leaf; B-section of pycnidium; C-conidiophores; D-conidia.

SPORES 1-CELLED IN PYCNIDIA, DARK COLORED:

9. SPHAEROPSIS: Pycnidia separate or grouped, erumpent, conidia large, dark, ovate to elongate. Causes leaf spots, fruit rot and mummified fruits of apple, grape, etc.

S. malorum on apple. A-leaf spot; B-black rot wrinkled mummy of fruit with pycnidia; C-section of fruit with pycnidia; D-pycnidium; E-conidia.

10. CONIOTHYRIUM: Pycnidia erumpent; conidia very small, dark, ovoid or ellipsoid. Causes cankers on rose canes, cane fruits, grape and apple, etc. Two species cause rose cankers.

C. fuckelii. A-canker on rose cane; B-section of pycnidium; C-conidiophores; D-conidia.

SPORES 2-CELLED, LIGHT COLORED:

11. ASCOCHYTA: Pycnidia immersed. Conidia hyaline, ovoid to oblong. Principally causing leaf spots. Also on stems and pods of peas.

A. pisi on peas. A-lesions on pod; B-lesions on leaf; C-conidia.

12. DARLUCA: Pycnidia are formed in rust sori. Conidia fusoid with bristle-like appendages at both ends. Parasitic on rust fungi--mostly on uredia.

D. filum on telial sorus of *Puccinia* sp. A-enlarged view of Darluca in sorus; B-section of pycnidium; C-conidia.

SPORES 2-CELLED, DARK COLORED:

13. DIPLODIA: Pycnidia immersed, erumpent; conidia dark, ellipsoid or ovoid. Parasitic or saprophytic. *D. zeae* is widespread on ears and stalks of corn. *D. natalensis* causes fruit rot, gummosis, and wood rot of citrus.

D. zeae on corn. A-numerous pycnidia above node on stalk; B-section of pycnidium; C-conidia (larger and longer than typical of genus).

SPORES 3-MANY CELLED, LIGHT COLORED:

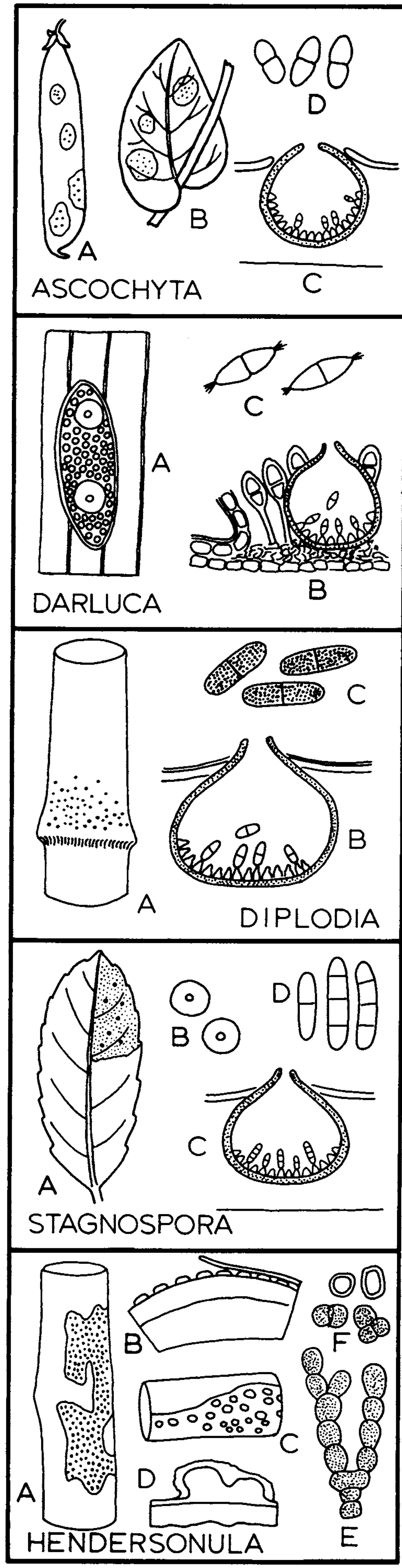
14. STAGNOSPORA: Conidia three or more celled, elliptical or cylindrical. Causes leaf spots, principally on grasses.

S. meliloti on alfalfa. A-lesion on leaflet; B-surface view of pycnidia; C-section of pycnidium; D-conidia.

14a. ASCHERSONIA: Pycnidia sunken in yellow to reddish stroma. Conidia fusoid, many celled. Best known as parasite on scale and other insects on citrus trees in Florida.

SPORES 3-MANY CELLED, DARK COLORED:

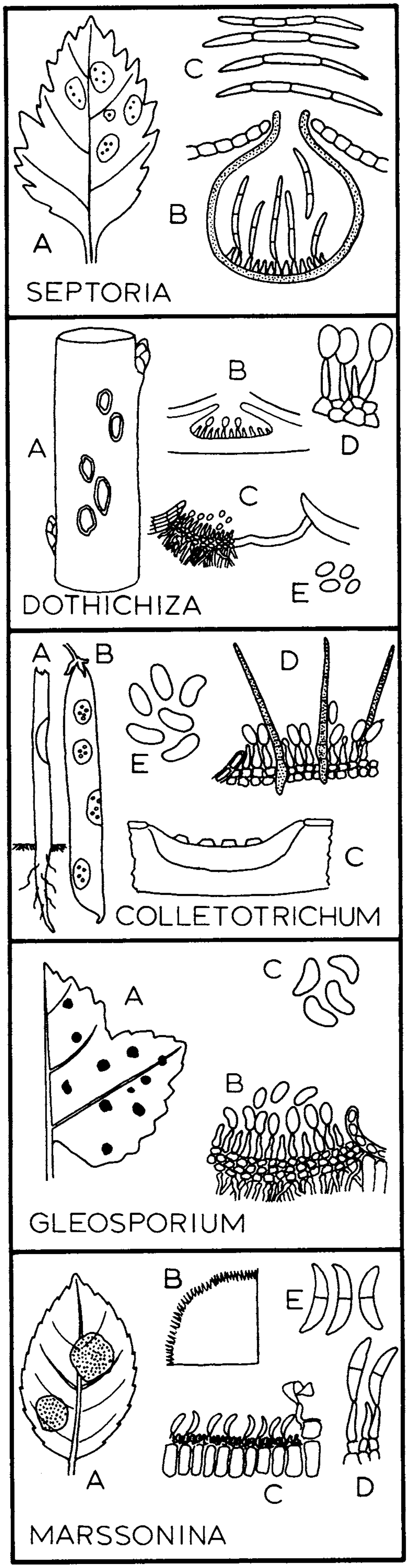
15. HENDERSONULA: Conidia dark, elongate to fusoid. Causes sooty canker on walnut, mulberry, ash, sycamore, citrus, etc.



Ascochyta Darluca Diplodia Stagnospora Aschersonia Hendersonula

SPHAEROPSIDALES: Spores in pycnidia, 2-celled, & 3-many celled

FUNGI IMPERFECTI - 3



<u>SPORES FILIFORM, LIGHT COLORED</u>:

16. SEPTORIA: Pycnidia produced on spots, erumpent. Conidia slender, several septate, usually curved. An important genus of over 100 species, typically causing leaf spots.

<u>S</u>. <u>petroselina</u> var. <u>apii</u> on celery. A-lesions on leaflet; B-section of pycnidium; C-conidia.

17. DOTHICHIZA: <u>D</u>. <u>populea</u> is important on poplars. Pycnidia erumpent, roundish, flattened, resemble acervuli, irregularly dehiscent; conidia ovoid.

A-Pycnidia breaking through bark of canker; B-young pycnidium; C-mature pycnidium; D-conidiophores and conidia.

M E L A N C O N I A L E S

<u>CONIDIA PRODUCED ON ACERVULI</u> (Cushion-like base), <u>1-CELLED, LIGHT COLORED</u>:

18. COLLETOTRICHUM: Acervuli waxy, disc-shaped, with few to many <u>dark spines among conidiophores</u>. Conidia ovoid to oblong, slightly curved (often salmon-colored in mass). Spines somewhat scarce or absent. Parasitic on vegetables and fruits causing sunken "anthracnose" lesions.

<u>C</u>. <u>lindemuthianum</u>, major on beans. A-stem lesion; B-pod lesions; C-section of pod lesion - diagrammatic; D-acervulus; E-conidia.

19. GLEOSPORIUM: Very similar to <u>Colletotrichum</u>, but has <u>no</u> <u>spines</u>. Parasitic chiefly on leaves and fruits. Both <u>Colletotrichum</u> and <u>Gleosporium</u> are conidial stages of <u>Glomerella</u> (Ascomycete).

<u>G</u>. <u>ribes</u> on currant. A-lesions on leaf; B-part of acervulus; C-conidia.

19a. SPHACELOMA: Similar to <u>Colletotrichum</u> and <u>Gleosporium</u>, but acervuli thinner. Conidia ovoid to oblong. Imperfect stage of ELSINOE (Ascomycete).

<u>SPORES IN ACERVULI, SPORES 2-CELLED, LIGHT COLORED</u>:

20. MARSSONINA: Acervuli, subepidermal, pale; conidia 2-celled, ovoid to elongate. Parasitic, mostly on leaves. Black spot of rose, walnut, poplar, ash, etc. <u>M</u>. <u>rosae</u>, conidial stage of <u>Diplocarpon</u> <u>rosae</u>, Black spot, major on roses.

A-black spot lesion on leaflet; B-fringed margin of lesion; C-acervulus; D-conidiophores; E-conidia.

SPORES IN ACERVULI, SPORES DARK, 3-MANY CELLED:

21. CORYNEUM: Acervulus black, discoid, subcutaneous or subcortical. Conidiophores slender. Conidia dark, oblong to fusoid, 3 to many celled. Causing cankers on bark of trees.

C. kunzei on oak. A-acervuli on oak twig; B-acervuli breaking through bark; C-acervulus; D-conidiophores and conidia; E-conidia; F-acervulus and spores of C. beijerinckii.

22. PESTALOTIA: Acervuli dark, discoid, subcutaneous. Conidiophores short. Conidia with several dark cells, and hyaline, pointed end cells with 2 or more apical appendages at tip end. Causes leaf spots. P. guepini var. vaccinii on cranberry.

A-lesions on Rhododendron leaf; B-acervuli breaking through epidermis; C-acervulus; D-conidia with appendages.

22a. ENTOMOSPORIUM: Acervuli dark, discoid. Conidia of 2 large and 2 small lateral cells, setae on apical and lateral cells. Parasitic on leaves and fruit.

SPORES IN ACERVULI, FILIFORM, 1-CELLED OR SEPTATE:

23. CYLINDROSPORIUM: Acervuli subepidermal, pale. Conidiophores short. Conidia slender, straight or curved, 1 to many celled, white en masse. Cause leaf spots, cherry, etc.

C. padi, conidial stage of Coccomyces hiemalis, major on cherry. A-lesions on leaf; B-young acervulus; C-mature acervulus; D-conidia; E-lesion enlarged.

SPORES IN ACERVULI, LIGHT, 3 to MANY CELLED:

23a. SEPTOGLOEUM: Acervuli subepidermal, erumpent, pale; conidiophores short, simple; conidia several-celled, oblong to fusoid. Parasitic. S. acerinum occasionally defoliates Norway and Schwendler maples in the Midwest.

M O N I L I A L E S

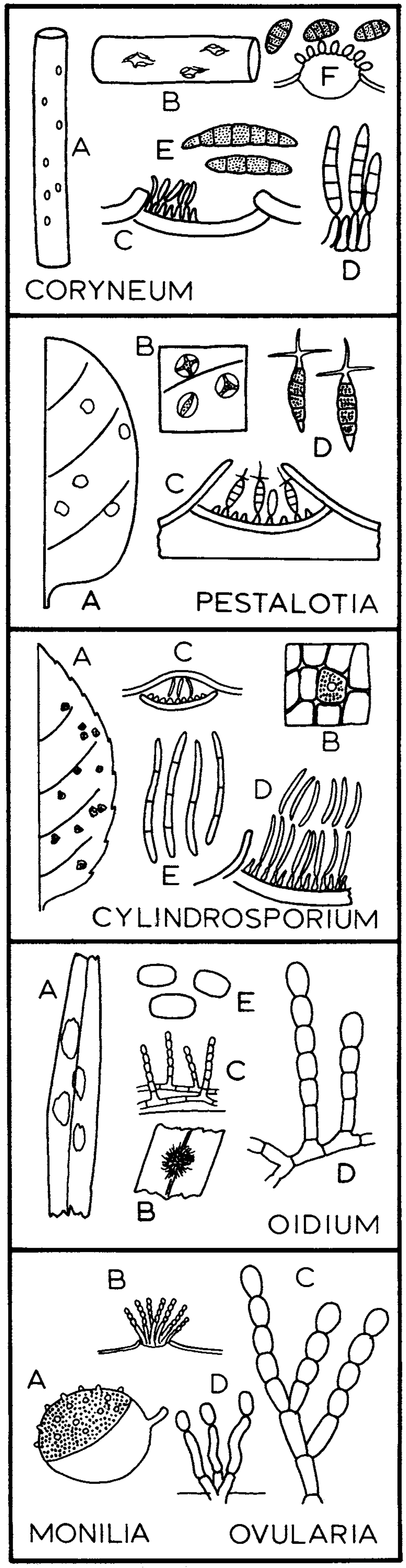
CONIDIA HYALINE, 1-CELLED, ON HYPHAE OR CONIDIOPHORES:

24. OIDIUM: Mycelium external on hosts, white. Conidiophores simple, upright. Conidia barrel-shaped, in chains. Conidial stages of the powdery mildews.

O. monilioides, conidial stage of Erysiphe graminis. A-surface growth on barley leaf; B-growth enlarged; C-hyphae and conidiophores; D-conidiophores; E-conidia.

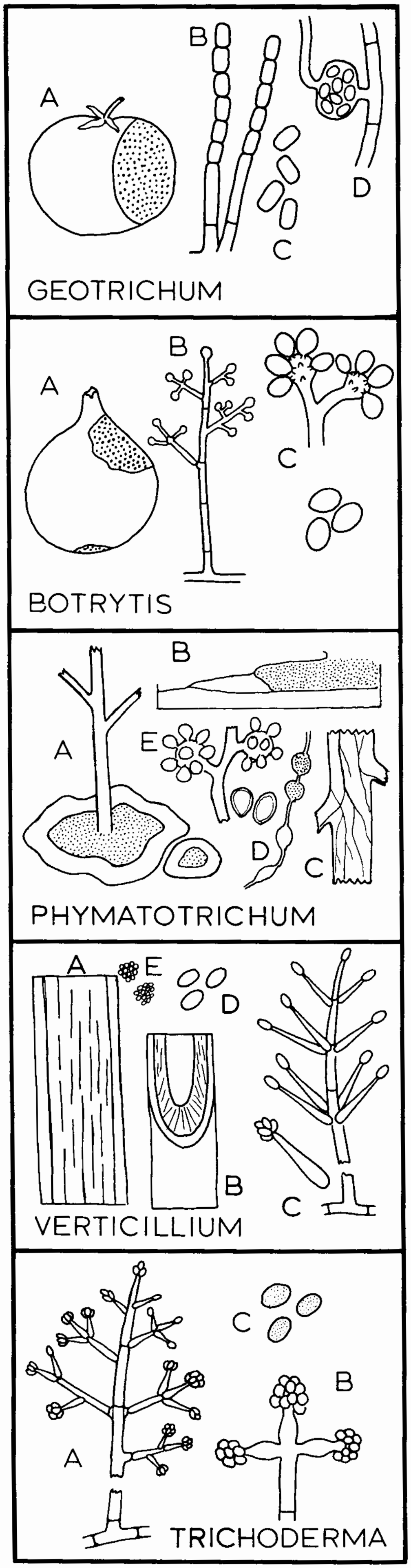
25. MONILIA: Conidia tan or grayish in mass, barrel-shaped in chains. Often produced in small tufts. Conidial stage of MONILINIA (in part SCLEROTINIA) spp. causing brown rot of fruits, especially stone fruits. Conidial stage of Monilinia fructicola.

A-conidial tufts on plum fruit lesion; B-conidial tuft enlarged; C-conidiophore and conidia.



Monilia Oidium Septogloem Cylindrosporium Entomosporium Pestalotia Coryneum

FUNGI IMPERFECTI - 5 MELANCONIALES: Spores in acervuli, 3-many celled or filiform



CONIDIA HYALINE, 1-CELLED, ON HYPHAE OR CONIDIOPHORES:

25a. OVULARIA: Conidiophores emerging from leaves in clusters. Conidia 1-celled, ovoid or elliptical. Causes leaf spots. Conidiophores and conidia.

26. GEOTRICHUM: Conidia cylindric with truncate ends, formed from segmentation of hyphae. Causes a wet, sour rot of citrus, grapes and tomatoes, etc.

G. candidum on tomato. A-rot on green fruit; B-conidiophores segmenting; C-cylindrical conidia; D-ascus stage (rare).

CONIDIOPHORES BRANCHED, MORE OR LESS TREE-LIKE:

27. BOTRYTIS: Mycelium grey, growing rapidly in culture. Conidiophores long, branched with apical cells enlarged and globoid, covered with conidia on short sterigmata. Conidia ovoid, gray in mass. The fungus sometimes produces irregular black sclerotia. Causes the "gray mold" rot of vegetables, fruits and ornamentals. Three species on stored onions.

A-rot on onion bulb; B-conidiophore; C-detail of tip of conidiophore and conidia.

28. PHYMATOTRICHUM: Conidiophores produced in vast numbers in powdery "spore mats" on moist soil. They are irregularly branched with enlarged tips bearing "spores" like Botrytis. These spores tan in mass very rarely germinate. Distinctive feature of the one important parasitic species which is limited to semiarid Southwest of the United States and Northern Mexico is the acicular hyphae (see illustration) produced on the strands of hyphae found on the surface of infected roots. Small (2-4 mm.) dark sclerotia sometimes form a hyphal strand in late summer.

P. omnivorum. A-old, powdery spore mat around base of cotton plant, showing new cottony border; B-diagram of new and old parts of spore mat; C-tap root of cotton showing root rot strands on surface; D-young and mature sclerotia on root rot strands in soil; E-spore bearing branch and spores.

29. VERTICILLIUM: Conidiophores slender and more or less verticillately branched (in whorls). Conidia solitary or in small apical clusters in moist environment. Causes important vascular wilts in cotton, vegetables and woody plants. Some strains of the principal parasitic species *V. albo-atrum* are white in culture, others have numerous tiny black microsclerotina.

V. albo-atrum on cotton. A-brown streaks in woody stems; B-greenish streaks in sapwood of maple; C-conidiophore showing whorled branches; D-conidia; E-microsclerotia.

CONIDIOPHORES BRANCHED, MORE OR LESS TREE-LIKE:

30. TRICHODERMA: Conidiophores much branched, but not verticillate. The terminal segments produce ovoid, conidia in clusters, dark green in mass. Some species, especially T. lignorum, parasitic on other fungi. Grows rapidly. Illus. p. 7.16.

T. lignorum parasitic on Phymatotrichum omnivorum. A-conidiophore showing nonverticillate branching; B-tip of conidiophore and spores; C-conidia.

31. PENICILLIUM: Conidiophores produced very freely with mono- or bi-verticillate branching, bush-like. Conidia produced abundantly in chains, spherical, often brightly colored in mass.

A-mono- and B-Bi-verticillate branching; C-conidia. Asci similar to those in Aspergillus are uncommon.

32. ASPERGILLUS: Conidophores produced freely, with swollen tip bearing phialids directly or on a basal row of cells. Conidia produced abundantly in chains forming spherical heads, often colored in mass, borne on primary or secondary sterigmata.

Conidiophores; A-with primary sterigmata; B-with secondary sterigmata; C-sterigmata and spores; D-asci scattered in cleistothecium (not commonly seen).

CONIDIA HYALINE, 2-CELLED:

33. RHYNCHOSPORIUM: Mycelium subcuticular, later superficial. Conidia 2-celled, upper cell with lateral beak from very short conidiophores. Causes leaf scald of barley, rye and grasses. Lesions are at first a steely blue.

R. secalis on barley. A-lesion on leaf; B-very short conidiophores and beaked spores.

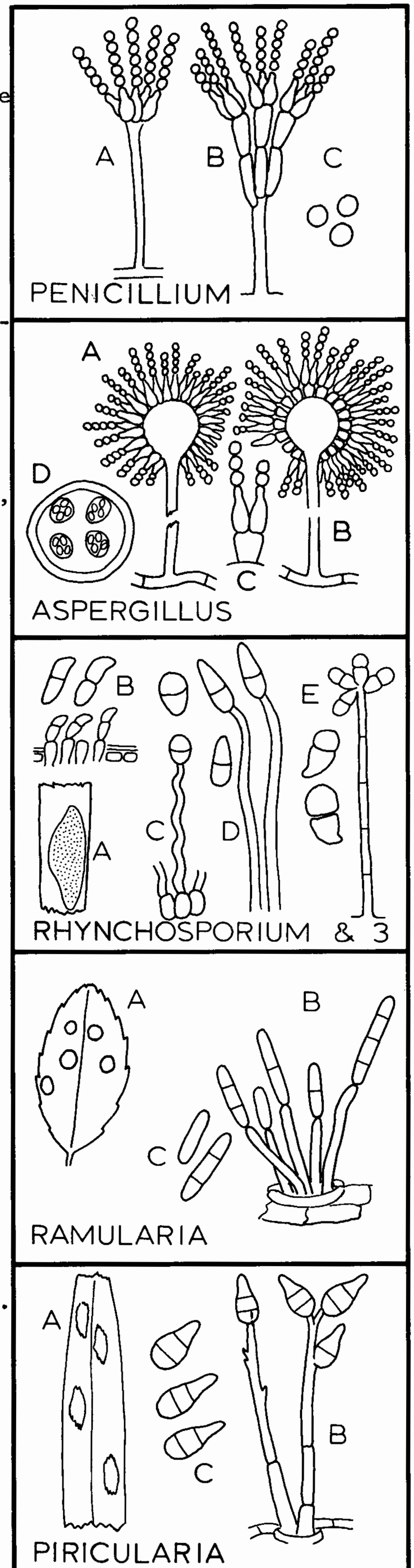
33a. CEPHALOTHECIUM: Conidiophores long, slender, bearing groups of 2-celled ovoid conidia at apex.

C. roseum is weakly parasitic on apply. E-C. roseum, conidiophores and spores.

33b. SCOLECOTRICHUM: Conidiophores clustered, unbranched, pigmented. Conidia dark, 2-celled, ovoid to oblong, usually pointed. Causes leaf spots on grains and grasses. D-conidiophores and conidia.

33c. POLYTHRINCIUM: Conidiophores very dark, in dense clusters, wavy. Conidia 2-celled, terminal. P. trifolii is parasitic on leaves of white clover.

C-P. trifolii, undulate conidiophores and conidia.



Trichoderma Penicillium Aspergillus Rhynchosporium Scolecotrichum Polythrincium Cephalothecium

MONILIALES: Spores 2-celled & 3-m celled

CONIDIA 3-MANY CELLED, HYALINE:

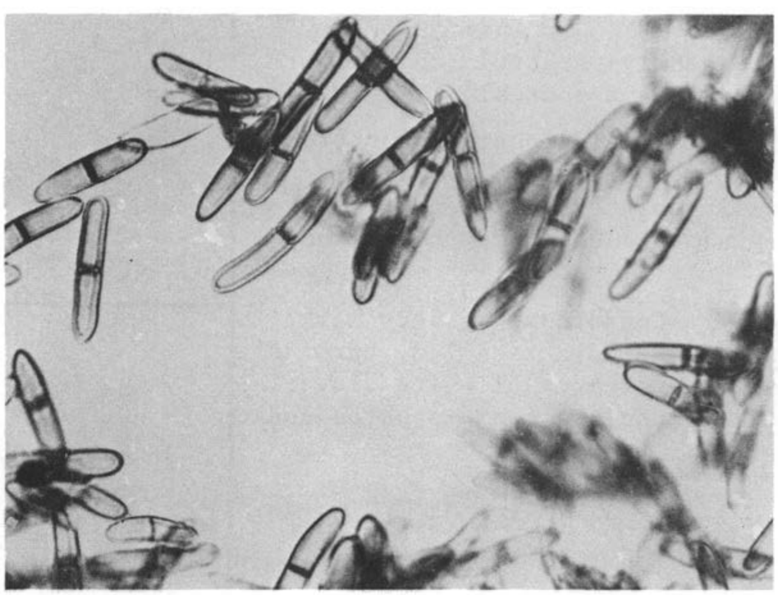
34. RAMULARIA: Conidiophores clustered at stomata; hyaline to dark. Conidia hyaline, mostly 2-celled, cylindrical, sometimes in short chains. Many species causing leaf spots. Illus. p. 7.17.

R. tuslanii on strawberry. A-leaflet with lesions; B-conidiophores and conidia; C-conidia.

35. PIRICULARIA: Conidiophores long, slender, septate, single or in tufts. Conidia usually pyriform with pointed tip, 2-3-celled, hyaline. On rice and grasses. Illus. p. 7.17.

P. grisea on Setaria sp. A-lesions on Setaria leaf; B-conidia and conidiophores; C-conidia.

Group of conidiophores of Helminthosporium.



Conidia of Deplodia zeal.

CONIDIA DARK, 1-CELLED, VARIOUSLY BORNE ON CONIDIOPHORES:

36. THIELAVIOPSIS: Conidiophores on short lateral branches subhyaline to dark. Terminal cell swollen at bottom and tapering, producing hyaline endogenous spores (like beans in a bean-shooter). Endoconidia rod-shaped. Apical cells of other hyphae become dark, thick-walled chlamydospores which eventually break apart. Parasitic on dates, sugar cane, pineapple, et al. Some are conidial stage of CERATOCYSTIS.

T. paradoxa causing trunk rot of date palm. A-vascular bundles with surrounding pith destroyed; B-chlamydospores in pith cells; C-conidiophores producing endoconidia.

37. MONILOCHAETES: Conidiophores dark, septate, erect. Conidia at first hyaline, single or in chains.

M. infuscans causes scurf of sweet potato. A-dark brown surface lesions on root; B-section of lesion with conidiophores; C-conidiophores and conidia.

38. CHALARA: Mycelium typically dark. Conidiophores usually have some pigment; few-celled, apical cell tapered producing rod-shaped hyaline conidia, often in chains. C. quercina is conidial stage of Ceratocystis (Endoconidiophora) fagacearum, the cause of oak wilt.

A-split in bark caused by fungus mats; B-section showing regular and pressure mats in cambium and splitting of bark; C-cross section of oak trunk showing wood discoloration; D-graft of oak roots permitting spread of infection; E-conidiophore; F-endoconidia.

39. NIGROSPORA: Conidiophores short, dark, somewhat inflated, bearing a very dark, globose or flattened 1-celled conidium. N. sphaerica rots the cobs of corn. Two species cause cob rot of corn.

A-partial cross section of ear; B-kernel and chaff showing spore formation; C-conidiophores and conidia.

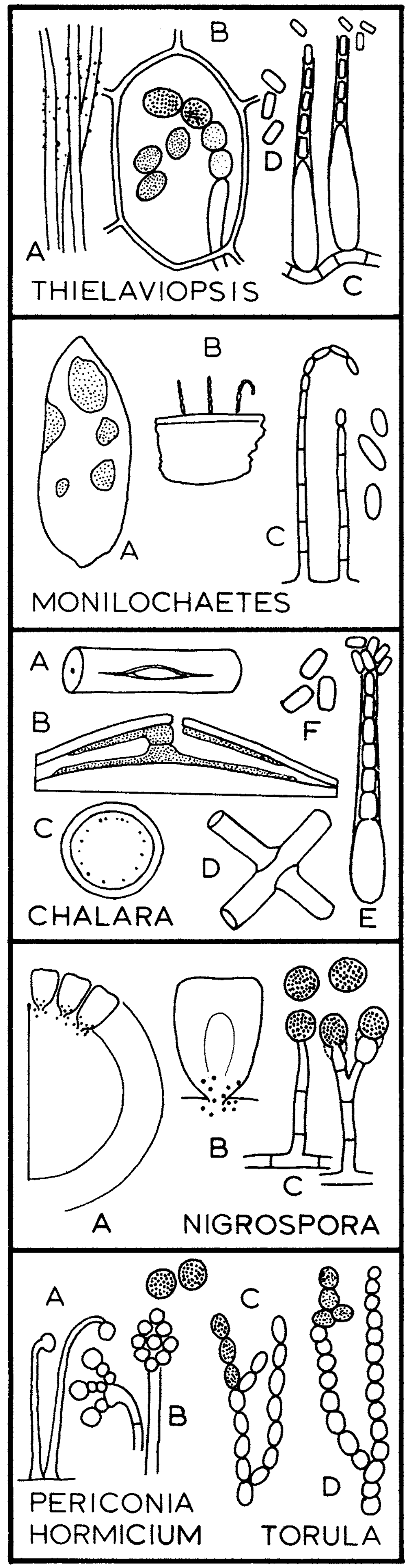
40. PERICONIA: Conidiophores long and stout, dark, bearing at apex a group of very dark globose conidia.

P. circinata causes Milo disease, a root rot of sorghum. A-rot of base of stalk; B-conidia and conidiophores.

40a. HORMISCIUM: Branching mycelium on surface of stems, etc., divides into rounded or oblong, dark 1-celled conidia, separating with difficulty.

A saprophyte often encountered on dead stems, etc. C-conidia adhering to each other.

40b. TORULA. See p. 7.20.



Torula

Cladosporium

MONILIALES: Conidia dark, 2-celled & 3-many celled

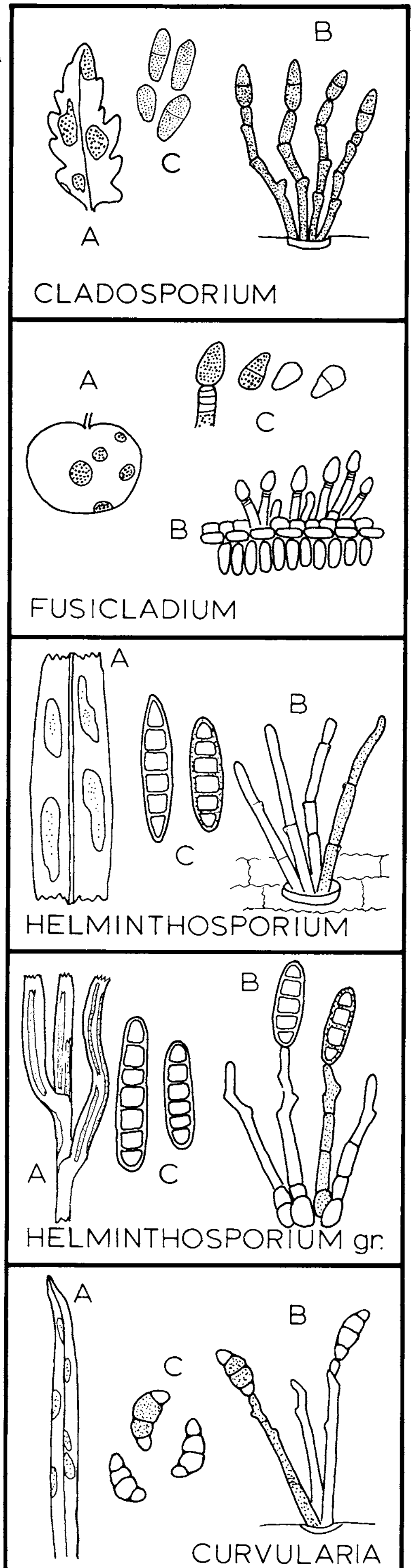
Fusicladium

Helminthosporium

Helminthosporium gr.

Curvularia

FUNGI IMPERFECTI - 9



CONIDIA DARK, 1-CELLED, VARIOUSLY BORNE ON CONIDIOPHORES:

40b. TORULA: Mycelium divides into simple or branched chains of dark elliptical conidia which separate easily. Another saprophyte often encountered on dead stems, etc. (Illus. p. 7.19)
D-mycelium on surface of dead stem. Conidia easily separated.

CONIDIA AND/OR CONIDIOPHORES DARK, 2-CELLED:

41. CLADOSPORIUM: Conidiophores variously branched, usually in clusters, dark. Conidia 1- or 2-celled, dark, variable in size and shape. Causing dark to olive green downy-mildew like lesions on leaves and other plant parts. Leaf mold (C. fulvum) on tomato is typical.
C. fulvum on tomato. A-olive green downy lesions on leaflet; B-conidiophores and conidia; C-conidia.

42. FUSICLADIUM: Mycelium subcuticular, conidiophores short and dark in a pallisade-like layer. Conidia dark, 1- or 2-celled, pyriform or ellipsoidal. Apple and pear scab are conidial stages of VENTURIA (Ascomycetes).
F. dendriticum (Venturia inaequalis) on apple. A-scab lesions on fruit; B-conidiophores and conidia on fruit; C-conidia.

CONIDIA 3-MANY CELLED, DARK:

43. HELMINTHOSPORIUM: Conidiophores quite dark septate, irregular, bearing conidia successively on new growing tips. Conidia are among our largest spores, dark, 3-many (usually 5 to 10) celled, cylindrical, sometimes slightly curved, heavy-walled. Many species causing leaf spots on grains and grasses.
H. turcicum on sorghum. A-lesions on leaf blade; B-conidiophores; C-conidia.

44. HELMINTHOSPORIUM: H. gramineum, cause of stripe on barley. A-long lesions on barley (systemic); B-conidiophores and conidia; C-mature conidia.

45. CURVULARIA: Conidiophores similar to those of Helminthosporium. Conidia dark with end cells lighter; 3 to 5-celled; typically bent or curved with one or more central cells enlarged. Parasitic on grasses.
C. lunata on lawn grass. A-dark lesions on grass blade; B-conidiophores and conidia; C-conidia.

CONIDIA 3-MANY CELLED, DARK:

46. HETEROSPORIUM: Conidiophores like Helminthosporium. Conidia dark, 3 to 5-celled; cylindrical, wall echinulate. H. gracile causes a major leaf spot of Iris.

H. gracile on iris. A-lesions on iris leaf; B-conidiophores; C-conidia.

46a. STIGMINA: Conidiophores short and dark, in clusters from stomata, producing single conidium. Conidia dark, 3 or more celled when mature; ovoid to ellipsoid. S. platani causes a leaf spot on sycamore.

CONIDIA FILIFORM, CONIDIA OR CONIDIOPHORES DARK:

47. CERCOSPORA: Conidiophores dark, in clusters from stomata. Conidia borne successively on new growing tips. Conidia hyaline to dark, filiform, several-celled. Many species causing leaf spots on vegetables and other plants. C. beticola causes a major leaf spot on red and sugar beets.

C. beticola on sugar beet. A-lesions on leaf; B-conidiophores and conidia; C-conidia.

CONIDIA FILIFORM, HYALINE:

47a. CERCOSPORELLA: Conidiophores hyaline, slender bearing single conidia apically or on short branches. Conidia hyaline, several-celled, oblong, cylindrical to filiform, straight or curved. Parasitic.

SPORES MURIFORM, HYALINE:

No common parasites are known in this group.

SPORES MURIFORM, DARK:

48. ALTERNARIA: Conidiophores dark, simple, usually short with simple or branched chain of conidia. Conidia dark, muriform (both cross and longitudinal septa). Species variable in size, shape and septation of spores, and length of terminal cells, and therefore hard to identify. Many species causing leaf spots, fruit spots and secondary rots of fruits and vegetables.

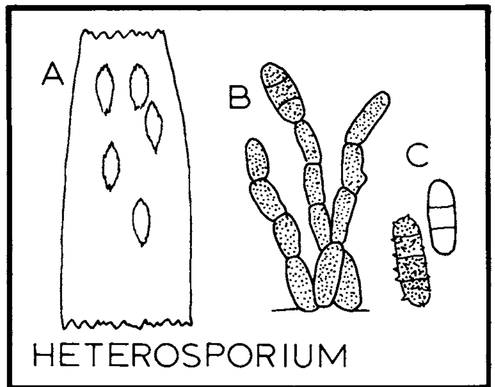
A. solani, cause of early blight of potato. A-dark lesions on leaflet; B-muriform conidium; C-conidiophores and conidia of A. tenuis.

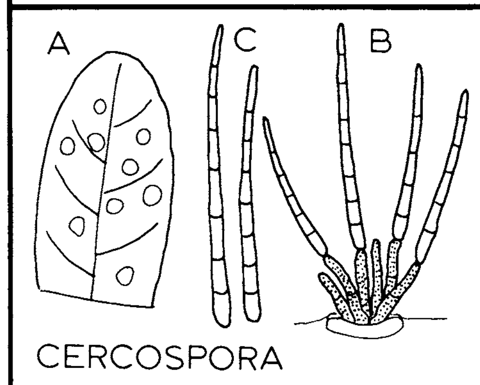
49. MACROSPORIUM: An Alternaria-like fungus producing single spores on a conidiophore. Many consider this genus no longer valid, and that the specimens should be referred to Alternaria.

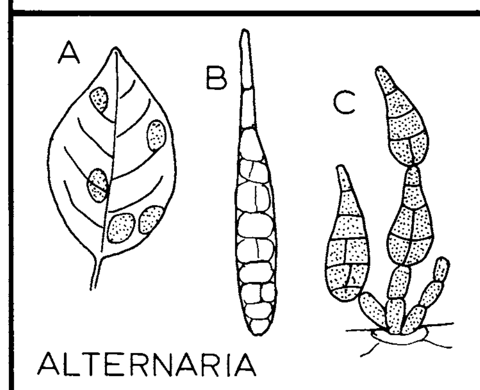
M. cucumerinum on cantaloup leaf. A-tan lesions on leaf; B-conidium; C-conidiophores and young conidium.

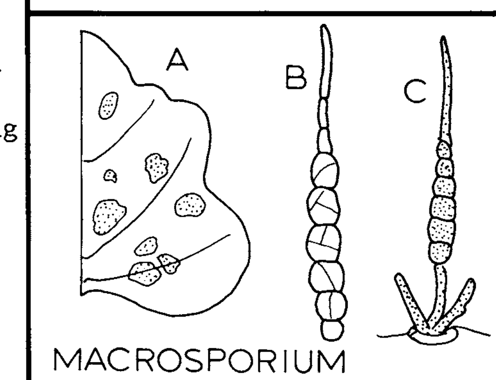
50. STEMPHYLIUM: Conidiophores dark, short bearing a single apical conidium. Conidia dark, muriform, broadly ellipsoidal without a terminal point. Parasitic, a cause of leaf spots.

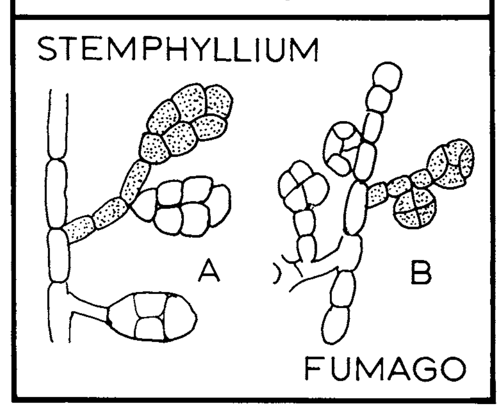
A-stemphyllium sp. on vegetables, conidiophores and conidia.

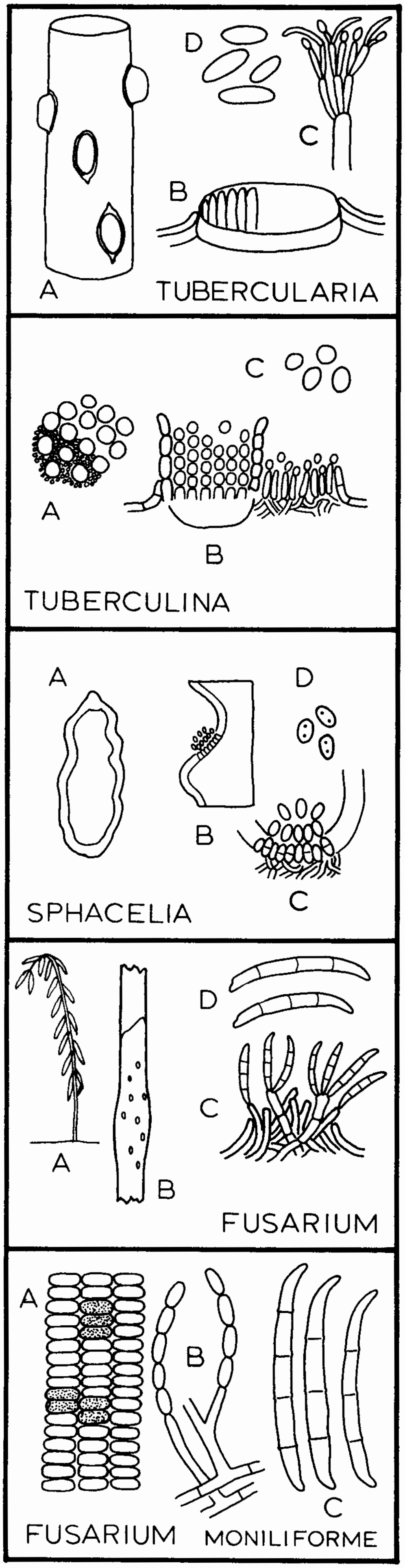












M O N I L I A L E S

SPORES MURIFORM, DARK:

50a. FUMAGO: Dark mycelium appressed to surface of leaves, etc. Conidiophores dark, bearing muriform conidia laterally or terminally. A "sooty mold" commonly saprophytic on "honeydew" of aphids. (Illus. p. 7.21)

B-*Fumago* sp. on honeydew leaves, conidiophores and conidia.

HYPHAE AND CONIDIOPHORES COMBINED IN A SPORODOCHIUM:
(A tight, spore bearing mass)
(Family Tuberculariaceae)

51. TUBERCULARIA: Sporodochia 2 to 3 mm. across, orange, bleaching to straw color, breaking through bark. Conidiophores hyaline, repeatedly branched, bearing terminal conidia. Conidia hyaline, 1-celled, elongate to ovoid. *T. vulgaris* is conidial stage of *Nectria cinnebarina* on currant, etc.

T. vulgaris on currant. A-sporodochia on branch; B-diagram of sporodochium; C-branching conidiophore; D-conidia.

52. TUBERCULINA: Parasitic on rusts, usually aecia. Sporodochia in or near rust pustule, pale violet or purplish. The color is distinctive. Conidiophores hyaline, simple with terminal conidium. Conidia hyaline, 1-celled, ovoid, globose or irregular. *T. persicina* is common parasite of cotton rust (*Puccinia stakmanii*.)

T. persicina on aecium of cotton rust. A-aecial sorus invaded by mildew-like *Tuberculina*; B-section of cotton leaf showing *Tuberculina* in sorus and mesophyll; C-conidia.

53. SPHACELIA: Sporodochium spreads stroma-like. Conidiophores hyaline, septate, bearing terminal conidia in compact pallisade. Conidia hyaline, small, ovoid, 1-celled in a sugary "honeydew." Parasitizing ovaries of grains and grasses.

The imperfect stage of CLAVICEPS (Ergot). *S. segetum*. A-young ovary of rye overrun by Sphacelia; B-diagram of portion of surface; C-conidiophores and conidia; D-conidia.

54. FUSARIUM: Some species produce sporodochia. Species which do not, might be placed under Moniliales with Cercosporella. (Listed both places for convenience.) Conidiophores variable, slender and simple, or short, stout branched, or with a whorl of phialides, single or grouped into sporodochia. Conidia hyaline, of two kinds: (1) macroconidia several-celled, species varying in amount of curvature, ends more or less pointed, basal end with a definite foot; (2) microconidia; 1-celled, ovoid or oblong, borne single or in chains. (3) some conidia are intermediate, 2 or 3-celled and oblong or slightly curved.

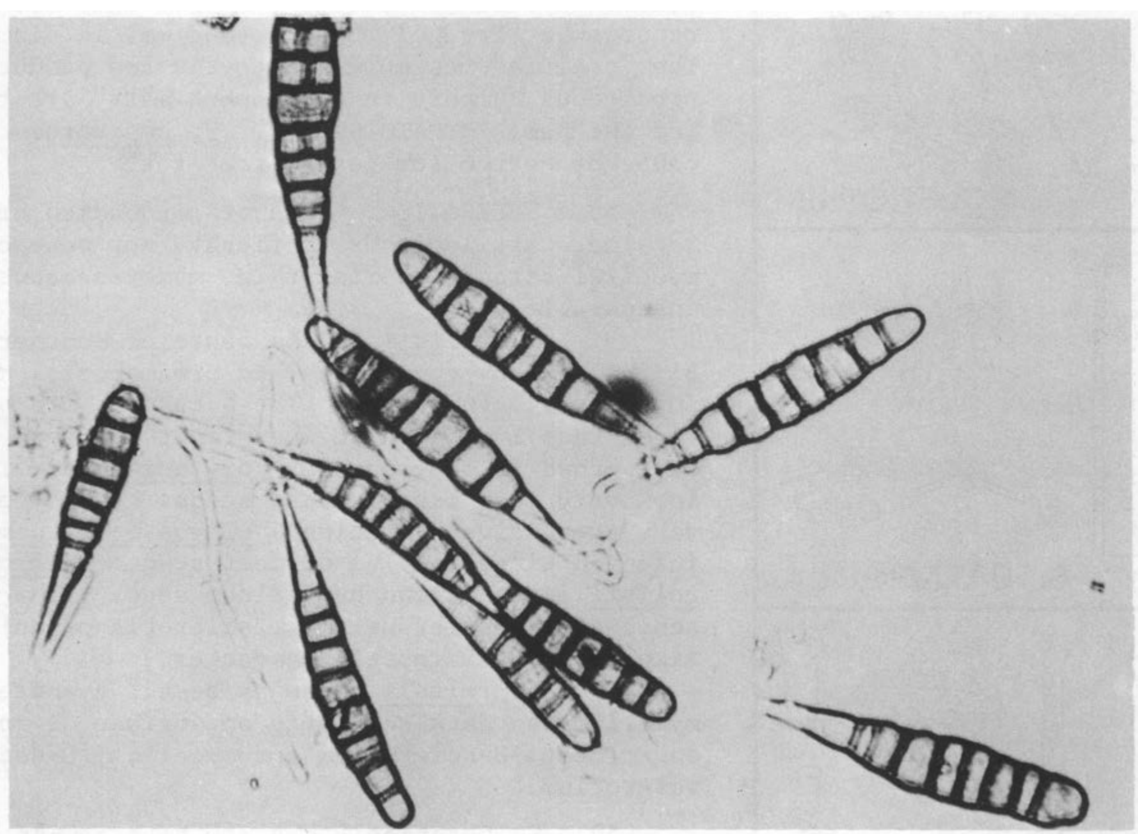
See *F. lini*, p. 7.23.
See *F. moniliforme*, p. 7.23.

HYPHAE AND CONIDIOPHORES COMBINED IN A SPORODOCHIUM:
(A tight, spore bearing mass)
(Family Tuberculariaceae)

The genus Fusarium is readily recognized by the unique shape of the macrospores, but species identification is usually left to a few specialists. The genus contains many major parasites causing wilts or cortical rots, or fruit rots. In the recent, generally accepted classification, many old species based on host plants attacked, but morphologically indistinguishable, have been placed in group species and the old species based on pathogenicity have been designated by the symbol f. (forma), e.g., Fusarium lini becomes Fusarium oxysporum f. lini.

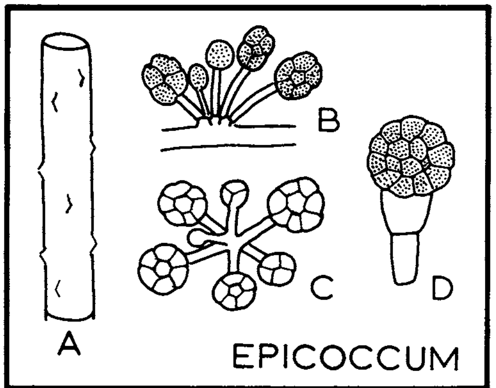
F. lini, the cause of flax wilt. A-wilted young flax plant; B-sporodochium with macrospores; C-macroconidia. (Illus. p. 7.22)

55. FUSARIUM moniliforme, the cause of kernel rot of corn. A-part of ear of corn showing groups of infected kernels; B-conidiophores and microconidia in chains; C-macroconidia. (Illus. p. 7.22)

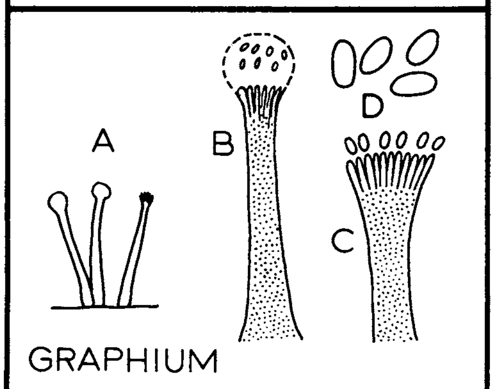


Conidia of Alternaria porri.

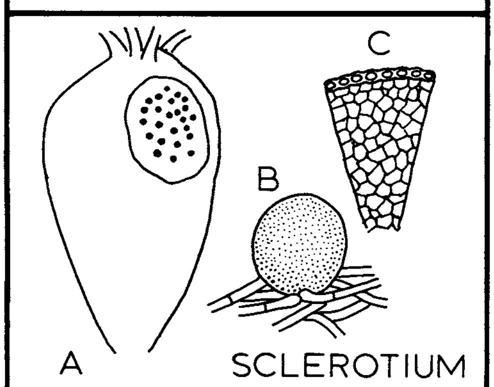
Epicoccum



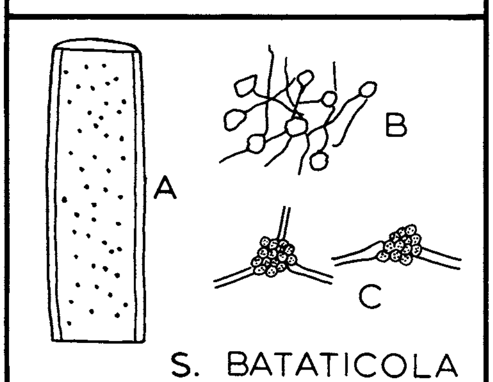
Graphium



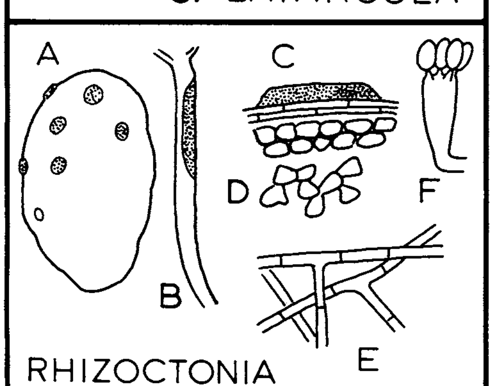
Sclerotium



S. Bataticola



Rhizoctonia



HYPHAE AND CONIDIOPHORES COMBINED IN A SPORODOCHIUM:
(A tight, spore bearing mass)
(Family Tuberculariaceae)

56. EPICOCCUM: Conidiophores borne on small dark cushions, short; conidia dark, 1 to many-celled, globose. Many saprophytic on plant tissues.

A-dark sporodochia on dead stem; B-side view of conidiophores and conidia and C-top view of same; D-conidiophore and spore.

FAMILY STILBACEAE

57. GRAPHIUM: Conidiophores united into a tall, dark stalk (synnema) bearing a rounded terminal mass of 1-celled, elliptical spores in a mucus. Conidial stage of CERATOCYSTIS ULMI (Dutch elm disease).

A-synnemata from elm; B-diagram of synnema with spores in mucus; C-detail of tip of synnema showing conidiophores and conidia; D-conidia.

STERILE MYCELIA

57a. OZONIUM: Young mycelium diffuse, whitish. Usually encountered as tawny strands of hyphae resembling thick fuzzy threads on surface of parasitized roots. "Fuzz" is composed of the distinctive acicular hyphae with right-angled branches.

Sclerotia, dark brown when mature, are formed on strands in late summer. They are spherical or somewhat irregular and 1 to 3 mm. in diameter. The "conidia" resembling Botrytis and produced in prodigeous numbers in the "spore mats" are the basis for the name PHYMATOTRICHUM. P. omnivorum is the cause of cotton (or Texas) root rot.

58. SCLEROTIUM: Sclerotia roundish or irregular, cartilaginous to fleshy, not connected by mycelial strands; cortex thin, membranaceous, inseparable.

S. rolfsii is the cause of Southern Blight of many vegetables and ornamentals, mostly in the southern states. The sclerotia are small, (less than 1 mm.) white when immature, then tan to dark brown as they mature, very numerous. They look very much like mustard seeds. The mycelium is very aggressive producing a cottony, white mass on infected tissues. The perfect stage, Pellicularia rolfsii is now known but seldom seen. (The presence of the numerous small sclerotia of uniform size is best diagnostic character.)

S. rolfsii on sugar beet. A-white mycelium and dark sclerotia on surface of rooted sugar beet; B-sclerotium and mycelium; C-sector of sclerotium.

59. S. bataticola has now been connected with a spore form, Macrophomina phaseoli. The fungus causes disease in a variety of plants: Ashy Stem Blight on bean and soybean; Charcoal rot of sorghum and corn; Stem rot on watermelon and sesame; and root rot and wood rot of citrus. (See p. 7.25)

(There are two diagnostic characters: (1) The presence of numerous tiny black irregular sclerotia in the pith of infected stems or stalks and (2) Sometimes the presence of the small, black pycnidia, usually on the surface. Mounts of pycnidia pricked out with a needle will reveal the Phoma-like conidia.

S. bataticola cause of charcoal rot of sorghums. A-section of sorghum stalk with pith decayed and numerous microsclerotia; B-microsclerotia; C-detail of microsclerotia.

Other species infect onion, rice and tulip.

60. RHIZOCTONIA: Sclerotia variable in form, cortex thin, inseparable.

Rhizoctonia solani is the sterile stage of Pellicularia filamentosa (See under Basidiomycetes). Formerly called Corticium vagum var. solani. Sterile mycelium turning yellowish or light brown with age; branching approximately at right angles, often forming sclerotia-like tufts of short, broad cells, more or less triangular, which function as chlamydospores. Also forms brown to black sclerotia (especially on surface of potato tubers) of coarse, short-celled, hyphae. Perfect stage is infrequent; but formed under high humidity as a thin mildew-like growth on stems just above the ground line. (Under microscope, the club-shaped basidia show sterigmata and spores.)

R. solani of potato. A-potato tuber with sclerotia; B-potato stem with underground lesion; C-diagram of sclerotium; D-triangular sclerotial cells; E-brown distributive hyphae with right-angle branching; F-basidium and spores of Pellicularia perfect stage.

R. crocorum the sterile stage of Helicobasidium purpureum causes Violet Root Rot of alfalfa, sweet potato and other plants. The mycelium is unique, occurring as definitely purple strands on the surface of infected roots. No lens is necessary.

T H E   L O W E R   F U N G I

THE SLIME MOLDS (MYXOMYCETES) are mostly microscopic in size, occurring as saprophytes in moist, shady places, and appearing sporadically in the form of a naked plasmodium which in a few days matures into a spore-bearing body or bodies.

THE PLASMODIOPHORALES include two fairly important parasites: *Plasmodiophora brassicae*, which causes swellings on the roots of crucifers, and *Spongospora subterranea*, which causes pitting of potato tubers.

THE CHYTRIDIALES are a small group of few-celled microscopic forms lacking a well developed mycelium. They complete their life history within a cell or group of adjoining host cells. *Olpidium* invades roots; *Physoderma*, corn leaves. *Synchytrium endobioticum* causes rough galls (warts) on potato tubers; *Urophlyctis alfalfae* causes galls on crowns of alfalfa. Other species cause microscopic leaf galls.

The parasitic species of OOMYCETES have a mycelium without cross walls and sexual reproduction is by oospores embedded in the host tissues. The conidia are really sporangia which germinate by releasing swimming spores with two flagella of equal length, or in some cases by a germ tube.

Important parasites are in three families: (1) *Albuginaceae* (WHITE RUSTS) - A single genus *Albugo*, has conidia in caeoma-like blisters. (2) Family *Pythiaceae* has two major parasitic genera: *Pythium*, causing DAMPING OFF of seedlings and stem and root rots of succulent plants; and *Phytophthora*, a genus having a half dozen species causing root and trunk rots of citrus and other trees, root rots of vegetables, and fruit rots of tree fruits and berries and vegetables. LATE BLIGHT caused by *P. infestans* is still the major fungus disease of potatoes. (3) Family *Peronosporaceae* (DOWNY MILDEWS) includes five genera separated by type of branching of the tree-like conidiophores. Many species are of major importance on vegetables, farm crops, and ornamentals. DOWNY MILDEW caused by *Plasmopara viticola* has long been a major disease of grapes.

ZYGOMYCETES also have a mycelium without cross walls; but sexual reproduction is by zygospores formed by two gametes of equal size. Asexual reproduction is by stalked sporangia. Conidia have no flagella and germinate by a hypha. Most genera are saprophytic but three are parasitic: (1) *Rhizopus* with abundant coarse mycelium and sporangia causes important postharvest soft rots on sweet potatoes, squash, strawberries, etc.; (2) *Mucor* occasionally causing a clay-colored firm rot of sweet potatoes; and (3) *Choanephora* causing a black rot of cucurbit blossoms and young fruit in the field.

M Y X O M Y C E T E S

TRUE SLIME MOLDS: Saprophytic (mostly tiny) in moist, shady places, naked plasmodia which form spore bodies. *Fuligo*, *Physarum*.

PLASMODIOPHORALES: Always parasitic. No mycelium. Zoospores with two unequal flagella.

C H Y T R I D I O M Y C E T E S

CHYTRIDIALES: 83 genera, 300 species. No mycelium or very little. Zoospores with one posterior flagellum. *Olpidium*, *Synchytrium*, *Physoderma* (*Urophlyctis*).

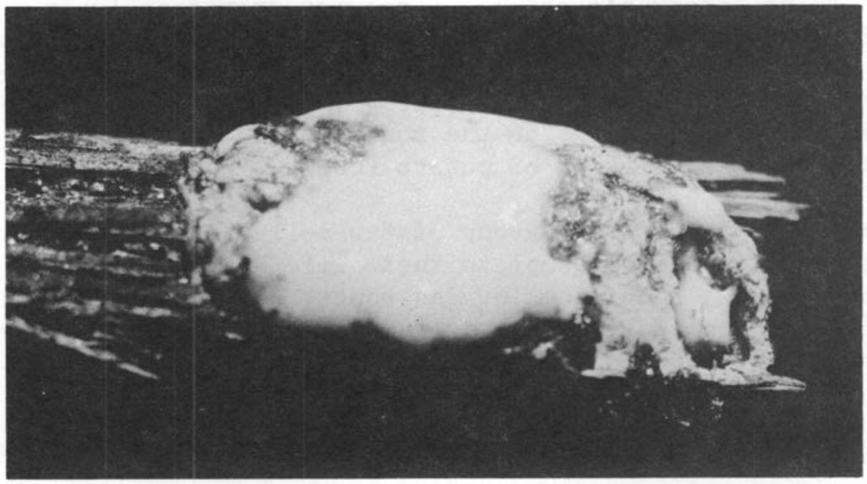


Fig. 111. Naked plasmodium of Myxomycete growing on decayed wood. This mass will mature into spore bearing bodies in a few days. X 2.

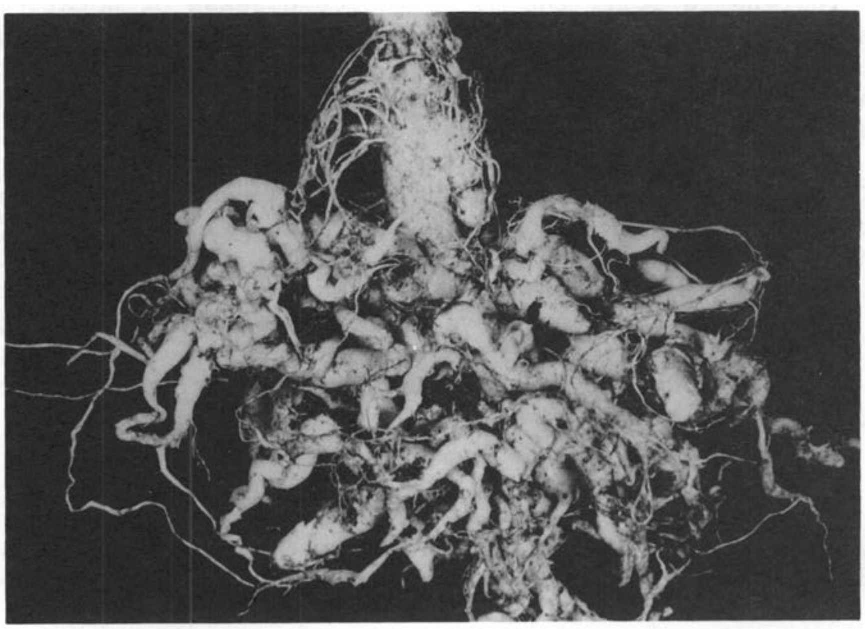


Fig. 112. Root system of cabbage plant with numerous galls caused by the club-root fungus, Plasmodiophora brassicae. Cross sections of these galls do not show the tiny dark cysts found in root knot nematode galls.

O O M Y C E T E S

Vegetative hyphae without cross walls. Sexual reproduction typically by oospores. Zoospores with two equal flagella.

PERONOSPORALES:

Fam. Albuginaceae - WHITE RUSTS: Conidia in caeoma-like white blisters, Oospores embedded. -*Albugo*

Fam. Pythiaceae - DAMP-OFF FUNGI: Zoospores in sporangia. Oospores embedded, intracellular mycelium. -*Pythium*, *Phytophthora*.

Fam. Peronosporaceae - DOWNY MILDEWS: Conidia (sporangia) borne on more or less branching conidiophores, Oospores embedded, mycelium intercellular. -*Peronospora*, *Plasmopara*, *Bremia*, *Sclerospora*, *Pseudoperonospora*.

Z Y G O M Y C E T E S

Vegetative mycelium without cross walls. Sexual reproduction by zygospores.

MUCORALES: 50 genera, 250 species, mostly saprophytic. Abundant mycelium, conidia in sporangia.

Fam. Mucoraceae - Black molds - *Rhizopus*, *Mucor*.

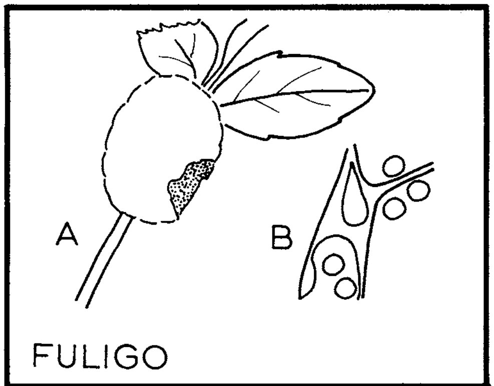
Fam. Choanephoraceae - Has macro- and microsporangia. -*Choanephora*.

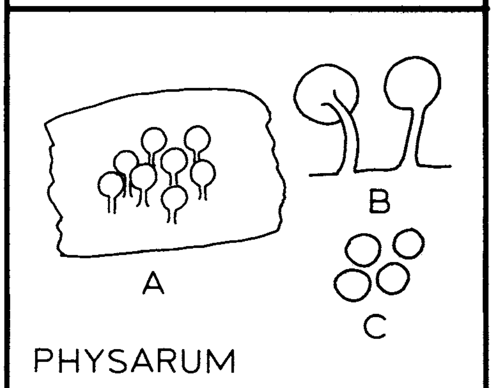
PLEASE NOTE: The tables on pages 7.9 - 7.10, and outlines on pages 8.1, 9.1, and 10.1 are not complete keys to be used for keying out genera, but are summaries of the principal parasitic genera in the major groups of fungi.

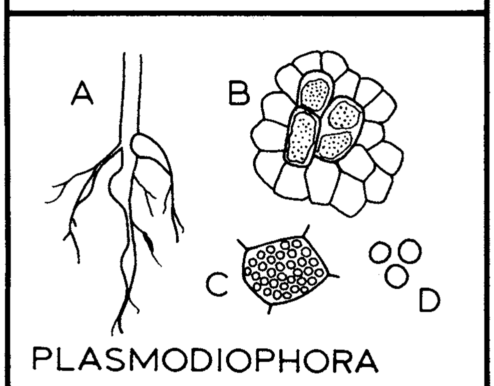
The classification of fungi has undergone almost continuous change as more species have been found and additional information secured on the "old" species. The classification of the Fungi Imperfecti and the Basidiomycetes (except in the fleshy fungi) has become fairly stabilized, but the Phycomycete and Ascomycete classification varies with almost every author.

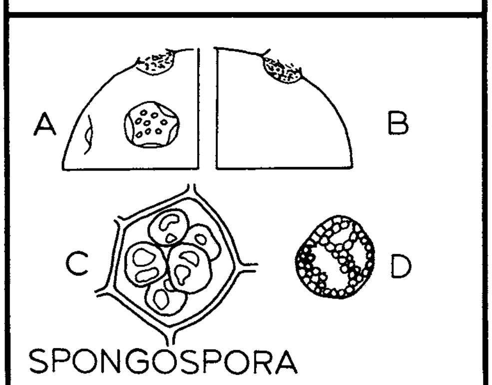
The classifications presented here strive to be simple and easy to follow and the users of this volume need not be concerned about taxonomic details. Commonly used synonyms are given in parentheses to avoid confusions when referring to other literature. R. B. Streets

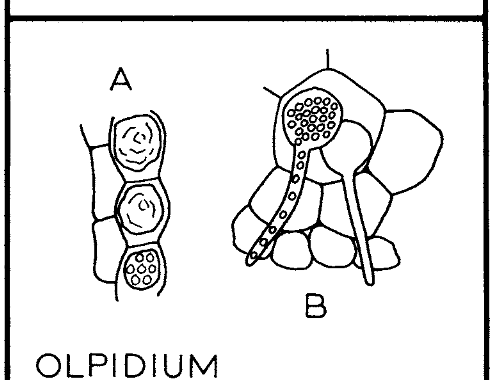
M Y X O M Y C E T E S
(True Slime Molds, saprophytic)











61. FULIGO: F. septica forms cherry-sized powdery masses, black inside, white outside on vegetation (strawberries, bermuda grass, etc.). Smothering but not parasitic. (Often submitted for identification.)

F. septica on strawberry. A-white encrusted powdery black spore mass on petiole; B-capillitium and spores.

62. PHYSARUM: This and similar slime molds sometimes abundant on grass and other vegetation. Tiny (1 mm.) dark gray sporangia, usually stalked. Saprophytic.

P. cinereum on decaying bark. A-group of fruiting bodies; B-stalked bodies enlarged; C-spores.

PLASMODIOPHORALES

63. PLASMODIOPHORA: Causes "club root" - spindle-shaped galls on tap root and lateral roots of crucifers. Multinucleate plasmodia in parenchyma cells form microscopic spherical spores. (Visible in stained slides.)

P. brassicae on cabbage. A-swellings on roots of young cabbage; B-plasmodia in host cells; C-spores developed from plasmodium; D-spores enlarged. (Do not confuse with root knot nematode galls.)

64. SPONGOSPORA: A single species (S. subterranea) causes powdery scab on potato tubers. Slightly raised brownish lesions on tubers enlarge to 5 mm.; epidermis peels back exposing yellow-brown spore balls containing many cells. (Make temporary slide of spores and observe under low and high power of microscope.)

S. subterranea on potato tuber. A-lesions on surface of tuber; B-section of tuber with lesion; C-spongy spore ball.

CHYTRIDIOMYCETES
Chytridiales

65. OLPIDIUM: Infects roots of cabbage and lettuce (big vein). One or more zoosporangia per cell with hypha-like neck through which zoospores escape from host. (Observe under high power of microscope. Use dilute stain.)

O. brassicae on cabbage. A-resting cells in root cells; B-sporangia in host cells. (After Woronin.)

O O M Y C E T E S

PERONOSPORACEAE - DOWNY MILDEWS

Key to Downy Mildews:

PLASMOPARA: Conidiophores monopodial, with branches arising more or less at right angles, tips obtuse.

PERONOSPORA: Conidiophores dichotomously branched, tips acute. Conidia not papillate or only slightly so.

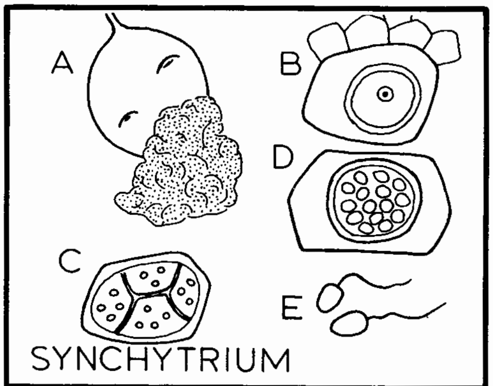
PSEUDOPERONOSPORA: Conidiophores subdichotomously branched, branches arising at acute angles, with subactue tips, conidia papillate.

BREMIA: Conidiophores dichotomously branched, with disc-shaped tips from the border of which sterigmata arise bearing conidia with apical papillate.

SCLEROSPORA: Conidiophores stout with heavy branches clustered at apex.

(Adapted from Walker, Plant Pathology, 2nd Ed.)

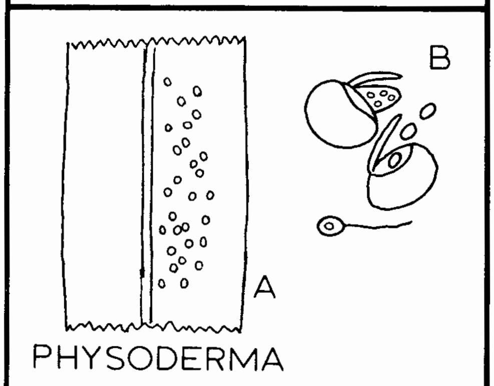
Synchytrium



66. SYNCHYTRIUM: One species (S. endobioticum) causes potato wart, causing rough, black crown-gall-like growths mostly on the tubers. Fortunately nearly eradicated from U. S. Other species form tiny leaf galls containing a single sporangium. (Free hand sections, or crush gall and observe under microscope.)

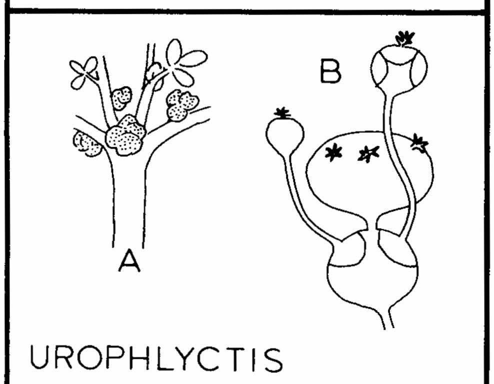
S. endobioticum on potato tuber. A-"wart" on potato tuber; B-summer spore in potato cell; C-prosorus; D-sporangium; E-swimming spores.

Physoderma



67. PHYSODERMA: P. zeae infects corn, causing clusters of tiny brown sporangia embedded in leaf. Sporangium opens by a "trap door." (Free hand sections.) P. maydis on corn. A-small brownish lesions on leaf; B-sporangia and spores.

Urophlyctis



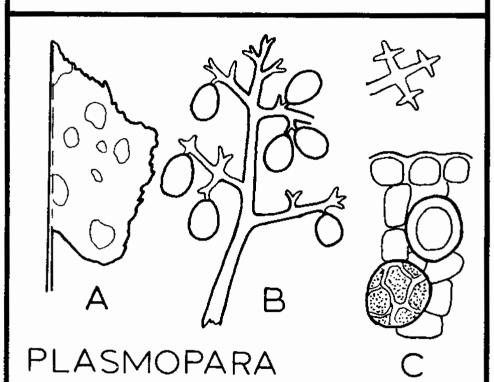
68. UROPHLYCTIS: U. alfalfae causes light-colored galls 1/4" to 1" on crowns of alfalfa in spring. They later turn brown and decay. Unique oospores and branching.

U. alfalfae on alfalfa. A-young galls on crown of plant; B-turbinate cells and resting sporangia. (After Jones & Dreschler)

O O M Y C E T E S

PERONOSPORACEAE - DOWNY MILDEWS

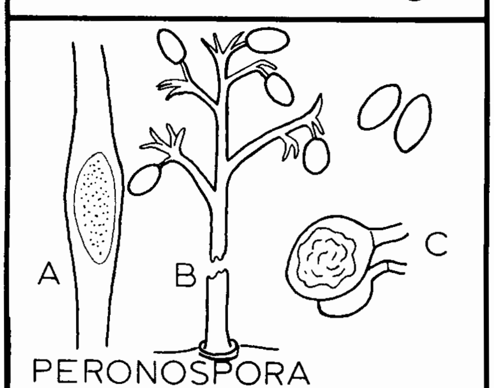
Plasmopara



69. PLASMOPARA: P. viticola has been a major disease on American varieties of grapes. The conidiophores form dense white patches on underside of leaves on young growing tips, blossoms and young berries. Conidiophores monopodial, with branches more or less at right angles, tips obtuse. Conidia ovate, attached at blunt end. Oospores produced inside infected canes.

P. viticola on grape. A-downy mildew on leaf; B-conidiophores and conidia; C-young and mature oospores in leaf tissue.

Peronospora



70. PERONOSPORA: P. destructor causes downy mildew of onion. In humid weather the fungus fruits on the leaves and stems, producing a violet downy mildew. In dry weather, white spots without spore production may occur. P. effuse causes yellow spots on leaves of spinach which produce a violet downy mildew on lower surface. P. trifolii produces pale spots on leaves of alfalfa.

P. destructor on onion. A-downy mildew on leaf; B-conidiophore and conidia; C-oospores.

71. PSEUDOPERONOSPORA: P. cubensis causes downy mildew of cucurbits, especially cucumber and muskmelon. Infected areas are yellow on upper side, with purplish downy mildew below when humidity is high and weather is cool.

P. cubensis on cantaloup. A-mildew on leaf; B-conidophores and conidia.

72. BREMIA: B. lactucae causes downy mildew of lettuce but also infects a large number of wild and economic composites. Large, pale yellow spots, often limited by veins, bear a white downy mildew on lower surface. The disc-like tips bearing conidia are unique. Oospores are formed in the tissues.

B. lactucae on lettuce. A-white mildew on leaf; B-portion of conidiophores showing discs at terminal; C-detail of disc with four sterigmata and spores.

73. SCLEROSPORA: Conidiophores and conidia are few, small and evanescent. Oospores, brown, abundant and conspicuous, revealed by rupture of tissues. Parasitic on grasses.

S. graminicola occurs on Setaria spp. including millets, and on corn. A-mildew on leaf; B-shredded leaf exposing oospores; C-conidiophore and conidia; D-conidia; E-oospore.

PYTHIACEAE - DAMP-OFF FUNGI

74. PHYTOPHTHORA: At least 16 cause common plant diseases; at least five cause major diseases and attack several to many host plants. A few species, such as P. phaseoli, causing downy mildew of lima bean; and P. fragariae, causing red stele of strawberry, have restricted host range. Among the major diseases are:

Late blight of potato and tomato: P. infestans. A-large water-soaked lesion on leaflet of potato; B-surface rot of tuber; C-conidiophore and conidia; D-conidium.

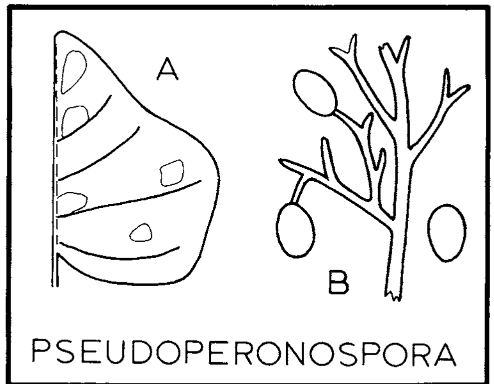
75. Brown rot of citrus trees and fruit: P. citrophthora and P. parasitica. P. citrophthora. A-decay of bark of citrus tree; B-rot of lemon fruit; C-conidia and swarm spores; D-oospore formation

Root rot of avocado pine (little leaf) and many other trees and shrubs: P. cinnamomi.

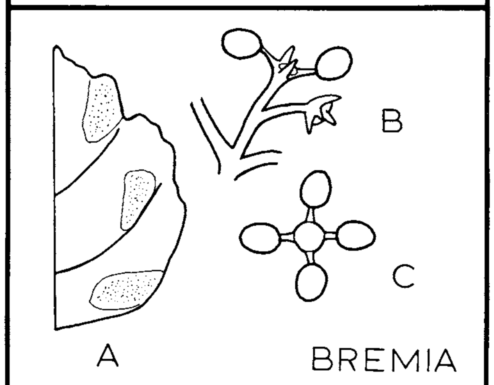
Fruit rots of watermelon, apple, pear, etc.: P. cactorum.

Tentative identification may be made of basis of host plant. Precise identification is very difficult. (Even the specialists are often not in agreement.)

Mycelium is typically abundant in moist air, appearing as a downy-mildew growth on under side of leaves. Mycelium has no cross walls. Conidiophores are slender and branched, with ovoid conidia which produce zoospores.

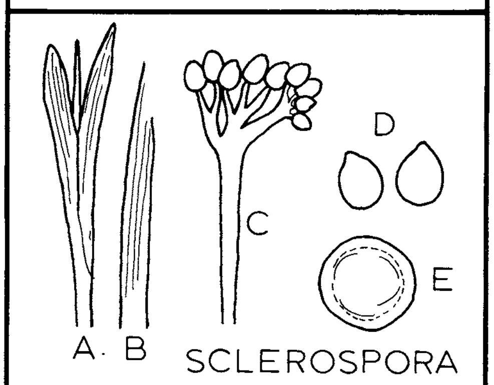


Pseudoperonospora

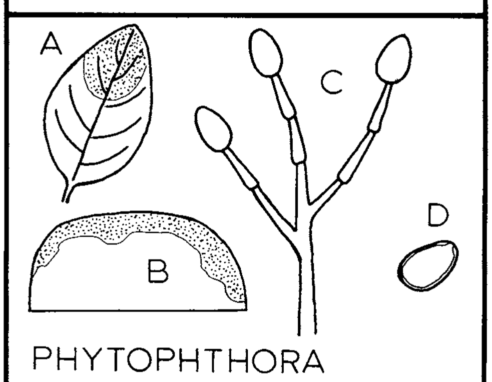


Bremia

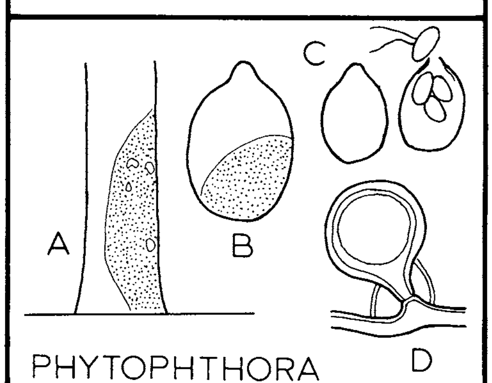
PERONOSPORACEAE, PYTHIACEAE



Sclerospora



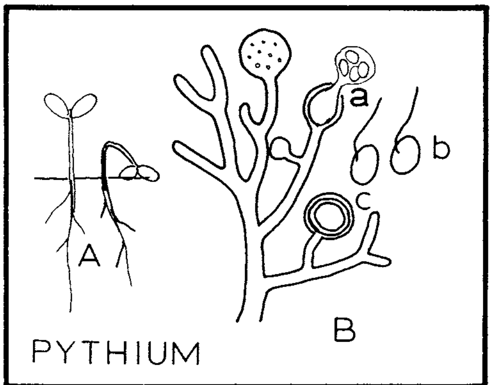
Phytophthora



Phytophthora

OOMYCETES - 15

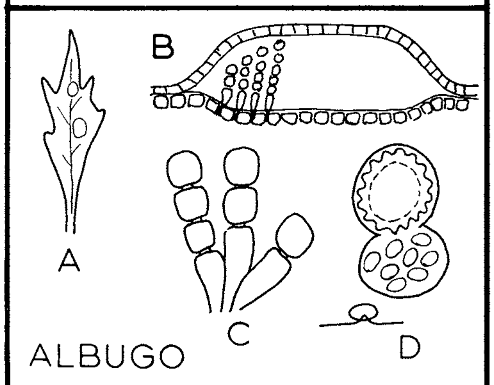
O O M Y C E T E S



76. PYTHIUM: P. debaryanum is most common as cause of damping-off of seedlings. Zoosporangia or "conidia" globose to elliptic, usually papillate; gemmae similar; oospores globose, hyaline, smooth. White mycelium abundant.

P. debaryanum. A-causing damping-off of pepper seedlings; B-mycelium showing (a) sporangia and swarmspores, (b) swarmspores, (c) oospore.

ALBUGINACEAE - WHITE RUSTS

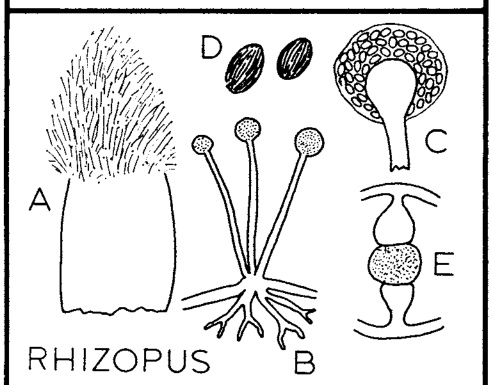


77. ALBUGO: Some 15 species causing "white rusts." Conidia borne in white blister-like sori under the raised and finally ruptured host epidermis. Conidiophores short, club-shaped; conidia globose in chains. Oospores embedded in old lesions; their surface markings (tuberculate, ridged or reticulate) are used in identifying species. Examine free-hand sections under microscope.

A. candida on crucifer. A-"white rust" lesions on leaf; B-diagram of young fruiting body; C-conidiophores and conidia in chains; D-oospore releasing swarm spores.

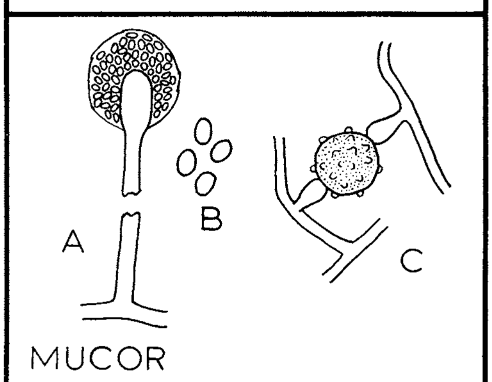
Z Y G O M Y C E T E S

MUCORALES



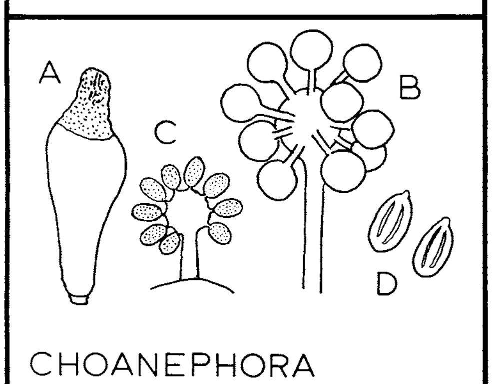
78. RHIZOPUS: Distinctly a wound parasite, causes a rapid-growing soft rot of stored vegetables, especially sweet potatoes and squash. Aerial mycelium coarse, becoming brownish. Rhizoids numerous, sporangiophores in groups; sporangia globose, blackish. Columella hemispherical, subglobose, gray to brown. Zygospore black with round warts.
The salt-and-pepper whiskery growth is distinctive. (Observe sporangia under low and high power.)

R. nigricans. A-soft rot on sweet potato with abundant growth of "whiskers"; B-group of sporangia and rhizoids; C-section of sporangium showing columella; D-conidia showing ridges; E-zygospore formation.



79. MUCOR: M. racemosa causes a firm clay-colored rot of stored sweet potato. Mycelium all of one kind. Sporangia globose, cylindric, pyriform, or clavate.

A-section of sporangium showing columella; B-conidia; C-zygospore formation.

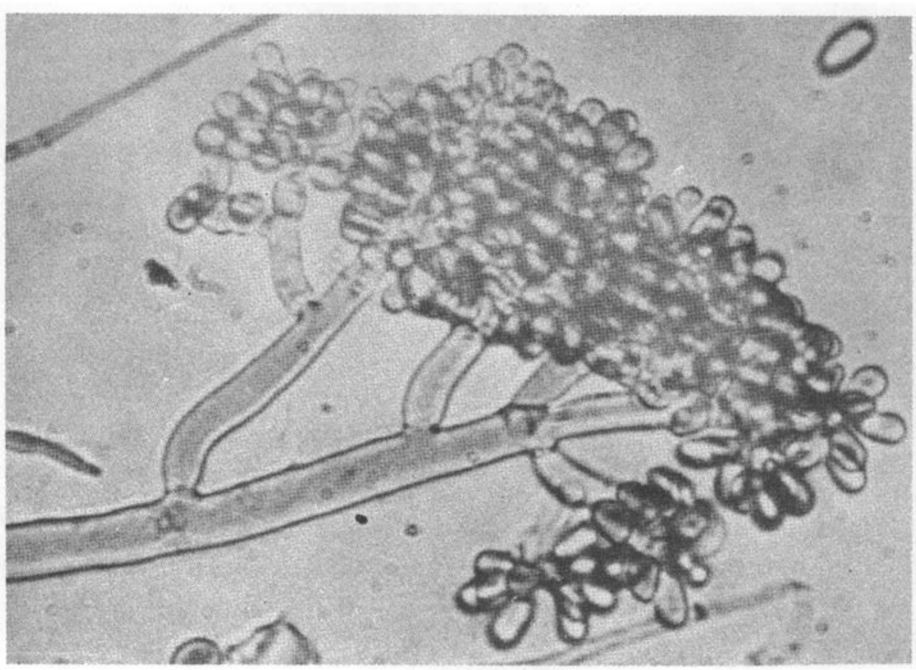


80. CHOANEPHORA: C. cucurbitarum causes of blighting of blossoms and decay of young fruit of cucurbits, especially squashes and pumpkins in east and south. Sporangia of two kinds, macrosporangia globose, columella small, spiny, spores few on simple or branched, erect sporangiophores; microsporangia clavate, one-spored simulating conidia and borne in heads on enlarged apices of umbellately branched sporangiophores. Zygospores as in Mucor.

A-black infected tip of young squash fruit; B-head of sporangium; C-spores produced on secondary head; D-ridged conidia.

Oospore of Sclerospora.

Conidiophore and conidia of Peronospora.



Conidiophore and conidia of Botrytis.

A S C O M Y C E T E S

The mycelium is septate and conidia are produced in most, but not in all, species. Other structures are commonly produced: Chlamydospores---resting spores, modified from existing cells; stromata--cushions of hyphae forming a mat, in or on which fruiting bodies of the fungus are borne; and sclerotia--masses of white mycelium with a dense dark cortex which functions as resting bodies.

The distinctive feature of the group is the sac-like ascus containing typically 8 spores (2, 4, or 16 in a few species). Asci may be produced singly as in _Nematospora_ or in a pallisade layer as in _Taphrina_. They may be produced in a flask-shaped body lacking an ostiole which must break down to release the spores as in the case of the Powdery Mildews, whose conidial form is in most cases an _Oidium_. Form-genera _Aspergillus_ and _Pencillium_ likewise have closed ascocarp but the asci are scattered, not in an hymenium.

PYRENOMYCETES: This large and varied subclass has perithecia with well developed walls borne independently or in or on stromata; or they may be immersed in stromatic tissue without definite walls as in the Dothidiales. In the Sphaeriales and several other orders the perithecia are minute and separate and easily confused with pycnidia of the Imperfecti--until the bodies are sectioned or crushed to reveal the contents--asci or conidia. In one order, the Hypocreales, perithecia, and stroma are bright colored--red, yellow, purple.

DISCOMYCETES: This subclass consists largely of the Helotiaceae or CUP FUNGI which bear their asci in a pallisade layer on a cup-shaped apothecium. They are mostly saprophytes, but three genera contain important parasites. _Monilinia_, causing brown rot of stone and pome fruits, produces apothecia from over-wintering sclerotial mummies of infected fruit; conidial form is _Monilia_. Several important species of _Sclerotinia_ cause a wet rot of many vegetables in the field and postharvest. Sclerotia are nugget-like, quite variable in size and shape. Pseudopeziza produces fly speck size (1 mm.) apothecia and no conidia.

ORDERS OF ASCOMYCETES INCLUDING COMMON PLANT PARASITES
(THE SAC FUNGI - - 1,800 genera, 15,500 species)
Adapted from various sources.

1. ENDOMYCETALES: YEASTS. Small group, several parasitic. _Nematospora_ (--_Ashbya_).

2. TAPHRINALES: Asci arising from hyphae forming hymenium. One genus of aggressive parasites. _Taphrina_ (--_Exoascus_).

TRUE ASCOMYCETES

3. EUROTIALES (PLECTASCALES) - BLUE AND GREEN MOLDS, etc.: 60 genera, 250 species. Ascocarp closed. Asci not in hymenium. Form-genera _Aspergillus_, _Penicillium_.

4. MICROASCALES: Asci in beaked perithecia with definite ostiole. _Ceratocystis_ (syn. _Endoconidiophora_).

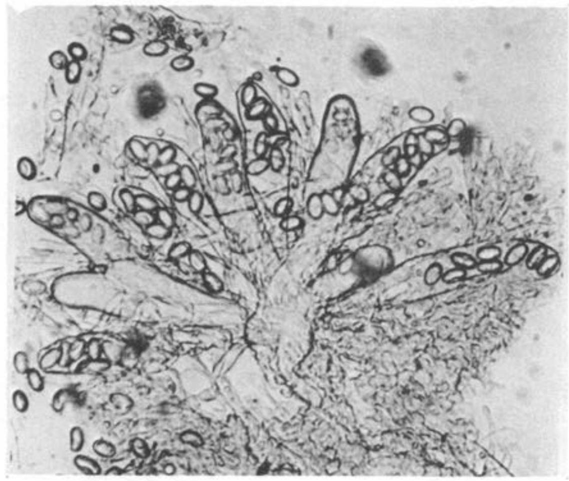


Fig. 113. Discomycete: Fragment of cup-shaped fruiting body showing asci and ascospores.

Fig. 114. Sclerotia of ergot on grains and grasses. Upper left: Barley. Lower left: Rye. Center: *Bromus inermus*. Right: *Agropyron smithii*.

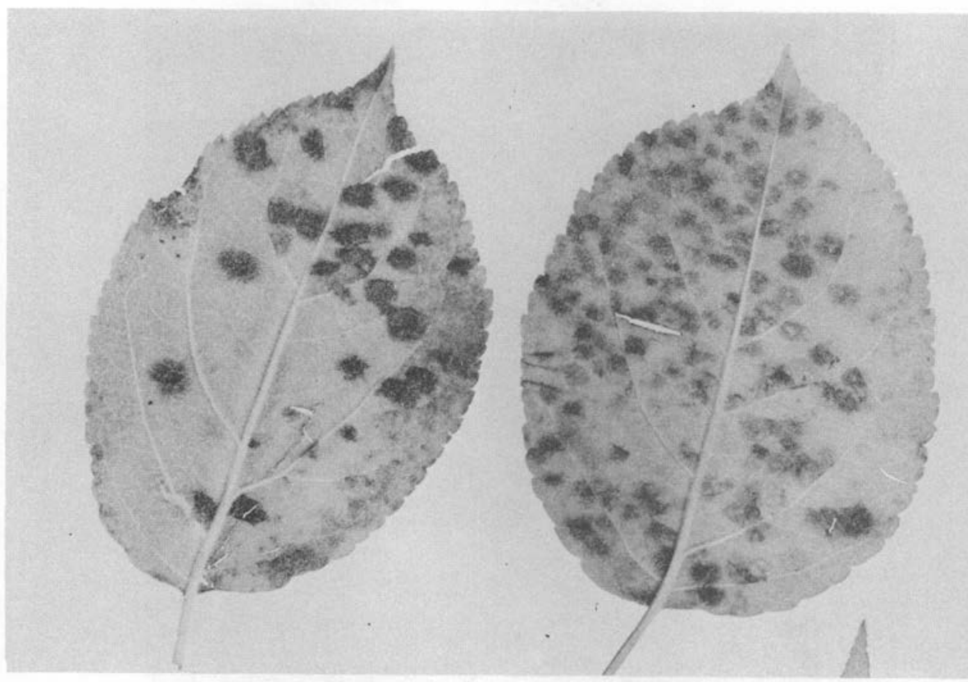


Fig. 115. Late season conidial stage lesions of apple scab on under side of leaves.

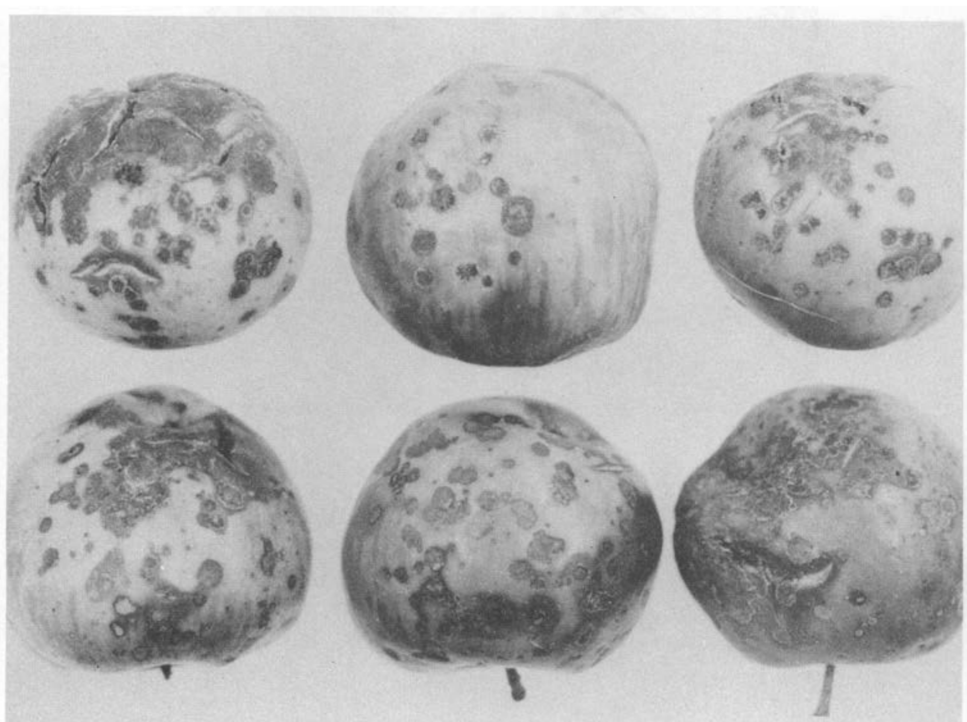


Fig. 116. Late season conidial stage lesions of apple scab on fruit. Early season infections cause large confluent lesions and deep cracking of fruit.

Fig. 117. Apple scab. Ostioles of deeply embedded perithecia on surface of dead leaf infected the previous season. X 10.

Fig. 118. Photomicrograph of perithecia of sweet potato black rot fungus (Ceratocystis fimbriata). Perithecia are globular with a very long beak. X 125.

Fig. 119. Appendages of powdery mildews. Grape mildew, Uncinula necator with coiled tips.

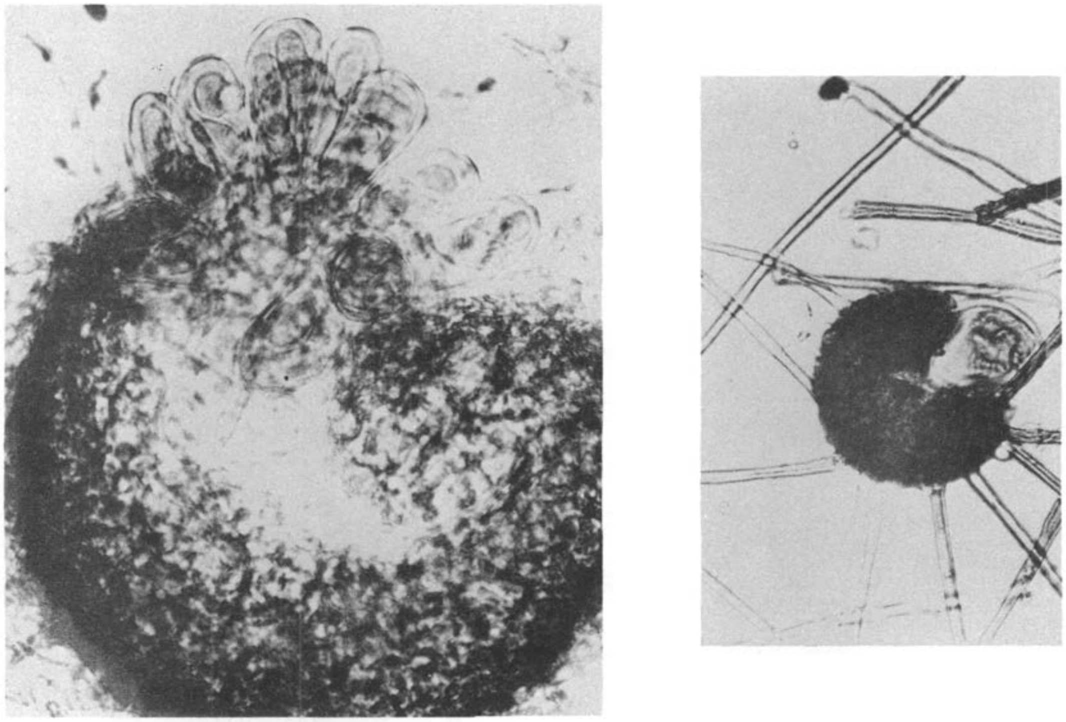


Fig. 120. Powdery mildew cleistothecia. A. *Microsphaera* with one ascus. B. *Erysiphe* with several asci. This is *E. cichoracearum* with 2-spored asci. Picked from leaf surface with wet corner of razor blade, mounted in KOH and crushed to show asci.

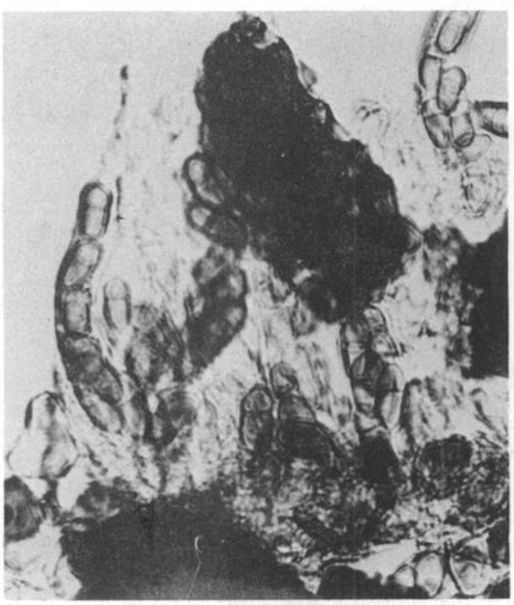


Fig. 121.

Apple scab. *Venturia inaequalis.* Perithecium dissected from dead leaf with wet needle point, mounted in KOH and crushed revealing asci with characteristic ascospores.

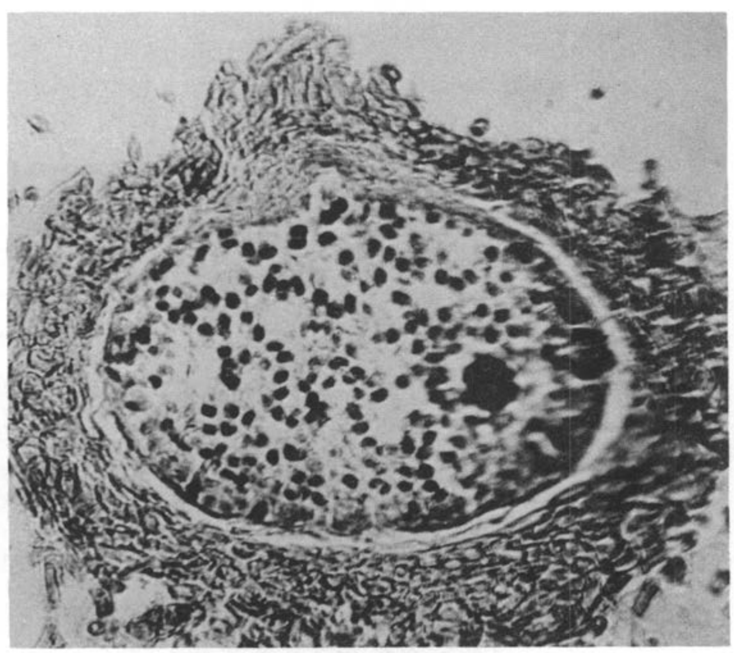


Fig. 122.

Photomicrograph section of perithecium of *Ceratocystis fimbriata.* Ascus walls are evanescent, suggesting that spores are conidia; they are ascospores. Approx. X 500.

P Y R E N O M Y C E T E S (Sub-class) - - SPHERE FUNGI AND ALLIES
Ascocarp closed, Asci in hymenium. Over 10,000 sp.

5. ERYSIPHALES (PERISPORIALES) - POWDERY MILDEWS: Perithecia mostly without ostiole, almost all parasitic. Uncinula, Erysiphe, etc.

6. MELIOLALES - DARK MILDEWS: 45 genera, 1000 species. Mycelium dark, perithecia ostiolate, without appendages. Meliola.

7. MYRIANGIALES: 53 genera, 100 species. Asci borne singly in locules in stroma. Elsinoe.

8. DOTHIDIALES: 145 genera, 600 species. Stromata with asci in perithecial cavities without a definite wall. Mycosphaerella, Guignardia, Dibotryon.

9. PLEOSPORALES: Stroma perithecium like. Asci clustered in locules. Venturia, Pleospora, Leptosphaeria, Ophiobolus, Botryosphaeria.

10. SPHAERIALES - SPHERE FUNGI: 430 genera, 4,500 species. Perithecia dark, usually globose, ostiolate with distinct wall, free or embedded in stroma. Hypoxylon, Nummularia, Rosellinia, Xylaria, Phyllachora.

11. DIAPORTHALES: Perithecia ostiolate, ascal bases gelatinizing. Gnomonia, Endothia, Diaporthe, Glomerella, Valsa.

12. HYPOCREALES: 120 genera, 800 species, perithecia ostiolate, stroma fleshy or membranaceous, bright-colored. Nectria, Gibberella.

13. CLAVICIPITALES: Perithecia within a well developed stroma. Asci threadlike. Claviceps.

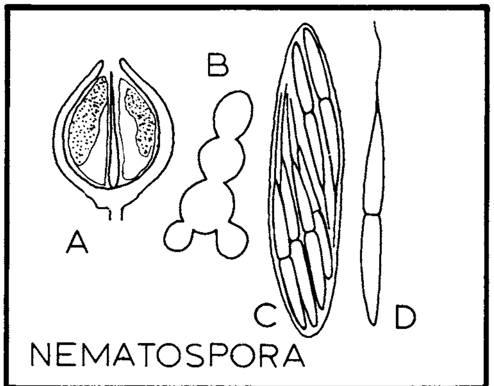
D I S C O M Y C E T E S (Subclass) - - Cup fungi, ascoma at maturity open, more or less cup-shaped. A large group with important parasites.

14. PHACIDIALES: 56 genera, 250 species. Ascoma roundish, opening by radiating fissures. Rhytisma.

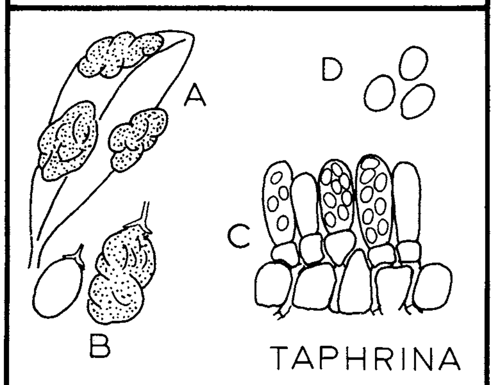
Includes: HYSTERIALES: 17 genera, 110 species. Ascoma opening by a longitudinal fissure. Lophodermium and 10 or more other genera.

15. HELOTIALES - CUP FUNGI: Ascoma opening early, more or less fleshy. Monilinia, Sclerotinia, Pseudopeziza.

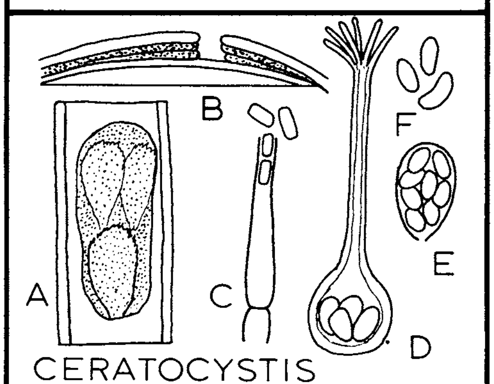
Nematospora



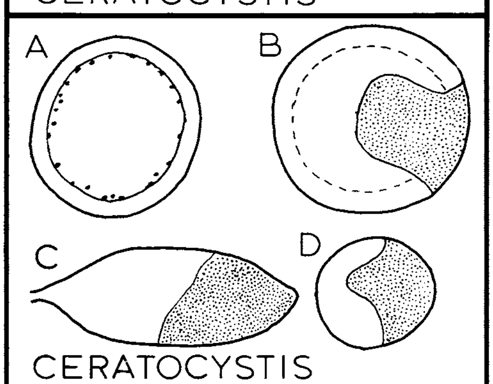
ERYSIPHALES Taphrina



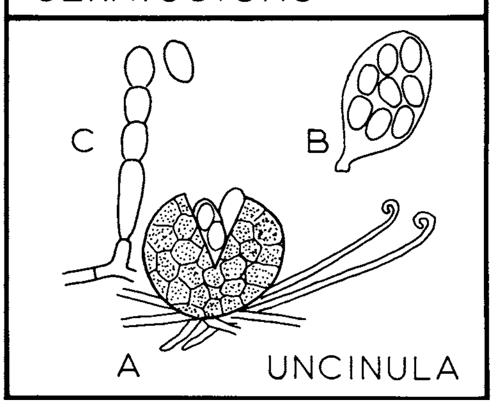
MICROASCALES Ceratocystis



TAPHRINALES Ceratocystis



ASCOMYCETES - 17 Uncinula



ENDOMYCETALES

81. NEMATOSPORA: Several parasitic species of yeasts, spread by feeding punctures of insects. P. phaseoli on lima bean; P. gossypii on cotton bolls, pomegranates and citrus fruits (dry rot). Cotton bolls are stunted, lint is matted, coffee-brown.(Soak material in 1% KOH, tease out fragments with needle and mount for observation of evanescent 8-spored cylindrical asci. Ascospores are hyaline, non-septate and slender, with a long flagellum.)

N. gossypii on cotton. A-stunted cotton boll with matted stained lint; B-vegetative cells budding (rarely seen); C-ascus; D-ascospore.

TAPHRINALES

82. TAPHRINA: Some 20 species, mostly on stone fruits, but also on a wide variety of woody plants. Mycelium annual or perennial, asci 4- to 8-spored or by budding in ascus, multispored. Asci borne on surface of blisters or other hypertrophied areas; cylindrical or clavate.

T. deformans (Exoascus) causes peach leaf curl; leaves much distorted and curled, yellow to reddish, becoming darker as a plush like layer of asci ruptures cuticle. Infected twigs usually die and infected flowers and fruit drop prematurely, as do the leaves. Freehand sections of leaves may show some detail, but stained slides are much better.

T. pruni cause "plum pockets" on American plums and also kills young twigs. Infected fruits are greatly enlarged, spongy, and bear a layer of asci on surface.

A-T. deformans on peach leaf; B-T. pruni on plum, healthy and infected fruit; C-Asci and spores on surface of leaf; D-Ascospores.

83. CERATOCYSTIS: C. fagacearum on oak. A-Bark removed from trunk to show mycelial mat; B-Diagram of mat showing mycelial growth splitting bark; C-Conidial stage (Chalara); C. fimbriatum on sweet potato. D-Perithecium and asci; E-Ascus; F-Ascospores.

84. CERATOSYSTIS -- ENDOCONIDIOPHORA: C. fagacearum on oak. A-Cross section of trunk showing discolored areas in wood; B-E. paradoxa -- Cross section of trunk of palm showing heart rot; C-C fimbriata causing black rot of sweet potato root; D-Cross section of same.

85. UNCINULA: U. necator causes the well-known powdery mildew of grapes and Ampelopsis. More injurious in Calif. than in the East. Covers leaves, canes and young fruits with whitish growth. U. salicis is prevalent on willows and poplars, sometimes causing shedding of leaves.

U. necator on grape. A-Perithecium (several asci) and hooked appendages; B-Ascus and spores; C-Conidial stage (Oidium).

86. PHYLLACTINA: P. corylea is prevalent on several dozen kinds of trees and shrubs. The relatively large cleistothecia are abundant in the fall. The spike like appendages with a bulbous base are distinctive.

P. corylea on oak. A-Cleistothecium, with bulbous-based spine-like appendages; B-Ascus and spores; C-Conidiophore and single apical conidium (Ovulariopsis).

87. PODOSPHAERA: P. leucotricha causes powdery mildew of apple, crabapple, pear, quince and photinia. Gray to white patches are formed on the leaves, which are often curled and distorted. Twigs, blossoms and fruit may be stunted and disfigured. Infections on year-old twigs form dense patches of blackish cleistothecia which are conspicuous.

P. leucotricha on apple. A-Cleistothecium with single ascus; B-Single ascus and spores; C-Detail of tip of appendage showing dichotomous branching; D-Conidiophore and conidia (Oidium).

P. oxycanthae, a very similar species, occurs on cherries and other stone fruits, pome fruits and related ornamentals. Seldom serious except on nursery stock.

88. MICROSPHAERA: M. alni is widespread on lilac, but also attacks other trees, shrubs and vines. Oaks are very susceptible. The rather diffuse white coating becomes dotted with numerous dark cleistothecia in fall.

M. alni on lilac. A-Cleistothecium and appendages; B-Ascus and spores; C-Detail of tip of appendage; D-Conidiophore and conidia (Oidium).

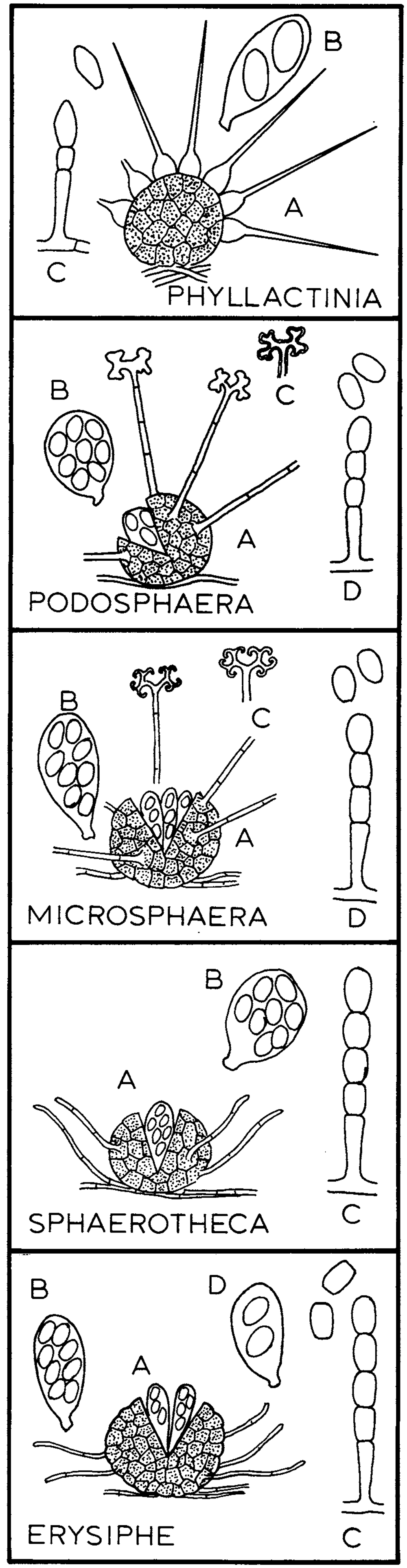
89. SPHAEROTHECA: S. pannosa var. rosae is found wherever roses are grown, and is especially prevalent along the Pacific Coast and in the semi-arid Southwest. Infections of tender flower pedicles and buds may prevent flowering and very susceptible varieties become "just white" with mildew, Cleistothecia are rarely seen in the U.S.

S. pannosa var. rosae on rose. A-Cleistothecium with simple undifferentiated appendages; B-The single ascus and spores; C-Conidiophore and conidia (Oidium).

S. pannosa var. persicae causes mildew on peach and other stone fruits. Immature fruit have brown blotches and are malformed and scabby.

S. mors-uvae causes the American gooseberry mildew, often a limiting factor in gooseberry production.

S. lanestris causes a serious infection on Coast Live Oak, Q. agrifolia, in Calif. on the coastal plain. Young terminal shoots are swollen, fleshy, and rosetted, with pale yellow leaves which dry and shrivel forming witches' brooms. Both surfaces of leaves, etc., are covered with mildew, at first grayish white, then brown. Cleistothecia are sometimes abundant, sometimes scarce.



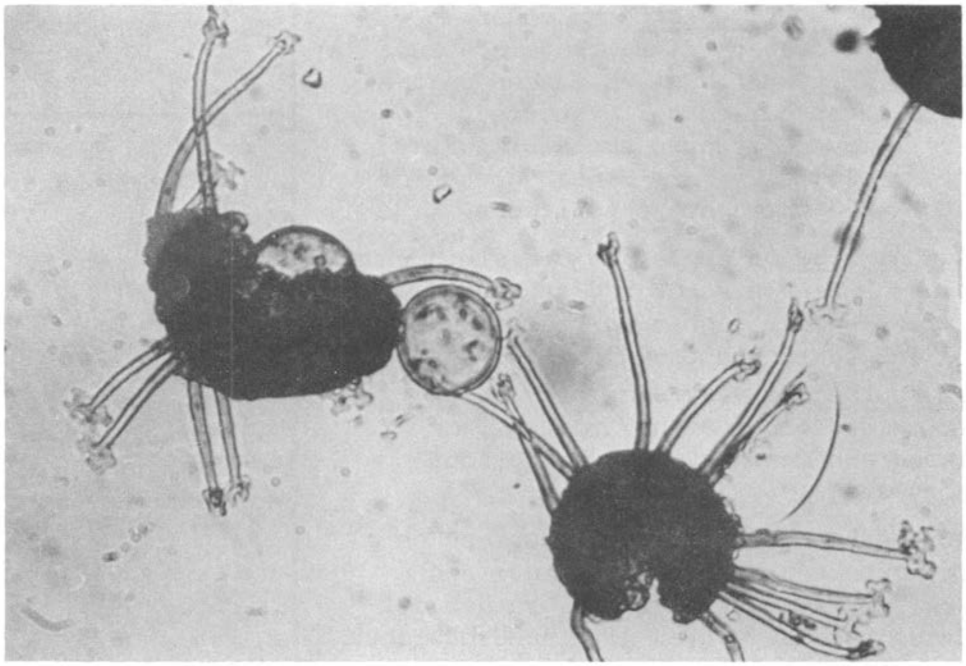
Phyllactina

Podosphaera

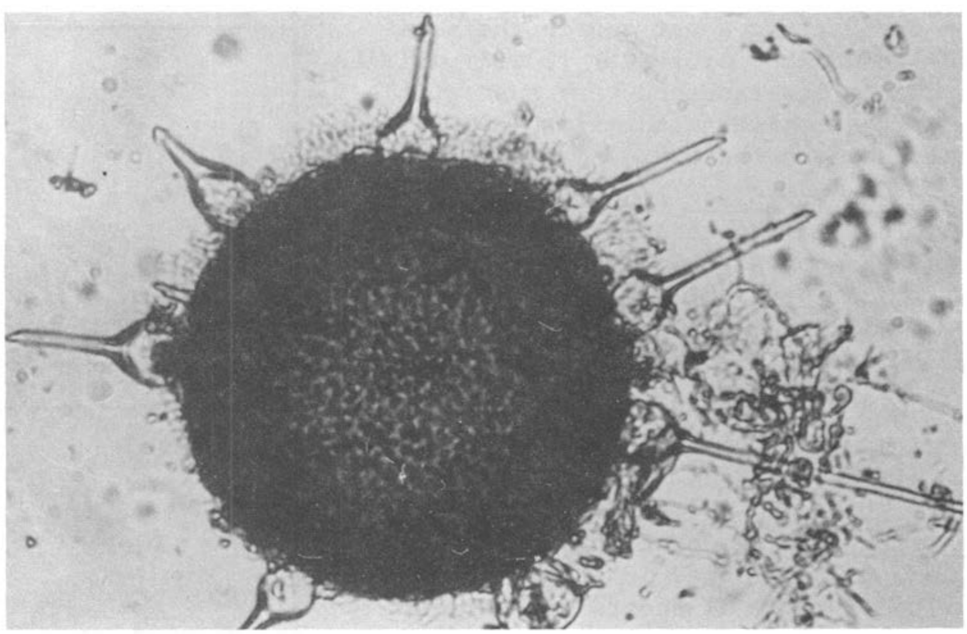
Microsphaera

Sphacelotheca

90. ERYSIPHE: E. graminis is widespread on cereals and grasses. It is important on small grains and lawn grasses. Leaf blades show abundant patches of white conidia, turn yellow and shrivel. Cleistothecia often form in fall, but do not mature spores until spring. (Illus. p. 9.9 and 9.11)



Cleistothecia of Microsphaera, crushed to show single ascus.



Cleistothecium of Phyllactinia, showing acicular appendages with bulbous base.

E. cichoracearum is the powdery mildew of cucurbits and many ornamentals, mostly composites. There are nearly 300 hosts. Cleistothecia are small and asci are 2-spored, which is distinctive.

E. polygoni is the mildew of legumes, but also attacks some 200 species of vegetables and ornamentals. This mildew may be severe in arid regions of the western states, as leaves and pods become completely coated with white mildew. Asci have 3 to 6 spores. Many flowers are quite susceptible.

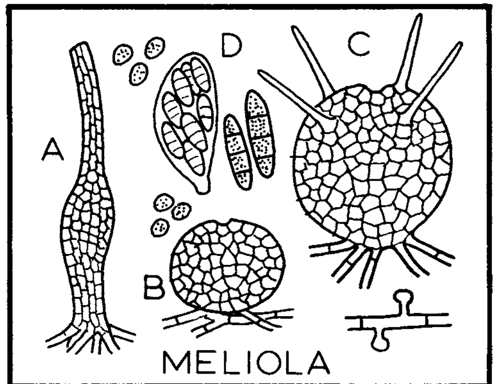
(Examine fresh conidia in a drop of water; dried conidia in 1% KOH; cleistothecia in 1% KOH. To determine number of asci, press gently on cover glass - just enough to crack the fruiting body and expose the asci.)(E. graminis illus. p. 9.9)

E. graminis on barley. A-Cleistothecium with simple undifferentiated appendages; B-One of several asci and spores; C-Conidiophore and conidia (Oidium). D.-2-spored ascus of E. cichoracearum.

MELIOLALES

Perisporiaceae - "Black Mildews"

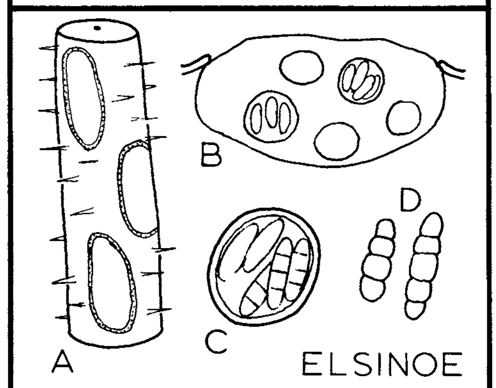
91. MELIOLA: Genus of over 130 species whose dark mycelium grows superficially over leaves and twigs. M. penzigi occurs on citrus forming a sooty black mold, and subsisting on "honey dew" produced by aphids, scales and other insects. Reproduction is by abundant conidia, pycnidia and stylospores. Perithecia are often scarce. See Webber in Stevens p. 194.



M. penzigi on honeydew on citrus leaf. A-Pycnidium and spores; B-Other form of pycnidium; C-Perithecium; D-Ascus and ascospores. (After Webber)

MYRIANGIALES

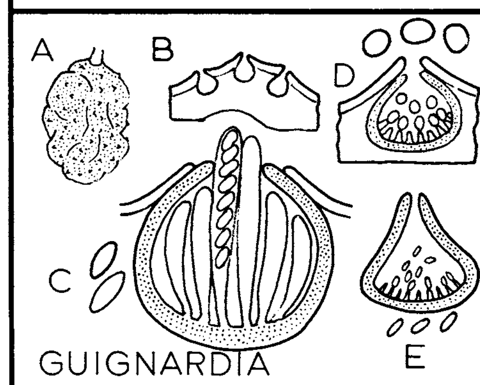
92. ELSINOE: 40 species in warmer areas. Causes scab or anthracnose lesions with single asci scattered through stromatic tissue. Imperfect stage a Sphaceloma. E. fawcetti causes citrus scab; E. ampelina causes grape anthracnose; E. veneta causes raspberry anthracnose; and S. perseae causes scab of avocado.

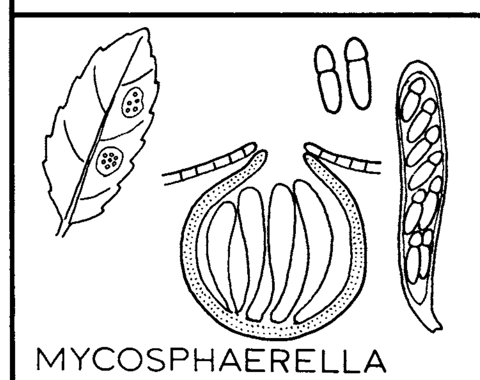


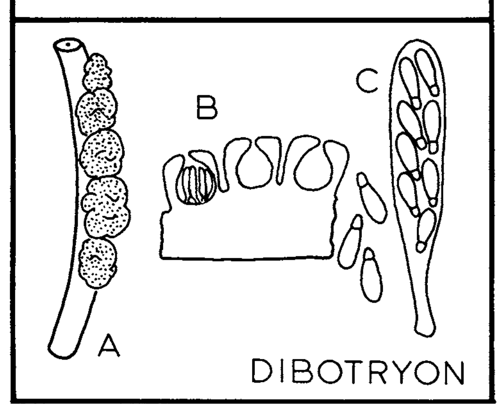
E. veneta on black raspberry. A-Lesions on canes; B-Sectional diagram of stroma and asci; C-Ascus and spores; D-Ascospores.

DOTHIDIALES

93. GUIGNARDIA: G. bidwellii causes greater losses in grapes than the total of all other diseases. All green parts of the grape and Ampelopsis are attacked. The reddish brown leaf spots develop black pycnidia. Pale spots on half grown fruit turn brown as rot involves entire berry, which becomes a shriveled black mummy, shedding or clinging to cluster. Subepidermal perithecia are produced abundantly on the overwintering mummies. Ascospores are elliptical to oblong and non-septate. The 1-celled conidia







are produced in pycnidia and are referred to as _Phyllosticta labruscae_. Slender bacterium sized microconidia are produced in flask-shaped pycnidia. The name Black Rot is descriptive of the fruit symptoms.

Spores and fruiting bodies can be examined by pricking out fruit bodies with a wet needle and crushing them on the slide or sections may be made.

G. bidwellii on grapes (Black Rot). A-Numerous perithecia on mummified overwintered grape; B-Detail of embedded perithecia; C-Perithecium, asci and ascospores; D-Pycnidium and spores; E-Pycnidium and microconidia.

94. MYCOSPHAERELLA: A genus of over 500 species containing several important and serious plant pathogens. Perithecia subepidermal, ostiole depressed or short papillate; asci cylindrical to clavate; spores hyaline, ellipsoidal, 2-celled. No paraphyses. The conidial stages occur in at least 12 genera of the Imperfect Fungi. (Illus. 9.9)

M. fragariae occurs as a leaf spot in almost every strawberry planting. Conidia (--_Ramularia tulasnei_) are abundant in early summer on reddish spots; conidiophores single; conidia elliptic, 2-3 celled. Perithecia are produced late in season; asci few, clavate; spores hyaline with acute tips, two-celled. (Spore forms often scarce in drier areas. Section leaf or prick out perithecia.)

M. fragariae on strawberry. A-Lesions on leaflet; B-Section of perithecium; C-Ascus and spores; D-Ascospores.

95. DIBOTRYON (_Plowrightia_): _D. morbosum_ causes Black Knot of plum and cherry and other stone fruits. The rough, black spindle-shaped or cylindrical enlargements of the twigs are distinctive. The young knots are covered in late spring with an olive green, velvety layer of conidiophores and one-celled hyaline conidia (_Cladosporium_ or _Hormodendron_). Later black stromata cover the tissues which harden. Asci are produced in perithecia which cover the surface of the knots. Ascospores are top-shaped with very unequal cells. (_So distinctive, it hardly needs microscopic verification_.) (Illus. p. 9.9)

D. morbosum causing Black Knot of plum. A-Black, gall-like swellings on plum twig; B-Diagram of surface of "knot" showing perithecia; C-Ascus and ascospores.

PLEOSPORALES

96. VENTURIA: Over 50 species, several causing similar diseases. The conidial stages are parasitic; the ascigerous stages limited to dead leaves, etc.

V. inaequalis: Apple scab is the major apple disease of the world and occurs on apples everywhere except certain semi-arid regions. Conidial stage is produced on olive-drab spots, 1/4" to 1/2" without a definite margin. Leaves may drop prematurely, as do young fruits when pedicel, calyx or small fruit is infected. Twig infections are uncommon. Fruit lesions are similar but often become larger. Old lesions may become raised and corky, and fruit may split.

Conidial stage (Fusicladium dendriticum): Conidiophores closely septate, brown; conidia solitary, terminal, obclavate, yellowish-olive, at length becoming two-celled.

Perithecia first form on lower leaf surface in October and mature in February to April. Perithecia globose, short-necked, embedded in dead leaves, spores yellow-green, unequally 2-celled, upper cell shorter and broader.

Conidial spores may be observed by scraping lesion or sectioning. Perithecia are so hidden it is necessary to use a hand lens (10X) to detect the tiny pimples where the ostiole penetrates the cuticle. Prick out with a wet needle and crush on the slide.

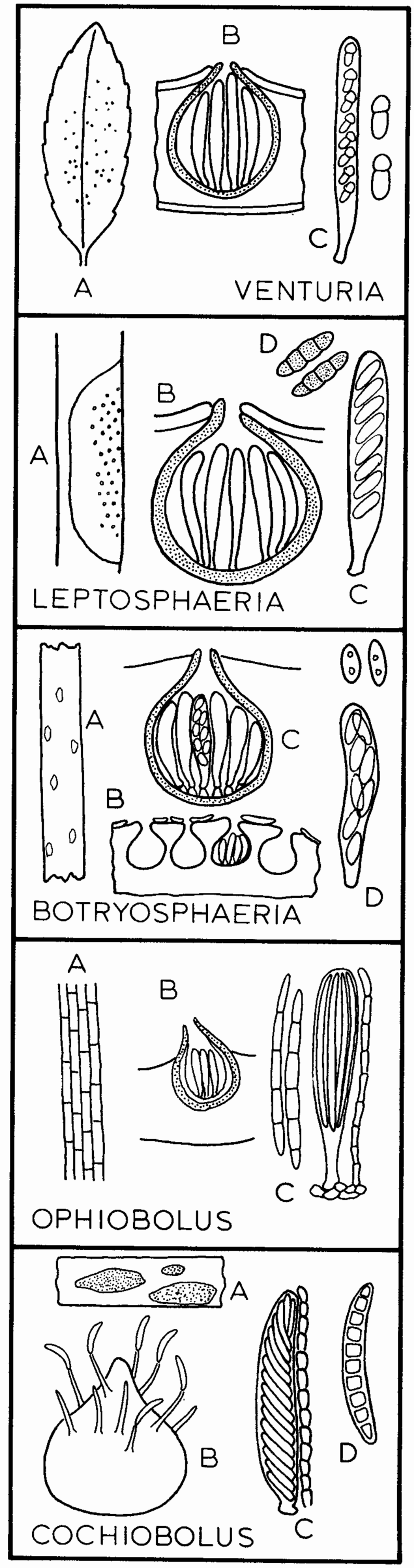
V. inaequalis on apple. A-Perithecia on fallen leaf in spring; B-Diagram of perithecium in leaf; C-Ascus and ascospores.

97. LEPTOSPHAERIA: About 500 species, many with conidial stages in 7 genera of the Imperfect Fungi.

L. coniothyrium causes Common Canker of rose, Raspberry Cane Blight, and attacks apple fruit, peach and Virginia creeper. Two other species of Coniothyrium cause rose cankers. Brown cankers often girdle and kill canes of rose and raspberries. Sooty masses of very small, olive-brown spores occur in lesions. Ascospores oblong 3-septate, constricted, fuscous. Conidial stage (Coniothyrium fuckelii)spores ovate, continuous, fuscous and very small.

L. coniothyrium on raspberry. A-Perithecia and dark spore masses on cane lesion; B-Diagram of perithecium; C-Ascus and ascospores.

98. BOTRYOSPHAERIA: B. ribes is the perfect stage of Dothiorella gregaria, the cause of Dothiorella rot of Citrus and Avocado, and of Black rot of Apple and Pear. On citrus fruits, especially



Venturia

Leptosphaeria

Botryosphaeria

Cochiobolus

Ophiobolus

PLEOSPORALES - 20

Botryosphaeria

lemons, it causes a brown, leathery rot at the stem end, which later becomes olivaceous black. On ripening avocados it is a fast-spreading surface rot. Fruiting bodies are present on twigs and leaf spots. (Prick out with a needle and examine on slide. Crush if necessary.) (Illus. p. 9.13)

B. ribes on avocado. A-Stromata on avocado twig; B-Diagram of perithecia embedded in stroma; C-Diagram of perithecium; D-Ascus and ascospores.

Ophiobolus

PLEOSPORALES

99. OPHIOBOLUS: A genus of some 125 species, commonly on grasses. O. graminis causes Take-all Disease of wheat, barley, oats, rye and many grasses. Field symptoms: Often stunts or kills all plants in local areas--hence the name. Plants cease growing, become yellow and gradually die. Microscopic: Most reliable symptom is the presence of sheets of parallel dark mycelium between leaf sheaths and culms at base of the plant. These can be put in water mount for microscopic examination. Perithecia scattered, ostiole papillate, ascospores filiform, becoming 5- to 7-septate when mature in late autumn or winter. (Illus. p. 9.13)

O. graminis on wheat. A-Mycelial plate of dark hyphae under basal leaf sheath; B-Diagram of perithecium; C-Ascus, paraphysis and ascospores.

Cochiobolus

100. COCHIOBOLUS: 7 species differing from Ophiobolus in having spiral instead of straight ascospores. Perfect stage of Helminthosporium species cause diseases of corn, sugar cane and rice.

C. heterosporus on corn: A. Small dark bordered lesions on leaf. B. Perithecium bearing conidiophores and conidia. C. Mature ascus with ascospores in spiral. D. Conidium of Helminthosporium maydis. (After Drechsler J.A.R. 31: 701-726, 1925.) (Illus. p. 9.13)

101. PYRENOPHORA: Ascocarps flattened at base with numerous setae. Ascospores muriform and colored. Perfect stage of Helminthosporiums on barley.

P. teres on barley: A. Perithecia on old straw. B. Ascocarp with dark setae. C. Mature ascus with spores. D. Detail of spores.

102. PHYLLACHORA: Over 200 species all parasitic on grasses. P. graminis: Tar spot, or Black leaf spot of numerous grasses. Stromata causing conspicuous glossy black spots on leaves of host. Perithecia immersed, ostiolate, ascospores ovoid, hyaline. Paraphyses filiform, No conidia known. (Stromata may be hard to section, pre-soften as directed and section leaf.)

P. graminis on Panicum. A-Black stromata on leaf blade; B-Diagram of stroma and perithecia; C-Ascus and ascospores.

103. PLEOSPORA: Over 225 species mostly saprophytic. Perithecia black, globose, ascospores elongate or ovate, muriform, paraphyses present.

P. gramineum: Perfect stage of Helminthosporium gramineum cause of Stripe Blight of Barley. Infection is systemic, as evidenced by long brown streaks on leaves and infected or aborted Heads. In moist air, very dark conidiophores and conidia can be seen under a hand lens. The very large conidiophores can be picked up on the point of a razor blade for a water mount. The conidia are long cylindric, with 4-7- cells and thick walled. Perithecia are black, globose; spores are elongate or ovate, muriform, with paraphyses present.

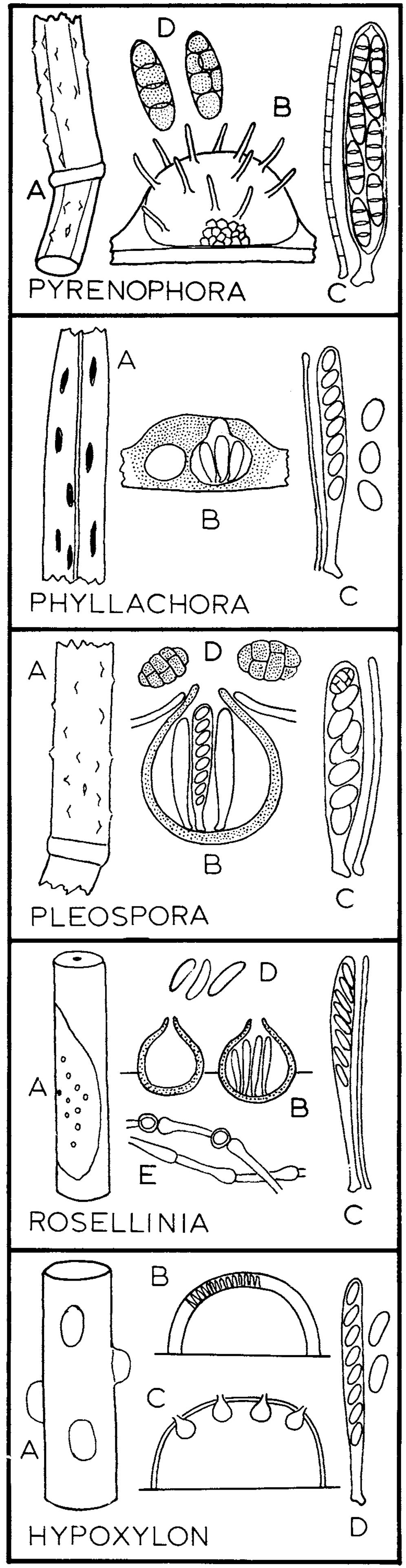
P. graminis on barley. A-Perithecia on barley culm; B-Diagram of perithecium; C-Ascus and paraphysis; D-Dark, muriform ascospores.

SPHAERIALES

Largest group in the Ascomycetes containing over 6,000 species.

104. ROSELLINIA (Dematophora): R. necatrix is a destructive fungus attacking roots of nearly all kinds of plants. A vigorous white mycelium attacks small roots, progressing into larger ones and into the trunk. The mycelium remains sterile a long time, but develops large branching and interlacing rhizomorphs which become brown. Perithecia smooth, ostiolate, ascospores oblong to fusoid, 1-celled, olive to brown. Not always found. Causes a white root rot of avocado, pome and stone fruits, walnuts, fig, grape and ornamentals.

R. necatrix on walnut. A-White mycelium with perithecia on root; B-Diagram of perithecia; C-Ascus and paraphysis; D-Ascospores; E-Detail of mycelium.

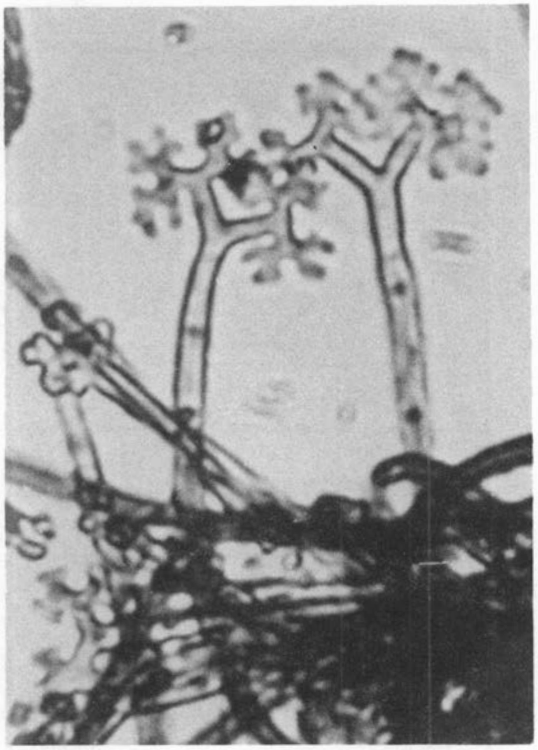


Pyrenophora
Phyllachora
Pleospora
Rosellinia
Hypoxylon

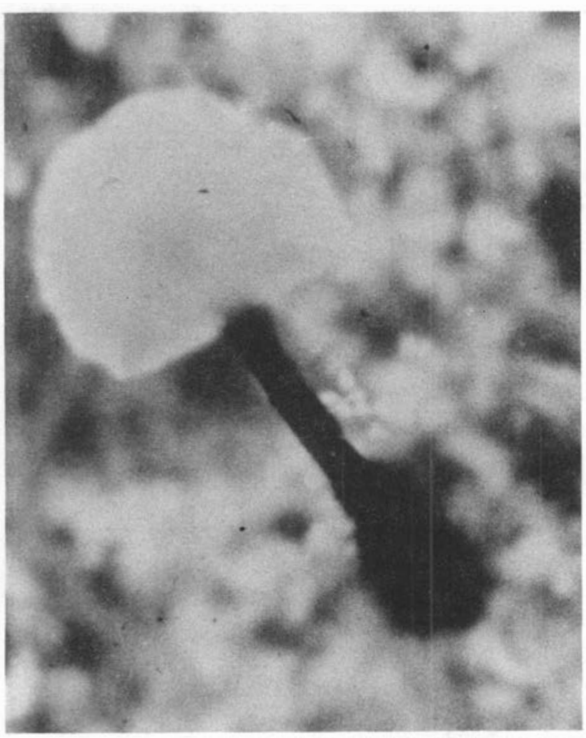
SPHAERALES
PLEOSPORALES

105. HYPOXYLON: 100 species. Cushion-shaped stromata, black to red, on perennial cankers, at first frosty with conidia, later full of embedded perithecia when canker is three years or older. Ascospores oblong, 1-celled, brown. H. pruniatum causes severe mortality on aspens before they reach pulp wood size in Great Lakes states and elsewhere.

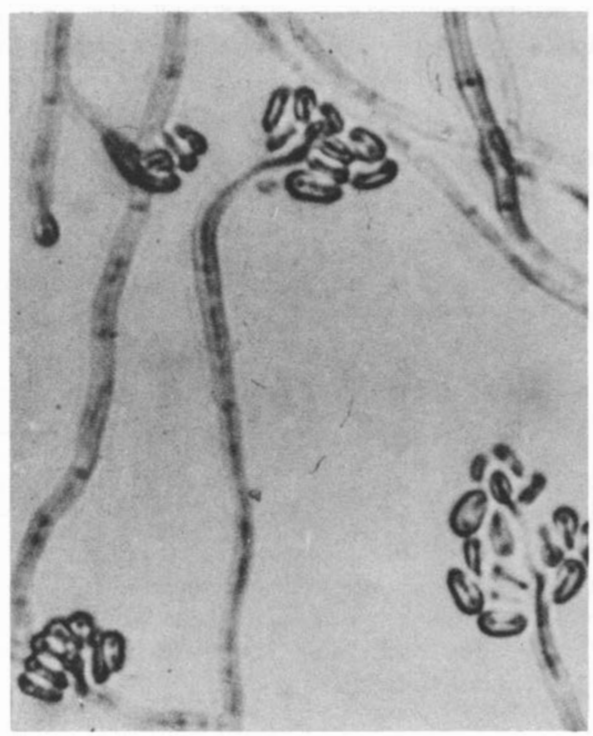
H. pruniatum on poplar. A-Young (red) stromata on twig; B-Diagram of stroma with powdern conidial layer; C-Mature stroma with perithecia (diagram); D-Ascus with ascospores. (Illus. p. 9.15)



Dichotomous branching of appendages of Microsphaera (a downy mildew).



White spore mass on fruiting body of Ceratocystis.



Endoconidia of Ceratocystis.

106. NUMMULARIA: 40 species, one (N. discreta) a serious parasite of apple in Illinois. Mature stromata in bark appear as "nail heads," hard and black with embedded, long-necked, flask-shaped perithecia.

N. discreta on apple bark. A-Stromata breaking through bark; B-Diagram of stroma with perithecia; C-Ascus, paraphysis; D-Ascospores.

DIAPORTHALES

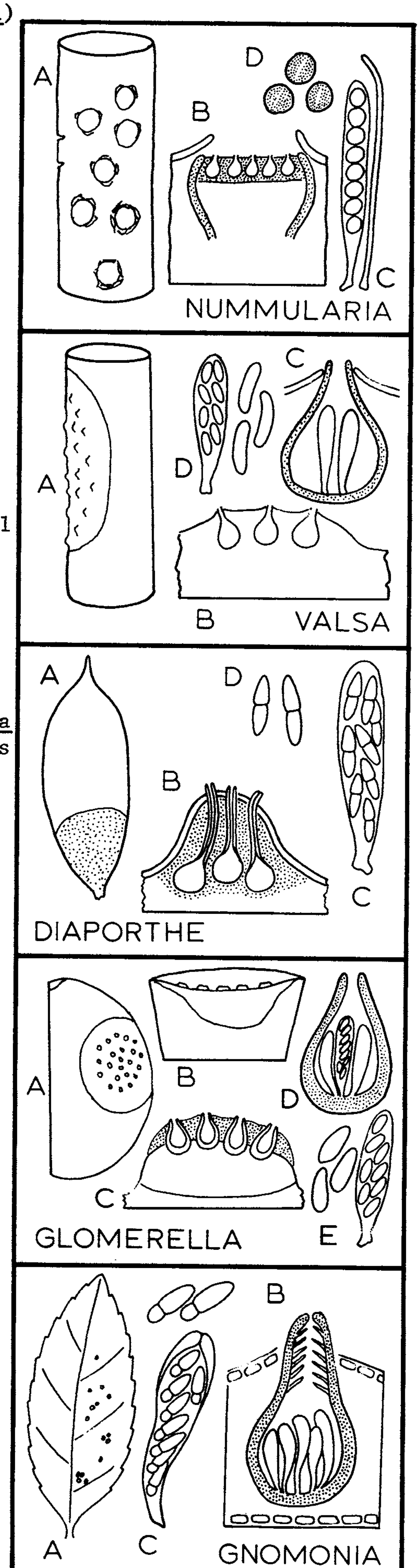
107. VALSA: A half dozen species having species of Cytospora as an imperfect stage. Generally rated as a weak parasite entering through wounds or following winter injury, but sometimes appearing actively parasitic. Stromata strongly convex, immersed in bark, contain many flask-shaped perithecia with long necks reaching to surface. Ascospores hyaline, 1-celled, curved, slender.

V. leucostoma--Apple Canker. The conidial stage (Cytospora rubescens) is often found causing Dieback, Twig Blight and Canker on pome and stone fruits, willow and mountain ash. Severe on young apple orchards in New Mexico. Conidia produced in convoluted galleries of pycnidia embedded in a reddish stroma.

V. sordida, the perfect stage of Cytospora chrysosperma, a very common canker disease of poplars and willows, especially in the West. On slender twigs with thin bark the pycnidia are small and the ostioles show as tiny pimples. On branches and trunks with heavy bark the ostioles are not evident, except that following a soaking rain they will ooze threads of masses of orange conidia. In dry weather these dry down into much smaller threads or masses and darken to a tangerine orange, or if wet by a light shower will spread out over the surface of the bark and dry as a pale orange layer, often visible from the ground.

(A wet needle will pick up hundreds of conidia from fresh exudations, or from a fragment of dried spore mass softened in 1% KOH. Sections of twig or bark will show structure of the pycnidium and stroma. The Valsa stage is often scarce. Look for it in old, long dead bark.)

A-Limb canker with fruiting bodies; V. sordida on cottonwoods and willows. (The conidial stage, Cytospora chysosperma, is much more prevalent.) B-Diagram of bark canker with perithecia; C-Perithecium; D-Ascus and ascospores.



Nummularia

Valsa

Diaporthe

Glomerella

Gnomonia

Diaporthe

108. DIAPORTHE: --Perithecia in a hard black stroma, immersed then erumpent, spores, fusoid or ellipsoid, hyaline, 2-celled. Imperfect stage is a Phomopsis with 2 types of spores; conidia ovate to fusoid, hyaline, 1-celled; stylospores bent or curved.

D. citri: is the perfect stage of Phomopsis citri, the cause of Stemend rot and Melanose on citrus, and Shell bark of Lemon. The stem-end rot of fruit is leathery, buff to brown and spreads rapidly. Melanose occurs on leaves, twigs and fruits as small, brown scabby spots, often forming "tear stain" streaks. (Diplodia and Dothiorella cause similar stem end rots of citrus fruits. Check for presence of organism.)

Diaporthe vexans is the perfect stage of Phomopsis vexans and the cause of Phomopsis Blight and Fruit rot of Eggplant. All above ground parts are affected. Seedlings damp-off; leaves develop gray to brown spots with light centers bearing black pycnidia; cankers form on stems; and large brown spots with many pycnidia cause a soft rot of the fruit. (Prick out pycnidia from leaf or fruit spots and crush on slide. Look for regular conidia and stylospores.)

D. batatatis causes stem rot and dry rot of sweet potato roots. (Illus. p. 9.17)

A-Rot of fleshy root; B-Section of stroma and perithecia; C-Ascus; D-Ascospores. (After Harter & Field)

Glomerella

109. GLOMERELLA: --G. cingulata is the perfect stage of Collectotrichum gleosporioides and causes Anthracnose, Canker, Dieback, Withertip and Fruit rot of a good many plants. On citrus fruits there is a withertip of twigs; a tan leaf spot with pink spore masses in wet weather; and dry sunken lesions on fruit. While the fungus is considered a weak parasite, it causes anthracnose and withertip on many fruits and vegetables. (The best diagnostic character is the presence of acervuli bearing salmon-pink 1-celled, conidia. If these are not evident, 24 to 48 hours in a moist chamber may bring them out.) Perithecia are usually beaked with only neck protruding; ascospores are hyaline, 1-celled, asci thickened at tip; paraphyses present. (Illus. p. 9.17)

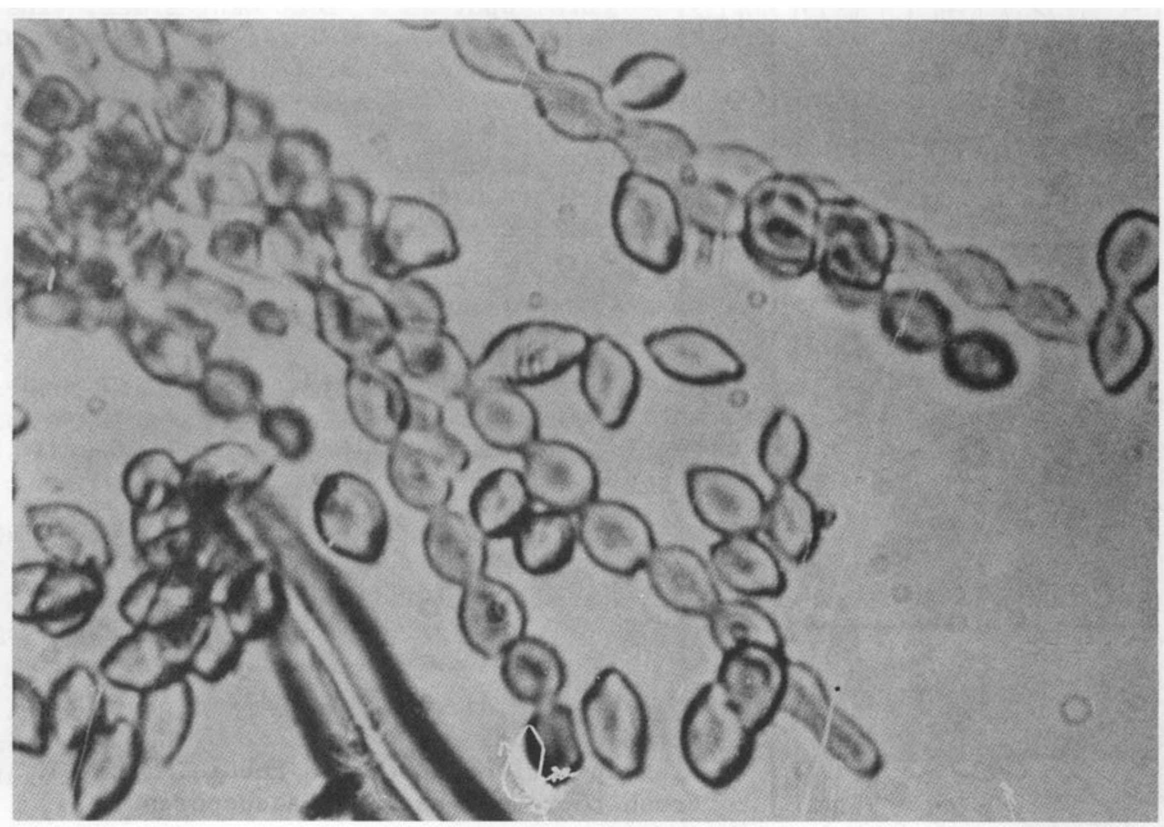
G. gossypii is the perfect stage of Colletotrichum gossypii and causes Anthracnose of cotton. Lesions bearing acervuli occur on the stems, leaves, and bolls of cotton. Conidia are oblong, flesh-colored in mass; setae are single or tufted, dark at base and hyaline above. Perithecia are very abundant, single or in groups, brown to black, subglobose to pyriform with beak; asci numerous, spores elliptic, hyaline, rarely curved; paraphyses very abundant.

G. cingulata causes bitter rot of apple. A-Lesion on apple fruit; B-Diagram of leison with conidial stage (Gleosporium rufo-maculans)C-Diagram of stroma with perithecia; D-Perithecium; E-Ascus and ascospores. Asci are evanescent.

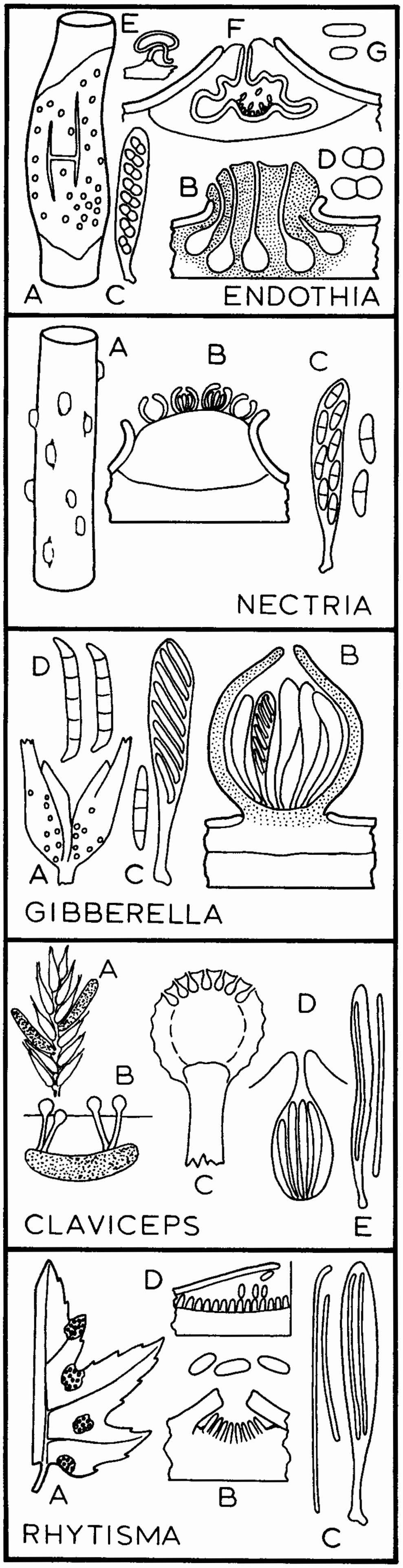
110. GNOMONIA: Some 60 species with 7 genera of Imperfect Fungi having the conidial forms. Ascigerous form usually follows as a saprophyte the parasitic conidial stage.

G. veneta: The perfect stage of Gleosporium platani causing anthracnose of Sycamores and Burr and White Oaks. Young sycamore leaves turn brown and trees may be practically defoliated. Acervuli on under side of veins ooze flesh-colored conidia in wet weather. Twigs and branches have sunken cankers. Perithecia are embedded in fallen leaves with a long beak protruding; asci with apical thickening at terminal pore; spores 2-celled, basal cell very small. No paraphyses.

G. ulmi of elm. A-Lesions on leaf; B-Diagram of leaf section showing protruding neck of perithecium; C-Ascus and ascospores. (Illus. p. 9.17)



Chains of lemon-shaped conidia of Monolinia fructicola, cause of brown rot of stone fruits.



111. ENDOTHIA: Perithecia deeply embedded in a reddish to yellow stroma, necks long but not beaked. No paraphyses. Ascospores 2-celled, hyaline. Conidia borne in lobed pycnidia, 1-celled.

<u>E. parasitica</u> has almost eradicated our native chestnuts in eastern United States, and is now relatively rare. Conspicuous reddish bark cankers, often swollen or split, girdled branches or trunk. The conidial stage is produced abundantly and is exuded in threads (cirrhi) of yellow to reddish spores. Later the ascospores are extruded en masse. Fans of buff-colored mycelium may occur under infected bark.

A-Typical canker on branch of chestnut; B-Diagram of stroma and perithecia; C-Ascus; D-Ascospores; E-Cirrhus of conidia exuding from pycnidium; F-Diagram of lobed pycnidium; G-Conidia.

This order is characterized by the brighter color -- yellow, purple, red, scarlet, etc., and more tender texture of its perithecia -- soft, fleshy, cottony; patellate or effused.

112. NECTRIA: Perithecia in groups on stroma, bright colored. Spores 2-celled, hyaline, produces cankers on trees and shrubs.

<u>N. cinnebarina</u> causes Twig Canker or Coral Spot on a great many trees, vines, and shrubs. While often saprophytic, it can be weakly parasitic, and sometimes definitely parasitic on maples, and some other ornamentals. Usually first appears as small depressed cankers around wounds. The flesh-colored or <u>coral pink sporodochia are conspicuous</u>. Sapwood has a greenish stain. The conidial stage is <u>Tubercularia vulgaris</u>.

<u>N. cinnebarina</u> on currant. A-Stromata on infected cane; B-Diagram of stroma and perithecia; C-Ascus and ascospores.

113. GIBBERELLA: Stromata tuberculate; perithecia superficial, asci clavate, 8-spored; spores fusoid, 4 to many celled, hyaline. Conidia stage, <u>Fusarium</u>.

<u>G. zeae</u>: Root, ear and stalk rot of corn and Scab of wheat, barley, etc. Corn is attacked at all ages and roots and kernels rotted. Black perithecia are abundant on overwintered corn stalks. Conidia are pink in mass.

Make water or 1% KOH mounts of mycelium or sporodochia and examine for Fusarium spores. Pick up perithecia with a needle, mount in KOH and crush to reveal asci and ascospores.

<u>G. zeae</u> on wheat. A-Perithecia on glumes of wheat; B-Diagram of perithecium; C-Ascus and ascospores; D-Spores of conidial stage. (Fusarium)

CLAVICEPITALES

114. CLAVICEPS: Infection confined to ovaries of grasses, developing first a conidial stage, which is a Sphacelia. A large, dark sclerotium forms from infected ovary and protrudes conspicuously from head of grass. Overwintered sclerotia germinate in spring producing numerous perithecia embedded in globular head on stalks 5 to 15 mm. long.

C. purpurea is the common ergot of rye, wheat, barley and numerous grasses. The small oval, hyaline 1-celled conidia are produced on a compact pallisade layer of cylindrical conidiophores. The asci are slender, and the ascospores threadlike.

Conidial stage is inconspicuous, except for the honey dew secreted. Dip needle in this and make a spore mount. Sclerotia are black, firm and white inside and distinct enough for identification if associated with the host grass. (Illus. p. 9.20)

C. purpurea causes ergot of rye and many grasses. A-Sclerotia protruding from head of rye; B-Stromata developed from germinating sclerotia; C-Diagram of stroma bearing perithecia; D-Perithecium; E-Ascus and ascospores.

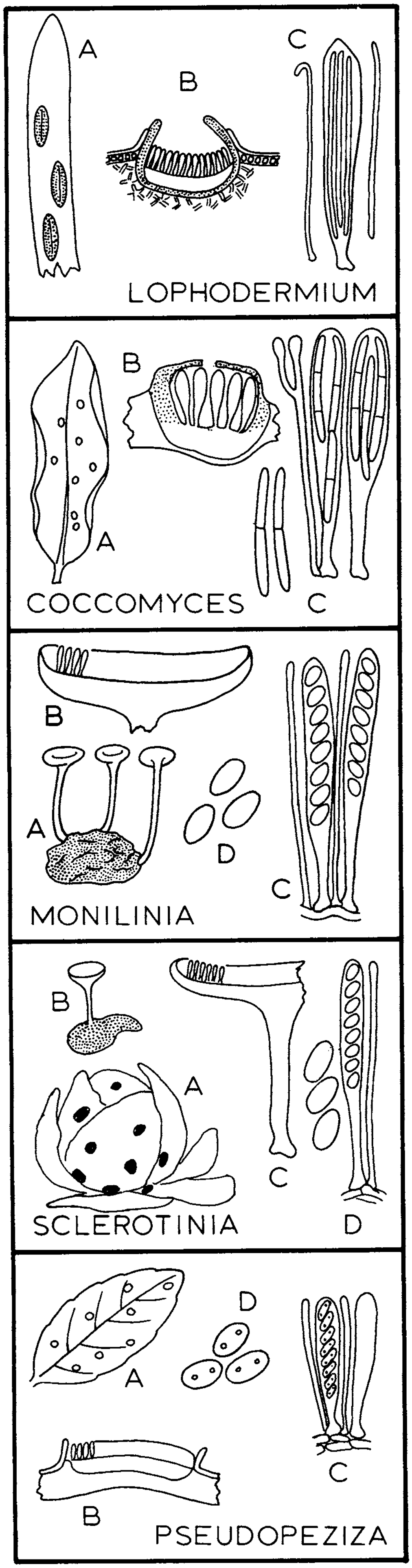
PHACIDIALES

115. RHYTISMA: Some 25 species forming "tar spots" on foliage--more disfiguring than injurious. Apothecia united with epidermis in black spots on fallen overwintered leaves. Ascospores filiform, typically hyaline. (Illus. p. 9.20)

R. acerinum causes tar spot of maple. Lesions at first light green, becoming black and forming conidial stage, *Melasmia acerina*, conidia small, one-celled, hyaline in extended hymenium.

R. punctatum produced large groups of pin-head tar spots on leaves of big-leaf maple.

R. acerina on maple. A-Tar spots on leaf; B-Diagram of apothecium; C-Ascus, ascospore and para-physis; D-Diagram of pycnidium and conidia.



116. LOPHODERMIUM: Fruiting body an elongated compressed perithecium opening by a narrow slit. Ascospores filiform; paraphyses hooked at tip. Most species cause needle-casts of conifers. Genera Bifusella, Elytroderma, Hypoderma, Hypodermella, Naemacyclus, Rabdocline, Rhizosphaera and Hemiphacidium also cause needle-casts. Symptoms are quite similar.

L. pinastri causes premature shedding of needles (needle-cast) of pines. Fruiting bodies are black, short and elliptical.

L. pinastri on pine. A-Tip of needle with oblong dark apothecia opening by slit; B-Diagram of open apothecium; C-Ascus, ascospores and paraphysis.

117. COCCOMYCES: (HIGGINSIA) Apothecia on overwintering dead leaves very small (1 mm.), black leathery, opening by star-like slit. Asci broadly clavate, spores hyaline, 1-celled. Conidia in acervuli, hyaline, filiform comprise the Cylindrosporium stage.

C. hiemalis causes a major disease of sweet and sour cherries. Numerous small lesions cause premature yellowing and shedding of leaves. Tiny white tufts of conidial spores are visible on lesions (lower surface) on living leaves. Repeated defoliation greatly injures or kills trees.

C. hiemalis, cause of cherry leaf spot. A-Apothecia on overwintered leaf of cherry; B-Diagram of apothecium; C-Asci, ascospores and paraphysis.

D I S C O M Y C E T E S

(Asci borne in cup-shaped apothecium)

HELOTIALES

118. MONILINIA (Sclerotinia): Fungus hyphae form a sclerotial layer enveloping mummified fruit Tan, waxy cup-shaped apothecia formed at soil surface at blossom time. Asci slender, 8-spored; spores 1-celled, ellipsoidal, hyaline. Conidia in buffy-gray tufts, on fruit, flowers, or cankers; in chains.

M. fructicola: Causes brown rot of blossoms, twigs and fruit of stone fruits and other fruits. Our most destructive peach disease. Prevalent east of the Rocky Mountains.

Monilinia laxa: Causes blossom blight and also green and ripe fruit rot on the Pacific Coast on stone fruits primarily, but also on pome fruits. Fungus is very similar to *M. fructicola*.

M. fruticola on stone fruits.
A-Apothecia growing from sclerotial tissue of mummified fruit; B-Diagram of apothecial cup; C-Asci and paraphyses; D-Ascospores.

119. SCLEROTINA: Sclerotia very irregular in shape and size (1/8" to 1"); black on surface, white within. Schlerotia are produced in abundant white mycelium, on surface or within pith of stems. Conidia lacking. Apothecia arising from sclerotia, light brown, saucer-shaped at maturity. Ascospores hyaline 1-celled, ovoid. Cloud of ascospores visible if lid of moist chamber containing mature apothecia is quickly removed.

Sclerotina

S. sclerotiorum: Causes watery soft rot of vegetables in the field and cottony rot of vegetables in transit and storage. Probably the most important vegetable rot. Causes collapse of leaves into a slimy, wet mass with abundant white mycelium and usually many black sclerotia. Also causes a stem rot on many annual and perennial flowers and a black rot on bulbs. (Illus. p. 9.22)

S. sclerotiorum on lettuce. A-Dark sclerotia and white mycelium on lettuce head; B-Apothecium growing from sclerotium; C-Diagram of apothecium; D-Ascus, ascospores and paraphysis.

120. PSEUDOPEZIZA: Apothecia tiny (1 mm.) a flat disc slightly raised on leaf surface. Ascospores 1-celled, hyaline, ovoid. Paraphyses present.

Pseudopeziza

P. medicaginis: Almost universal on leaves of alfalfa, especially lower leaves in humid periods. Ascus stage often immature. Try freehand sections. No conidial stage. (Illus. p. 9.22)

P. medicaginis: On alfalfa.
A-Apothecia on leaflet; B-Diagram of apothecium; C-Asci and paraphyses; D-Ascospores.

B A S I D I O M Y C E T E S

This group includes five distinct forms: SMUTS, RUSTS, PORE FUNGI, GILL FUNGI, and PUFFBALLS. The common structure is the basidium, a club-shaped or tubular cell bearing four basidiospores externally. Exobasidium produces a layer of basidia like the layer of asci in Taphrina on the surface of gall tissues.

SMUTS: Fisher's Manual (6) recognizes 22 genera, 276 species and a few varieties on species of 242 host genera. Not a few are new in the sense that they are consolidated species, often of long established species, changes not always generally acceptable to pathologists. Most smut fungi attack grains and grasses replacing the ovary with "smut ball" of black spores.

In covered smuts, the smut ball persists; the spores of "loose" smuts are quickly dispersed by wind. Other smuts attack the leaves of monocots and dicots, often forming long, narrow sori within the leaf, best seen by transmitted light.

Most smut fungi can grow slowly on culture media, but cultures are not used in diagnosis. A wet needle dipped in the spore mass will transfer an abundance of spores to a drop of KOH for observation under a microscope. Fisher's Manual (6) gives complete keys, descriptions, and photomicrographs of spores. The four-celled promycelium arising from the germinating spore is the basidium. In Entyloma the thick-walled, light-colored spores are embedded in the leaf and germinate in place. The hyaline sporidia are often mistaken for conidia of an imperfect.

RUSTS: The four-celled promycelium of the germinating teliospore is the basidium. Long-cycle rusts may have five different kinds of spores as outlined on page 10.6. All forms may occur on one host species or the pycnial-aecial stages may occur on an entirely different host plant. Originally, many rusts were described and placed in form-genera when only one spore stage was known. Now, nearly all of these "imperfect rusts" have been connected with an alternate stage and have taken the name of the telial stage.

The rusts are all obligate parasites and cannot be grown on culture media. For purposes of inoculation, the rust sorus is considered a pure culture, and water suspensions of spores may be sprayed on plants to be inoculated. Spores of fungi other than rusts will not "contaminate" the inoculation, but if different rusts are being used, isolation is advisable to keep cultures "pure." To use the telial stage for inoculation, place it on a screen above plants to be inoculated, saturate the inoculum, and keep whole setup in moist chamber. Basidiospores from rusted grama grass so placed readily infected cotton seedlings with Puccinia stakmanii (aecia).

Rust spores are most easily examined by dipping a wet needle in the rust sorus and transferring the spores to a drop of KOH on a slide and examining under low and high power of the compound microscope. Teliospores are best for diagnosis. Most important economic rusts can be identified by the teliospores and the host. Naming the species of other rusts is a task for a rust specialist, and should be referred for accurate diagnosis. Arthur's Manual, Revised '57 (7), and Cummins Genera of the Rust Fungi (5), are the standard references.

THE HIGHER BASIDIOMYCETES (HOMOBASIDIOMYCETES): The fruiting body in this group varies widely as to form, size, shape, texture (soft, punky, or woody), annual or perennial. A hymenium layer of club-shaped basidia each bearing four spores covers the spore-bearing surface of the fruiting body. These fungi are placed in four groups depending upon the surface covered by the hymenium: (Continued p. 10.6)

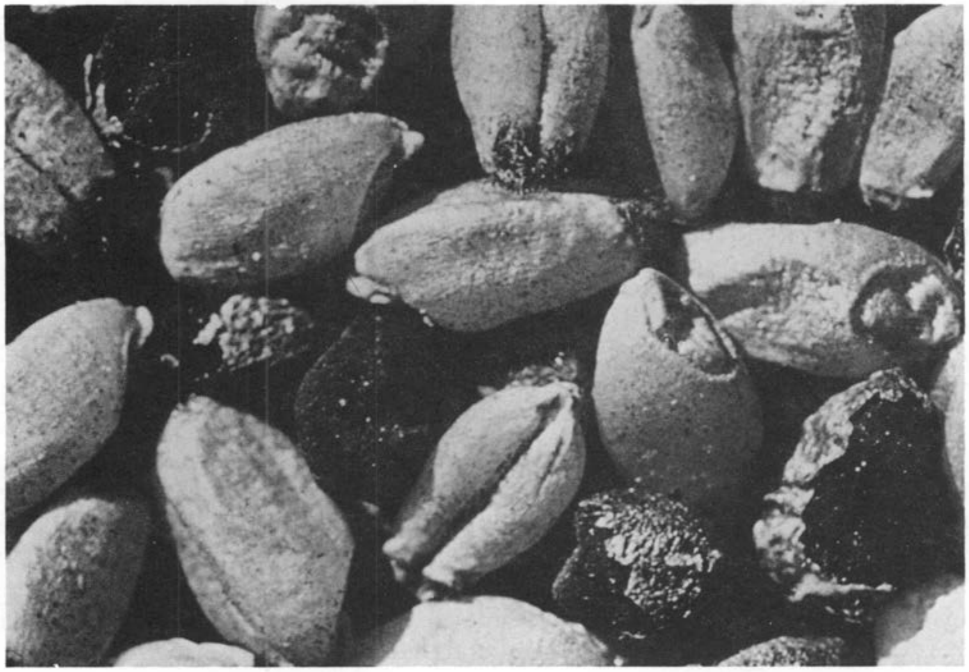


Fig. 123. Smut balls of covered smut of wheat. The membranes have been broken in threshing and wheat kernels are heavily dusted with smut spores.

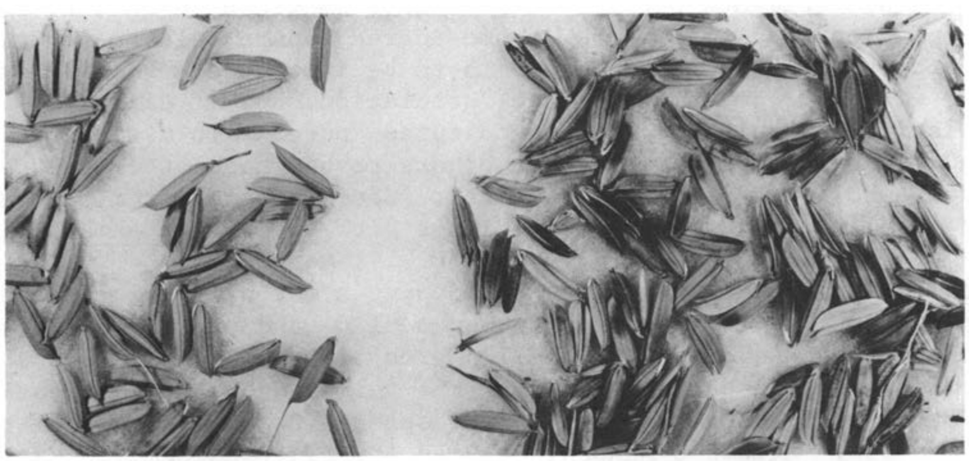


Fig. 124. Kernel smut of rice. Left: clean seed. Right: smut infested seed.

Fig. 125. Loose kernel smut on head of grain sorghum. Membrane covering long sori soon splits releasing spores.

Fig. 126. Leaf smuts of grains and grasses have sori visible as long, black streaks embedded in the leaf itself. X 3/4.

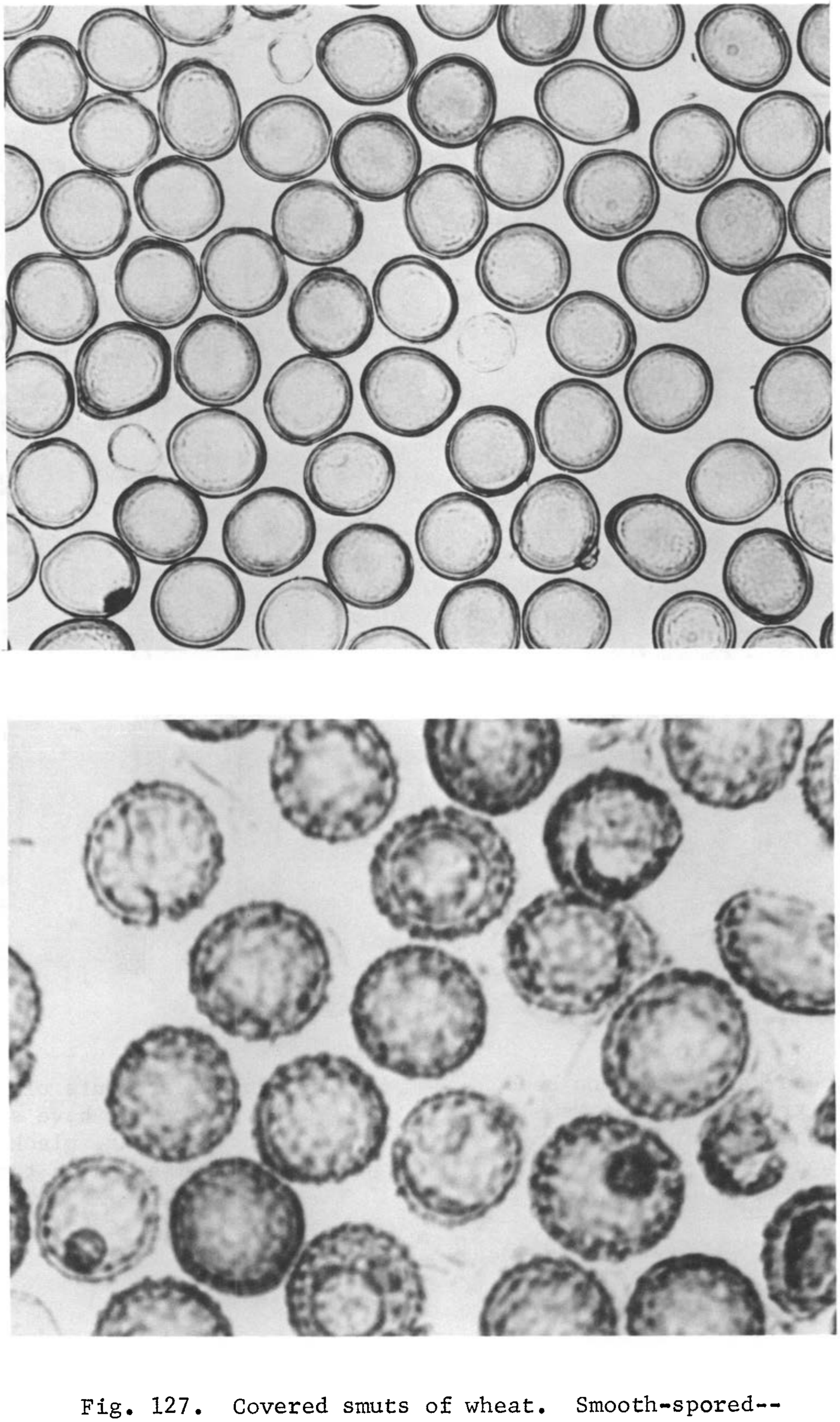


Fig. 127. Covered smuts of wheat. Smooth-spored-- Tilletia foetida; and rough-spored-- Tilletia caries. Spores picked up on wet needle and mounted in 1% KOH.

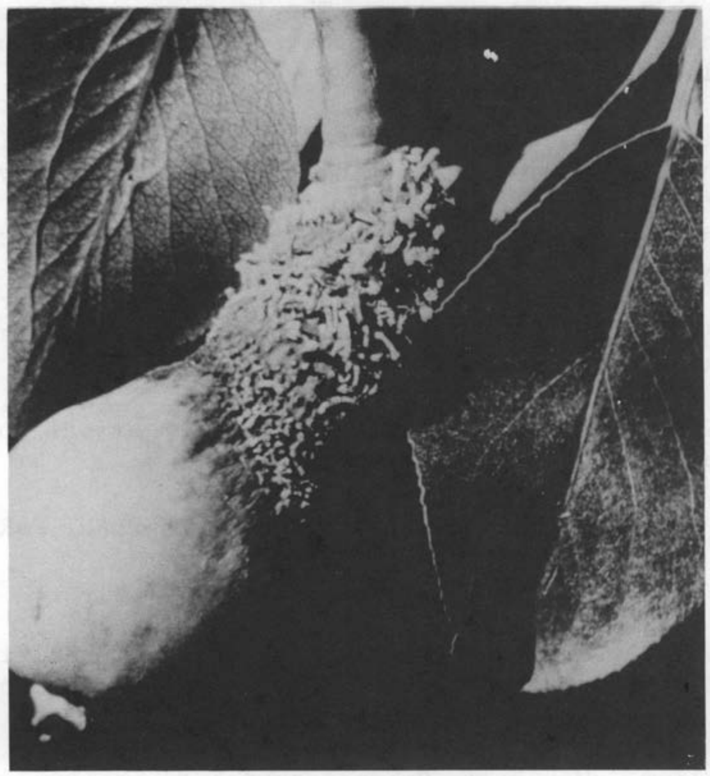


Fig. 128. Aecial stage rust on young fruit of pear. X 2.

Fam. Thelephoraceae: hymenium smooth.

Fam. Hydnaceae: hymenium covering spines or teeth.

Fam. Agaricaceae: hymenium covering gills.

Fam. Polyporaceae: hymenium lining pores.

Most of this group incite decay of mature wood (slash, heartwood, or lumber) and many of them are obligate saprophytes. The few parasitic species that concern us have macroscopic characters of the sporophore or the decay caused which aid in diagnosis. (See following pages.)

Major division in the mushrooms are based on spore color which is best determined by a spore print. This is secured by cutting off the stem of a young mature mushroom and placing it on white and black paper for 48 hours. Wrap in waxed paper or plastic to maintain high humidity. The deposit of spores en masse will be white hyaline, pink, yellow, brown, or black. To make the spore print permanent, spray gently with fixative from an aerosol can, and label. Black paper makes the best background for the light-colored spores. To record fresh appearance and color of soft sporophores, make color photos.

The Puffballs (Gasteromycetales), which produce spherical to elliptical bodies 1/2" to 12" full of powdery spores, are saprophytic.

ORDERS OF BASIDIOMYCETES INCLUDING COMMON PLANT PARASITES

Adapted From Various Sources

USTILAGINALES: SMUTS; 42 genera and about 700 species. Parasitic on flowering plants, especially grasses and sedges. Usually limited to ovaries but inflorescence, leaves, and stems may be attacked.

Fam. Ustilaginaceae -- basidiospores, produced on sides of a 4-celled promycelium. Ustilago, Sphacelotheca, Cintractia.

Fam. Tilletiaceae -- basidiospores elongate, produced at the end of a simple promycelium, the 8 or more spores fuse in pairs. (These characters are not readily observable and a simpler, morphological key is given.) Tilletia, Urocystis, Entyloma.

Fam. Graphiolaceae -- catenulate spores in black erumpent sor. Graphiola.

UREDINALES: RUSTS: about 114 genera, some 4,600 species. Obligate parasites of seed plants and ferns. Cosmopolitan. Mycelium intercellular with haustoria. Typical long cycle rusts produce five stages in regular sequence.

- 0 -- Spermagonia bearing spermatia and receptive hyphae
- I -- Aecia bearing aeciospores
- II -- Uredia bearing uredospores
- III -- Telia bearing teleutospores (teliospores)
- IV -- Promycelia bearing basidiospores

Some rusts have stages 0 and I on totally distinct host plants. (e.g., Puccinia graminis on Barberry, Black stem rust of wheat.)

A considerable number of rusts are "short-cycle" omitting one or more of the spore forms from the life cycle.

Fam. Melampsoraceae -- Teliospores sessile, single or grouped within the host tissue or united laterally in layers or columns. Cronartium, Coleosporium, Melampsora.

Fam. Pucciniaceae -- Teliospores pedicillate or sessile, free or fascicled but not united laterally except when borne on a compound stalk. Ravenelia, Tranzschelia, Phragmidium, Gymnoconia, Puccinia, Uromyces, Gymnosporangium.

Form-Genera: Teliospores unknown, only aecia or uredia.
Aecia only: Aecidium, Peridermium, Caeoma, and Uracium.
Uredia only: Uredo.

TREMELLALES: JELLY FUNGI: 500 sp. saprophytic on dead wood. Helicobasidium purpureum is perfect stage of violet root rot fungus.

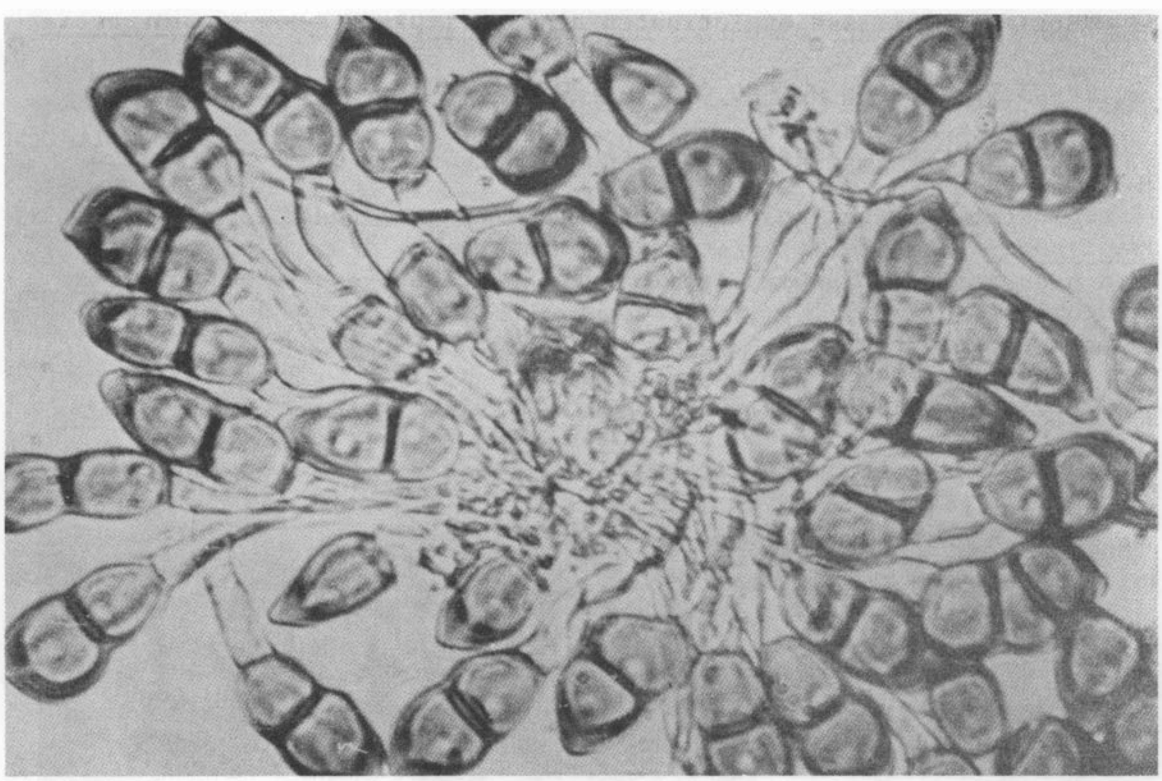
The following four orders are after Martin:

EXOBASIDIALES: Hymenium on galls or hypertrophied tissues of vascular hosts -- Exobasidium.

POLYPORALES: PORE FUNGI: Hymenium lining pores; fruiting body woody, tough or membraneous, but never soft.
Polyporaceae -- Poria, Polyporus, Fomes, Lenzites, Ganoderma, Fistulina.
Hydnaceae -- TOOTH FUNGI: Hymenium covering spines or teeth.
Echinodontia, Hiericium.

AGARICALES: GILL FUNGI: Hymenium covering gills, MUSHROOMS. About 125 genera and 4,000 species. Mostly saprophytes but Armillaria, Clitocybe, etc., are parasitic.

THELEPHORACEAE -- Hymenium smooth. Pellicularia filamentosa is perfect stage of Rhizoctonia solani, and P. rolfsii of Sclerotium rolfsii.



Spores from telial sorus of a rust (Puccinia).

B A S I D I O M Y C E T E S

USTILAGINALES -- S M U T S

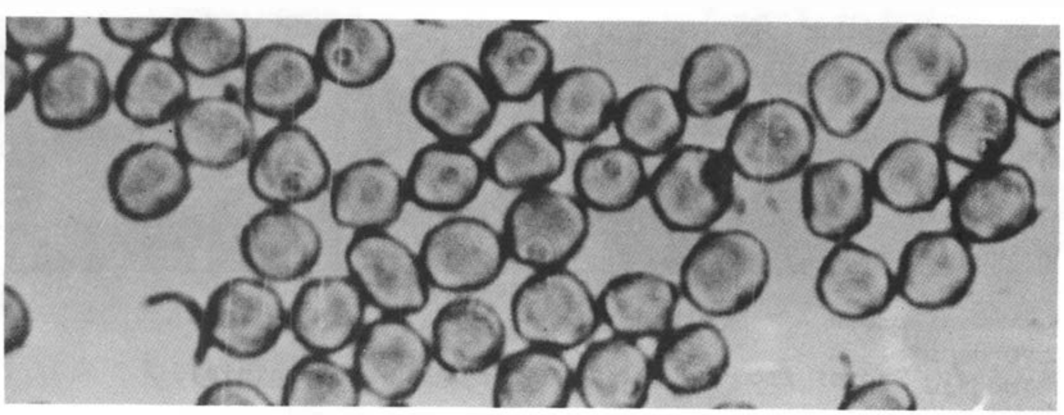
The common smut fungi primarily infect the ovaries of grains and grasses, and the sooty masses of spores makes it easy to recognize them as smuts. The six common genera also are easy to recognize from the following key: (The division of the smuts is based on whether the dark chlamydospores germinate with a four-celled promycelium which bears four sporidia laterally; or a stout, nonseptate promycelium which bears 8 sporidia in a terminal cluster. This is too slow and difficult to determine for routine diagnosis.)

Chlamydospores separate

- Sori dusty at maturity
  - Without a definite false membrane---------------- Ustilago
  - With a false membrane of fungus cells------------ Sphaerotheca
- Sori more or less agglutinated at maturity------------ Cintractia
- Sori possessing a more or less durable membrane;
  - Spores reticulate, spherical--------------------- Tilletia
- Cluster of light-colored spores remaining embedded
  - in host tissues, germinating in place------------ Entyloma

Chlamydospores in balls

- Sori dusty; Spore balls of 1 to 3 fertile cells
  - and several sterile cells------------------------ Urocystis



Chlamydospores of Ustilago.

Ustilaginaceae

121. USTILAGO: Clinton reported 72 species in America. This genus contains the largest number of species on economic and wild hosts. Most of species infect the seedling before it emerges from the soil.

U. tritici on wheat is typical of the Loose Smuts which shed their spores promptly at heading time, leaving the bare rachis with a few spores adhering. U. nuda on barley is similar.

U. zeae causing the Common Smut of corn is different in that it infects young tissues of leaves and nodes as well as kernels and flowers in tassels. The smut sori are often large (1 to 3 inches in length) and covered by a delicate white membrane which dries and splits, releasing the spores.

U. zeae on corn. A-smut sori on ear; B-smut sori on tassel; C-spores. U. tritici on wheat. D-rachis after loose smut spores are shed; E-spikelets on emergence from boot -- full of spores; F-spores.

122. SPHACELOTHECA: Sori usually in the inflorescence, often limited to the ovaries, with more or less temporary false membrane, covering a dusty spore mass and a central columella.

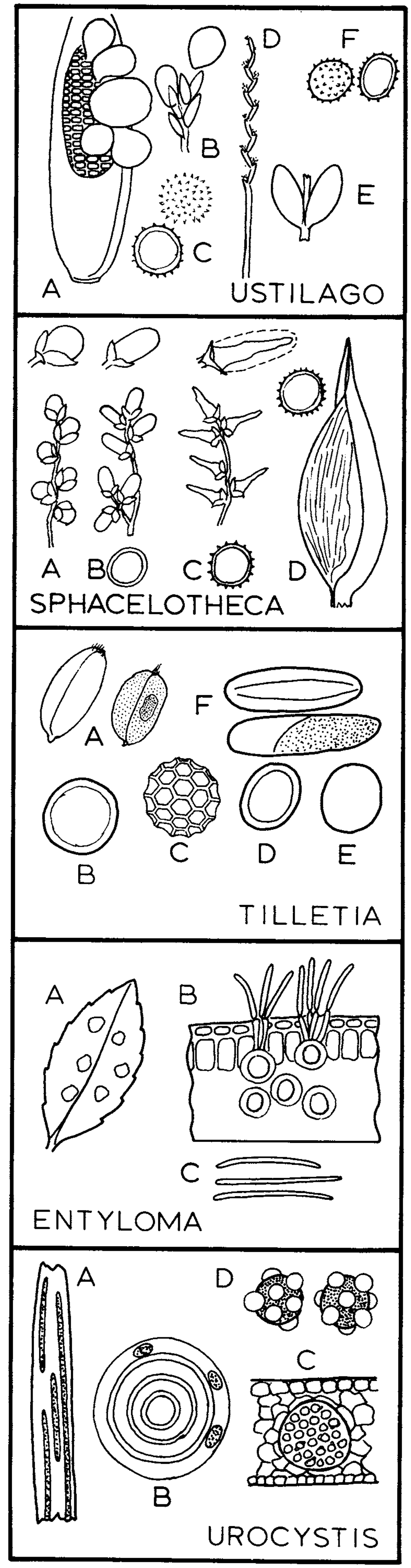
S. sorghi: Covered Kernel Smut of Sorghum and varieties. Sori in ovaries forming blunt bodies 3 to 12 mm. in length, protected by a persistent membrane. Columella slender and short, not conspicuous. Spores subspherical to spherical, smooth, contents often granular, 5.5 to 8.5 mμ diameter.

S. cruenta: Loose Kernel Smut of Sorghum and varieties. Sori in ovaries forming pointed fruiting bodies 5 to 12 mm. in length, with delicate membrane which is soon ruptured. Columella long and stout, conspicuous. Spores, 6.5 - 10 mμ.

S. reiliana: Head Smut of Sorghum varieties, and corn. Sori large and prominent involving all or most of panicle (or ear in corn) 2 to 6 inches long. A whitish membrane, soon ruptured, encloses the black-brown spore mass and slender remains of peduncles. Spores somewhat opaque, spherical or ovoid, minutely verruculose, 9 to 14 mμ long.

Sphacelotheca on grain sorghums. Small branches of head. A-healthy sorghum; B-S. sorghi, covered kernel smut and spore; C-S. cruenta loose kernel smut and spore; D-S. reiliana, head smut involving whole infloresence and spore.

CINTRACTIA: Smut of sedges. Sori replace ovaries, forming a firm black ball of spores. (Soften sorus in 1% KOH to free spores for examination on slide.)



Ustilago

Sphacelotheca

Tilletia

Entyloma

Urocystis

BASIDIOMYCETES, USTILAGINALES - 25

Ustilago

Sphacelotheca

Tilletia

Entyloma

Urocystis

BASIDIOMYCETES, USTILAGINALES

Tilletiaceae

123. TILLETIA: Sori usually in the ovaries, forming dusty spore masses. Only 3 of 22 American species are of economic importance: (Illus. p. 10.9)

T. foetida: Smooth-spored bunt, Covered Smut of Wheat. General with host. Sori in ovaries, more or less concealed by glumes; spores light to dark brown, subspherical or spherical, occasionally oblong or somewhat angular, 16 to 22 mμ, surface smooth. Gives off a "mousy" odor.

T. caries: Rough-spored bunt, Dwarf Covered Smut. Sori in ovaries, more or less concealed by glumes. Spores light to dark brown, chiefly subspherical, with prominent winged reticulations, 16 to 22 mμ diameter. (Best field mark is stunting of stems to 1/2 to 2/3 height of healthy stems.)

T. horrida: Kernel Smut of Rice. Sori in ovaries, but often only partially invading them, but partially concealed by the glumes. Spores usually present in different stages of development. Mature spores almost opaque, chiefly subspherical to spherical. Sori dusty when crushed. (Illus. p. 10.11)

Covered smut of wheat. A-smutted ovary enlarged; B-T. foetida (Stinking Smut) Smooth spores; C-T. caries (Rough-spored bunt) Reticulated spores; D-T. horrida (Kernel smut of rice) Tuberculate spores; F-smut spores concealed by glumes.

124. ENTYLOMA: A foliar smut of broad-leafed plants. Sori permanently embedded in tissues; spores single in groups beneath discolored area in leaf. Germination by a short promycelium, bearing a terminal group of sporidia which usually conjugate in pair (like Tilletia) and produce secondary sporidia or infection threads. (Freehand sections of leaves will reveal embedded spores and sporidia. Students have mistaken this fungus for an Imperfect--they missed the embedded spores!) (Illus. p. 10.9)

E. ellisii causes pale white spots on leaves of spinach. E. australe is common and destructive on many species of Physalis. Conidia linear, somewhat curved, 30-55 x 1-2 mμ.

E. australe on Physalis. A-white spots on infected leaf; B-section of leaf showing embedded hyaline spores germinating; C-basidiospores.

125. UROCYSTIS: Sori usually in leaves or stems, producing dark colored spore balls consisting of 1 to 3 dark colored fertile cells with a cortex of tinted sterile cells.

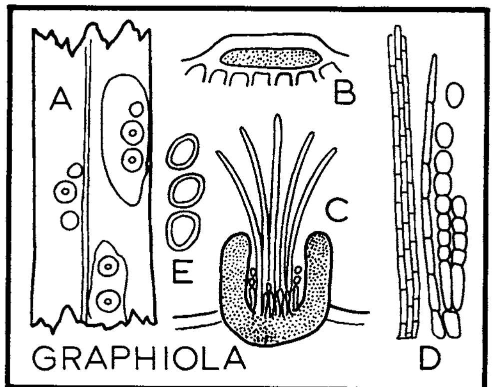
U. cepulae causes Onion Smut. Sori in leaves may run almost entire length of leaf. Fertile cells 1, rarely 2, with cover of small sterile cells. (Illus. p. 10.9)

Urocystis occulta causes Leaf Smut of Rye. Sori in leaves, linear, often very long. Fertile cells 1 to 4; incompletely covered by sterile cells.

Graphiolaceae

126. GRAPHIOLA: A fungus of unknown relationship, is sometimes placed with the smuts. One species, G. phoenicis, causes a leaf spot of Phoenix (Date) and other palms. Tiny (1 mm.) raised black bodies form on the leaves, and in late spring a tuft of sterile hairs and conidiophores bearing 1-celled fawn colored spores. The spores are quite small and variable in shape.

G. phoenicis on date palm. A-lesions on pinna of date leaf; B-section of young lesion; C-section of mature fruiting body sporulating; D-conidiophores, conidia, and sterile hairs; E-conidia.



Graphiola

UREDINALES - RUSTS

I. MELAMPSORACEAE: Teliospores sessile (no pedicel) single or grouped within the host tissue or united laterally into layers or columns.

Teliospores 1-celled, catenulate (in chains) adhering laterally, wall colorless, aecia with prominent peridium.

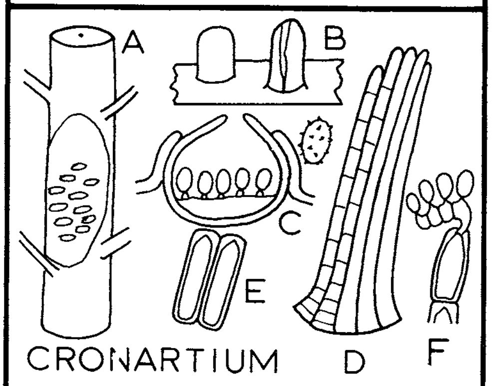
Telia erumpent, long filiform, urediospores pedicillate---------------------- CRONARTIUM

Telia forming cushion-like masses, with gelatinous walls, Urediospores catenulate-- COLEOSPORIUM

Teliospores 1-celled, compressed laterally into layer 1-cell thick, wall colored----MELAMPSORA

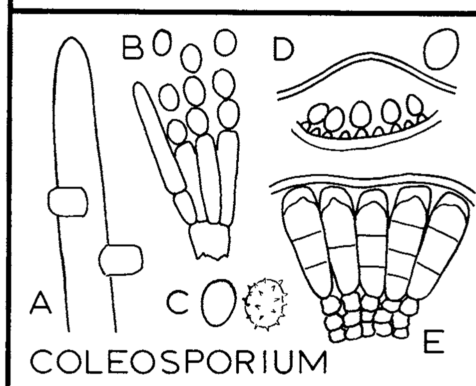
127. CRONARTIUM: Cronartium ribicola - White Pine Blister Rust. The most important disease affection of (5-needle) white pines, now occurring on both coasts. II, III occur on Ribes species, wild and cultivated. Uredia are hypophyllous and yellow; spores are somewhat sticky and are windborne to other Ribes. Telia are inconspicuous brown bristles bearing 4 basidiospores which infect white pine needles and pycnia develop. Bark infection produces yellow aecia, yearly until the twig dies and is visible as a red-brown "flag," (a good field symptom). (Your diagnosis will need verification as similar diseases occur.)

C. ribicola on white pine and currant. A-aecia on stem canker on young pine; B-aecia, one with split peridium; C-diagram of uredium and uredospore; D-telial horn on currant; E-Teliospores; F-teliospore germinating.

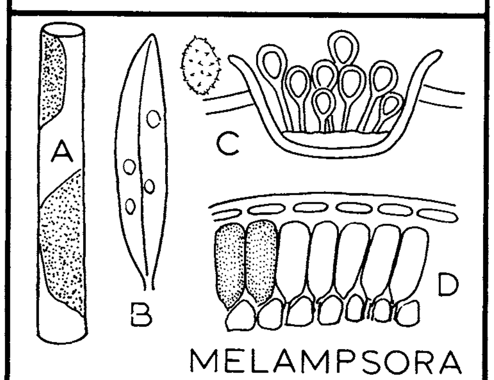


Cronartium

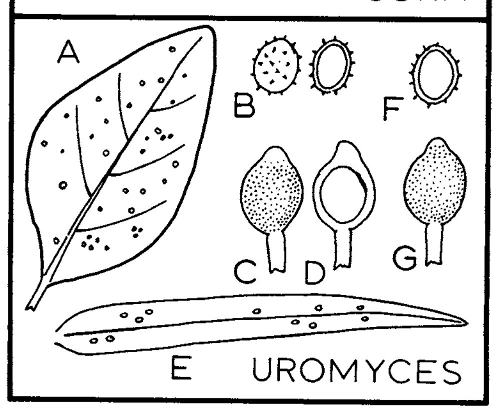
128. COLEOSPORIUM - Coleosporium asterum (C. solidaginis): Needle Blister Rust of Pine. 0, I on all 2 and 3 needle pines in eastern U. S. II, III on aster, goldenrod and other Composites. The aecia are taller than they are long and are fairly common on pines in gardens. Uredo stage on composites has bright orange-yellow pustules on under surface of leaves.



Coleosporium



Melampsora



Uromyces

DISTINGUISHING CHARACTERS OF LEADING CEREAL RUSTS

	Stem Rust of Small Grains	Leaf Rust of Wheat	Stripe Rust of Wheat and Rye	Crown Rust of Oats
Uredospores:				
Color in mass-	Brick Red	Bright Orange	Yellow	Light Orange
Shape and relative size-				
Appearance of uredinium-				
Epidermis-	Torn open	Not torn	Not torn	Not torn
Teliospores:				
Color in mass-	Black	Steel gray	Black	Black
Shape and relative size-				
Appearance of telium-	Superficial	Buried	Buried	Buried
Hosts:				
II and III-	Grains and grasses	Wheat, Barley, grasses	Wheat, Rye, grasses	Oats, grasses
0 and I-	Barberry	Meadow Rue	Not known	Buckthorn
Distribution in North America-	General	General Mostly in Eastern U.S. In S.E. particularly	W. Canada to Ariz. and Westward Texas and Mexico	General

Taken from: Chester, K. S., Nature and Prevention of Plant Diseases, Blakiston Co., 1942.

There are 8 distinct rusts of small grains.

"Needle Rust" of Pines. A-aecia on tip of pine needle; B-diagram of part of acecium with spores in chains; C-aeciospores; D-diagram of uredosorus, and spore; D-teliospores adhering laterally in sorus.

129. MELAMPSORA: Melampsora lini, Flax Rust. All stages are on the flax plant but 0, I stages are seldom seen. Uredo stage occurs as yellow sori on leaves and stems. Telial stage occurs as slightly raised blackish areas on the stem. (Sections of the stem show a pallisade layer of large, dark, one-celled teliospores.)

M. albertensis: Douglas Fir Needle Rust, Poplar Rust. Pycnia are on current-season needles; aecia are of the caeoma type and are orange-yellow. II, III occur on native poplars: uredia are yellow; telia are dark and subepidermal and may cause leaf shedding. (Sections of needles and leaves will show details.)

M. lini on flax. A-black telialsori on flax stem; B-yellow uredosori on flax leaf; C-diagram of uredosorus; D-dark brown teliospores in pallisade layer.

UREDINIALES - RUSTS

II. PUCCINIACEAE: Teliospores with pedicel, 1, 2, or more celled.

Teliospores 1-celled, aecia aecidoid-- UROMYCES

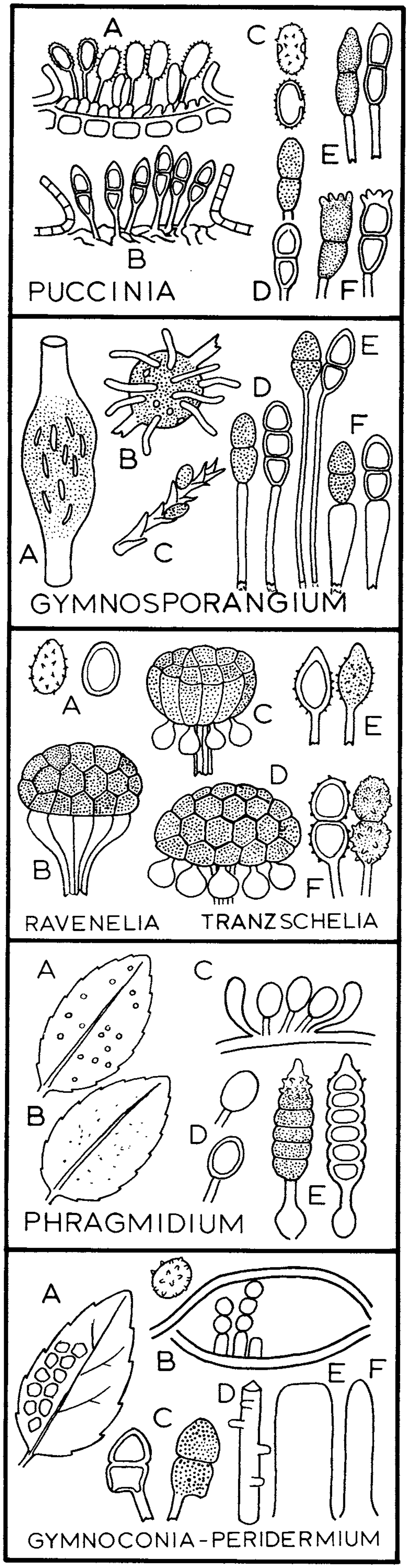
Teliospores 2-celled, aecia aecidoid-- PUCCINIA

Teliospores 2-celled, rarely more, pedicels gelatinous, aecia cupulate or cornute, with or usually without uredia----------- GYMNOSPORANGIUM

130. UROMYCES phaseoli typica causes rust of common beans. All spore stages occur on bean, 0, I, II, III. Pycnia and aecia are scarce and rarely seen. Uredosori II are brown and powdery. Teliosori III are black and typically produced in early to midfall.

Uromyces caryophyllinus: Carnation Rust. 0, I on Euphorbia in Europe. Uredia on leaves, dark cinnamon-brown, teliospores chestnut brown.

U. phaseoli var. typica on bean. A-brown uredo and black telialsori on leaflet; B-uredospores; C-teliospores; U. caryophyllinus on carnation. E-uredo and telialsori on leaf; F-uredospore; G-telial spore.



Puccinia

Gymnosporangium

Ravenelia-Tranzschelia

Phragmidium

Gymnoconia-Peridermium

131. PUCCINIA graminis: Black Stem Rust of Wheat and other grains and grasses. 0, I on Barberry; II, III on Wheat, etc. Uredia on leaves and sheath, reddish-brown. Telia black, chiefly on leaf sheaths, several mm. long, breaking through cuticle which rolls back.

Puccinia malvacearum: Hollyhock Rust. Telia on lower surface of hollyhock leaves, chestnut-brown, grayish by germination of spores (IV) in place. Only telial spore stage known, III. Also on other cultivated and wild Malvaceae.

P. graminis on wheat. A-diagram of uredosorus; B-diagram of telialsorus; C-uredospores; D-teleutospores; E-teleutospores of P. malvacearum on hollyhock; F-teleutospores of P. coronata (crown rust) on oats.

132. GYMNOSPORANGIUM: Infections on hosts of telial stage show three distinct types of symptoms: (1) Cherry to walnut sized spherical galls on small twigs--Cedar rust of apple; (2) Dense witches brooms 6 to 18 in. in diameter; (3) Large spindle-shaped galls girdling trunk or branches.

G. juniper-virginianae: Cedar-Apple Rust is the most important Gymnosporangium rust on a crop plant, as 0, I stages on apple leaves cause premature defoliation. Peridial membranes of aecia are long, splitting and recurving.
Life cycle takes two years: 4 to 6 months on apple and 18 to 20 months on cedar. The cedar galls produce orange-colored gelatinous "horns" in April-May and teliospores germinate in place. (The cedar galls, gelatinous horns and recurved peridium on aecia are distinctive.)

G. kernianum: Telia, III, occur on western junipers; 0, I on pear and amelanchier. Telia arise between leaves on green twigs, but mycelium is perennial in stems causing dense witches brooms.

G. globosum: Hawthorn Rust. 0, I mostly on hawthorn, but also on apple, pear and mountain ash. III on Eastern Red cedars and Rocky Mtn. junipers. Aecia are common on fruits of hawthorn. Cedar galls annual, not over 1/2 inch.

G. calvipes: Quince Rust. 0, I on fruits and young stems of many pome fruits and other Pomaceae. Aecia on fruits of English Hawthorn have conspicuous long white peridia. This rust is more on fruit than on leaves. Spindle-shaped swellings occur on twigs and branches of cedar which may die. Gelatinous ribbons emerge from the cracks and bear teliospores.

A-yellow ribbon-like telial horns exuding from spindle shaped branch gall on Juniperus; B-yellow spore horns arising from spherical gall on red cedar; C-tiny galls in axils of leaves of Juniperus monosperma; D-telial spores of G. speciosum; E-telial spores of G. juniperi-virginiae; F-telial spores of G. inconspicuum.

Teliospores united into a head on a compound pedicel with hyaline cysts--------- RAVENELIA

Teliospores 2-celled with joint pedicels and fascicled base-------------------- TRANZSCHELIA

Teliospores typically many-celled, verrucose or smooth, with 2 or 3 pores to each cell------------------------------ PHRAGMIDIUM

Teliospores smooth, 2-celled, without uredia, aecia caeomoid----------------- GYMNOCONIA

133. RAVENELIA—TRANZSCHELIA.

133a. Ravenelia versatilis: Uredia forming witches brooms with abundant chocolate-brown spores on cat's claw, Acacia greggii. Telial heads chestnut-brown, 5-8 cells across, peripheral cysts pendant. (Illus. p. 10.13)

A-typical uredospores; B-D-types of teliospores: B-R. epiphylla; C-R. cassiacola; D-R. opaca.

133b. Tranzschelia pruni-spinosae: O, I, on Ranunculaceae - Anemone, Ranunculus, etc. Uredia on lower surface of leaves of stone fruits. Cinnamon-brown. Telia form in early fall, dark-brown. Spores of two cells which are easily separated.

On apricot: E-uredospores; F-teliospores. (Illus. p. 10.13)

134. PHRAGMIDIUM disciflorum (P. mucronatum): Rose Rust. On cultivated roses, O, I stages are scarce and seldom seen. Uredia hypophyllous, yellow. Telia blackish bearing relatively small numbers of large, black, 5 to 9-celled spores with a pointed tip (visible with a hand lens). Serious on Pacific Coast, causing defoliation, less so elsewhere. (Illus. p. 10.13)

P. disciflorum on rose. A-yellow uredosori on leaflet; B-black teleutosori on leaflet; C-diagram of uredosorus; D-uredospores; E-large, heavy-walled teliospores.

135. GYMNOCONIA—PERIDERMIUM.

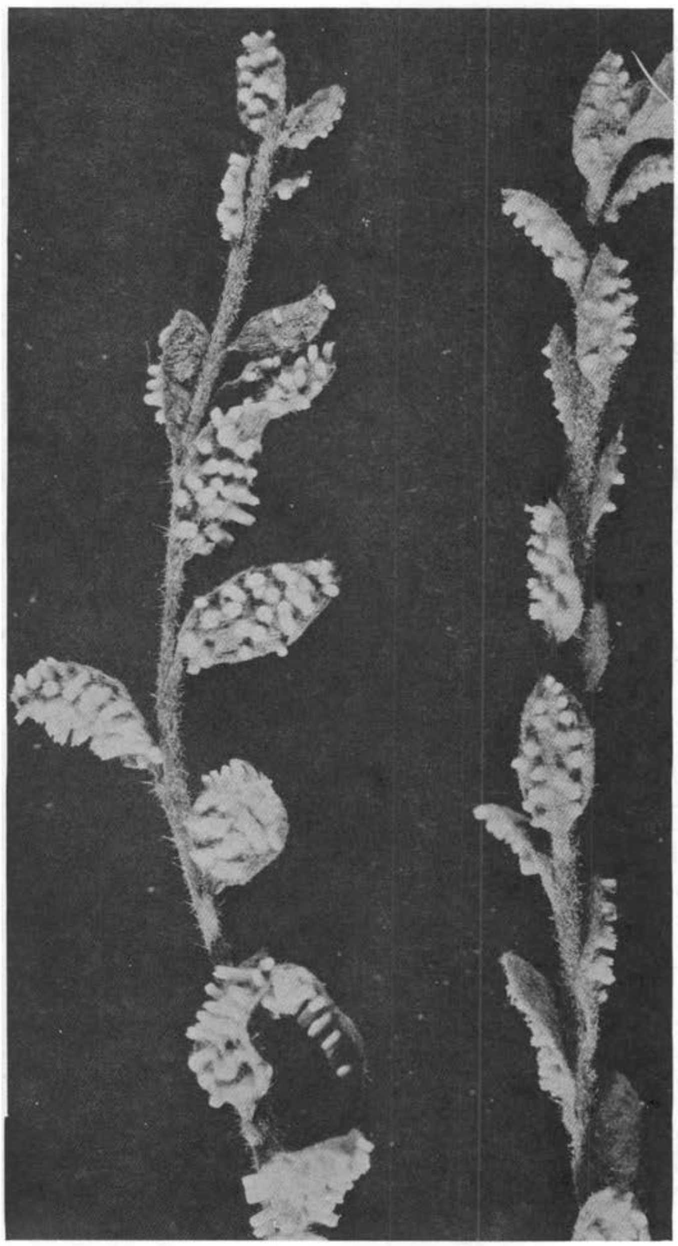
135a. Gymnoconia peckiana (G. interstitialis): Orange Rust of Blackberry. O, I, III on blackberry, dewberry and black raspberry. Symptoms appear with the new leaves. Pycnia epiphyllous, abundant, prominent. Aecia caeomoid crowded over lower surface of leaves, golden-yellow when fresh (bleach to straw color on drying). Uredia wanting. Telia hypophyllous, small, dark-brown; spores variable with hyaline papillae around each pore. (Illus. p. 10.13)

135b. G. interstitialis (Orange Rust) on blackberry. A-aecial stage on dwarfed leaf; B-diagram of aecium (Caeoma) stage and spore; C-odd shaped teleutospores.

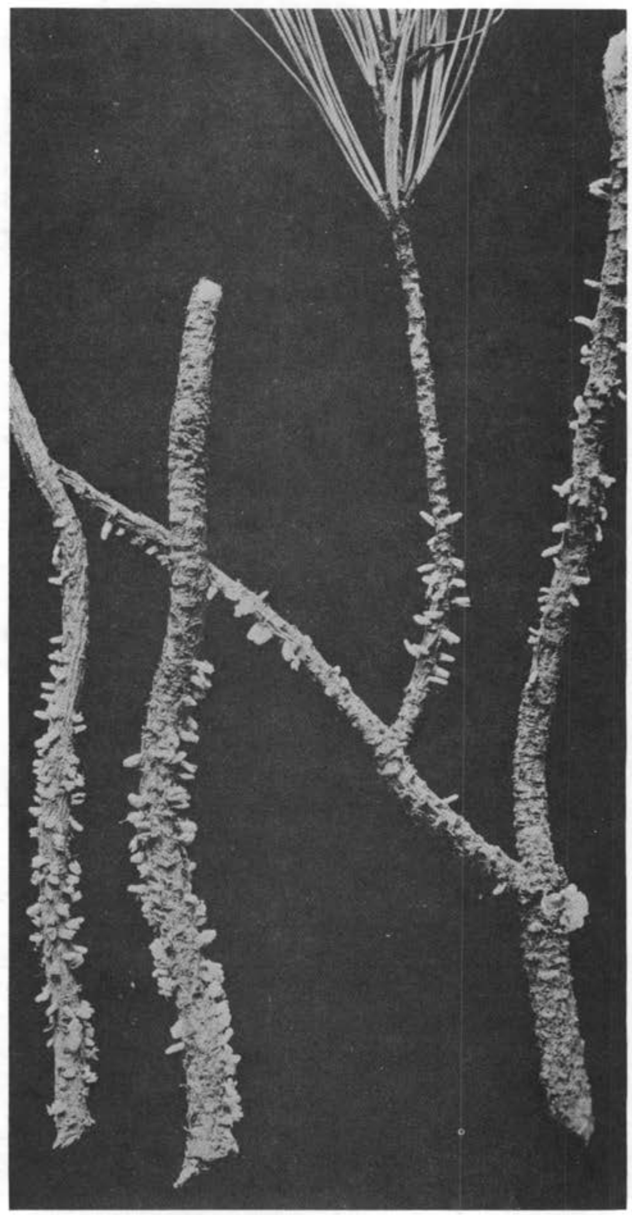
135c. Peridermium: Rusts with peridia occurring on coniferous hosts, with no known telial stage. Aecia cylindric, tongue-shaped or irregular, usually conspicuous. (Illus. p. 10.13)
Peridermium (Form Genus). D-Aecia on pine needle; E, F-side and end view of columnar aecium.

III. FORM GENERA: "Imperfect" rusts, only one spore form known.

Aecidium	- aecia
Peridermium	- peridia on Gymnosperm hosts
Caeoma	- aecia without peridium
Uracium	- stylosporic aecia
Uredo	- uredia only known



Aecial stage of rust on Cressa.



Limb rust (<u>Peridermium</u> <u>filamentosum</u>) on Ponderosa Pine.

EUBASDII

136. EXOBASIDIUM: 10 species causing marked hypertrophy on leaves, buds and/or stems of Ericaceae (Azalea family). Mycelium intercellular. Hymenium subcuticular, erumpent, basidia 2 to 8 spored, spores elongate.

E. vaccinii: Azalea Leaf Gall. On azalea, rhododendron and many other ornamental shrubs of family Ericaceae. On azaleas and other ornamentals the galls form (blisters) bladders involving all or part of leaf. These are white or pink and soft when young; hard and red-purplish with age. (Sections of the young leaf gall show basidia and spores.) E. vaccinii on azalea. A-leaf galls; B-section of gall with basidia and spores; C-basidiospores.

E. camelliae: Camellia Leaf Gall. Causes enlargement and thickening of leaves and new shoots. Sections of leaf show basidia and spores on under surface.

Thelephoraceae

137. PELLICULARIA: Mycelium coarse, branched at right angles, basidia stout on a membranous layer of mycelium.

P. filamentosa is the perfect stage of Rhizoctonia solani. P. rolfsii is the perfect stage of Sclerotium rolfsii.

P. filamentosa on potato. A-stem of potato with (a) sunken brown lesion below soil surface and (b) white powdery-mildew-like sporulating area above ground; B-basidia and spores; C-basidiospores.

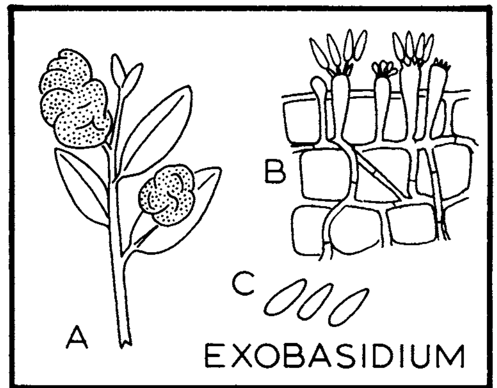
Hydnaceae

138. HERICIUM (HYDNUM): H. erinaceus causes a white rot of many deciduous trees, chiefly oaks. The rotted wood is soft and mushy. Many large holes filled with masses of light yellowish fluffy mycelium in heartwood. Sporophore 2 to 12 inches wide, white then yellowish to brownish, covered with fleshy teeth 1 to 4 inches long.

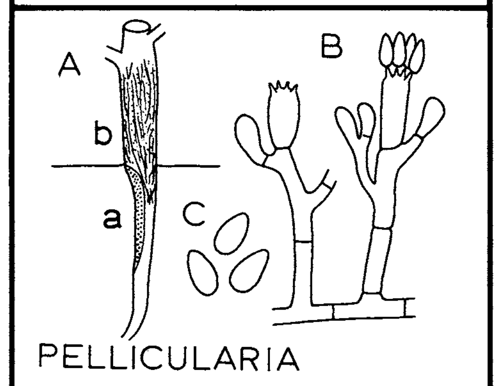
A-whitish sporophore with soft, often branching, spines or "teeth" which bear spores; B-cross section of spine showing spore bearing layer; C-basidium and spores.

139. ECHINODONTIUM: Similar to Hydnum but woody and perennial with concentric zones. E. tictorium, ("Indian paint fungus" - on account of brick-red interior). A-section of large brown, woody sporophore showing blunt teeth; B-cross section of spine showing spore bearing layer; C-basidium and spores.

140. PORIA: Sporophore entirely resupinate (a flat layer); the base leathery or punky, pores small, round, covering almost the entire surface.

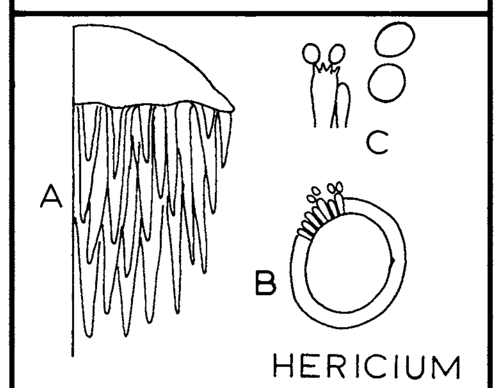


Exobasidium

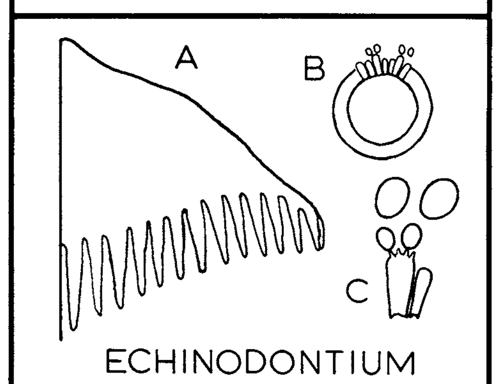


Pellicularia

TELEPHORACEAE

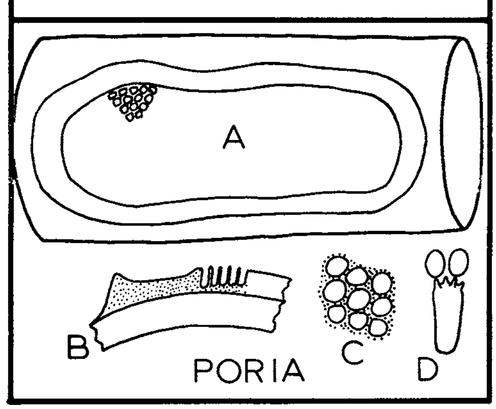


Hericium



Echinodontium

HYDNACEAE

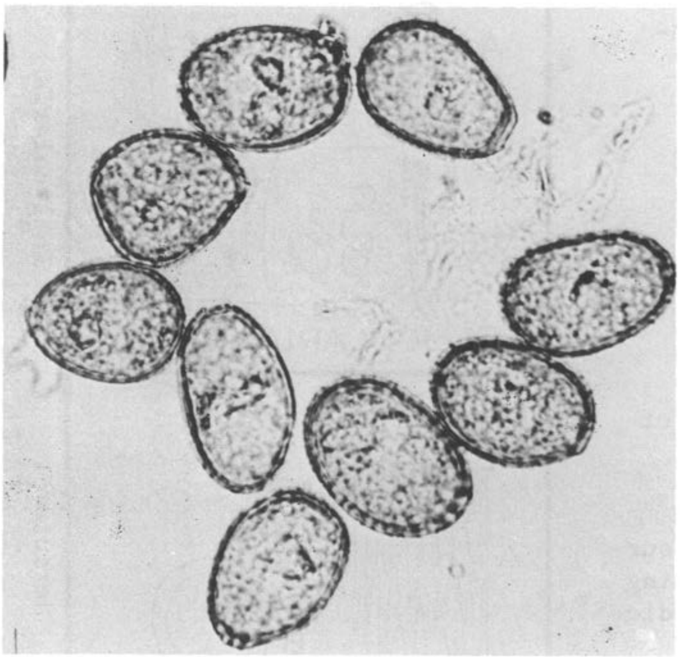


Poria

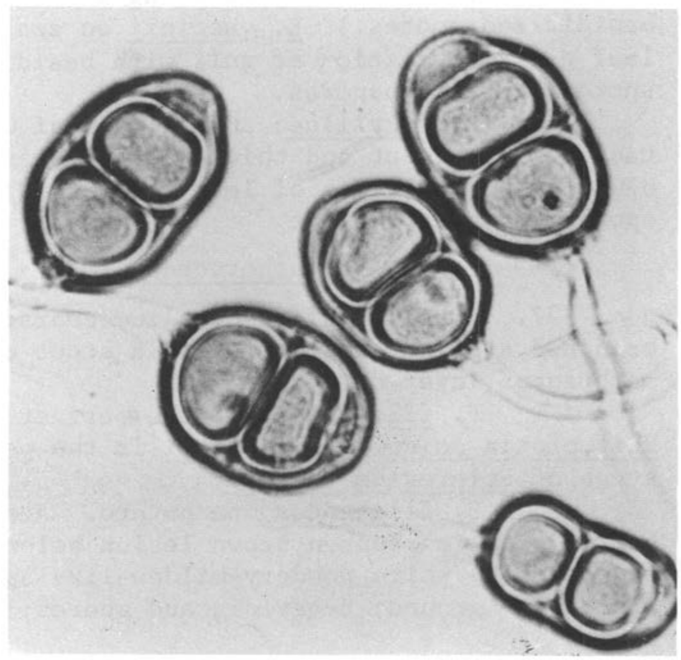
BASIDIOMYCETES - 28

Poria

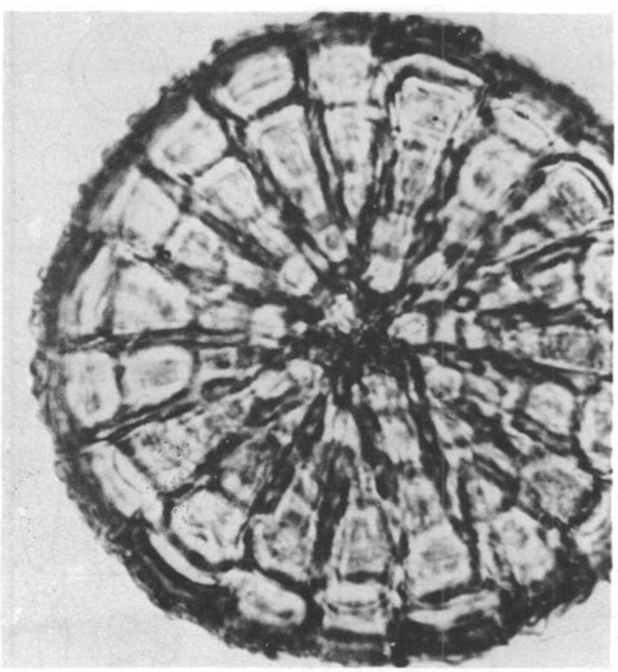
P. subacida: A common saprophyte on deciduous trees or butt and heart rot on coniferous trees often mistaken for a parasite. Frequently follows true parasite, as in case of Phymatotrichum root rot. It is sometimes parasitic. P. subacida on branch. A-resupinate sporophore with shallow pores; B-section of sporophore showing pores in section (some species have tubes 1/2 inch deep); C-surface view of pores, enlarged; D-basidium and spores. (Illus. p. 10.17).



Uredospores of Bean Rust.



Teliospores of Puccinia abrupta.



Teliospore "head" (top view) of Ravenelia.

Chlamydospores of Tolyposporella.

POLYPORACEAE
Pore Fungi

141. POLYPORUS: Sporophore usually annual, rather thick, fleshy, leathery, or corky, stipitate or shelving.

P. sulphureus: Called sulphur fungus due to its deep yellow color (bleaches to straw color with age). Causes a brown, cubical rot in heartwood of living hardwoods and conifers. Sporophores in large clusters of soft, fleshy, moist shelves with wavy edges.

P. sulphureus: A-group of wavy-margined fruiting bodies; joined at base, and pores; B-section of fruiting body; C-surface view of pores, enlarged; D-basidium and spores.

P. anceps: Red Ray Rot, on ponderosa pine causing heart rot of living trees. Useful as it causes rapid rotting of slash in the forest. Sporophores rare on living trees. Cottony white mycelium forms between bark and wood.

142. POLYSTICTUS: Sporophores leathery, usually thin. Pores developing from the center. The genus is merged with Polyporus by some authorities. P. pergamenus causes a sapwood rot of practically all species of deciduous trees; often on dead trees, occasionally on injured living trees. Sporophores very numerous, lower surface pale violet, tubes 1 to 3 mm. long.

A-tree trunk with numerous sporophores; B-section of pileus; C-surface view of pores, enlarged; D-basidium and spores.

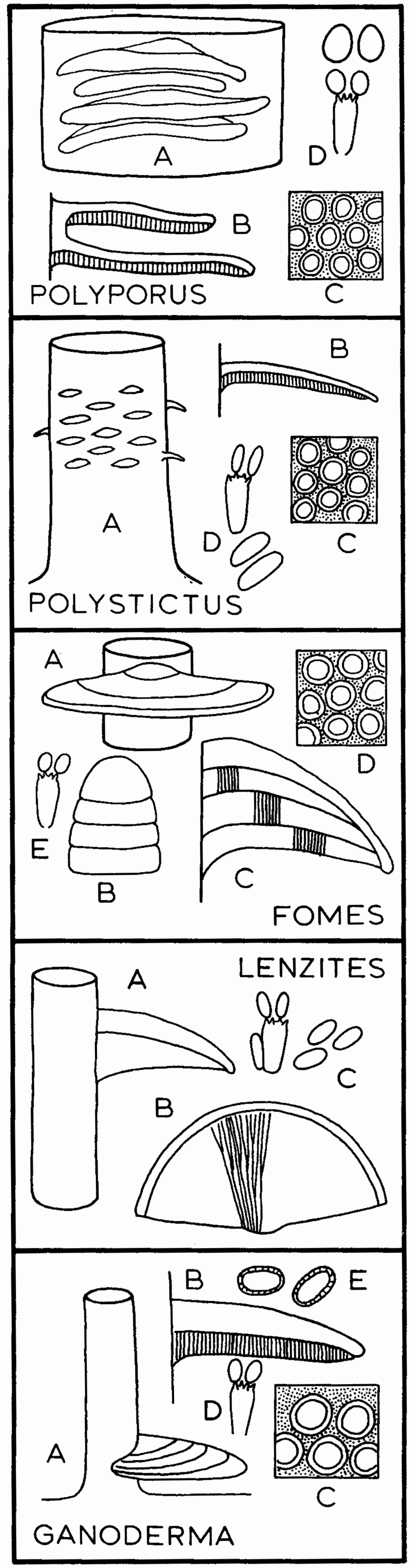
143. FOMES: Fruiting body woody, perennial, hoof-shaped or shelf-like, tubes in layers. Spores vary from hyaline to dark-brown.

F. igniarius: White Spongy Rot. A heart rot of a wide variety of hardwoods, but not conifers. In advanced stage the rot is soft, white, with narrow black lines running through it. Conks are usually hoof-shaped, to 8 inches wide, upper surface rough, under surface brown.

F. pini: Red Ring Rot. A very important cause of decay in coniferous forests. Infected heartwood at first reddish, but in advanced stage of decay has many white fibrous pockets. Conks variable, shelf to hoof-shaped; 4 to 9 inches wide, rough above, brown to gray on under side.

F. pinicola: A-large (to 12") shelf-like sporophore. F. igniarius on aspen. B-hoof-shaped perennial sporophore; C-section of a perennial conk showing 3 layers of tubes; D-basidium and spores.

144. LENZITES: Conks small, shell-shaped, tomentose (woolly) and zonate above. Pores elongated radically to resemble gills.



Polyporus
POLYPORACEAE
Polystictus
Fomes
Lenzites
Ganoderma
BASIDIOMYCETES - 29

L. saepiaria: Brown pocket rot. Primarily on dead sapwood, but rarely a heart rot of living trees. Gills become completely lamellate. (Genus *Daedalea* has elongated pores.)

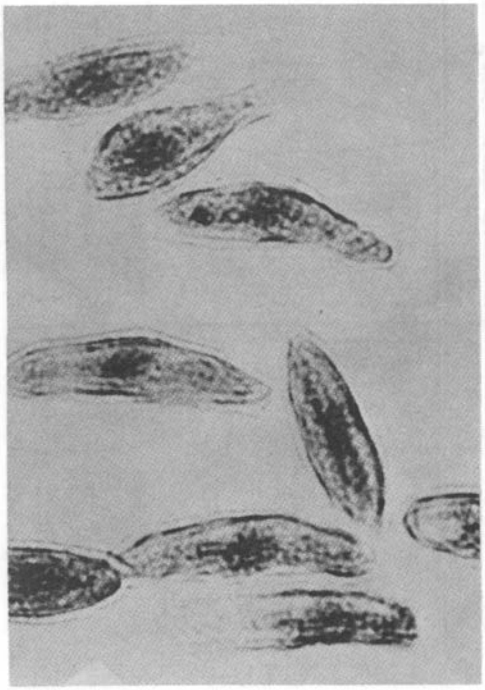
A-section of conk showing pores; B-under surface of conk showing elongated pores; C-basidium and cylindrical basidiopores. (Illus. p. 10.19)

145. GANODERMA: Similar to *Fomes*, but upper surface of conks smooth and spores flattened at the end and spines extending into exospore. (See E at right.)

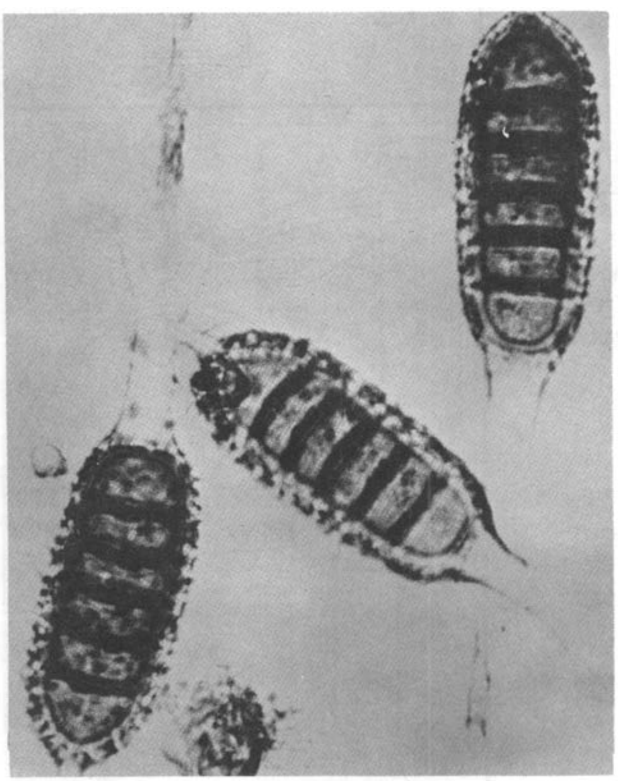
G. applanatum: White Mottle Rot. Widespread in hardwoods, occasional in conifers. Ordinarily saprophyte, but causes a heart rot, entering through wounds. Conk large, to one foot or more, upper surface smooth, gray; lower surface white. (Used by artists for etching pictures.)

G. lucidum: Varnish fungus on account of the smooth reddish lacquered upper surface of the shelf-like conks, often 6 to 10 inches wide. Causes a heart rot and butt rot of hardwoods and conifers. The rot is white, spongy with black spots scattered through (a distinctive mark). The conks are annual often with a lateral stalk. (Color of conk and black spots in the white rot are distinctive.)

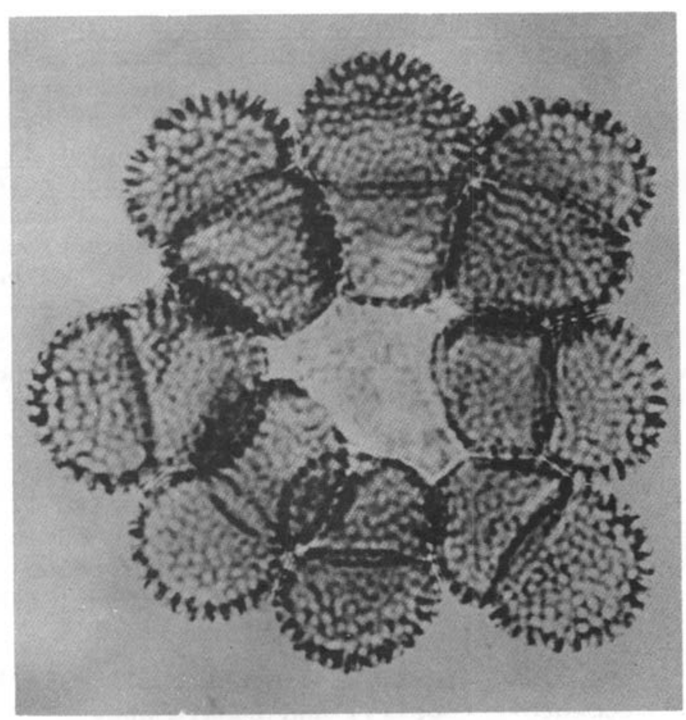
G. lucidum on *Rhus lancea*. A-large, flat conk at butt on Rhus; B-section of conk; C-detail of pores; D-basidium and spores; E-detail of spores. (Illus. p. 10.19)



Uredospores of a fern rust (*Uredinopsis*).



Teliospores of *Phragmidium* on Ribes.



Teliospores of *Tranzschelia*. Spores verrucose and cells easily separated.

POLYPORACEAE

146. FISTULINA: F. hepatica. Beefsteak Fungus: Causing a rot of oak and chestnut. Cap 3 to 8 inches wide, tongue-shaped, bright red to red-brown, with short lateral stipe, shelf-like, more or less lobed; smooth, sticky when wet. (Shape and color are distinctive.)

A-under surface of conk; B-lateral view in section; C-cross section of pore, enlarged; D-basidium and spores.

AGARICACEAE
Gill Fungi

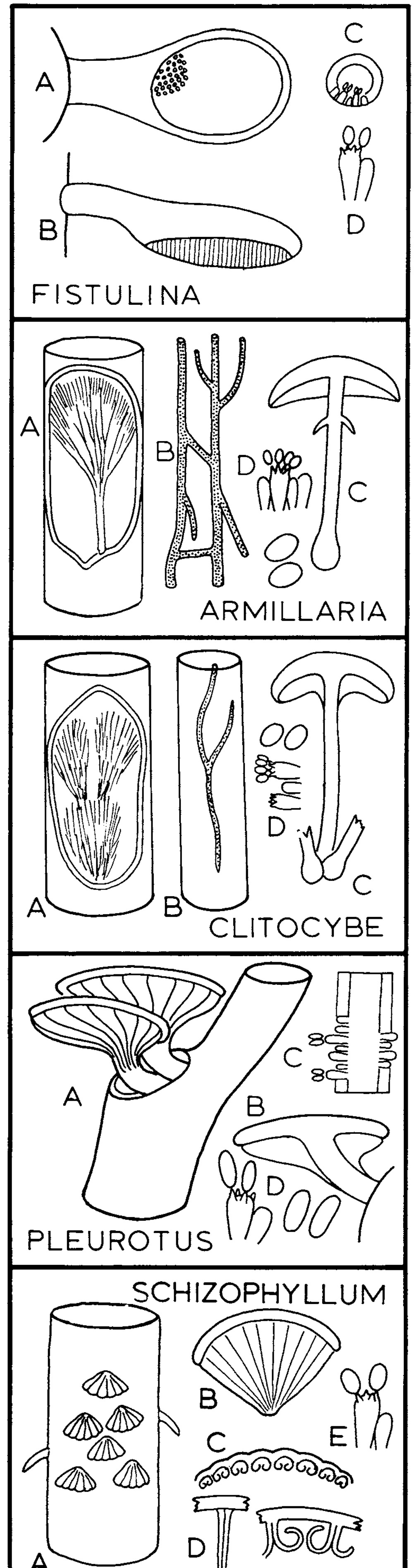
147. ARMILLARIA: Cap-shaped mushrooms, stalk with a ring but no cup at base. Gills attached to the stem; spores white.

A. mellea: Oak-Root Fungus, also called Honey Mushroom due to its color, and Shoestring fungus due to the black rhizomorphs in the soil. Kills fruit and nut trees, ornamental and forest trees and shrubs on West Coast, especially California. Less injurious in eastern U. S. Field symptoms: Slow decline of trees, thin foliage, death of trees in two or three years. Inspection of roots shows dead bark on larger roots, with bark loosened and white mycelial fans in cambium region. "Shoestring" rhizomorphs are found on and around roots. On West Coast, mushrooms appear in late fall and winter during the rainy period. In the East they appear in late summer. They typically occur in dense clusters, and are honey-colored, soft in texture and decay or dry out promptly. (Mycelial fans and rhizomorphs can be found any time, mushrooms only briefly.)

A. mellea on citrus. A-white mycelial fans under bark of infected root; B-black "shoestring" rhizomorphs under dead bark; C-section of mushroom showing gill attachment and ring; D-basidium and spores from gill surface. Spore print is white.

148. CLITOCYBE: Mushrooms resembling Armillaria but gills run down the stem which has neither ring nor cup. Spores white or whitish.

Clitocybe tabescens: Clitocybe Root Rot is a major disease of citrus and other fruits and many ornamental trees and shrubs in Southeast U. S. Reported on more than 200 species in 59 plant families. Field symptoms: Tops show slight yellowing and lack of vigor and decline is quite slow. Even at this stage many roots are dead and mycelial fans are present between bark and wood. No rhizomorphs are formed, but black, hard fungus outgrowths develop in cracks of infected roots. The clusters of light tan mushrooms appear from mid-September to December. Spore print yellowish.



Fistulina POLYPORACEAE

Armillaria AGARICACEAE

Clitocybe

Pleurotus

Schizophyllum

AGARICACEAE

(The attachment of gills down the stem and absence of ring and cup distinguish Clitocybe from Amillaria.)

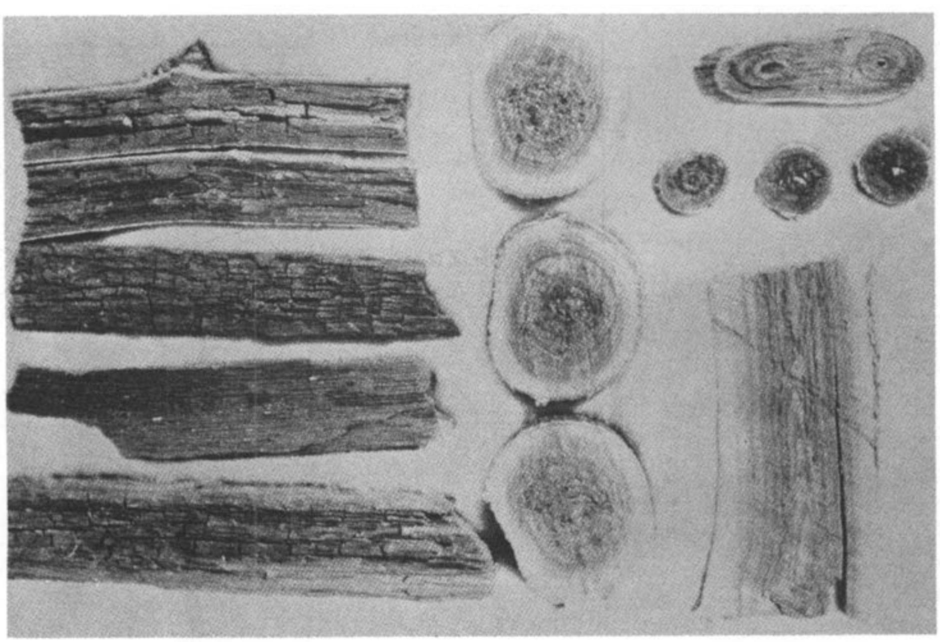
C. tabescens on Casuarina. A-mycelial fans under bark of infected root; B-black, firm mycelial growth in crack of infected root; C-section of mushroom; D-basidium and spores.

149. PLEUROTUS: Cap of mushroom laterally sessile or excentrically stipitate. P. ostreatus ("Oyster Mushroom" - edible) is common as a heart rot of deciduous trees, but is mainly saprophytic. Mushroom large, white, soft, quite variable in shape--convex or plane, or lobed, stem short or lateral, or none. Usually occur in groups.

A-sporophores on apple limb; B-section of sporophore showing decurrent gills; C-basidium and spores. (Illus. p. 10.21)

150. SCHIZOPHYLLUM: S. cummune is a very small, thin, shelf-like fungus very commonly found on dead parts of living trees of many species, especially fruit, nut and shade trees. The fruiting bodies are often numerous, 1 to 1-1/2" wide, fan-shaped, gray-white downy on upper surface, gray forked gills below. (When dry, the gills split and each half rolls up--a distinctive mark.) Spore print white. (Illus. p. 10.21)

A-small, white fan-shaped sporophores on trunk of peach; B-lower surface of fan showing gills; C-dry sporophore in section showing splitting and inward rolling of gills; D-gill before splitting; E-basidium and spores.



Heart rot of the umbrella tree invades even the smaller branches. This is a brown cubical rot.

INDEX OF LINE DRAWINGS OF FUNGI

GENERAL INDEX

APPENDIX

SELECTED REFERENCES

Chosen for their usefulness in diagnosis of plant diseases.

IDENTIFICATION OF FUNGI

(1) Alexopoulos, C.J., and E.S. Beneke. 1962. Laboratory Manual for Introductory Mycology. Burgess Pub. Co., Minneapolis, Minn. 199 pp.

(2) Alexopoulos, C.J. 1962. Introductory Mycology. 2nd Ed., John Wiley & Sons, New York. Glossary. 613 pp., 194 Figs. (Rather preoccupied with life cycles, but has many useful drawings of spore-bearing bodies.)

(3) Schwartze, C.A. 1917. The Parasitic Fungi of New Jersey. New Jersey Agri. Exp. Sta. Bull. 313. 226 pp., 1056 Figs. (Available) (Excellent drawings of spores and spore bodies of a great many common plant parasites, with brief descriptions of the fungus species.)

(4) Barnett, H.L. 1960. Illustrated Genera of the Imperfect Fungi. 2nd Ed., Burgess Pub. Co., Minneapolis, Minn. 225 pp., 462 Figs. (Brief description of 302 genera with drawings illustrating a typical species. Includes many saprophytes.)

(5) Fisher, G.W. 1953. Manual of North American Smut Fungi. Ronald Press Co., New York. 343 pp., 136 Figs. (Keys to genera and species, with photos of symptoms and photomicrographs of spores.)

(6) Cummins, G.B. 1959. Illustrated Genera of Rust Fungi. Burgess Pub. Co., Minneapolis, Minn. 131 pp. (Keys to the genera of rusts with excellent drawings.)

(7) Arthur, J.C. 1960. Manual of the Rusts in United States and Canada. Rev. Ed. Purdue Research Foundation, Lafayette, Ind. 438 & 26 pp. (The standard manual with keys to genera and species, species descriptions and illustrations.)

(8) Stevens, F.L. 1913. Fungi Which Cause Plant Disease. MacMillan Co. (1966 printing is available from Johnson Reprint Corp., New York, N.Y.) 754 pp., 448 Figs. (Has the best keys available for many groups. More complete than his later "Plant Disease Fungi.")

(9) USDA. 1960. Index of Plant Diseases in the United States. U.S. Dept. of Agriculture, Agri. Handbook 165. 531 pp. (Lists over 1,200 host genera and some 50,000 parasitic and non-parasitic diseases. No descriptions.)

(10) Conners, I.L. 1967. An Annotated Index of Plant Diseases in Canada. Res. Branch, Canada Dept. Agr., Pub. 1251. Ottawa. 391 pp. (Similar to (9) listing diseases recorded in Canada under host plants.)

METHODS

(11) Tuite, John. 1969. Plant Pathological Methods. Burgess Pub. Co., Minneapolis, Minn. 239 pp. (Includes a great many laboratory methods for isolating and studying plant pathogenic fungi and bacteria--with references. Formulas for 272 culture media and solutions for special purposes are given.)

(12) Altman, Jack. 1966. Phytopathological Techniques, Laboratory Manual. Pruet Press, Boulder, Colo., 259 pp. (Formulas of media, stains and preparations used in the plant pathology laboratory, and details used in isolation, inoculation, and identification are described.)

PLANT DISEASES AND THEIR CONTROL

(13) Walker, J.C. 1969. Plant Pathology. 3rd Ed., McGraw-Hill, New York. 819 pp., 204 Figs.

(14) Heald, F.D. 1943. Introduction to Plant Pathology. 2nd Ed., McGraw-Hill, New York. 603 pp., 246 Figs. (Good chapters on non-parasitic maladies, pp. 463-574.)

(15) Westcott, Cynthia. 1971. Plant Disease Handbook. 3rd Ed., D. Van Nostrand Co., Inc., New York. 782 pp. (Very useful for information on diseases of minor host plants and on ornamentals often omitted from textbooks.)

(16) USDA. 1953. Plant Diseases, USDA Yearbook, 1953. Washington, D.C. 940 pp., 112 Color Figs. (Nontechnical discussions of most common diseases.)

(17) Parris, G.K. 1970. Basic Plant Pathology. Pub. by author, State College, Miss. 462 pp. ("Written primarily for undergraduate students who will take no further course in plant pathology." Good definitions of symptoms. See discussion of non-parasitic diseases, pp. 81-91, and mycoplasmas, pp. 204-207. 137 diagram sketches. Glossary.)

(18) Kenaga, Clare B. 1970. Principles of Phytopathology. Balt Publishers, Lafayette, Ind. 334 pp., 104 Figs. ("For use in undergraduate, introductory plant pathology courses." See mycoplasmas, pp. 41-49; non-infectious plant disease, pp. 113-130; market pathology, pp. 131-139.

(19) Barnes, Ervin H. 1968. Atlas and Manual of Plant Pathology. Appleton-Century-Crofts, N.Y. 325 pp., 222 Figs. (Many photomicrographs of spores, fruiting bodies, often with paired ink drawings. Also close-up photographs.)

(20) Agrios, G.N. 1969. Plant Pathology. Academic Press, New York. 629 pp., 144 Figs. (Includes good life-cycle diagrams.)

(21) Streets, Rubert B. Sr. 1969. Diseases of Cultivated Plants of the Southwest. Univ. of Arizona Press, Tucson. 390 pp., 177 Figs. (For problems of the arid climates.)

(22) Wellman, F.L. 1971. Plant Diseases. Natural History Press, Garden City, N.Y. 130 pp. (An introduction for the layman. Impact on the food economy, control. Line drawings of pathogens and symptoms.)

DISEASES OF SPECIAL HOSTS OR HOST GROUPS

(23) Dickson, J.G. 1952. Diseases of Field Crops. 2nd Ed., McGraw-Hill, New York. 517 pp., 101 Figs. (Covers field, forage, fiber and oil crops.)

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(25) Klotz, Leo J. 1961. Color Handbook of Citrus Diseases. 3rd Ed., University of California, Berkeley. 119 pp., 40 Color Plates. (Brief, nontechnical text, color illustrated.)

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