Proceedings of the 1974 APDW workshop on crown rot of apple trees

Editedby D. L. McIntosh[1]

At a workshop sponsored by the Apple and Pear Disease Workers and held at Summerland, British Columbia, 16-17 August 1974, participants from the USA, UK, Poland, and Canada considered problems associated with collar rot of apple trees incited chiefly by *fhytophthora cactorum.* Topics included pathogens, symptomatology, methods of isolating *P. cactorum,* evaluation of resistance, pathogenic variation in *P. cactorurn,* cultural practices and predisposition, control, ecological studies, and areas requiring further research.

Can. Plant Dis. Surv. 55:109-116. 1975

Les 16 et 17 août ont eu lieu a Summerland en Colombie-Britannique des journées d'etude parrainees par les phytopathologistes de la pomme et de la poire. Les representants des Etats-Unis, de la Grande-Bretagne, de la Pologne et du Canada qui y participaient ont etudie les problemes relatifs au mildiou du collet chez le pommier dont le principal agent causal est *fhytophthora cactorum.* On a etudie en particulier la nature de l'agent pathogene, la symptomotologie, methodes d'isolement de P. *cactorum.* l'évaluation du degre de resistance, la variation de la pathogenicite chez *P. cactorum,* les methodes de culture et la predisposition des arbres a la maladie, les moyens de lutte, l'écologie. On a egalement établi les domaines necessitant des recherches plus poussees.

The Apple and Pear Disease Workers (APDW), with financial support from the Cooperative State Research Service of the United States Department of Agriculture, convened a Workshop for discussion of the crown rot disease of apple trees at the Agriculture Canada Research Station, Summerland, British Columbia, August 16-17, 1974. The following scientists participated: *H. S. Aldwinckle,* New York State Agricultural Experiment Station, Geneva, N.Y. 14456; *Anne M. Alvarez,* University of Hawaii, Honolulu, Hawaii 96822; *S. V. Beer,* Cornell University, Ithaca, N.Y. 14850; *Z. Borecki,* Institute of Pomology, 96-100 Skierniewice, Poland; *R. F. Carlson,* Michigan State University, East Lansing, Michigan 48824; *C. N. Clayton,* North Carolina State University, Raleigh, N.C. 27607; *R. P. Covey, Jr.,* Tree Fruit Research Center, Wenatchee, Wash. 98801; *J. N. Cummins,* New York State Agricultural Experiment Station, Geneva, N.Y. 14456; *H. J. Dubin,* University of Maine, Orono, Maine 04473; *C. O. Gourley,* Research Station, Agriculture Canada, Kentville, N.S. B4N 1J5; *H. W. Guengerich,* Stark Bros. Nurseries, Louisiana, Mo. 63353; *K. D. Hickey,* Winchester Fruit Research Laboratory, Winchester, Va. 22601; *B. F. Janson,* Ohio State University, Columbus, Ohio 43210; *A L. Jones,* Michigan State University, East Lansing, Michigan 48824; *A. J. Julis,* North Carolina State University, Raleigh, N.C. 27607; *I. C. MacSwan,* Oregon State University, Corvallis, Ore. 97331; *R. C. McCrum,* University of Maine, Orono, Maine 04473; *C. D. McKeen,* Agriculture Canada, Central Experimental Farm, Ottawa, KIA 0C6; *J. L. McIntyre,* Connecticut Agricultural Experiment Station, New Haven, Conn. 06504; *J. Mircetich,* ARS, USDA, University of California, Davis, Calif. 95616; *R. W. Miller,* Clemson University, Clemson, S.C. 29631; *J. E. Mitchell,* University of Wisconsin, Madison, Wisc. 53706; *W. J. Moller,* University of California, Davis, Calif. 95616; *P. C. Pecknold,* Purdue University, W. Lafayette, Ind. 47907; *D. H. Petersen,* Pennsylvania State University, University Park, Pa. 16802; *R. C. Pearson,* Hudson Valley Laboratory, Highland, N.Y. 12528; *R. M. Rosher,* Agriculture Canada Research Station, Summerland, B. C., VOH 1Z0; *G. W. F. Sewell,* E. Malling Research Station, Nr. Maidstone, Kent, England; *E. Shabi,* University of Missouri, Columbia, Mo. 65201.

Topics dealt with are listed below in the order in which they were discussed. The problems encountered by those who have some involvement with crown rot of apple studies or diagnosis were described. Suggestions were offered for overcoming some of them. Many questions were asked about the host-parasite relationship, about the epidemiology of the disease, about its recognition, about the techniques required for manipulation of the pathogen, and about a reliable method of evaluating rootstock resistance. Not all of them could be answered with certainty. The statements which follow were gleaned by the editor from the discussions and from written submissions. Wherever possible the source of information is supplied in brackets following the statement, so readers who wish more detail on the subject can contact the individual directly.

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The pathogens

Phytophthora cactorum (Lebert & Cohn) Schroet. has

Figure 1. Root crown affected by crown rot, Note darker color of infected bark where main roots join the trunk.

been considered the incitant of collar rot and crown rot of apple trees but other pythiaceous fungi also may cause bark rotting. In Poland, collar rot is caused primarily by *Phytophthora cactorum,* less frequently by *Phytophthora syringae* and occasionally by *Pythium* spp., probably *Pythium ultimum.* Symptoms similar to collar rot will also develop after artificial inoculation with *Phytophthora megasperma, P. cryptogea, P. cinnamomi, P. drechsleri,* and *P. citricola.* An epiphytotic of collar rot disease on 6-year old apple trees was attributed to infection by *Pythium ultimum.* It developed as a result of damage to the trunk bark while digging around the trees in the autumn (*Borecki*). In California, several *Phytophthora* spp. have been isolated repeatedly from apple trees affected with crown and root rot from 11 orchards surveyed in Santa Cruz and Sonoma counties. Three unidentified *Phytophthora* spp. as well as *P. megasperma, P. cambivora,* and *P. drechsleri* were recovered from trees 1-18 years old. Three or four different *Phytophthora* species were often recovered from the same orchard and occasionally from the same tree. *P. cactorum* was not isolated from any of the 57 apple trees sampled in the survey, although this species has recently been isolated from crown rot-affected lilac, live oak, and walnut trees elsewhere in California *(Mircetich).* Studies in Wisconsin reveal that *Cytinostroma galactinum* (formerly *Corticium galactinum)* was the cause of a decline of apple stocks in one orchard *(Mitchell).*

Symptomatology

Phytophthora cactorum, causes a *collar rot,* i.e. a rot of the bark of the trunk at or above ground level, as well as a *crown rot,* i.e. rot of the bark around the root crown below ground level. Collar rot may affect the scion variety, or the rootstock if the union is well above ground. Crown rot originates in the rootstock where the main roots join the trunk.

During the 1950s in England, when most orchard trees were low-worked on M2 or M9 rootstocks, *Phytophthora* problems were almost entirely associated with infections of scion variety bark and tissues (i.e. collar rot) at or near soil level. The most susceptible cultivar was **Cox's** Orange Pippin, and infections of rootstock tissues below soil level (i.e. crown rot) were relatively rare. More recently, extensive orchard plantings have been made using trees worked onto Malting-Merton rootstocks, often with the graft-unions raised above soil level to avoid scion variety infection. With these changes the *Phytophthora* problem has also changed and many disease outbreaks now involve infections of rootstock tissues below soil level (i.e. crown rot). Foliar symptoms of crown rot (general chlorosis often with red coloration of veins and margins) frequently occur long before

Figure 2. Marbled appearance of lesion in which *Phytophthora cactorum* is active. Note sharply defined margin between infected and healthy-appearing tissue.

rootstock stem lesions are apparent at or near soil level. This feature, together with examinations of lifted trees, indicate that most infections initially occur at the bases of the main roots (*Sewell*).

In British Columbia, crown rot disease is characterized by a rot of the bark below ground where the main roots join the trunk (Fig. 1). Frequently the rot progresses upward to the stock-scion union. Often the bark of lateral roots is not affected except close to the trunk. Recently invaded tissue, or an active lesion, is several shades of tan to reddish brown in a marbled pattern. The margin between diseased and healthy-appearing tissue is sharply defined (Fig. 2). Often the appearance of the bark surface over an active lesion does not indicate the condition of the tissue beneath. Usually young vigorous-looking trees which are severely damaged by infection during the growing season, do not show obvious symptoms of distress above ground until mid-August or September when leaves, or initially just midribs, take on a purplish-red color. This coloration intensifies with time until diseased trees can be readily distinguished from others in the planting whose leaves still are green. Premature purpling of the foliage late in the season is not always indicative of crown rot infection. In this region Golden Delicious frequently develops such foliage color without the involvement of crown rot infection. However trees with such coloration are easily spotted in the planting and examination of their bases below ground more often than not reveals a severe crown rot infection. By the time such foliage symptoms appear so much of the trunk circumference is diseased that trees either die or do not grow satisfactorily for several years thereafter.

If an infection affecting an appreciable portion of the trunk below ground is not detected during the season in which it has developed, growth on that side will be delayed the following season. Leaves will be small, fruit will be highly colored, and terminal growth poor. Examination of the bark below ground reveals tissue dead to the cambium but by this time other secondary organisms have been active and the probable cause is not so evident (*McIntosh*).

The symptoms first observed in the spring by South Carolina growers are a lighter green coloration of foliage and a subsequent lack of vigorous growth. Sometimes these trees will set a fruit crop and produce some small fruit but other times they die. When symptoms appear in early or midsummer, they are characterized by a slow rate of growth, a change in color to light green which is often accompanied by yellowing. The keen observer develops an "eye' for affected trees. Occasionally there is an upward folding of the leaves and a discoloration (pink or reddish) of the leaf lamina and midrib from exposure to sunlight. One- to 5-year-old trees suspected of being severely infected often feel loose or poorly anchored when the trunks are grasped and shaken. Trees with a heavy crop may just topple.

Bark discoloration usually extends no more than 25 cm above the soil, mostly in dark brown streaks. Most discoloration and girdling occurs at or below the soil line. Some is found in the primary root system. During dry weather bark on cankered areas dries out and cracks, delineating the cankered area. Callus tissue may or may not encircle the previously infected tissue. Problems which can be mistaken for collar rot if a careful examination is not made are cold injury, mouse damage, southern stem blight *[Sclerotium rolfsii]*, occasionally borer damage, and fire blight on susceptible stocks (*Miller*).

In Virginia, the most obvious symptom of crown rot is a partial or complete girdling of the trunk at or near the ground line. Generally the entire underground portion of the stem is watersoaked and brown and the necrotic area usually extends upward to the graft union. Infection may extend into the scion above the union in trees planted below the graft union. On newly infected trees the roots may appear normal except for 5 to 15 cm next to their point of attachment to the trunk. Such trees often show first symptoms near the soil line during late summer or early winter and by the next spring may be completely girdled. Trees that have made normal to above normal growth and have borne one or two crops are affected more than juvenile trees 2 to 3 years old. Affected trees which are completely girdled by spring show poor terminal growth accompanied by a pronounced off-color in the foliage in early September. These trees usually are completely girdled by December and die the following growing season *(Hickey).*

In Poland, lesions in the lower part of the tree trunk are extensive, reaching a height of 40 cm. Most damaging are lesions girdling the trunk at rootstock-scion junction. Collar rot, in the form of a lesion girdling the stem, is most frequent on the semi-dwarf rootstocks M7, MM106, and others of the MM series. The regenerative ability of the tree has an important influence on the symptoms of collar rot. On artificially inoculated apple trees, the wounds often reach dimensions of more than 12 mm but this necrosis does not progress thereafter and the wound gradually heals. A completely different type of symptom occurs on susceptible varieties of pears, particularly on Russian clones. In their case, the disease involves the entire inoculated shoots, passing in to older branches and the tree trunk. This causes dieback of the entire tree in a single season, similar to that caused by fire blight *[Erwinia amylovora] (Borecki].*

There was some discussion of how to distinguish between the symptoms of crown rot, winter injury, and "wet feet'. Lesions caused by recent activity of *P. cactorum* are not a problem. The characteristic tan to red brown mottling of the affected bark tissue is diagnostic (Fig. 2). Problems arise the year after the pathogen has been active, when above ground symptoms of poor leaf and shoot development are seen early in the season. At this time, after the dead bark has been invaded by secondary organisms, the actual cause of tree death may be difficult to ascertain. The following observations may be helpful in making diagnoses:

1. Winter injury is more likely to affect the trunk at and above ground, while crown rot (as opposed to collar rot) affects tissue below ground.

2. After winter temperatures low enough to cause trunk damage, it is likely that there will be a higher percentage of trees affected in individual plantings than usually are damaged by crown rot in a single season. Five to 10 percent affected in any one season could be attributed to crown rot. Higher percentages would be expected for winter injury.

3. Bark injured by sub-zero temperatures will, in time, separate readily from the underlying wood. This is not characteristic of tissue affected by crown rot.

4. Winter injury often affects only one side of the tree, i.e. that facing the southwest.

5. Much of the wood is discolored in trees damaged by winter. This is not always the case in trees damaged by crown rot when they are examined soon after symptoms of delayed development appear.

Mechanics of isolating Phytophthora cactorum

Sewell and McIntosh stated that the most important factor in the successful isolation of *P. cactorum* is the selection of cortical tissues from the margins of *active-appearing* lesions where infected discolored tissues border healthy-appearing tissues. Strips of bark about 5 mm wide are cut lengthwise through the margin to the depth of the cambium. Chances of recovery are enhanced if the bark pieces are irrigated in tap water for 2-3 days. At the end of this period they can be either cut into 5 mm lengths and transferred to cornmeal agar or examined under a wide-field microscope for development of the characteristic *Phytophthora* mycelium from the edges of the bark. Those bearing *Phytophthora-like* hyphae can be inserted into apple fruits and the wounds sealed with petroleum jelly or adhesive tape. Firm brown lesions develop in the fruit in 4-8 days. Tissue transferred aseptically from the margins of these lesions yields pure cultures of *Phytophthora.*

Isolation from older apparently inactive lesions is much more uncertain, but the same procedure should be followed. However it likely will be advantageous to add to the agar medium compounds which will suppress unwanted fast-growing secondary invaders and bacteria. Good success has been achieved in isolating *P. cactorum* from both active and older lesions by washing infected tissue 30-60 min in running tap water, placing tissue on Difco cornmeal agar containing 100 ppm Nystatin + 200 ppm Vancocin HC1 + 100 ppm quintozene (PCNB). Transferring mycelium growing from this tissue after 3-5 days to plates of the same medium produces pure cultures of *P. cactorum* (*McIntyre).* For a review of the literature on selective media see Tsao, P.H. 1970. Selective media for isolation of pathogenic fungi. *Annu. Rev, Phytopathol.* 8:157-186.

Does treating the bark tissue with reducing agents or antioxidants increase the chances of successful isolation? Hickey and Mircetich had some success using ascorbic acid but results were not consistent. Does the kind of fruit to be injected with bark or soil have any effect on the results? Borecki stated that some primitive apple types available in Poland were much more useful than dessert varieties. Golden Delicious was not too useful in Argentina *(Alvarez).* Green varieties are preferable to red skinned fruits *(McIntosh).* Sewell compared 15 different varieties in England for this purpose and found no differences.

Evaluation of resistance in rootstocks and scions

Many people have been frustrated and puzzled by their lack of success in producing infection through artificial inoculation. This lack of consistency in response to inoculation undoubtedly has been responsible to some extent for the differing resistance ratings given by individual investigators to the same rootstock.

Aldwinckle has used a technique for evaluating resistance in rootstocks and scions which is similar to one described by Borecki and Millikan (*Phytopathology* 59:247, 1969). Dormant 1-year wood is collected in late winter; sticks are cut into 60 mm internodal lengths; the epidermal layer is removed to expose phloem; four sticks are placed in a petri dish with moistened filter paper to prevent desiccation; a 4 mm plug of V8-juice agar bearing actively growing mycelium is placed in the center of the upper surface of each piece; after incubation for 4 days at about 24°C the length of brown lesions is measured.

Sewell and Borecki agreed that apple scion cultivars react more uniformly to artificial inoculation than do apple rootstocks, and the resistance of scion tissues can be evaluated readily by inoculating stems using a cork borer to remove bark tissue and allow the placement of an agar disc of mycelium.

Comparative studies of varietal resistance among apple cultivars are valid only if the varieties are worked on similar, preferably very vigorous, rootstocks and if all inoculations are made near the "pink bud' stage of development. Lesions in Cox stems can be up to eight times larger with a vigorous stock (MM104) than with a dwarfing stock (M9). Resistance of scion varieties to artificial inoculation is least during the period from bud-burst to full blossom; resistance increases substantially with the commencement of extension growth *(Sewell).*

For evaluation of resistance of rootstocks, Borecki compared six different methods and found the most reliable to be inoculation of budded rootstocks, at least 4 years old, under field conditions. Agar discs of mycelium were satisfactory as inoculum. Evaluation of disease development was not made until at least 1 year after inoculation. Inoculation of young unbudded rootstocks under field conditions was the least reliable method. Borecki found considerable variation in the reaction to inoculation during the season. One main peak of susceptibility occurred during flowering, and a second less conspicuous peak occurred in midsummer. He suggested that for rootstock resistance evaluation the stock should be budded with a susceptible scion. If the scion is inoculated the pathogen will progress from the scion into the rootstock, and the size of the rootstock lesion which develops can be measured.

From Sewell's experience it seems that no inoculation method yet tried has given results which reflect reliably the resistance of rootstocks under orchard conditions. Direct inoculation of young rootstock stem tissues of all clones resulted in only small lesions which healed rapidly. This method gave little or no indication of the susceptibility of MM104 or M106 which has been revealed by their field behavior.

Sewell has experimented with zoospore inoculum and has found that young stems of MM104 are resistant to multipoint inoculation (by pin prick wounding under zoospore suspensions); young plants of unworked rootstock clones also responded inconsistently to zoospore **soil** drench applications. The latter method generally resulted in wilt, due to destruction of the fine root system, followed by gradual but complete recovery. Secondarily thickened *root* tissues of more mature plants may be less resistant than rootstock *stem* tissues. It is possible that environmental factors associated with host predisposition may be of prime importance in determining field behavior of the rootstock clones. Certainly at present, reliable assessments of rootstock resistance can only be derived from field experience. This fact emphasizes the necessity for full confirmation of the causal agent of root and crown disorders, i.e. whether it is winter injury, mechanical damage, or some other pathogen.

At the conclusion of this section there was some speculation about factors which might affect the resistance displayed by artificially inoculated stocks. Cummins was concerned with stress factors, and whether water-logging, drought, winter injury, or the onset of fruiting might lower resistance or somehow predispose trees to invasion. The question arose as to whether winter injury plays a part in the development of crown rot. McIntosh stated that his records of crown rot incidence did not show an obvious increase in losses to the disease after particularly low winter temperatures.

Rootstock and scion resistance ratings

Rootstocks considered susceptible in some regions are believed resistant in others. What are the reasons for such differences? Are the differences real or the result of differences in methods of assessment, or are they due to factors not yet defined? While there were no simple authoritative answers to these questions, there seemed agreement that MM104 and MM106 are likely to suffer the most damage from crown rot (Table 1). MM111 has been troublesome in British Columbia but not in Michigan or Pennsylvania. M7 has proven susceptible in B.C., South Carolina, and Poland but not in Michigan. Robusta 5 is not being planted in Michigan because of *Phytophthora* problems. Stocks which seem to have suffered least from crown rot include M2, M4, M9, M26, and Antonovka seedlings.

Pathogenic variation in P. cactorum

Pathogenic variation has been proposed as a reason for differences in resistance of individual rootstock clones reported from various regions. Is there any convincing evidence for such pathogenic variation among isolates of *P. cactorum?*

Aldwinckle and his colleagues at Geneva, N.Y., have obtained such evidence by mass inoculating with zoospores apple seedlings grown in flats and also by inoculating excised twigs with agar plugs bearing mycelium. They were able to divide the isolates used into four groups by the way each interacted with six test cultivars in the twig test. Within these groups there were differences in the level of pathogenicity to all cultivars ("aggressiveness" sensu van der Plank). A larger number of test cultivars might allow further subdivision of the four groups. Statistically significant differential interactions were found between 31 cultivars and 3 *P. cactorum* isolates that had not been differentiated by the 6 test cultivars. The four pathogenicity groups do not appear to have been determined by host or area of origin. Representatives of each group had been isolated from apple in Missouri.

Comparison of pathogenicity among *P. cactorum* isolates in Poland and among other species showed that all of

Table 1. Survey of APDW collar/crown rot workshop participants August 16-17, 1974: Regional experience with *Phytophthora* on common apple rootstocks

Respondent	Geographic area covered by response	Rootstocks which are no longer planted or should not be planted because of *Phytophthora* problems	Rootstocks which occasionally have *Phytophthora* problems	Rootstocks which never have *Phytophthora* problems
H.S. Aldwinckle	New York	Maybe MM106	MM106	
A.M. Alvarez	Rio Negro Argentina		MM104	
Z. Borecki	Poland	M7, MM106, MM104	M2, Alnarp 2	M9, Antonovka sdlg.
R.F. Carlson	Michigan	MM109, MM104, Robusta 5	MM106, Alnarp 2, M26	M7, M8, MM111
C.N. Clayton	North Carolina	MM106	M7	
R. Covey	Washington	MM104, MM106	Sdlg, M7, M9	M26
H.J. Dubin	Maine	MM104		
C. Gourley	Nova Scotia		MM106	
H.W. Guengerich	U.S.		All rootstocks including sdlg.	None
K.D. Hickey	Virginia (Shenandoah Valley)	MM104, MM111?, MM106	Std. sdlg., M7. M2	Std. sdlgs., M9
B.F. Janson	Ohio		MM106, M26, M7	M9
A.L. Jones	Michigan	MM104	MM106, sdlg.	
I.C. MacSwan	Oregon	MM104		
D.L. McIntosh	British Columbia	MM104, MM106, M7, MM111	M2. M26, M9, M4	
R.W. Miller	South Carolina	MM106, M7	MM111	
J.E. Mitchell	Wisconsin	MM104?	MM106, M7	
W.J. Molter	California	Not yet clear	MM106, MM104, std. sdlg.	None
P.C. Pecknold	Indiana	MM106, MM104		
D.H. Petersen	Pennsylvania	MM104, MM106	M26. M2. M7	EM9, MM111
G.W.F. Swell	Kent, England	MM104	MM106 locally severe MM109, less common	M2, M9, MM111 M26

them caused necrotic lesions on trunks of apple trees, but the various isolates exhibited distinct differences in their degree of pathogenicity. Among 63 isolates of *P. cactorum*, 6 of Polish origin and 4 of USA origin were the most pathogenic. One isolate of *P. citricola* also was highly pathogenic. Isolates of *P. cactorum* differ widely in the appearance of the culture on exposure to high temperatures, in the intensity of sporulation, in their pathogenicity to different hosts, and in the structure of the sexual and asexual spore forms. It is difficult on the basis of these criteria to identify specific biotypes. After culturing several score *P. cactorum* isolates over the previous 6 years and isolating the pathogen every 6 months from plant tissue, pathogenicity proved a relatively stable character of the fungus. The most pathogenic isolates used in the early period, 1968-69, of the experiments have retained their characteristic pathogenicity (*Borecki*).

McIntosh pointed out the difficulties of obtaining uniform woody host material for studies of pathogenic variation; and the desirability of having a suitable host range for this purpose; he also suggested that initially some use might be made of herbaceous annuals in determining differences in pathogenicity among isolates of *P. cactorum*. In this connection, the recent report from Wisconsin on the susceptibility of safflower was interesting.

Workers interested in studying pathogenic variability should note that isolates of *P. cactorum* are available from the sources listed in Table 2.

Cultural practices and predisposition to infection

Several participants postulated that excess soil moisture favored development of the disease. Incidence of crown and root rot in some apple-growing areas of California reached epidemic proportions following unusually high winter and early spring rainfall in 1973 and 1974 (*Mircetich*). In Virginia the disorder is commonly found in old orchard sites or in low areas of orchards having heavy, poorly drained soils (*Hickey*).

Table 2. Survey of APDW collar/crown rot workshop participants, August 16-17, 1974: Isolates of *Phytophthora* available

Name	Geographical source of isolate	Number of *Phytophthora cactorum* isolates available and source
H.S. Aldwinckle	New York	2
A.M. Alvarez	Rio Negro, Argentina	3-4 (Apple)
Z. Borecki	Poland	63
C.N. Clayton	North Carolina	10
R. Covey	Washington	8 (Apple. pear, irrigation water)
C.O. Gourley	Nova Scotia	2 (Apple)
K.D. Hickey	Virginia (Shenandoah Valley)	2
B.F. Janson	Ohio	10+
A.L. Jones	Michigan	48
I.C. MacSwan	Oregon	2 (Apple)
D.L. McIntosh	British Columbia	Several
J.L. McIntyre	Connecticut	2
J. Mircetich	California	Some (From hosts other than apple)
J.E. Mitchell	Wisconsin	50 ±
W.J. Moller	California	Several: *P. cactorum* *P. megasperma* *P. drechsleri* + 3-4 *Pythium* sp.
G.W.F. Sewell	Kent, England	40 ±

Several workers have observed that newly planted trees placed in holes made by an auger frequently settle an inch or two below the original level as the soil is wetted and compacted. They believe that the saucer so created collects water and provides favorable conditions for infection by ***P. cactorum.*** Mounding newly set trees around the trunk with sand was suggested as a means of correcting this situation and of preventing wind-rocking. As sand trickled down around the trunk in spaces created by wind-rocking, anchorage would be improved.

Planting of trees on mounds was reported to be beneficial in preventing or reducing losses from *Phytophthora* infection in California and Australia.

There was much speculation on whether injury to trunk and root systems from low winter temperatures made trees more vulnerable to crown rot infection. It was postulated that tree losses may be attributed sometimes to crown rot when actually winter injury was the cause.

The only cultural practices correlated with crown rot occurrence in British Columbia were those favoring extreme vigor in young trees. Serious losses to crown rot have occurred on sandy-gravelly loam slopes where drainage appeared to be satisfactory, and more problems have been encountered on light than on heavy soils (***McIntosh***).

It was obvious from the discussion that there is a great deal yet to be learned about the epidemiology of this disease.

Control

Unfortunately there seems to be no single simple satisfactory measure by which the disease can be prevented or cured. Several participants have explored the effects of applying chemicals to soil and to affected trees, but in none of the trials were the results dramatic enough for the treatments to be recommended. McIntosh mentioned the need for a suitable means of evaluating the results of applying chemicals either to the soil or to the tree trunks. Some trees may be infected at the time of treatment, but not display any signs of the infection above ground. Allowance must be made for this situation, either by examing trees before treatment, or by repeating the treatment annually for several years.

Planting trees on mounds above the grade of the orchard has been found beneficial but growers seem reluctant to change their planting methods unless they have learned from experience that it is worthwhile.

Manipulation of the pathogen in ecological studies

Most of the information discussed under this heading has already been published in articles by Sewell, Sneh, and Meyer in 1973-74.

Borecki described some endogenous factors in bark tissue which affect the growth of *P. cactorum* in vitro. Biologically active compounds are extractable from phloem-cambium tissues with 0.01 M NaOH plus 2% Na_2SO_3. Extracts from the resistant apple tissue either inhibit or have no effect on fungus growth, while those from susceptible tissues stimulate growth. Spectrophotometric studies of the extract obtained from inner bark tissue of apple trees indicate the presence of three biologically active fractions. Phloridzin content was thought initially to influence resistance of apple trees to collar rot but the amount in a resistant variety is not sufficient to inhibit in vitro growth of *P. cactorum.*

The S fraction has a stimulatory effect on the in vitro growth of *P. cactorum.* It has been identified by Missouri workers as a 4-5 sRNA. Concentrations between 0.4 and 2.0 ng sRNA/ml result in a maximum stimulation of *P. cactorum.* This effect is specific for apple sRNA.

Petersen suggested there may be mechanical as well as chemical resistance to *P. cactorum* colonization.

Cummins suggested there may be some value in examining the effect of exogenous growth regulators on resistance of apple to *P. cactorum.*

New candidate rootstocks

Probably the only satisfactory and permanent solution to the crown rot problem will be found in resistant rootstocks which are also horticulturally suitable for the regions where apples are grown. What candidates are there? Where are they being developed?

During the period 1958-1970 in Poland, M4 and M9 were crossed with the hardy apple cultivar Antonovka to develop hardy rootstocks resistant to frost damage and to *Phytophthora.* First selections among seedlings were made at the four-leaf stage by watering plants with zoospore suspensions. Whether or not the survivors are immune to crown rot is not known yet. Stock numbers P-I, P-II, P-XVI, and P-XXII have resistance comparable to or greater than that of M9. P-II and P-XXII are more tolerant of low winter temperatures than M9 (*Borecki*).

Carlson described a series of MAC rootstocks that have been selected in Michigan. They were derived from open-pollinated seed gathered in a block that contained M I to M16, Robusta 5, and Alnarp 2. The rootstocks display different degrees of dwarfing, precocity, and ease in rooting. Currently they are being evaluated by Cummins at Geneva, N.Y., for resistance to woolly aphids, fire blight, and *P. cactorum.*

Cummins and colleagues at Geneva, N.Y., are also seeking rootstocks to replace specific targets, e.g. M9, M26, MM106. Breeders at East Malting and at Skierniewice have similar objectives. They are quite concerned about *Phytophthora* resistance and are exposing seedlings to zoospore inoculum at an early age. This is effective in eliminating large numbers of candidate seedlings but there is some uncertainty about whether resistance displayed at this age will be present in the trees later in the orchard. Progenies of Dolgo crab have a high percentage of survival in this zoospore test. Similar results occur with progenies of a cultivar from Japan designated 613 in N.Y. Very few progeny of M7 x MM106 survive. Parents which are very hardy seem to have progeny with high resistance to *P. cactorum.*

In response to a question of what could be used to replace MM104 and MM106 lost to crown rot, M9 was suggested as a stock with resistance to *Phytophthora* and adaptability to wet soil situations. For greater vigor than M9, M2 or M4 may be suitable.

Is there any potential for an interstem tree using rootstocks that are resistant to *Phytophthora?* With a multipiece tree the chances of troubles developing are increased because of possible sensitivity to viruses in one of the components.

Does it help to inarch rootstocks that have been severely damaged by crown rot? The consensus seemed to be that trees would not recover their vigor for several years at least, and it would be better to replace trees less than say, 10 years old.

Aspects on which research is warranted

It was obvious from the discussions that we are lacking much knowledge of the disease and the factors which influence its development. Participants offered the following suggestions for future research:

1. Ecology of the pathogen in its environment and its variability. A method is needed by which quantitative data on soil inoculum levels can be obtained.
2. How infection occurs and the histopathology of lesion development.
3. Effect on infection of soil water content, different methods of irrigation, and other cultural practices.
4. Elucidation of the mechanism of resistance, whether it be chemical or physical, so that breeders may be able to make use of the information in their breeding programs for resistance. A prerequisite of course is a reliable method of evaluating resistance.
5. Some means of protecting susceptible rootstocks that have been planted, either biological, eg. by soil amendments, or by recognizing and exploiting natural antagonisms to the pathogen.
6. Elucidation of factors that predispose trees to infection, and the effects of such factors on rootstock susceptibility.