Association of Wood Decay Fungi with Decline and Mortality of Apple Trees in Minnesota

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ABSTRACT

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A 10-yr study of decline and mortality of apple trees in two orchards in Minnesota indicated that wood decay fungi were causal agents. A survey of 140 6-yr-old trees in 1972 showed 93% healthy, 6% declining (symptoms: papery or rough bark, cankers, dieback, and internal decay), and 1% dead and extensively decayed. Percentages for the same sample group in 1976 and 1982 were 54, 23, and 23 and 2, 19, and 79, respectively. *Irpex tulipiferae* was most common on cankered trees in both orchards. Field inoculations of healthy 3-yr-old *Malus pumila* 'Connell Red' confirmed that *I. tulipiferae, Coriolus versicolor*, and *Schizophyllum commune* could cause symptoms associated with decline and mortality of apple trees growing on less than optimal sites in Minnesota.

Decline of apple trees (*Malus* sp.), reported from many parts of the world, has been attributed to such causes as adverse climate, unfavorable soil, and wood decay fungi associated with sunscald injuries, frost cracks, split branch axils, pruning wounds, and other wounds as summarized by Eide and Christensen (5). They believed that wood decay fungi, in association with other factors, were the primary cause of early senescence and mortality of apple trees in Minnesota during the 1930s. Mineral nutrition has been discussed as a predisposing factor for decay in young apple trees (2,7).

Reports from Australia (2,7) suggest that *Coriolus versicolor* (L. ex Fr.) Quél., a common saprophyte, is also capable of acting as an aggressive parasite that kills sapwood and cambial tissues of apple trees. This fungus is believed to enter the host through wounds. Symptoms caused by *C. versicolor* include white rot of wood, blistering and peeling of bark (papery bark), and dieback. These symptoms were produced by artificial inoculation of healthy apple trees with *C. versicolor* in the greenhouse (7) and field (2), but not all trees were susceptible.

Recently, several reports from Washington State have associated *C. versicolor* and 16 other wood decay fungi with dieback of apple trees (1,3,4). Symptoms are similar to those reported from Australia. Dieback and decay in Washington have usually occurred in maturing trees, but young trees were also occasionally affected. The greatest incidence of decay occurred in the 20- to 24-yr age class (3).

In 1973, Setliff and Wade (6) reported a severe, rapid decline and mortality of many cultivars of young apple trees in one orchard in central Wisconsin. They believed the site was unsuitable for an orchard but did not state why this was so. *Stereum purpureum* (Pers.) Fr. was the only wood decay fungus reported to be associated with this decline. Affected trees showed dieback, cankers, and decay of the main stem, especially around pruning scars. Setliff and Wade (6) did not report seeing papery bark or the silvery leaf symptom normally associated with diseases caused by this fungus.

During the past 20 yr, attempts have been made to increase apple production in Minnesota. Several orchards have been established on sites with infertile sandy soils, which tend to be droughty. These orchards have had extensive decline, decay, and mortality problems since their establishment. The objective of this paper is to report the results of a 10-yr study on decline, decay, and mortality of relatively young apple trees growing on suboptimal sites in Minnesota.

MATERIALS AND METHODS

The incidence of decline and decay of young apple trees was studied in two orchards in Minnesota: one west of Monticello, Wright County (central Minnesota), and the other north of Stillwater, Washington County (east central Minnesota). Both orchards were on well-drained, sandy soils.

At Monticello, 312 apple trees representing two age classes (6 and 8 yr old) and 11 cultivars were selected randomly by row, examined yearly from 1972 to 1976, and examined again in 1982. The general condition of each tree was recorded as either healthy or dead or in a stage of decline characterized by the following symptoms: papery/rough (dead) bark, dieback, cankers, and internal decay. Three categories of decline were recorded but are not differentiated in this paper. Sporocarps of wood-rotting fungi were the only signs of decay recorded.

A soil test at Monticello in 1972 indicated no serious nutrient deficiencies; however, the sulfur content was low. In 1972, soil specialists recommended 5–6 lb of ammonium nitrate be added to the root zone of each tree every year. Apple leaf tissue analyses indicated calcium, copper, zinc, and molybdenum to be somewhat below normal, but application of these materials was not recommended. An irrigation system was also installed to correct soil moisture deficiencies.

At Stillwater, 313 apple trees (about 9 yr old) representing nine cultivars were selected as described for Monticello and examined during October 1976. This was the only observation made because the orchard was eliminated before 1982. Soil and foliage were not tested in Stillwater, and the orchard was not equipped with irrigation.

All species of wood-rotting fungi found fruiting in both orchards were collected and cultured. Fungi that appeared to be primarily responsible for decay at Monticello in 1972 were used to inoculate healthy trees in that orchard.

On 13 July 1973, 21 3-yr-old *M. pumila* 'Connell Red,' planted in April 1973, were inoculated with six isolates (three trees each) of wood-rotting fungi from the Monticello orchard. All cultures were grown on sterile grain (1:1 barley-oat mix) in Erlenmeyer flasks for about 6 wk at 19–22 C. Trees were inoculated by drilling a 1-cm-diameter hole 0.6 cm deep in the main stem of each tree about 0.4 m above the root-graft union and filling the hole with inoculum. In addition, three trees were inoculated with sterile grain and three were not inoculated. The holes were covered with masking tape, which was removed in September 1973. The condition of all trees was evaluated each year from 1973 to 1976.

RESULTS

At Monticello in 1972, 93% of the 6-yr-old trees were healthy, 6% were declining, and 1% were dead and extensively decayed (Table 1). The corresponding percentages in 1976 and 1982 were 54, 23, and 23 and 2, 19, and 79, respectively. By 1982, cultivars Fireside and Regent had

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Table 1. Cultivars of *Malus pumila* planted in 1964 and 1966 at Monticello, MN, with symptoms and signs of decline, decay, and mortality associated with wood decay fungi (1972–1982)[a]

Cultivar	Trees (no.)	1972 Healthy (%)	1972 Declining (%)	1972 Dead (%)	1972 PR (%)	1972 D (%)	1972 C (%)	1972 ID (%)	1972 S (%)	1976 Healthy (%)	1976 Declining (%)	1976 Dead (%)	1976 PR (%)	1976 D (%)	1976 C (%)	1976 ID (%)	1976 S (%)	1982 Healthy (%)	1982 Declining (%)	1982 Dead (%)
Planted 1966																				
Haralson	20	90	10	0	85	10	20	40	0	60	30	10	85	40	15	50	70	15	30	55
Connell Red	20	80	20	0	80	20	30	75	0	30	40	30	85	65	50	85	71	0	25	75
Regent	20	100	0	0	60	0	10	45	11	60	10	30	65	30	35	60	33	0	5	95
Red Delicious	20	90	5	5	85	10	10	10	0	40	35	25	85	60	25	40	88	0	40	60
Fireside	20	100	0	0	95	0	10	55	0	65	10	25	95	25	30	55	46	0	5	95
McIntosh	20	90	10	0	45	10	15	30	0	60	10	30	45	20	35	40	25	0	10	90
Prairie Spy	20	100	0	0	85	0	0	40	0	60	30	10	85	40	45	70	50	...	...	...
Total trees	140																			
Averages		93	6	1	76	7	14	42	1	54	23	23	78	40	34	57	55	2	19	79
Planted 1964																				
Cortland	50	76	9	13	81	11	18	31	29	46	39	15	81	32	26	42	40	0	28	72
Minjon	22	46	23	32	82	36	36	64	21	41	27	32	82	32	41	59	77	0	5	95
Connell Red	20	40	55	5	90	60	20	80	19	20	50	30	85	80	20	85	59	0	25	75
Regent	20	90	10	0	95	10	60	85	0	25	70	5	100	70	90	95	58	0	45	55
Beacon	30	73	27	0	93	23	13	83	8	37	17	47	73	43	30	67	35	0	28	72
Oriole	30	50	33	17	90	40	30	87	8	17	7	76	90	63	30	83	36	0	14	86
Total trees	172																			
Averages		62	26	11	88	30	30	72	14	31	35	34	85	53	40	72	51	0	24	76

[a] Percentages based on total number of trees (per cultivar) observed. PR = papery/rough bark, D = dieback, C = cankers, ID = internal decay, and S = sporocarps.

Table 2. Wood decay fungi collected from cultivars of *Malus pumila* at Monticello and Stillwater, MN (1972–1982)

Fungus	Location and dates: Monticello	Location and dates: Stillwater
Bjerkandera adusta (= *Polyporus adustus* Willd. ex Fr.)	1972–1982	1976
Cerrena unicolor (Bull. ex Fr.) Murr. (= *Daedalea unicolor* Bull. ex Fr.)	1972–1982	1976
Coriolus versicolor (= *Polyporus versicolor* L. ex Fr.)	1972–1982	1976
Irpex tulipiferae (= *Polyporus tulipiferae* (Schw.) Overh.)	1972–1982	1976
Lenzites betulina (L. ex Fr.) Fr.	1972–1982	...
Merulius sp.	1982	...
Panellus stipticus (Fr.) Krast. (= *Panus stipticus*)	1976–1982	...
Pleurotus ostreatus Fr.	1982	...
Peniophora cinerea (Fr.) Che.	1972–1982	...
Coriolus hirsutus Wulf. ex Fr. Quél. (= *Polyporus hirsutus* Wulf. ex Fr.)	1972–1982	...
Schizophyllum commune	1972–1982	1976
Stereum complicatum (Fr.) Fr. (= *S. rameale* (Schw.) Burt)	1972–1982	...

Table 3. Symptoms of decline, decay, and mortality associated with wood decay fungi in 10 apple cultivars at Stillwater, MN (1976)

Cultivar	Trees	Condition: Healthy (%)[b]	Condition: Declining (%)	Condition: Dead (%)	Symptoms[a]: PR (%)	Symptoms[a]: C (%)	Symptoms[a]: ID (%)
Beacon	26	81	4	15	0	23	18
Golden Delicious	27	15	15	70	0	70	70
Greening	26	62	15	23	0	25	60
Haralson	49	38	8	54	27	20	24
McIntosh	26	54	6	42	12	18	18
McIntosh	27	100	0	0	0	0	0
Minjon	25	84	8	8	4	8	12
Red Delicious	54	13	43	44	0	92	92
Spartan	27	100	0	0	0	4	0
Wealthy	26	81	4	15	0	18	18
Total trees	313						
Averages		56	13	31	5	33	36

[a] PR = papery/rough bark, C = cankers, and ID = internal decay.
[b] Percentages based on total number of trees (per cultivar) observed.

the highest level of mortality (95%), followed by McIntosh (90%), Connell Red (75%), Red Delicious (60%), and Haralson (55%). Papery/rough bark was the symptom most commonly observed on diseased trees in 1972 and 1976 (Fig. 1), but broken branch unions caused by decay were commonly observed (Fig. 2). Incidences of dieback and cankers in 1976 were 40 and 34%, respectively. Sporocarps of wood decay were found most commonly on the cultivar Regent in 1972, but by 1976, 55% of all trees had sporocarps of at least one wood decay fungus.

The most common wood decay fungus found on diseased trees at Monticello was *Irpex tulipiferae* Schw., usually on cankers along the main stem or major branches. This fungus was common on both age classes (Fig. 3). *C. versicolor* and *Schizophyllum commune* Fr. were commonly observed and were frequently, but not always, found on cankers. Other species of wood decay fungi observed less frequently or not seen until 1982 are listed in Table 2. *Pleurotus ostreatus* Fr. and *Merulius* sp. were observed only on severely decayed trees in 1982.

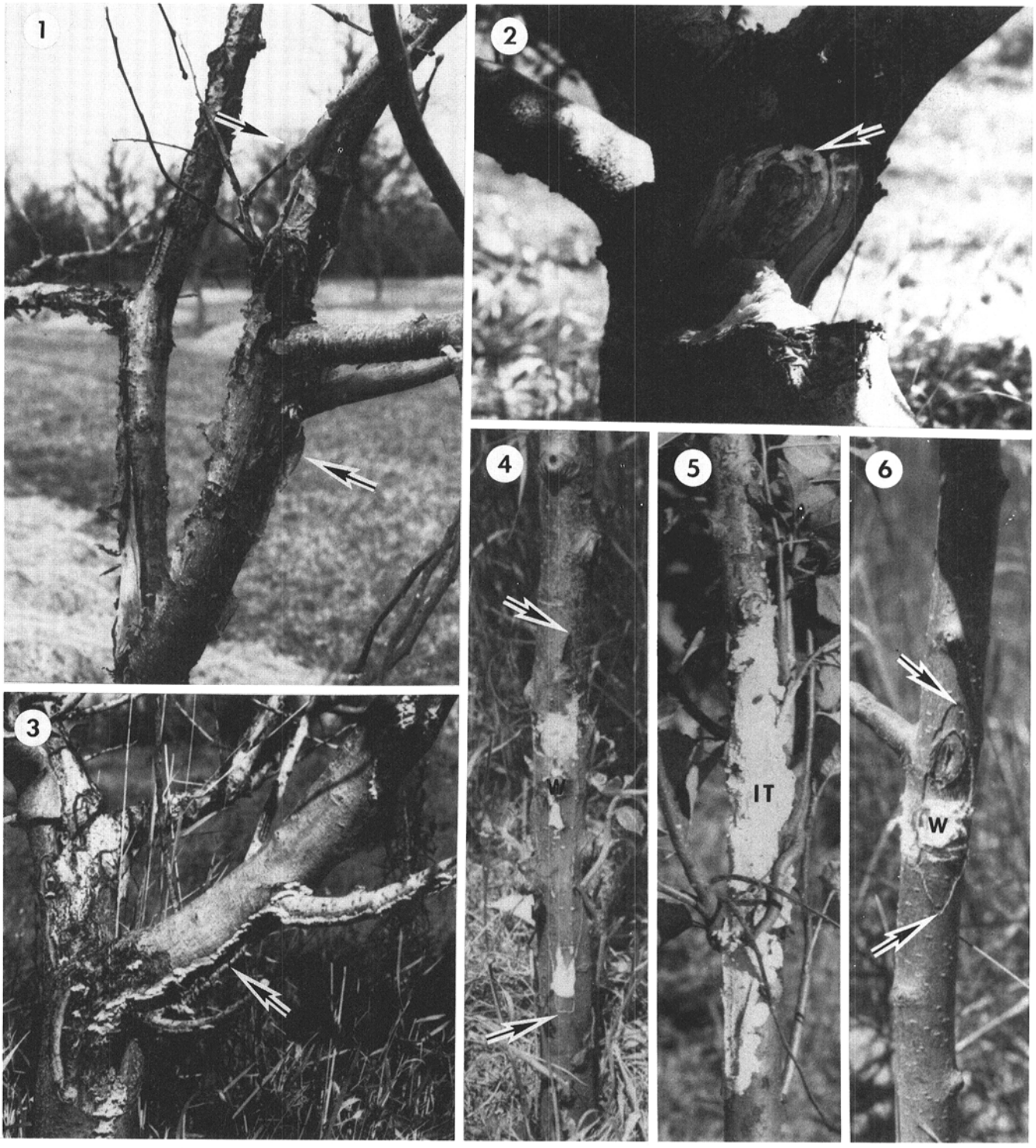
Symptoms and signs of decline, decay, and mortality were more advanced in 8-yr-old trees than in 6-yr-old trees in 1972 (Table 1). By 1982, however, little difference was evident between age classes in the overall percentage of trees that were either declining or dead. Data for 1973–1975 are not included, but they reflect the continued decline and mortality of all cultivars as shown for 1976.

In 1976 at Stillwater, the cultivar Golden Delicious had the greatest amount of mortality (70%), and all dead trees bore cankers or were decayed (Table 3). Red Delicious had 44% mortality, but 92% of trees of this cultivar bore cankers

and/or were decayed. The papery/rough bark symptom was not observed in this orchard except on Haralson (27%), McIntosh (12%), and Minjon (4%).

I. tulipiferae was the most common wood decay fungus found at Stillwater. *C. versicolor* and *S. commune* were observed less frequently than *I. tulipiferae* on cankered trees. *Bjerkandera adusta* (Willd. ex Fr.) Karst. was collected only once.

Cankers developed within about 10 wk on all trees inoculated with *I. tulipiferae* and on one tree inoculated with *C. versicolor* (Table 4, Figs. 4–6). By September 1974, cankers also were found on trees inoculated with *S. commune* and an unknown fungus (isolate 4). In addition, three more trees inoculated with *C. versicolor* had cankers in 1974, and by 1976, all trees inoculated with this fungus had cankers and extensive internal decay behind the point of inoculation. Internal decay was first



Figs. 1–6. (1) Papery/rough bark (arrows) on 8-yr-old apple tree at Monticello, MN (1972). **(2)** A 10-yr-old Connell Red apple tree at Monticello (1972) with internal decay at the branch union. Limb was easily broken, exposing internal decay (arrow). **(3)** An 8-yr-old Regent apple tree at Monticello (1972) with sporocarps of *Irpex tulipiferae* (arrow) along margin of a canker. **(4)** A 4-yr-old Connell Red apple tree at Monticello 11 mo after inoculation with *I. tulipiferae*. Canker 20.5 cm long (arrows) is centered on the inoculation wound (W). **(5)** Same tree 14 mo after inoculation. Note elongated, resupinate white sporocarp of *I. tulipiferae* (It) and sprouts near canker. Top of the tree is dead. **(6)** A 4-yr-old Connell Red apple tree 11 mo after inoculation with *Coriolus versicolor*. Elliptical canker (7.5 cm long) surrounds point of inoculation (W). Sporocarps of *C. versicolor* and papery bark developed on this tree 26 and 38 mo, respectively, after inoculation.

Table 4. Number of Connell Red apple trees with symptoms[a] after inoculation (13 July 1973) with six isolates of wood-rotting fungi at Monticello, MN

Treatment	Trees (no.)	28 Sept. 1973				26 Sept. 1974				25 Sept. 1975				22 Oct. 1976			
		PR	C	ID	M	PR	C	ID	M	PR	C	ID	M	PR	C	ID	M
Coriolus versicolor (isolate 6)	3	0	1	0	0	0	2	2	1	0	2	2	1	1	3	3	1
(isolate 7)	3	0	0	0	0	0	2	2	1	0	2	2	2	1	3	3	2
Irpex tulipiferae	3	0	3	0	0	0	3	3	1	0	3	3	1	2	3	3	1
Lenzites betulina	3	0	0	0	1[b]	1	0	0	1[b]	1	0	0	1[b]	1	0	0	1[b]
Schizophyllum commune	3	0	0	0	1	0	1	3	2	0	1	3	2	0	1	3	2
Unknown fungus (isolate 4)	6	0	0	0	1	0	2	4	2	0	2	5	3	1	3	5	3
Sterile grain	3	0	0	0	0	0	0	0	1	0	0	0	1[b]	0	0	0	1[b]
No treatment[c]	3	0	0	0	0	0	0	0	0[b]	1	0	0	0	2	0	0	0

[a] PR = papery/rough bark, C = cankers, ID = internal decay, and M = mortality.
[b] Mortality not related to inoculation.
[c] Not wounded or inoculated.

observed in 1974. By 1976, all trees inoculated with *C. versicolor, I. tulipiferae, S. commune*, and isolate 4 had extensive decay of the xylem and many trees were dead. A single, elongated canker formed at the point of inoculation, and mycelium of the inoculated fungus was evident in the region of the cambium. Isolations made directly from this mycelium and from the transition zone between decayed and nondecayed wood resulted in recovery of the fungus originally inoculated. Only *C. versicolor, I. tulipiferae*, and *S. commune* produced identifiable sporocarps, but isolate 4 only produced an unidentifiable nonsporulating mass of mycelium on the canker. All but two trees that were inoculated with sterile grain or left uninoculated remained free of symptoms or signs previously shown to be associated with this apple tree decline and mortality problem. The two exceptions were uninoculated trees, each of which developed only a slight papery/rough bark symptom on one branch by 1976. None of the trees that had been left uninoculated, or those inoculated with sterile grain or *L. betulina*, had died by 1976. Cross sections of these trees revealed no macroscopic evidence of decay, so isolations were not done.

DISCUSSION

Reports of apple tree decline and decay from Australia (7), Washington (3), Wisconsin (6), and Minnesota (5) in addition to this report indicate that wood decay fungi can limit growth and development of apple trees in some areas. It is not clear what predisposing factors may be involved, but drought, poor soil nutrition, severe weather, and wounding have been implicated.

These studies indicate that certain wood decay fungi are aggressive parasites of apple trees. Our inoculations and those of others have shown that *C. versicolor* is pathogenic. In this study, we have shown that *I. tulipiferae, S. commune*, and one unknown fungus (isolate 4) are also capable of causing symptoms of decline, decay, and mortality of living apple trees. *I. tulipiferae* appeared to be the most aggressive, causing cankers on all inoculated trees within 2 mo and extensive decay within 1 yr.

All cultivars of apples grown at Monticello appeared to be susceptible to wood decay. Whether significant differences exist between cultivars was not established.

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