A Canker Disease of *Abies concolor* Caused by *Nectria fuckeliana*

MARK E. SCHULTZ, Former Graduate Research Assistant, and JOHN R. PARMETER, JR., Professor, Department of Plant Pathology, University of California, Berkeley 94720

ABSTRACT

Schultz, M. E., and Parmeter, J. R., Jr. 1990. A canker disease of *Abies concolor* caused by *Nectria fuckeliana.* Plant Dis. 74:178-180.

A canker disease of *Abies concolor* caused by *Nectria fuckeliana* killed suppressed trees and cankered more vigorous trees, mainly in overstocked stands. Inoculations consistently showed that *N. fuckeliana* isolated from cankers caused the disease. Commonly isolated nonsporulating fungi and the fungus *Ascocalyx tenuisporus* (fruiting on the margins of cankers) occasionally caused small cankers in inoculation tests. Perithecia of *N. fuckeliana* were produced on bark associated with inoculations. On vigorous trees, most of the cankering occurred within 1–2 yr after inoculation; calluses then grew over the wounds. On suppressed trees, cankering either killed trees within a year or resulted in slowly expanding lesions. *N. fuckeliana* was found in overstocked stands of predominantly white fir in northern California and southern Oregon.

White fir (*Abies concolor* (Gord. & Glend.) Lindl.) is an important timber species. Nearly 70% (275 MM m^3) of the white fir volume in North America is in California (6). Plywood and dimensional lumber marketed as white fir are produced from five *Abies* spp., including *A. concolor.*

Nectria fuckeliana C. Booth (3,4) was first reported in North America in 1937 on Anticosti Island, Quebec, Canada, infecting balsam fir (*A. balsamea* (L.) Mill.) and white fir (7). A similar fungus was found infecting balsam fir killed by spruce budworm in eastern Canada (2), but only the *Cephalosporium* state was identified. In 1978, cankers were observed in California on white fir trees that had broken following stand thinning. Stem breakage was associated with perennial cankers. Because of losses that might accompany thinning, studies on cause, development, and distribution of these cankers in California and southern Oregon were undertaken.

Accepted for publication 2 October 1989.

© 1990 The American Phytopathological Society

MATERIALS AND METHODS

Isolations. Fungi were isolated by cutting away the phellem and aseptically removing small (approximately 5 cm × 2 mm) slivers of phloem or xylem at various sites across affected areas of stems or branches. Slivers were plated on water agar and incubated at room temperature for 7 days. Hyphal tips from margins of resulting colonies were transferred to potato-dextrose agar (PDA) for identification and study. Isolations were made from 76 cankers (45 trees), 112 branch wounds (7 trees), and 16 dead branch tips (16 trees). Cankers generally yielded other fungi in addition to *N. fuckeliana;* nonsporulating fungi A and C were commonly isolated. Perithecia of *Ascocalyx tenuisporus* Groves were found on the margins of many stem cankers.

Pathogenicity. Bark disks were cut from a healthy white fir using a No. 1 (4-mm diameter) or No. 3 (7-mm diameter) cork borer and then sterilized by autoclaving. Small pieces of PDA containing mycelium of each fungal isolate were placed on the disks. Colonized bark disks were then used as inoculum. Bark inocula were kept in 5-ml vials containing moist filter paper or 1 ml of malt agar for at least 10 days before inoculation tests. Branch inoculations were made using disks taken with the No. 1 borer; stem inoculations were made using disks taken with the No. 3 borer. Treatment and control inoculations were made by placing an inoculated or uninoculated disk into an inoculum hole of equal size. All inoculations were covered with masking tape and examined after 4–12 mo.

Fourteen trees located in the Stanislaus National Forest near Strawberry, California, were given three stem inoculations each in November 1979. Each tree had a diameter at breast height (dbh) of 7.7–10.7 cm. (Breast height in this study was 1.4 m above the ground.) Eight trees were given one control inoculation and two *N. fuckeliana* inoculations; five trees were given three *N. fuckeliana* inoculations; and one tree was given three control inoculations. A total of 11 control and 31 fungal inoculations were given. Reisolations were later made from 20 *N. fuckeliana* inoculations and eight control inoculations chosen at random.

In June and September 1984, 34 trees (3.1–7.4 cm dbh) located in the Lassen National Forest near Burney, California, were given stem inoculations with *N. fuckeliana, A. tenuisporus,* fungus A, fungus C, and control inocula. Twenty-four trees were inoculated in June and 10 trees were inoculated in September. Inoculations were made every 20–30 cm along the stem, starting at 15 cm and ending at 213 cm above the ground, for a total of four to nine inoculations per tree. One inoculation was made per branch at a 5-cm distance from the stem; up to 23 branch inoculations were made per tree. Reisolations were later made from the stem inoculations of two trees

chosen at random.

In 1984 and 1985, stems of 20 trees (4.5–8.0 cm dbh) located in the Eldorado National Forest near Auburn, California, were inoculated with *N. fuckeliana, A. tenuisporus,* fungus A, fungus C, and control inocula. Eight trees were inoculated in November 1984, six in October 1984, and six in March 1985. Four or six inoculations (20–30 cm apart) were made per tree; at least one of the inoculations was with *N. fuckeliana.* Reisolations were made later from two inoculated trees chosen at random.

Canker extension. Nineteen natural cankers on 19 trees in the Lassen National Forest were measured to determine the rate of axial extension (increase in size proximally plus increase distally from the point of inoculation) in the tree-stem bark. Each canker was between 1 and 10 yr old. The age of each canker was determined by dissecting it laterally through the center and counting the number of growth rings back from the current year's growth to the point of the first discontinuity in the woody tissue.

We also measured axial extension in inoculated trees. In the Stanislaus National Forest, we measured three or four inoculations each on 15 trees (a total of 39 *N. fuckeliana* inoculations and 10 control inoculations) at 1 yr, 2 yr, and 3 yr after inoculation. In the Lassen National Forest, a total of 31 white fir branch inoculations (5 cm from the stem) were measured 1 yr after inoculation. Seven of these inoculations had been made with *N. fuckeliana,* 4 with *A. tenuisporus,* 4 with fungus A, 11 with fungus C, and 5 with sterile inocula.

Survey. Fifty stands in California and southern Oregon were examined for *N. fuckeliana.* The southernmost stand was on Mt. Palomar in southern California; the northernmost was at Crater Lake in Oregon. When *N. fuckeliana* cankers were found on standing or fallen trees (as they were in 14 stands), we ran a 20-m-wide transect through the stand and counted the numbers of fallen-dead and standing-dead white fir with and without *N. fuckeliana* fruiting bodies. At the point where *N. fuckeliana* was first encountered along a transect, we established a fixed-radius plot (16 m) and a variable-radius plot (nine-factor prism) to characterize the stand and determine the total basal area. Fixed- and variable-radius plots were also established 20 m from the stand boundaries of overstocked fir stands where *N. fuckeliana* was not found but could be expected to occur because of nearby inoculum.

RESULTS

Isolations. *N. fuckeliana* was isolated from 46% (35/76) of the stem cankers (Table 1). Whenever the fungus was isolated from the phloem, it was also isolated from the xylem of the same canker. Fungus A was isolated from 25% (19/76) and fungus C from 39% (30/76) of the stem cankers. Perithecia of *A. tenuisporus* were found on the bark of canker margins on 9% (7/76) of the stem cankers.

Twenty-five percent of natural branch wounds on trees with *N. fuckeliana* stem cankers were infected with *N. fuckeliana* (28 of 112 wounds on branches of seven trees). *N. fuckeliana* was isolated from three twigs (19%).

Pathogenicity. The percentage of inoculations that resulted in cankers varied according to the inoculum. The average cankering rates were 88% for *N. fuckeliana,* 34% for *A. tenuisporus,* 13% for fungus A, 28% for fungus C, and 5% for control inocula (Table 2).

N. fuckeliana was reisolated from 80% (16/20), 86% (6/7), and 100% (7/7) of *N. fuckeliana* inoculations at the three sites. *A. tenuisporus* was reisolated from 50% (1/2) of the *A. tenuisporus* inoculations in the Lassen National Forest. Fungus C was not reisolated from fungus C inoculations (0/3) in the Eldorado National Forest. *N. fuckeliana* perithecia and conidiophores of *Cephalosporium* spp. were formed on stroma that erupted from the bark associated with 51% (42/82) of the inoculations on 16 trees.

Canker extension. The mean annual axial extension of natural cankers was 3.0 cm for cankers 1–2 yr old ($n = 7$), 1.8 cm for cankers 3 yr old ($n = 4$), and 0.9 cm for cankers 4–10 yr old ($n = 8$). These means were significantly different ($F = 11.2$, $P = 0.001$).

Cankers on inoculated trees in the Stanislaus National Forest had the greatest axial extension (20.0 cm) in the first year after inoculation. The extension was significantly less in the second (7.0 cm) and third (1.5 cm) years ($F = 89.5$, $P < 0.001$).

The average extension of white fir branch inoculations in the first year after inoculation was 6.7 cm for *N. fuckeliana,*

Table 1. The number and percent (in parentheses) of small and large stem cankers, branch wounds, or dead twigs from which fungi were isolated

Fungi isolated[a]	Small stem cankers[b] ($n^c = 66$)	Large stem cankers[d] ($n = 10$)	Branch wounds[e] ($n = 112$)	Dead twigs[e] ($n = 16$)
Nectria fuckeliana	31 (47)	4 (36)	28 (25)	3 (19)
Ascocalyx tenuisporus	7 (11)	0 (0)	0 (0)	0 (0)
Fungus A	17 (26)	2 (18)	0 (0)	4 (25)
Fungus C	30 (45)	0 (0)	0 (0)	3 (19)
Other fungi	0 (0)	2 (18)	0 (0)	5 (31)

[a] Isolations were made from white fir bark (phloem and periderm) and xylem.
[b] 1–10 yr old.
[c] n = The total number of cankers, branch wounds, or twigs from which fungi were isolated. More than one fungus was isolated from many of the cankers.
[d] 9–21 yr old.
[e] 1 yr old.

Table 2. The number of inoculations and resulting cankers for the three fungi most commonly isolated from cankers on *Abies concolor,* the fungus fruiting at the canker margins (*Asocalyx tenuisporus*), and control treatments

			Nectria fuckeliana			Fungus A			Fungus C			*Ascocalyx tenuisporus*			Control		
Date	Location[a]	Type[b]	Tr[c]	In[d]	Ck[e]	Tr	In	Ck	Tr	In	Ck	Tr	In	Ck	Tr	In	Ck
November 1979	St	S-12	13	39	39	...	...	...	...	...	...	...	...	...	9	10	0
March 1984	E	S-4	6	6	2	6	6	0	6	6	0	...	...	...	...	...	...
June 1984	L	S-6	21	34	28	...	...	...	...	...	...	18	31	7	22	23	0
	L	B-6	12	28	28	...	...	...	...	...	...	9	11	7	8	19	0
September 1984	L	S-12	5	13	11	2	7	0	5	15	3	3	7	1	4	4	0
	L	B-12	5	16	16	2	4	2	5	16	7	5	12	8	8	12	0
	E	S-10	4	5	0	3	6	1	4	8	0	3	6	0	8	8	2
October 1984	E	S-4	6	35	32	...	...	...	5	5	4	...	...	...	6	6	1

[a] St = Stanislaus National Forest, L = Lassen National Forest, E = Eldorado National Forest.
[b] Inoculation type: B = branch, S = stem. Value indicates number of months elapsed between inoculation and inspection.
[c] Number of trees inoculated. Because each tree received more than one type of inoculation, individual trees are reported more than once.
[d] Number of inoculations.
[e] Number of cankers.

0.5 cm for *A. tenuisporus,* 1.8 cm for fungus A, 1.5 cm for fungus C, and 0.8 cm for control inoculations.

Survey. Cankers caused by *N. fuckeliana* were found in 14 of the 19 stands examined in the Lassen and Plumas National Forests. Stands with *N. fuckeliana* cankers were 74–100% white fir with 766–2,187 trees per hectare. The total basal area of trees in these stands ranged from 5 to 117 m^2/ha. *N. fuckeliana* was isolated in seven of nine stands that had stem cankers on live trees. By contrast, the stands where *N. fuckeliana* cankers were not present were 52–89% white fir with 445–605 trees per hectare. The total basal area of trees in these stands ranged from 72 to 108 m^2/ha.

Most of the cankers and tree deaths associated with *N. fuckeliana* occurred on suppressed trees (dead at the time of examination) with less than 15 cm dbh. *N. fuckeliana* fruited on the edge of cankers after tree death; perithecia were found around the canker margins on 53% (21/40) of dead trees. Only two (5.6%) of 36 live trees had perithecia. All *N. fuckeliana* infections that were over 3 yr old occurred on more vigorous, ungirdled trees.

DISCUSSION

N. fuckeliana was commonly isolated from the phloem and xylem at the margin of white fir cankers, from branch wounds, and from dead twigs. Eighty-eight percent of *N. fuckeliana* inoculations resulted in cankers. The reisolation of *N. fuckeliana* from inoculations and observation of fruiting *N. fuckeliana* at inoculation sites shows that this pathogen was the causal agent of a canker disease of white fir.

Invasion of phloem, phelloderm, and xylem by *N. fuckeliana* usually led to cankering within the first 2 yr after natural infection or inoculation of white fir stems. In many cases, calluses grew over the cankers; in others, cankers girdled trees and killed them. Large perennial cankers developed on some trees. Although it was not clear why these perennial cankers were not covered over by calluses, 88% (35/40) were infested with Lepidopteran insects (Noctuidae) that mined the callus tissues at the canker margins. This suggests that larval mining may continually breach the host callus and prevent containment of the fungus.

Surveys found white fir cankers caused by *N. fuckeliana* in the northern Sierra Nevada and southern Cascades, but not in the southern Sierra Nevada. The disease was found most often in stands with large numbers of small trees and in stands where white fir was a major component. The potential impact of *N. fuckeliana* was not assessed. In overstocked stands of small trees, natural thinning by *N. fuckeliana* might be beneficial. When managers have thinned stands to release selected crop trees, however, breakage among cankered crop trees could produce unsuitably low stocking. Such losses can be minimized by careful examination of stems during marking; trees with stem cankers should not be left as crop trees.

LITERATURE CITED

1. Aho, P. E., and Filip, G. M. 1982. Incidence of wounding and *Echinodontium tinctorium* in advanced white fir regeneration. Can. J. For. Res. 12:705-708.
2. Basham, J. T. 1959. Studies of forest pathology XX. Investigations of the pathological deterioration in killed balsam fir. Can. J. Bot. 37:291-326.
3. Booth, C. 1966. Studies of Pyrenomycetes. IV. Nectria (part 1). CMI Mycological Papers 73. 119 pp.
4. Booth, C. 1979. *Nectria fuckeliana.* Descriptions of pathogenic fungi and bacteria. Commonwealth Mycological Papers 624. 2 pp.
5. Dilworth, J. R. 1977. Log Scaling and Timber Cruising. Oregon State Book Stores, Corvallis, OR. 468 pp.
6. Franklin, J. F. 1981. The true fir resource. Pages 1-6 in: The Biology and Management of True Fir in the Pacific Northwest Symposium. C. D. Oliver and R. M. Kenady, eds.
7. Ouellette, G. B., and Bard, G. W. 1958. A perennial canker of balsam fir on Anticosti Island. Plant Dis. Rep. 50:722-724.