Infection of Austrian and Ponderosa Pines by Dothistroma pini in Eastern Nebraska

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ABSTRACT

Conidia of *Dothistroma pini* were found in stromata on needles of Austrian and ponderosa pines as early as 23 April; conidia were trapped as early as 15 May, and the dissemination period extended into October. Conidia were disseminated only during periods with rain. No evidence of long-distance dissemination was obtained; conidia were not caught in Hirst spore traps located within 152 cm (5 feet) of infected trees. Current-year needles of the two species did not become infected before 13 July. Infection of the previous seasons' needles occurred as early as 20-27 May and continued into September. First symptoms were observed as early as 7 September and as late as early November. The time between initial infection and first appearance of symptoms varied from 11 to 16 weeks. Amount of rainfall during the 4-month period (June-September) is a good indicator of amount of infection to be expected; the amount of rain in May is not a good indicator. Infection was extremely light in the two years when rainfall during the indicated 4-month period was approximately 28 cm (11 inches), but infection was heavy in 6 years when rainfall ranged from 38.1 to 58.4 cm (15 to 23 inches). Periods in which rainfall is sufficient to disseminate large numbers of conidia may not be accompanied by conditions which result in infection. Results provide a sound basis for determining when protective fungicides should be applied in eastern Nebraska.

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The fungus, *Dothistroma pini* Hulbary, has damaged pines in plantings in the midwestern United States for many years (5). Damage to Austrian and ponderosa pines has been especially severe. More recently, this needle blighting fungus has caused extensive damage to *Pinus radiata* in young plantations in the southern hemisphere (East Africa, New Zealand, Chile) (1).

Yearly differences in weather result in considerable yearly variation in amount of infection by foliar pathogens such as *D. pini*. Thus, adequate information for development of effective and economical control measures must be obtained over a number of years. Epidemiology of Dothistroma needle blight has been investigated in eastern Nebraska since 1959; intensive studies were conducted during the years 1963-1968. Some preliminary findings have been reported (3, 4). This paper summarizes and interprets all pertinent findings.

MATERIALS AND METHODS.—The investigations were conducted in Austrian and ponderosa pine (*Pinus nigra* Arnold and *P. ponderosa* Laws.) plantations established in 1935 in Pioneers Park, Lincoln, Nebr. Epidemics of Dothistroma blight have occurred in these plantings during the last 20 years.

Stroma development.—Needles were collected weekly throughout the year from both pine species and observed for development of stromata and evidence of sporulation.

Spore trapping.—Conidia were trapped on petrolatum-coated slides placed beneath shoots. An area of 84 mm^2 on slides was scanned for *D. pini* conidia. Hirst spore traps (2), with the orifice 1 m above ground level and a suction rate of 10 liters/min, were used to determine spore dispersal at various time intervals. Weather data taken in the immediate vicinity during the growing season included rainfall, temperature, and relative humidity. Weather data at other times were obtained from a Weather Bureau station 6 miles from the investigation site.

Spore germination on needles.—Plastic prints of needle surfaces were used to follow germination on needles. Needles were coated with cellulose acetate (4% in acetone). The film was stripped off and observed by means of a microscope.

Time of first infection.—The time of initial infection was determined by methods described previously (4). Shoots of Austrian and ponderosa pines were left unprotected for various periods of time. At the end of the exposure period, shoots were treated with Bordeaux mixture (8-8-100), which prevented further new infections. Treated shoots were removed from trees in the fall when symptoms of Dothistroma needle blight were well developed. Infection was evaluated by: (i) determining the percentage of infected needles in samples obtained from treated shoots, and (ii) rating shoots on the basis of numbers of lesions on infected needles.

RESULTS.—*Conidial development.*—Conidia were found in stromata as early as 23 April 1965, and in three other years they were first observed between 8 May and 13 May (Table 1). Time between first appearance of conidia in stromata and time of first trapping of spores varied from 2 to 4 weeks. The sexual stage (*Scirrhia pini* Funk & Parker) of the fungus was never detected during these investigations.

Conidial dissemination.—Although conidia were first disseminated between 15 and 27 May in 4 years (Table 1), only in 1965 were high numbers of conidia disseminated in May. Rainfall was unusually high (23

cm) in May of 1965; whereas, in the other 4 years rainfall ranged from 4.8 to 10.3 cm (normal 8.8 cm).

In 1966, more conidia were trapped in the months of June, July, and August than in September. In 1967, high numbers were trapped in June and July, with considerably fewer trapped in August and September. Conidia were not trapped in October though there was significant rainfall. In 1968, fewer conidia were trapped in June than in either July, August, or September. Also, in contrast to previous years, high numbers of conidia were trapped in September 1968, and considerable numbers of conidia were still trapped during the first 2 weeks of October.

Long-distance dissemination of conidia was apparently very limited. No conidia were collected in Hirst traps placed within 152 cm (5 feet) of infected trees, even during periods when high numbers of conidia were trapped on slides placed within the crown of these infected trees.

To determine whether conidia were being carried in wind-driven rain, cans 20.3-cm (8-inches) in diam were placed beneath and 61 and 152 cm (2 and 5 feet) from the drip line of the crown of infected trees. Numbers of conidia in cans located beneath trees were quite high, cans 61 cm from trees contained very few conidia, and cans 152 cm away seldom contained any.

Conidial dissemination was monitored daily from 7 June to 25 August 1966. These observations revealed that: (i) no conidia were trapped on rainless days; (ii) even small amounts of rain 0.23 cm (0.09 inches) resulted in large numbers of conidia being disseminated; (iii) the highest amount of rainfall which did not result in conidia being trapped was 0.13 cm (0.05 inches); (iv) the least amount of rain which resulted in conidia being trapped was a trace (less than 0.03 cm); conidial numbers in this instance were very low; and (v) large numbers of conidia were disseminated each day there was significant rainfall, even when there had been a heavy dispersal only 1 or 2 days earlier.

Time of initial infection.—Investigation during 5 years revealed that first infection occurred as early as 20-27 May and as late as 16-23 June (Table 1). First infection occurred in early to mid-June in 4 out of 5 years.

Infection occurred earlier (May) in 1965 than in other years, but not due merely to extensive early conidial dissemination. Moderate numbers of conidia were disseminated in May 1968, but infection did not occur early that year. Temperature probably contributed to this difference in time of infection: average temperature in May 1965 was 19.3 C (2.3 C above normal) and in May 1968 was 14.9 C. There were also differences in rainfall in May of these two years: 16 cm (6.28 inches) in 1965 and 5.3 cm (2.10 inches) in 1968. Rainfall can be heavy in May, however, without infection occurring: 22.6 cm (8.91 inches) fell in May of 1959, but essentially no infection resulted. Average temperature in May 1959 was 17.3 C.

Infection of first-year needles.—Needles emerged from leaf sheaths near mid-May 1967; buds started elongating in late April. First-year (current-year) needles of Austrian and ponderosa pines did not become infected before 13 July (Table 2). Lateness of infection was not due to unfavorable conditions, since over 60% of the second-year needles of these two pine species were already infected (Table 2). Infection of first-year needles remained low (7% or less) until after 3 August.

Many first-year needles became infected after late August in both 1967 and 1968. In 1967, 54% of first-year needles were infected by 24 August; at the end of the growing season, 100% were infected (Table 2). In 1968, infection of first-year needles had not occurred up to 21 August, yet at year end, 42% were infected.

Infection of second-year needles.—Results in 1966 and 1968 revealed that extensive infection can occur late in the summer. Infection of second-year needles of Austrian pine by 1 July 1966, was less than 1%; yet at the end of the season, 98% of the needles on nonsprayed shoots were infected (Table 3). In 1968, only 36% of the needles were infected by 10 July, but at the end of the season, 92% were infected (Table 2).

In 1964, on the other hand, 94% of second-year needles were infected by 7 July. Thus, extensive infection can occur during each of the months of June, July, August, and September.

First appearance of symptoms.—Symptoms were observed as early as 7 September. In 3 out of 5 years,

TABLE 1. Chronology of *Dothistroma pini* conidial development and dissemination, and subsequent infection on Austrian and ponderosa pines in Lincoln, Nebraska

Year	Conidia first found in stromata	Conidia first trapped	Time of initial infection[a]	Symptoms first observed	Maximum incubation period[b]
					weeks
1964	8 May	4 June	16-23 June	3 Oct.	14
1965	23 Apr.	23 May	20-27 May	16 Sept.	15
1966	13 May	27 May	10-17 June	7 Oct.	15
1967	11 May	25 May	8-15 June	7 Sept.	11
1968		15 May	5-12 June	7 Oct.	16

[a] Determined on second-year needles.
[b] Period between initial infection and first appearance of symptoms.

TABLE 2. *Dothistroma pini* infection of needles of Austrian and ponderosa pines sprayed with Bordeaux mixture after various exposure periods, 1967-68

Initial spraying date[a]	Austrian pine		Ponderosa pine	
	Infected needles[b]	Lesion rating[c]	Infected needles[b]	Lesion rating[c]
	%		%	
First-year needles, 1967:				
22 June	0	0	0	0
29	0	0	0	0
6 July	0	0	0	0
13	1	<1	0	0
20	4	<1	0	0
27	6	<1	2	<1
3 August	7	<1	1	<1
10	27	1.5	10	<1
17	57	2	24	1
24	54	1.6	42	1.5
Check (not sprayed)	100	3	68	1.5
Second-year needles, 1967:				
11 May	0	0	0	0
18	0	0	0	0
25	0	0	0	0
1 June	0	0	0	0
8	0	0	0	0
15	7	<1	12	<1
22	15	1.1	30	1.6
29	31	1.5	18	<1
6 July	34	1.7	13	<1
13	67	2	64	1.8
Check (not sprayed)	100	3	100	3
Second-year needles, 1968:				
9 May	0	0	0	0
15	0	0	0	0
22	0	0	0	0
29	0	0	0	0
5 June	0	0	0	0
12	1	<1	4	1
19	0	0	9	1
26	2	<1	10	1
3 July	4	<1	21	1.2
10	36	1.3	7	1.2
Check (not sprayed)	92	2.8	54	1.9

[a] Shoots were sprayed on all dates following initial application date.

[b] Basis: 50 needles on each of four shoots on each of two trees, except only one ponderosa pine tree in first-year needle sample.

[c] Basis: shoots rated by number of lesions on each infected needle: 0 = no lesions; 1 = 1-3; 2 = 4-20; 3 = more than 20.

however, symptoms were first observed in early October (Table 1). In 1963 and 1969, symptoms did not appear until after 15 October. In these 2 years, average temperatures in August were much higher than during the other years. Symptoms did not develop in 1963 until early November. Average temperatures were unusually high in both September and October 1963.

In 1967, symptoms developed earlier (7 September) than in other years. Average temperature in August of 1967 did not differ appreciably from 2 other years (1966 and 1968) in which symptoms appeared a month later. A record low temperature (8.9 C) 31 August, however, and a near record (9.4 C) on 27 August may have initiated symptom development.

Incubation period.—The time between initial infection and first appearance of symptoms varied from 11 to 16 weeks. In 4 of 5 years this period was between 14 and 16 weeks (Table 1).

Rainfall and infection.—Amount of rainfall in May is not a good indicator of amount of infection to be expected. Data from a control test in 1959 and from infection studies in 1965 are informative. Approximately 23 cm (9 inches) of rain fell in May of both 1959 and 1965; in 1959 there was practically no infection, but in 1965 infection started early and level of infection was high.

Amount of rainfall during the 4 months of June, July, August, and September is a better indicator of amount of infection to be expected. In both 1959 and 1966, just over 28 cm (11 inches) of rain fell in

TABLE 3. *Dothistroma pini* infection of first- and second-year needles of Austrian and ponderosa pines sprayed with Bordeaux mixture after various exposure periods, 1966

Initial spraying date[a]	Austrian pine		Ponderosa pine	
	Infected needles[b]	Lesion rating[c]	Infected needles[b]	Lesion rating[c]
	%		%	
First-year needles, 1966:				
13 May	0	0	0	0
20	0	0	0	0
27	0	0	0	0
3 June	0	0	0	0
10	0	0	0	0
17	0	0	0	0
24	0.2	0.1	0	0
1 July	0	0	0	0
Check (not sprayed)	0.5	0.1	0	0
Second-year needles, 1966:				
13 May	0	0	0	0
20	0	0	0	0
27	0	0	0	0
3 June	0	0	0	0
10	0	0	0	0
17	0.2	0.1	0.7	0.2
24	0.5	0.1	0.5	0.1
1 July	0.5	0.2	2.0	0.6
Check (not sprayed)	98	3	17	1.8

[a] Shoots were sprayed on all dates following initial application date.
[b] 50 needles on each of four shoots on each of two trees.
[c] Basis: shoots rated by number of lesions on each infected needle: 0 = no lesions; 1 = 1-3; 2 = 4-20; 3 = more than 20.

the 4-month period. Infection was practically nil in 1959 and very low in 1966. In contrast, infection was at epidemic levels in 6 other years when rainfall ranged from 38.9 cm (15.3 inches) to 58.9 cm (23.2 inches) during the 4-month period.

Periods in which rainfall is sufficient to disseminate large numbers of conidia may not be accompanied by conditions which result in infection. In 1966, large numbers of conidia were disseminated in June, yet no infection occurred that month. Plastic prints of needles collected in June revealed high numbers of conidia on needle surfaces, but they had not germinated. This failure to germinate is attributed to warm or hot drying weather soon after rainfall during June.

DISCUSSION.—The results of this investigation provide a sound biological basis for control of Dothistroma blight on Austrian and ponderosa pines in this area. The periods during which conidia are disseminated and during which infection can occur have been determined. Furthermore, the period during which current-year needles are resistant has been determined.

Because previous seasons' needles can become infected before current-year needles have emerged from needle sheaths, complete protection of needles of all ages would require two applications of fungicide. However, the data also show that in most years there would be low risk in leaving previous years' needles unprotected until the time when current-year needles have emerged sufficiently to be protected by fungicide. Thus, economical and satisfactory control could be achieved with one fungicide application in early June. A single fungicide application in June has provided excellent control of Dothistroma blight in pine plantings on the test site.

Current-year needles on a high percentage of ponderosa and Austrian pines in plantings in this area remain resistant the first year. On such trees, a single fungicide application could be made earlier, since there would be no need to wait until the new needles had emerged before applying fungicide.

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