EFFECT OF LIGHT INTENSITY ON INFECTION OF *PINUS RADIATA* BY *DOTHISTROMA PINI*

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ABSTRACT

Pinus radiata D. Don cuttings (taken from 5-year-old plants and set 3 years previously) and seedlings of two different ages (3-year-old and 6-month-old) were inoculated with **Dothistroma pini** Hulbary conidia and grown for 3 months in growth rooms (temperature 20°C day/12°C night) under four different light intensities (181, 133, 94, and 58 W/m^2). Light intensity did not affect either germination of **D. pini** conidia or early growth of the fungus on the needle surfaces. The pre-reproduction period of the fungus was less than 2 weeks for all treatments, except on cuttings grown under the lowest light intensity treatment where it was 6 weeks. The severity of infection of the cuttings decreased linearly with decreasing light intensity and seedlings were more severely infected than cuttings under all treatments. The degree of infection is related to the effect of light intensity on the host plant rather than on the fungus.

INTRODUCTION

Field observations have indicated that shaded foliage of radiata pine (*Pinus radiata* D. Don) is markedly less infected by *Dothistroma pini* Hulbary than foliage fully exposed to light. Similar observations have been made in Kenya and Gibson, Christensen and Dedan (1967) carried out field experiments using artificial and natural shading which showed that fewer lesions developed on shaded foliage. When Ivory (1972) inoculated shoots of radiata pine with *D. pini* and incubated them in clear and black polythene bags, he found that infection did not develop on the foliage kept in the dark. However, none of these experiments was done under controlled environmental conditions and light intensity was not the only variable affecting the results. In this paper we report the effect of four different light intensities on infection under conditions otherwise virtually identical.

METHODS AND MATERIAL

Four rooms at the Controlled Climate Laboratory of the DSIR, Palmerston North, were used for the experiment. In all rooms, air temperature was maintained at 20° ± 0.3°C during day and at 12° ± 0.3°C during night. This temperature regime was

found in previous work to be favourable to infection of radiata pine by *D. pini* (Gadgil, 1974). The vapour pressure deficit was 4 mbar which gave a relative humidity of 82% during day and 71% at night. Air flow between the plants was 0.3 - 0.5 m/s. The intensities of photosynthetically active radiation between 400 and 700 nm were arbitrarily chosen. Mean values were as follows:

Room A, 181; Room B, 133; Room C, 94; Room D, 58 W/m^2.

Light intensity was measured with an Eppley pyranometer and Schott RG8 filter system and it was adjusted to be within $\pm$ 10 W/m^2 over the area of the room. The different light levels were obtained by using shade-cloth screens. The given light conditions were maintained for 12 h and low intensity supplementary lighting (the same intensity in all rooms) was provided for a further 2 h on each side of the high intensity photoperiod, giving a total photoperiod of 16 h every 24 h. All rooms were provided with four wide-angle atomising spray nozzles. The sprays were turned on for 15 s every 10 min; this kept the foliage moist without any appreciable run-off.

Radiata pine plants of three different ages were used for the experiment: (a) rooted cuttings taken from 5-year-old trees of clones 448 and 459, and set 3 years previously (about 1 m high); (b) 3-year-old seedlings (about 50 cm high); and (c) 6-month-old seedlings (about 20 cm high). The cuttings were potted in 18-litre containers and the seedlings in 15-cm pots. Twelve cuttings (6 of each clone) and 12 seedlings of each age were placed on trolleys in each of the four rooms. The height of the trolleys was adjusted so that the tops of the cuttings and the seedlings were at about the same level. The plants were well separated to remove light competition effects.

All plants were inoculated by spraying them with a conidial suspension of *D. pini* (20 ml/cutting, 10 ml/seedling; conidial density 7×10^6 conidia/ml). Samples of needles were collected from the cuttings immediately after inoculation and 2, 4, 6, 8, 10, and 14 days after inoculation. These samples were used to calculate conidial density, conidial germination, and early development of the fungus on needle surfaces (for details of methods *see* Gadgil, 1974). No samples were taken from the seedlings.

The plants were examined twice a week and the time of appearance of the first stroma was noted for each treatment. Three months after inoculation, all needles (about 8000 on average) which had been present on the cuttings when the plants were inoculated were removed, all visibly infected and uninfected needles were counted, and the percentages of infected needles were calculated. Infected foliage on the seedlings was assessed by eye to the nearest 10 percent, according to the method routinely used for assessment of *D. pini* infection in the field (Bartram and Kershaw, 1974). This method of assessment was used as counting the needles from 96 seedlings would have taken too long to be practicable.

The data were treated by analysis of variance. An arcsin transformation was tried but this gave little distributional advantage over the use of raw percentages.

RESULTS

Counts of conidia on needles showed that there were 73 (standard deviation $\pm$ 40) conidia/mm^2. Germination percentages showed no significant differences between treatments (Table 1), and the pattern and amount of mycelial growth on the needle surfaces were also similar under the different light conditions. The amount of mycelium increased during the first 6 days and then began to decrease. Samples taken 14 days

TABLE 1—Conidial germination percentage and percentage of infected needles under different light intensities

Light intensity W/m²	Germination percentage*	Infected needles (percent) †			
		Cuttings (6)		3-year-old	6-month-old
		Clone 448	Clone 459	seedlings (12)	seedlings (12)
181	42	19	14	90	80
133	36	15	9	90	90
94	37	11	5	70	60
58	48	9	2	20	20

* Four days after inoculation, for cuttings only.

† For confidence limits, see Fig. 1. Values are means (number of plants in parentheses).

after inoculation had only a few faintly-staining hyphae. In all treatments plugs of hyphae were seen blocking stomata on samples taken 6 and 8 days after inoculation.

With seedlings the pre-reproduction period (the time from inoculation to appearance of conidia on stromata) was the same (less than 2 weeks) for all treatments. The fungus had a much longer pre-reproduction period (6 weeks) on the cuttings exposed to the lowest light intensity, 58 W/m², than on the cuttings which were given other treatments (less than 2 weeks). Response to treatment did not differ between clones.

The percentage of infected needles on cuttings decreased significantly ($P < 0.01$) with decreasing light intensity (Table 1). With cuttings the decrease was linear (Fig. 1), but with the seedlings there was no significant difference between the infection percentages of those exposed to the light intensity of 181 W/m² and those to 133 W/m². Seedlings given the 94 W/m² light intensity treatment were significantly less ($P < 0.01$) infected than the seedlings which had received the two higher light intensity treatments. Seedlings under the lowest light intensity treatment (58 W/m²) had the lowest infection percentage and this was significantly less ($P < 0.01$) than that of seedlings given the light intensity treatment of 94 W/m² (Table 1 and Fig. 1). The seedlings were significantly more severely infected ($P < 0.01$) than cuttings under all four treatments. Although the assessment of infection on the seedlings was not done as accurately as that on the cuttings, the difference in severity of infection between the two groups was much greater than could be accounted for by experimental error. There was no significant difference in infection between 3-year-old and 6-month-old seedlings for a given treatment. Neither were the infection percentages of the two clones significantly different. The variability for clone 459 at the lowest light intensity dropped markedly when the infection percentage approached zero, but leaving out the lowest light intensity comparison made no difference to the results of the analysis.

DISCUSSION

This experiment showed that infection of radiata pine cuttings and seedlings by *D. pini* was affected by light intensity and that the severity of infection of the cuttings decreased linearly with decreasing light intensity. It is possible that the conidia which

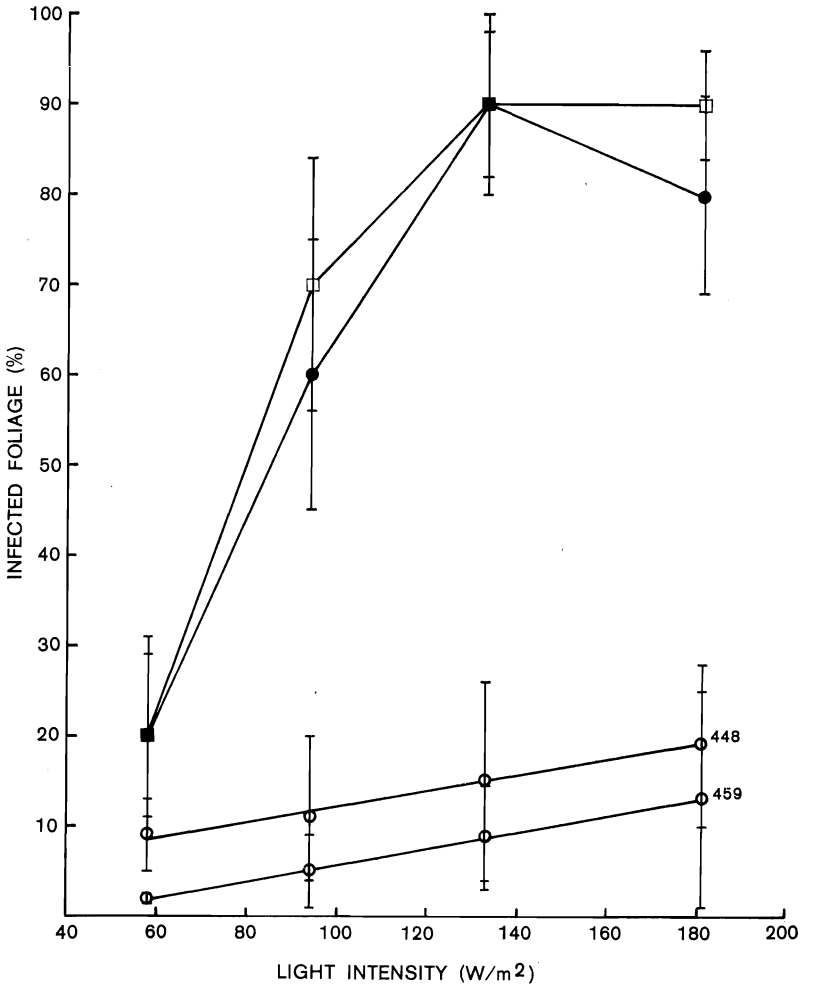

FIG. 1—Percentage of infected needles on plants given different light intensities (3 months after inoculation)
Open circles: Cuttings belonging to two clones — 448 and 459
Closed circles: 6-month-old seedlings
Open squares: 3-year-old seedlings
Vertical bars show the 95% confidence limits

were produced on the stromata on infected foliage caused reinfections and that these reinfections led to a greater disease severity than could be attributed to the original inoculum. As plants in all treatments were harvested at the same time, the treatment with the shortest pre-reproduction period would tend to be more heavily infected than treatments with longer pre-reproduction periods. However, the same pre-reproduction periods were observed for the first three light intensity treatments and the differences in disease severity noted between them cannot be attributed to differences in

secondary infections. In the lowest light intensity treatment, the pre-reproduction period was much longer (6 weeks compared with less than 2 weeks for the other treatments), and it is possible that the low level of infection found in this treatment was partly a result of a lower incidence of secondary infections.

Neither germination nor growth of the fungus on leaf surfaces was affected by the light intensities used in this experiment. Ivory (1972) also noted that on foliage kept in darkness, growth of the fungus up to the needle penetration stage occurred normally; in previous work on *D. pini* in artificial culture, Ivory (1967) had found no effect on growth or spore germination that could be attributed to reduced light intensity. This indicates that it is the response of the host, rather than the fungus, to low light intensities that results in reduced infection.

The experiment showed that, regardless of light intensity, the seedlings (which were younger than the cuttings) were much more severely infected than the cuttings. Earlier unpublished trials had indicated that under heavy inoculum pressure, cuttings taken from old resistant trees were not immune from infection but no comparison was made between the relative susceptibilities of cuttings and seedlings. The partial resistance to infection by *D. pini* shown by the cuttings in this experiment is a point in favour of using cuttings instead of seedlings as planting stock, and the cost of chemical control could be considerably reduced if new plantations were established with cuttings rather than with seedlings in areas where the needle-blight caused by *D. pini* is prevalent.

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