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Quantitative studies on dispersal of Pseudocercosporella herpotrichoides spores from infected wheat straw by simulated rain

B.D.L. FITT and D.J. NIJMAN*

Rothamsted Experimental Station, Harpenden, Hertfordshire, AL5 2JQ, UK

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Abstract

Splash dispersal of *Pseudocercosporella herpotrichoides* spores from infected wheat straw was investigated using simulated rainfall (rate 13.8 l h^{-1} m^{-2}, volume mean diameter 2.9 mm) and wind (2 m sec^{-1}) in a raintower/wind tunnel complex. Spores were deposited on the floor of the wind tunnel up to 1 m upwind and 2.5 m downwind from the centre of the straw and impacted on vertical surfaces at heights up to 36 cm above it. Fewer spores were collected with increasing distance from the straw and with increasing height. Most spore-carrying splash droplets were in the size range 400-600 μm and very few were less than 200 μm.

Our results show that these spores are generally dispersed over short distance, which is consistent with field observations.

Additional keywords: eyespot epidemiology, simulated wind, splash dispersal.

Introduction

Rainfall is probably the most important agent in the dispersal of spores of *Pseudocercosporella herpotrichoides* (Fron) Deighton, the cause of eyespot in winter cereals. In field experiments, most spores were collected on microscope slides near infected straw during rainfall (Ponchet, 1959; Fitt and Bainbridge, 1983). However, there is little quantitative information about the dispersal of spores from infected straws by rain-splash.

The classic experiments of Gregory et al. (1959) investigated splash dispersal of *Fusarium solani* (Mart.) Sacc. spores in still air with water drops falling onto shallow spore suspensions. Collecting splash droplets on microscope slides coated with gelatin dyed with naphthol green B, they estimated that one 5 mm drop falling onto a spore suspension (depth 0.1 mm, density 1.6×10^7 spores ml^{-1}) produced over 5000 splash droplets, of which over 2000 carried spores. Using fixed photographic film instead of coated microscope slides, Fitt et al. (1982) estimated that one 5 mm drop falling onto a spore suspension of *Pyrenopeziza brassicae* Sutton & Rawlinson (depth 0.5 mm, 1.2×10^5 spores ml^{-1}) produced over 7000 splash droplets, of which over 1500 carried spores, and dispersed over 90 000 spores. This paper describes a quantitative investigation of dispersal of *P. herpotrichoides* spores from infected wheat straw by simulated rain and wind.

* Student at the Agricultural University, Wageningen, the Netherlands.

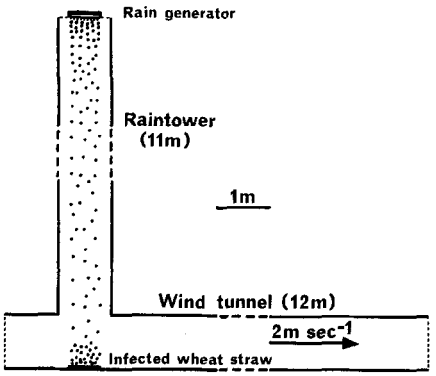

Fig. 1. Rothamsted raintower and wind tunnel.

Fig. 1. Rothamsted regentoren en windtunnel.

Materials and methods

Experiments were done in a raintower/wind tunnel complex at Rothamsted (Fig. 1). The raintower (height 11 m, cross-section 1 m^2) linked into the wind tunnel (length 12 m, cross-section 1 m^2, windspeed 2 m sec^{-1}) 1 m from the upwind end. Simulated rain (rate 13.8 l h^{-1} m^{-2}, volume mean diameter 2.9 mm) was produced by a rain generator, which consisted of a bank of hypodermic needles, area 52 × 67 cm, fed by a water reservoir (Byass, 1969).

The rain fell for periods of 15 min onto naturally infected wheat straw, spread over an area of 0.3 m^2 at the bottom of the raintower. There were three experiments, the first with a target of 100 straw (c. 50 000 spores per straw), the second and third with 225 straws and c. 50 000 and c. 10 000 spores per straw respectively. To collect spores deposited on the floor of the wind tunnel, microscope slides (two replicates) were placed at several distances upwind and downwind from the infected straw. Vertical strips of fixed photographic film, height 0-36 cm, placed downwind from the straw, collected droplets which impacted onto them.

To collect airborne *P. herpotrichoides* spores, suction samplers were placed, with the orifice at heights of 15, 30, 45, 60 and 75 cm, 6 and 8 m downwind from the centre of the straw in the third experiment. These suction samplers were filter holders with 1 cm diameter holes cut from the side which faced into the wind. They held cellulose acetate filter paper discs (diameter 2.5 cm, pore diameter 3 μm, Millipore Ltd., London) and operated at c. 10 l min^{-1}, approximately isokinetically.

Results

Results of all experiments showed a similar pattern; those presented in Table 1 are from the second and those in Fig. 2 from the third. Most *P. herpotrichoides* spores were deposited (on slides on the floor of the wind tunnel) close to the infected straw and more downwind than upwind. There were over 400 spores cm^{-2} on slides 0.5 m downwind from the centre of the straw, c. 150 spores cm^{-2} 0.5 m upwind and very few beyond 1.5 m downwind or 0.5 m upwind (Fig. 2). None were detected beyond 1 m upwind or 2.5 m downwind. Most spores were impacted on vertical film close to 'ground level' and close to the straws, numbers decreasing with increasing height (up to 36 cm)

Fig. 2. Numbers of *P. herpotrichoides* spores collected on horizontal slides at distances upwind (a) and downwind (b) from infected wheat straw on which simulated rain fell. Average of two replicates.

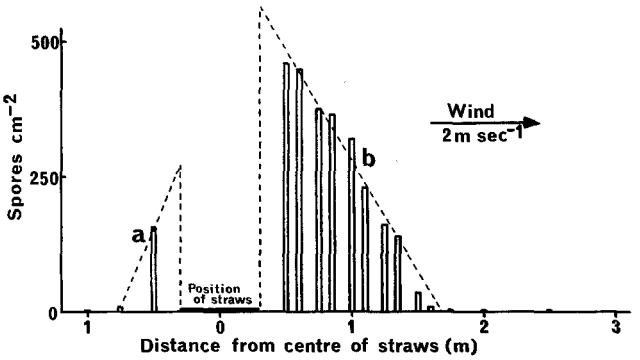

Fig. 2. Aantallen P. herpotrichoides sporen die tegen de wind in (a) of met de wind mee (b) op verschillende afstanden vanaf het infectieuze tarwestro, waarop de nagebootste regen viel, op horizontale vlakken werden opgevangen. Gemiddelden van twee herhalingen.

Table 1. Distribution of *P. herpotrichoides* spores and splash droplets with height and distance downwind from infected wheat straw on which simulated rain fell.

Distance (m)	Number of spores cm^{-2}: height (cm)						Number of droplets cm^{-2}: height (cm)					
	0-6	6-12	12-18	18-24	24-30	30-36	0-6	6-12	12-18	18-24	24-30	30-36
0.75	107	126	64	62	29	19	*	*	56	45	33	14
1.0	73	80	35	25	7	–	59	68	49	26	21	–
2.0	0	0	0	0	0	0	30	28	33	10	3	4
3.0	0	0	0	0	0	0	3	3	0	3	1	1

* Droplets number uncountable at distance 0.75 m, height 0-12 cm; – Missing data.

Tabel 1. Verdeling van de sporen van P. herpotrichoides en de spetterdruppeltjes met toenemende hoogte en afstand van het infectieuze tarwestro waarop nagebootste regen viel.

and increasing distance (up to 1 m) from the straw, e.g. there were 107 spores cm^{-2} on film at height 0-6 cm and 0.75 m from the centre of the straw, but only 7 spores cm^{-2} at height 24-30 cm and 1 m (Table 1).

On vertical film, the distribution of droplets with height and distance from the straw was similar to that for spores (Table 1). However, some droplets travelled further than the spores. These droplets were mostly in the size range 0-200 μm, whereas only 1 out of 184 spore-carrying droplets collected was < 200 μm (Fig. 3). There were most spore carrying droplets in the size range 400-600 μm, although the proportion of droplets collected which carried spores increased with increasing droplet size.

One *P. herpotrichoides* spore was collected by the suction sampler at a height of 15 cm and 8 m downwind from the centre of the straw. No spores were collected by the other samplers.

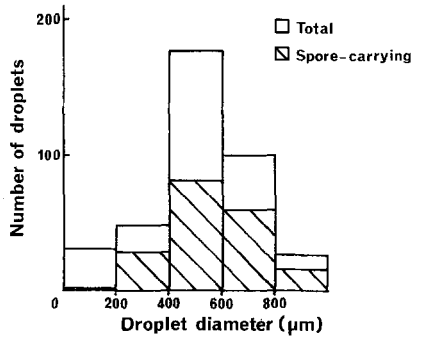

Fig. 3. Total numbers of droplets and spore-carrying droplets in different size categories impacted onto vertical film 0.7-1.0 m downwind from infected wheat straw on which simulated rain fell in two experiments.

Fig. 3. Totale aantallen spetterdruppeltjes en sporebevattende druppeltjes van verschillende groottes die met de wind mee op 0,7 en 1,0 m vanaf het infectieuze tarwestro, waarop de nagebootste regen viel, op verticaal geplaatste film werd opgevangen in twee experimenten.

Discussion

These results demonstrate the potential of rain-splash to disperse large numbers of *P. herpotrichoides* spores over short distances. Integrating along the x-axis of Fig. 2 (by calculating the areas a (upwind) and b (downwind) and ignoring the region covered by straw) an estimated 45 000 spores were deposited along a strip, 1 cm wide, parallel to the wind direction in the third experiment.

Assuming a similar distribution upwind and downwind along the whole width (c. 50 cm) of the target area an estimated 2.25×10^6 spores were dispersed in 15 min from 225 straws. With 3 mm drops, a rate of 13.8 l h^{-1} m^{-2} delivered about 85 000 drops over the target area in 15 min, indicating a dispersal of c. 26 spores per splash. This is considerably fewer than the numbers dispersed by one splash from concentrated spore suspensions of *F. solani* (Gregory et al., 1959) or *P. brassicae* (Fitt et al., 1982). However, with an average rainfall of 100 cm per annum, not unusual for some parts of Europe, each m^2 of ground would receive c. 10^8 raindrops annually, large enough to produce a splash (Gregory, 1973). Thus large numbers of *P. herpotrichoides* spores may be spread by rain-splash from infected crop debris to nearby healthy plants.

That most spores travelled less than 1 m is consistent with the evidence that the main agent in the dispersal of *P. herpotrichoides* spores is rain-splash rather than wind (Ponchet, 1959; Fitt and Bainbridge, 1983) and with the steep disease gradient of eyespot (Rowe and Powelson, 1973). Most spore-carrying splash droplets were in the size range 400-600 µm and nearly all were > 200 µm (fig. 3) as in the field (Fitt and Bainbridge, 1983), so this steep disease gradient is not surprising. Wind did, however, increase the distance which spores travelled (fig. 2), but very few became airborne. A density of 0.07 spores m^{-3} (i.e. 1 spore in 15 m^3 air sampled) is even lower than the 0.17 and 3.23 spores m^{-3} detected in the field (Fitt and Bainbridge, 1983).

Samenvatting

Kwantitatief onderzoek naar de verspreiding van sporen van Pseudocercosporella herpotrichoides van besmet tarwestro met behulp van nagebootste regen

Spetterverspreiding van *Pseudocercosporella herpotrichoides* van besmet tarwestro werd onderzocht met behulp van nagebootste regen (13,8 l uur^{-1} m^{-2}, gemiddelde druppel diameter 2,9 mm) en wind (snelheid 2 m sec^{-1}) in een proefopstelling van een

regentoren en een windtunnel. Sporen werden op de vloer van de windtunnel gedeponeerd tot 1 m afstand tegen de wind in, gerekend vanaf het centrum van het tarwestro, en met de wind mee tot 2,5 m afstand daarvan. Op verticale vlakken werden sporen op een hoogte van 0 tot 36 cm boven de vloer van de windtunnel opgevangen. Naarmate de afstand en de hoogte toenamen werden er minder sporen gevonden. De meeste spetters met sporen hadden een diameter van 400-600 μm en slechts enkele waren kleiner dan 200 μm.

Onze resultaten tonen aan dat de sporen in het algemeen slechts over korte afstanden verspreid worden, hetgeen overeenkomt met veldwaarnemingen.

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