# Ballistics of Mycosphaerella ligulicola Ascospore Discharge

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ABSTRACT

The mean horizontal distance of discharge of *Mycosphaerella ligulicola* ascospores was experimentally determined to be 3.1 mm. The maximum distance recorded was 6.2 mm. Initial velocities of discharge required to project *M. ligulicola* ascospores to these distances are calculated to be 21 and 50 m/sec, respectively. The calculated terminal velocity of these particles is determined to be $1.0 \times 10^{-3}$ m/sec.

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The horizontal distance of projection of ascospores of *Mycosphaerella ligulicola* Baker, Dimock & Davis was determined after the method of Carter (1). Pieces of chrysanthemum stem tissue bearing mature perithecia were placed vertically in the center of petri dishes containing solidified water agar. Petri dishes thus treated were placed overnight in an unlighted incubator set at 20 C. The following morning the stem sections were removed and each plate placed under the low power field of a compound microscope. Ascospores discharged overnight were readily visible at a magnification of 100X. An ocular micrometer was used to measure the distances of projection to the nearest 0.01 mm.

The data from four separate tests, summarized in Table 1, indicate a mean discharge distance of 3.1 mm. The maximum distance observed was 6.2 mm. These results compare favorably with those obtained by Carter (1), Ingold (3), and Walkey & Harvey (5) for ascospores similar to *M. ligulicola* in size and shape.

The distance to which a microscopic particle may be projected (stop distance = $\lambda$) is determined by the initial velocity $V_o$ of the particle and the atmospheric drag created by the motion of the particle through the air. The atmospheric drag of spherical particles $30\mu$ and less in diameter may be calculated from

$$\text{DRAG} = 6\,\pi\eta\,r\,v \qquad \text{(eq.1)}$$

derived from Stokes' law where $\eta$ = viscosity of air, r = particle radius, and v = particle velocity.

The terminal velocity of a particle is the rate at which it will settle in still air and may be of importance in studying particle deposition under certain conditions. Stokes' law may be used to calculate the terminal velocity, $V_t$, of a particle by determining the velocity at which the pull of gravity on the particle is negated by its air resistance (DRAG). Thus, when the negative or upward force of DRAG equals the positive downward force of mass X g, the particle is in equilibrium with its environment and falls at a steady velocity, $V_t$. A particle's mass may be determined by multiplying its spherical volume times its density, $\rho$(density assumed to equal one in these calculations). In other words, when $v = V_t$, DRAG = mass X g = $4/3\pi r^3 \rho g$. Equating this value for DRAG to equation 1 and solving for $V_t$, we get Stokes' law (6)

$$V_t = \frac{2r^2 g\rho}{9\eta} \qquad \text{(eq. 2).}$$

TABLE 1. Distance of horizontal travel of ascospores discharged by *Mycosphaerella ligulicola* perithecia

| | Distance[a] (mn) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 |
| Total no.[b] Ascospores | 43 | 80 | 96 | 76 | 50 | 8 | 3 |

[a]Mean distance = 3.1 mm, maximum = 6.2 mm.
[b]Total of four tests.

However, in the case of a nonspherical particle such as an *M. ligulicola* ascospore, the equivalent spherical radius must be determined before $\lambda$ or $V_t$ may be calculated. This is done by finding the particle volume and determining the radius of a sphere of equal volume, i.e.,

$$r = \sqrt[3]{\frac{3\ \text{vol}}{4\pi}} \qquad \text{(eq. 3)}.$$

The equivalent spherical radius thus obtained for an *M. ligulicola* ascospore of $14 \times 5\mu$ average dimension is $3.53\mu$ as determined by considering its shape to be a prolate spheroid whose volume is calculated from $4/3\ \pi\ ab^2$ where 'a' and 'b' are the major and minor semi-axes.

In addition, a dynamic shape factor, $\alpha$, which is dependent on particle shape must be included so that equation 2 becomes

$$V_t = \frac{2r^2\ g\rho}{9\alpha\eta} \qquad \text{(eq. 4)}.$$

For an *M. ligulicola* ascospore, $\alpha$ is estimated to be 1.2 from the table published by Chamberlain (2).

From equation 4, the $V_t$ of an *M. ligulicola* ascospore is calculated to be 0.10 cm/sec (0.006 mi/hr) where $g = 980$ cm/sec$^2$ and $\eta = 1.83 \times 10^{-4}$ dyne-sec/cm$^2$. Because of this low terminal velocity, the laminar settling of such spores can be disrupted by wind fluctuations of extremely small magnitude, thus demonstrating the fallacy of using terminal velocity calculations for determining distances of travel of airborne spores.

The parameter $V_t/g$ has the dimensions of time and is the time required for a particle to come into velocity equilibrium with the air into which it has been injected (2). In the case of an ascospore discharged horizontally into still air, $V_t/g$ is the time required for the initial velocity $V_o$ to be reduced to zero by atmospheric drag.

Having a measure of distance of discharge (Table 1) and relaxation time, $V_t/g$, the initial velocity of discharge $V_o$ of *M. ligulicola* ascospores may be solved from

$$V_o = \frac{\lambda\ g}{V_t}\ \theta \qquad \text{(eq. 5)}$$

as adapted from a formula used by May (4) for calculating inertial impaction of particles on surfaces in airstreams. The parameter $\theta$ represents turbulent flow and increases with velocity (is proportional to *the* Reynolds number). From the graph of equation 5 (Fig. 1), $V_o$ for ascospores travelling 3.1 mm is 21 m/sec whereas, $V_o$ for ascospores discharged 6.2 mm

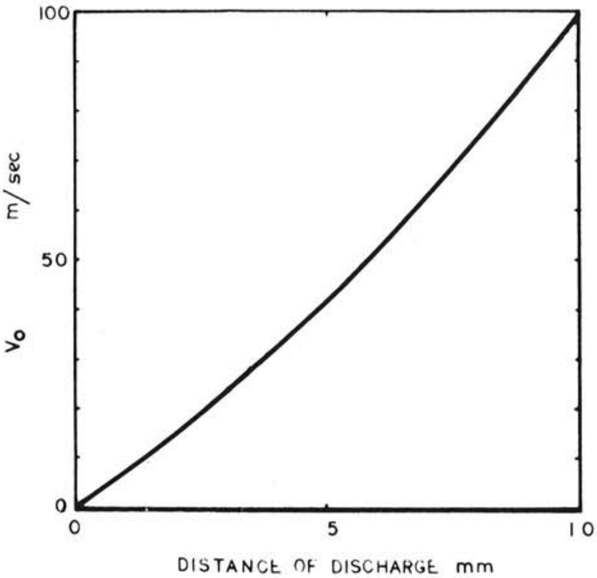


**Fig. 1.** Initial velocities of discharge, $V_o$, required for projection of *Mycosphaerella ligulicola* ascospores to distances up to 10 mm.

is 50 m/sec (over 110 mi/hr). The magnitude of explosive ascospore discharge is readily apparent from such figures. The fact that ascospores are discharged to distances of 3 to 6 mm ensures that they will pass through the laminar boundary layer of air surrounding the plant tissue. Failure to pass through the boundary layer would leave the spores unavailable for atmospheric transport to further susceptible infection sites.

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