A 7-Day Recording Volumetric Spore Trap

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ABSTRACT

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A recording volumetric spore trap that can be assembled in ~4 hr at a cost of less than $200 for parts has been designed, constructed, and tested. The trap will operate on AC or DC electrical power and is constructed of polyvinyl chloride (PVC) pipe and sheet. Spores are drawn through a slit-like orifice and are deposited on a clear tape mounted on the cylinder of a chart drive. The trap will sample 15 L of air per minute when a 12-V DC power source is used. Although similar in appearance and operation to the Burkard volumetric spore sampler, the efficiency of the PVC trap in capturing ascospores of *Venturia inaequalis* and conidia of *Monilinia fructicola* exceeded that of the Burkard trap in orchard and wind tunnel tests.

Additional key words: aerobiology, aeromycology, epidemiology.

Historically, discharge and dispersal of inoculum has played an important role in epidemiological studies, and monitoring inoculum dose plays no less an important role in current investigations. In 1981 and 1982, 18 papers published in PHYTOPATHOLOGY and PLANT DISEASE dealt directly with inoculum discharge, dispersal, and trapping. Most of these investigations (1,5,6,8,10,12–14,16–20,22,23) involved the use of recording volumetric spore traps, ie, traps that provided a quantitative record of the periodicity and frequency of airborne spores. Two of the commonly used 7-day recording volumetric spore traps are the Burkard volumetric spore sampler (Burkard Scientific Sales Limited, Rickmansworth, Hertfordshire, England) at a cost of approximately $2,000, and the Kramer-Collins 7-day drum sampler (GR Electric Manufacturing Co., Manhattan, KS, USA) at a cost of approximately $700. A third trap, the Kramer-Collins intermittent spore sampler, has been used widely (11,12,16,17), but is no longer available. The relatively high cost of these traps can restrict or prohibit their use in certain research projects. Our objective was to design, construct, and evaluate a less expensive 7-day recording volumetric spore trap.

MATERIALS AND METHODS

General design and operation. The instrument we designed and built is a 7-day recording volumetric spore trap (Fig. 1). The housing of the trap was constructed of polyvinyl chloride (PVC) pipe. Thin PVC sheets formed the wind vane and rain shield. A bearing assembly attached to the base of the housing allowed the trap to face the wind. The trapping surface was a coated plastic tape mounted on the drum of a chart drive similar to those found in hygrothermographs. Spores were drawn through a slitlike orifice and were deposited on the tape as it turned past the orifice, thus providing a continuous record of inoculum dose. The air stream then traveled through the trap housing, through the bearing assembly, continued through the base to the turbine blower, and was finally exhausted beneath the motor. Materials for the PVC trap were readily available, required little or no modification, cost less than $200, and required approximately 4 hr to assemble. The turbine blower operated on either AC or DC power. When used with a 12-V DC power source, the trap sampled 15 L/min.

Construction of the trap body, rain shield, and wind vane. The housing of the PVC trap consisted of four pieces (Table 1): two end clean-outs, a threaded cap, and a slip coupling. When pressed together (Fig. 2), they formed an air-tight, water-tight unit. A 2.22-cm (0.875-in.) hole was bored through the wall of the housing at 5.4 cm (2.125 in.) from the upper edge of the capped end (Fig. 2) to retain the orifice. The wind vane and rain shield were cut as shown (Fig. 3A and B) and attached to the housing with clear PVC cement (Hercules Chemical Co., New York, NY 10011). The wind vane was braced by two slip couplings (b in Fig. 4) that were glued to both the wind vane and the housing. The bottom plate (Fig. 3D, and l in Fig. 4) was then glued to the base of the housing.

Preparation of the chart drive, cylinder, and retaining plate. The chart drive mechanism was mounted on a retaining plate (Figs. 3D, and 8). When the cylinder was lowered into the housing, the

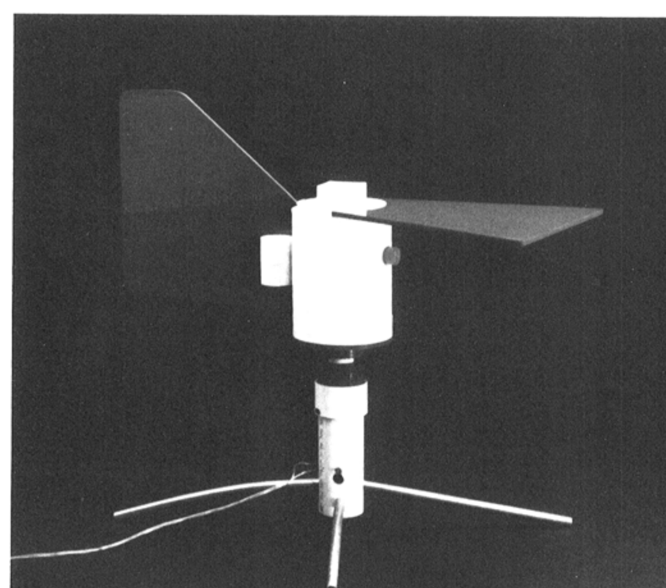

Fig. 1. Recording volumetric spore trap. The trap is constructed of polyvinyl chloride (PVC) pipe sheet and can be assembled in approximately 4 hr. When operated using a 12-V DC power source, the trap will sample 15 L/min.

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retaining plate rested on a shoulder inside the housing (Figs. 4 and 5). A flange at the base of the chart drive cylinder was removed by grinding before the retaining plate was fitted to the housing. Since perfect centration of the chart drive axis on the retaining plate was not possible, index marks (Fig. 5) were scribed on the surface of the retaining plate and the inner wall of the housing. Alignment of the index marks eliminated variations in the orifice to the trapping-surface gap due to shifting of the axis of rotation of the chart drive. The retaining plate was cut to the dimensions shown in Fig. 3D and then hand-filed to fit snugly within the housing.

Construction and installation of the orifice. The orifice was made by splitting a 2.85-cm length of 2.22-cm Plexiglas rod lengthwise. The cut edges were milled smooth and a 14 × 2 mm channel was cut into one of the halves. The rod was then cemented together with ethylene dichloride. The chart drive was then placed in the trap housing and the index marks were aligned. A 1.0-mm thickness gauge was inserted through the notch in the chart drive retaining plate (Fig. 5) and held against the cylinder. The orifice was then installed and held in place against the thickness gauge while silicone rubber cement was applied to secure the orifice and to plug any air leaks.

Construction of the bearing assembly. The bearing assembly was pressed together as shown in Fig. 6. One end of the 1.9-cm (0.75-in.)-diameter pipe was cut with a rasp to an outside diameter of approximately 2.54 cm (1.0 in.). This end was then forced into the bearing to a depth of 2 cm. The bearing was then pressed into one of the reduction bushings. The opposite end of the pipe was coated with PVC cement and pressed into the remaining reduction bushing. This reduction bushing was then cemented to the slip coupling (Fig. 6). The upper end of the bearing assembly was then cemented to the base plate of the housing (Fig. 4).

Construction of the base, installation of the motor, and final assembly. The base consisted of a single length of 5.08-cm (2-in.)-diameter PVC pipe. The aluminum legs were installed in holes drilled in the base (Fig. 4). The tubing was bent slightly to elevate the base, and two holes were drilled above the legs to ensure that exhaust air from the turbine blower was not impaired (Fig. 4). The 12-V DC turbine blower and motor were of the type found in small hair dryers (Fig. 7). The motor will operate on 120-V AC if a rectifier is included in the circuit. Instructions for wiring the motor

TABLE 1. Materials for construction of PVC spore trap

Section	Material	Supplier
Housing	Schedule 40 pipe fittings, white PVC Type I, 101.6 cm (4 in.): 2 end clean-outs, 1 threaded plug, and 1 slip coupling	F. W. Webb Company, Sumner Drive, Dover, NH 03820.
Wind vane, rain shield, base plate, and chart drive retaining plate	Polyvinyl chloride sheet, 6.35 mm thickness (0.250 in.)	McMaster-Carr Company, 2828 Paulina Street, Chicago, IL 60657.
Orifice	Polyvinyl chloride rod, 2.22 cm diam. (0.875 in.)	McMaster-Carr Company.
Chart drive and cylinder	PL-1452 chart drive with 9.29 × 9.36 cm (3.658 × 3.687 in.) cylinder, 168 hr rotation	Belfort Instrument Co. 1600 South Clinton St., Baltimore, MD 21224.
Turbine blower and motor	Blower heater assembly TM21K862	Herbach and Rademan, Inc., 401 East Erie Avenue, Philadelphia, PA 19134.
Bearing	Fafnir bearing S10KDD	Bearings, Inc., Dover Industrial Park, Dover, NH 03820.
Bearing assembly and base	Schedule 40 pipe fittings, white PVC Type I: 2, style 2 reduction bushings, 5.08 × 1.90 cm (2 × 0.75 in.); 1, 5.08 cm (2 in.) slip coupling; 30 cm of 5.08 cm (2 in.) pipe; and 10 cm of 1.90 cm (0.75 in.) pipe	F. W. Webb Company
Legs	Aluminum tubing, 1.27 cm (0.5 in.) O.D.	McMaster-Carr Company
Wind vane brace	Schedule 40 pipe fittings, white PVC Type I: 2, slip couplings, 2.54 cm (1 in.)	F. W. Webb Company

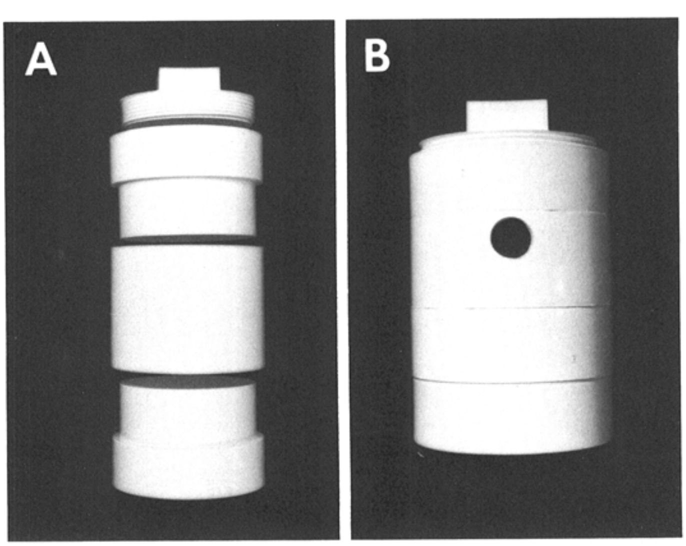

Fig. 2. Assembly of the housing components of the PVC trap. **A,** The components are, from top to bottom, a threaded cap, an end clean-out, a slip coupling, and another end clean-out. **B,** The pieces are pressed together. A hole has been bored through the housing to retain the orifice.

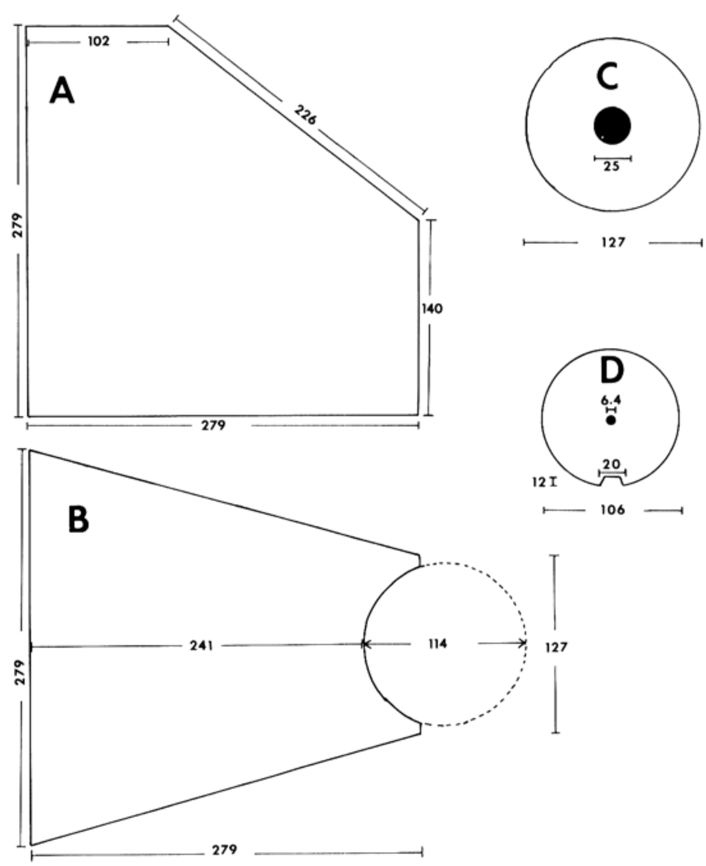

Fig. 3. PVC sheet components of the trap. (A) Wind vane. (B) Rain shield. (C) Bottom plate of housing. (D) Chart drive retaining plate. All components are cut from 5.6-mm PVC sheet. All dimensions shown are in millimeters.

were provided by the manufacturer (Table 1). Before pressing the turbine blower into the base, a strip of adhesive weather stripping made of urethane foam was wrapped around the blower housing to prevent air leaks (v in Fig. 4). The turbine blower was then pressed into the base, ~2 cm into the bore of the pipe. Two retaining screws (q in Fig. 4) were installed beneath the turbine blower and tightened until they just touched the casing of the motor (r in Fig. 4). Overtightening of the retaining screws damaged the motor. To complete the assembly of the trap, the slip coupling of the bearing assembly was pressed onto the base and secured in place with two retaining screws (q in Fig. 4).

Preparation of the cylinder and trapping surface. A 276-mm strip of clear Melinex tape (Burkard Scientific Sales, Ltd., Rickmansworth, Hertfordshire, England) was coated with silicone grease and fastened on the cylinder of the chart drive with a piece of double-sided sticky tape. The bottom edge of the tape was 4 mm above the edge of the cylinder (Fig. 8). The cylinder was turned so that when the index marks on the retaining plate and housing were aligned, the junction formed by the ends of the tape was centered behind the orifice.

Removal, dissection, and examination of the tape. A template made from a 35 × 300-mm piece of 6.35-mm-thick Plexiglas was used in dissecting the tape (Fig. 9). Lines scribed on the template at 39.5-mm intervals corresponded to trapping periods of 24 hr. The tape was cut into 39.5-mm sections and mounted in gelvatol on glass slides (Fig. 9). The tape was examined microscopically (×675) by scanning transects across the long axis of the tape at 2-mm (73-min) intervals. The number of spores observed in each transect was corrected for the proportion of the tape examined and the volume of air sampled and was recorded as spores per cubic meter. The counts were not adjusted for trap efficiency.

Wind tunnel comparison of the PVC and Burkard traps. The PVC trap was installed in a 1 × 1 × 2-m wind tunnel into which conidia of *Monilinia fructicola* were introduced. A Burkard volumetric spore sampler was also placed in the wind tunnel beside the PVC trap. Six peaches (*Prunus persica*) were inoculated with a

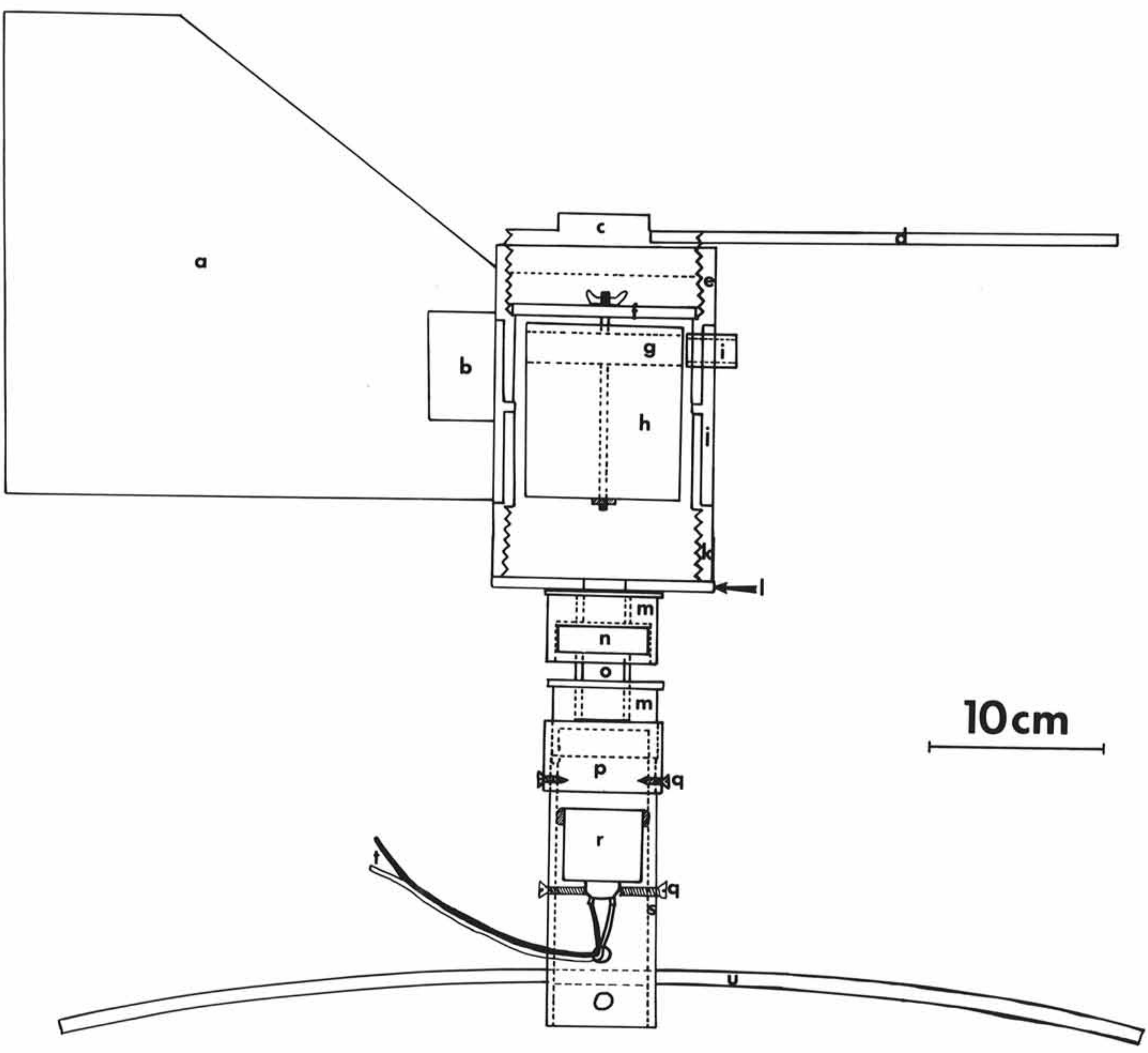

Fig. 4. Diagram of recording volumetric spore trap. (a) Wind vane. (b) Wind vane brace. (c) Threaded cap. (d) Rain shield. (e) End clean-out. (f) Chart-drive retaining plate. (g) Melinex tape. (h) Chart drive cylinder. (i) Orifice. (j) Slip coupling. (k) End clean-out. (l) Bottom plate. (m) Reduction bushings. (n) Bearing. (o) 1.9 cm PVC pipe. (p) Slip coupling. (q) Retaining screws. (r) Turbine blower and motor. (s) 5.08-cm-diameter PVC pipe. (t) Wire to power source. (u) Aluminum tubing legs. (v) Urethane foam adhesive weather stripping.

culture of *M. fructicola*, incubated in a moist chamber for 5 days, and placed behind the wind tunnel fan, upwind of the traps. Both traps were operated on 12-V DC power. The PVC traps sampled 15 L/min while the Burkard trap was adjusted to sample 10 L/min. The traps were operated continuously for 4 days. Wind speed in the tunnel was adjusted to 2.22 m/sec. The PVC and Burkard trap positions were switched daily. Tapes from both traps were examined for conidia of *M. fructicola*, as described above, at intervals that corresponded to times of 0800, 1200, and 2000 hours each day of operation.

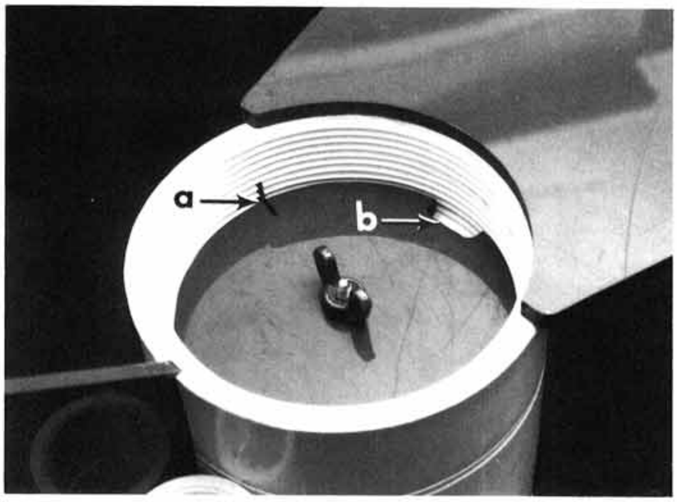

Fig. 5. Chart drive on retaining plate installed in housing. (a) Index marks for alignment of the retaining plate. (b) Notch for adjustment of orifice to trapping surface gap.

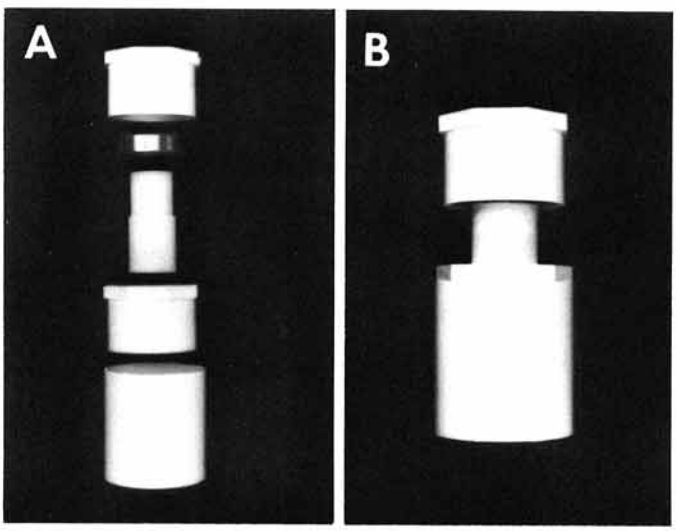

Fig. 6. Bearing assembly. **A,** Components are, from top to bottom, a reduction bushing, a bearing, a length of 5.6 cm PVC pipe filed to fit tightly in the bearing, another reduction bushing, and a slip coupling. **B,** The components are simply pressed together after an adhesive is applied to the lower reduction bushing to fasten it to the slip coupling.

Fig. 7. Bottom, side, and top view of turbine blower and motor. The motor is of the type normally found in small hair dryers. The motor will operate on either AC or DC power, depending on whether or not a rectifier is included in the circuit.

Fig. 8. Chart drive mounted on retaining plate (a). A silicon grease-coated Melinex tape (b) has been fastened around the base of the cylinder (c) to serve as the trapping surface.

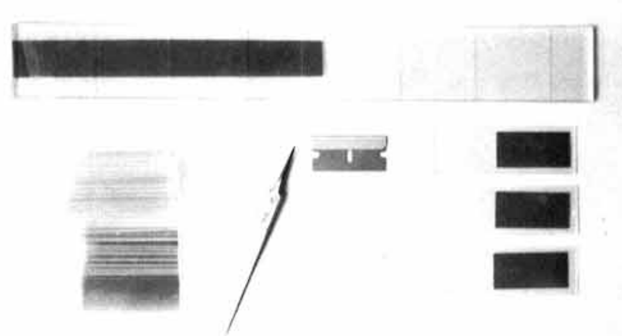

Fig. 9. Dissection of the Melinex tape. The tape is placed on a Plexiglas template and is cut into 39.5-mm pieces. Each segment corresponds to a 24-hr period. The segments are then mounted in gelvatol on glass slides and are examined microscopically.

Field comparison of PVC and Burkard traps. A PVC trap and a Burkard volumetric spore sampler were operated at the Mast Road Research Orchard in Durham, NH, during the 1981 and 1982 growing seasons. The traps were placed in a flat area of the orchard and were surrounded by a ring of wire-mesh trays containing overwintered leaves infected with *Venturia inaequalis*. The PVC and Burkard traps were powered by 12-V DC batteries and sampled 15 and 10 L of air per minute, respectively. The traps were operated continuously from 12 May to 12 June 1981, and from 29 April to 3 June 1982. Tapes from the PVC trap were examined for ascospores of *V. inaequalis* at 2-mm (73-min) intervals. Counts from the Burkard tape were made at 2-mm (60-min) intervals. The number of ascospores found on tapes from both traps was corrected for the proportion of the tape examined and the volume of air sampled. Data were recorded in units of inoculum density, or spores per cubic meter, for the times indicated. Since the consequences of a malfunction far outweighed the cost of replacement parts (~$3), the turbine blower of the PVC trap was replaced at the beginning of each growing season.

TABLE 2. Estimated frequency of airborne conidia of *Monilinia fructicola* in a wind tunnel as determined by Burkard and PVC volumetric spore traps

	Spores per cubic meter		
Time[a]	PVC	Burkard	Ratio[b]
0800 hours	1,803	1,101	1.64
1200 hours	1,454	919	1.58
2000 hours	1,528	967	1.58

[a]Tapes from both traps were examined at the indicated times on 4 days. Trap positions in the tunnel were switched daily.
[b]Ratio = (Estimated airborne spore density [PVC])/(estimated airborne spore density [Burkard]).

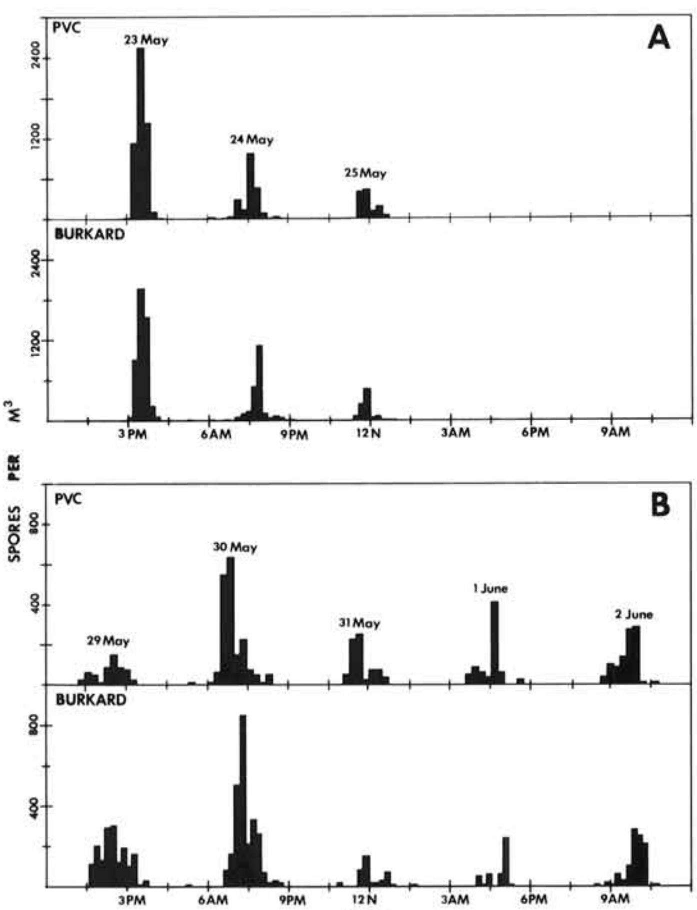

Fig. 10. Frequency of airborne ascospores of *Venturia inaequalis* at the Mast Road Research Orchard as monitored by the PVC and Burkard traps from **A**, 23 to 25 May and **B**, 29 May to 2 June, 1982. The traps were approximately 1.5 m apart in a level area of the orchard, surrounded by a ring of wire mesh trays containing overwintered, scabbed apple leaves. The PVC trap sampled 15 L/min, while the Burkard trap was adjusted to sample 10 L/min.

RESULTS AND DISCUSSION

When the trap catches of conidia of *M. fructicola* were corrected for the volume of air sampled in the wind tunnel studies, catches of the PVC trap always exceeded those of the Burkard trap (Table 2). The ratio of the PVC catch to the Burkard catch ranged from 1.58 to 1.64. The trap characteristics that have the greatest effect upon impaction efficiency are the velocity of the air stream in the orifice and the distance from the rear aperture of the orifice to the impaction surface (7). Generally, greater air stream velocities and lesser orifice-impaction surface distances result in higher efficiencies of impaction. Since the orifice dimensions and orifice-impaction surface distances of the PVC and Burkard traps were essentially the same, the greater efficiency of the PVC trap was probably due to a higher air stream velocity in the PVC trap. Increasing the flow rate of the Burkard trap from 10 to 15 L/min would increase the efficiency of impaction, but attempts to sample this volume of air damaged the DC motor of the Burkard trap.

In the orchard studies, ascospores of *V. inaequalis* were collected during 16 infection periods in 1981 and 1982. The diurnal periodicity of spore discharge seen in Fig. 10 occurred because ascospores of *V. inaequalis* are discharged primarily during daylight hours (2) and only when the leaves are wetted by rain. The PVC and the Burkard traps were each able to delineate the periods of ascospore discharge (± ~1 hr). However, when the estimated mean daily ascospore dose (ascospores per cubic meter per day) during each of the 16 infection periods monitored by the PVC trap was regressed against those of the Burkard (Fig. 11), the following equation was obtained: $Y = 5.04 + 1.24\ X$, in which Y = the estimated mean daily ascospore dose (MDD) of the PVC trap, and X = MDD of the Burkard trap. Therefore, even under orchard conditions, the PVC trap was approximately 1.24 times as efficient in capturing ascospores of *V. inaequalis* as the Burkard trap.

We have used volumetric spore traps in an apple disease management program and in evaluations of fungicides for control of apple scab (15). The estimates of ascospore dose are used in conjunction with ascospore maturity assessments (3,4) to advise

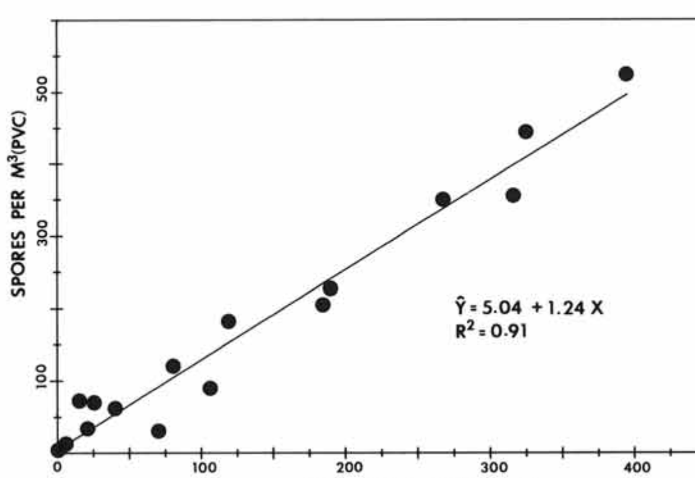

Fig. 11. Estimated mean daily ascospore dose of *Venturia inaequalis* at the Mast Road Research Orchard during 1981 and 1982 as determined by the PVC and Burkard volumetric traps. Regression of the PVC catch against that of the Burkard indicated that the efficiency of the PVC trap was approximately 1.24 times that of the Burkard trap.

growers in scheduling fungicide applications, and to schedule fungicide applications in our own research trials. Other researchers have found similar uses for volumetric spore traps (9,21,23), but a major restriction in their use is the relatively high cost of volumetric traps (21). The trap we have designed is relatively inexpensive, simple to build, efficient, and should be useful where cost is a limiting factor.

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