Comparison of the Design of Two Volumetric Spore Traps: A Reply

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Scientific contribution 1363 from the New Hampshire Agricultural Experiment Station.
Accepted for publication 13 September 1985 (submitted for electronic processing).

In 1983, we (4) described the design, construction, and operation of a 7-day recording volumetric spore trap constructed of polyvinyl chloride (PVC) and compared the PVC trap in orchard and wind tunnel studies to the Burkard volumetric spore sampler (Burkard Scientific Sales Limited, Rickmansworth, Hertfordshire, England). Our objective was to produce a less expensive alternative to commercially available volumetric traps. After two seasons of side-by-side comparison with the Burkard trap in an orchard, and 4 days of continuous operation in a small wind tunnel, we published the results (4). The PVC trap was relatively inexpensive, simple to build, efficient, and could be useful in aerobiological studies where cost is a limiting factor. Recently, G. M. Wili (15) of Burkard Manufacturing Ltd. has compared the design of the PVC to that of the Burkard trap. Wili criticized many features of the PVC trap. He concluded that the PVC trap would have little use in long-term aerobiological studies but that it might be useful for demonstrating the principles of operation of a volumetric trap at the student level. In this letter, we examine his comparisons and conclusions.

The distance from the rear aperture of the intake orifice to the impaction surface in the PVC trap was set at 1.0 mm. In our original description (4), we stated that the orifice-impaction surface distances of the PVC and Burkard traps were equal. The operating manual supplied with the Burkard trap (1) states that the orifice dimensions (14 × 2 mm) are the same as those of the Hirst automatic volumetric spore trap (6). We incorrectly assumed that the similarity extended to the orifice-impaction surface gap, which is 1.0 mm in the Hirst trap (6). However, the orifice-impaction surface gap in the Burkard trap is 0.6 mm (15). Wili stated that the increased gap in the PVC trap would greatly reduce trapping efficiency for spores with diameters of less than 20 μm. If only the orifice-impaction surface gap was varied, this statement would be true. However, the decreased capture of particles due to an increased gap can be compensated for by an increase in air stream and entrained particle velocity. The PVC trap sampled 15 L/min of air versus 10 L/min for the Burkard trap and the air stream velocities in the orifices were 890 cm/sec in the PVC trap versus 600 cm/sec in the Burkard trap. Greater particle velocities result in increased kinetic energy, and the tendency for particles to traverse the gap between the rear aperture of the intake orifice and the impaction surface may be increased.

Wili ignored the fact that in two seasons of continuous operation in an orchard, the efficiency of the PVC trap equaled or exceeded that of the Burkard trap in capturing ascospores of *Venturia inaequalis* (Cke.) Wint.; these ascospores are approximately 12 × 6 μm and should, according to Wili (15), be captured more efficiently by the Burkard trap. We obtained similar results in a wind tunnel comparison using conidia of *Monilinia fructicola* (Wint.) Honey, which range from 10 × 7 μm to 28 × 11 μm. We did not consider collection efficiency over a wide range of particle sizes and wind speeds as has been done with the Burkard trap (12), and further testing of the PVC trap is certainly warranted. However, our comparative data (4) indicated that the PVC trap performed as well as the Burkard trap within a range of particle sizes that would include the spores of many fungal pathogens.

Wili stated that there are certain disadvantages in the use of plastics in the construction of spore traps, i.e., degradation in UV light, uneven expansion of plastic and metal components, and the potential for a plastic spore trap to acquire electrostatic charges during operation. While we agree that these are potential disadvantages, we believe that the first two were exaggerated, and that the third is highly speculative. The housing of the PVC trap is constructed of Schedule 40 PVC pipe. This is a very sturdy, thick walled pipe, capable of withstanding an internal pressure of over 150 kg/cm^2. PVC is impact resistant, degrades very slowly in sunlight, and is frequently used for outdoor applications. To state categorically that all plastics are unsuitable as construction materials because some become weak or brittle with age is incorrect. The PVC trap at our research orchard has not deteriorated measurably since 1981.

Plastics and metals expand at different rates when heated. Wili stated that the 1.0 mm orifice-impaction surface gap in the PVC trap could not be maintained because the PVC housing of the trap would expand or contract more rapidly than would the aluminum drum that revolved past the orifice. The linear expansion coefficient of PVC is 190×10^{-6}/°C while the linear expansion coefficient of aluminum is 22×10^{-6}/°C (14). The range of temperatures under which we trapped ascospores of *V. inaequalis* in our orchard studies was 4–26 C. For every degree of temperature change, the radius of the PVC housing would change by 0.00857 mm, while the radius of the aluminum drum would change by 0.0009 mm. If the temperature of the PVC housing was 15 C at the time that the orifice was installed, the orifice-impaction surface gap would have varied by approximately 5% from 1.0 mm over the range of temperatures encountered in the orchard. This variation would have had a negligible effect on the performance of the PVC trap. At extreme temperatures, the variation in the orifice-impaction surface gap could be significant. Under these conditions, it could be necessary to shield the trap from direct sunlight, or preferably replace the aluminum drum with a PVC disk of the same diameter. A PVC disk of the proper dimensions and tolerances could be made at a cost of about $25.00.

PVC is a dielectric compound and it is possible to produce, by friction or other means, a surface field of several thousand volts on PVC parts. The questions are, do such surface fields develop during normal operation of the PVC trap, and are they of sufficient magnitude to alter performance of the trap significantly? Under field conditions, buildup of electrostatic charges would be maximized by low relative humidity and bright sunlight. In our orchard studies, we trapped ascospores of *V. inaequalis* only during or shortly after rain (4). Under these conditions, it is unlikely that large surface charges would develop on the PVC trap. Leach and Apple (9) found that field intensities on detached leaves reached 1,600 v/cm under hot, dry, and sunny conditions, but at night, when relative humidity was high, during cloudy weather, or during rain, field intensities were small or unmeasurable. Neither we (4) nor Wili (15) have measured surface charges on the PVC trap, thus it seem premature to conclude that electrostatic charges "would obviously alter the deposition of charged particles on the impaction surface" (15). Furthermore, the impaction surface in the PVC trap is not polyvinyl chloride, but the same Melinex tape used in the Burkard trap (1,4). If an electrostatic charge decreased efficiency of

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the PVC trap, it was not obvious in our data (4). Spores are in the airstream of the PVC trap for only 0.003 seconds and travel at a velocity of 890 cm/sec before they strike the impaction surface. McCartney, et al (10) reported that even surface charges of 6,000 volts had little effect upon sedimentation and impaction of conidia of *Erysiphe graminis* DC. Leach (8) reported that positively charged sporangia of *Peronospora destructor* Berk. were repelled from sporangiophores at a velocity of only 13.4–24 mm/sec when the onion leaves bearing the sporangiophores bore a positive charge of 800 volts. Weak surface charges have been reported for some fungal spores (2,3,5,7,13), but in the absence of actual measurements of surface charges on the PVC trap orifice and impaction surface, it is impossible to calculate the effect of any charge, either repellent or attractive, on performance of the PVC trap. However, considering the short residence time and relatively high velocity of spores in the orifice of the PVC trap, it seems unlikely that spore trajectory or impaction would be significantly affected by the relatively weak forces (2) associated electrostatic charges and fungal spores.

There are some minor points in Wili's letter that should be considered. Wili states that it was illogical to initially position the ends of the impaction tape behind the orifice in the PVC trap because the initial hour's spore deposit would be split onto opposite ends of the tape. This is a matter of opinion or personal preference only. We routinely used the PVC trap in our studies on *V. inaequalis* and changed the tape during fair weather. The first hour's catch was of no concern to us because it never contained ascospores of *V. inaequalis*. Others may wish to position the tape differently. Wili also questions our measurement of the air flow rate of the PVC trap and claims that Burkard traps are tested with a hot-wire anemometer. We tested the air flow rate of the PVC trap with a collapsing air bladder (11) and a ball flow meter and found that the rates indicated by both methods agreed closely. Burkard traps may be tested at the factory or in some labs with hot-wire anemometers, but to imply that routine field calibrations are performed in this manner creates an illusion of precise calibration, when in fact the air flow rate of the Burkard trap is calibrated in the field with a simple ball flow meter (1) similar to that used for the PVC trap.

The Melinex tape in the PVC trap was coated with silicone grease to trap spores (4). Wili states that this would alter the orifice-impaction surface gap in an inconsistent manner, particularly if the grease was not first dissolved in a solvent. However, the operating manual supplied with the Burkard trap recommends the use of silicone grease as an adhesive (1). We did dissolve the grease in carbon tetrachloride before applying it to the tape, but unfortunately omitted this detail from our report (4). We have since found what we believe to be a superior adhesive coating: 15 g of Tanglefoot (Tanglefoot Co., Grand Rapids, MI, 49504, USA) dissolved in 100 ml of carbon tetrachloride. Tapes are coated with this solution by painting it on with a fine-bristled brush and are then heated at 80 C for 15–30 sec. When heated, the Tanglefoot forms a smooth, soft, adhesive film approximately 5 μm thick, which remains so for several weeks after treatment.

Finally, it was implied that our original report (4) incorrectly listed the price of the Burkard trap as $2,000; the current price is $1,200 (15). Our report on the PVC trap was accepted for publication in May 1983, and at that time the price of the Burkard trap was approximately $2,000. The fluctuations in the exchange rate for U.S. dollars and British pounds is the reason for the difference between the figures quoted by Wili (15) and by us (4).

In conclusion, we find little to support Wili's contention that the PVC trap is unsuitable for aerobiological studies. His letter lacks any data comparing the two traps and he offers no explanation for our results in comparing the PVC trap to the Burkard trap. The fact that the PVC trap can be quickly and inexpensively built would indicate that there has been ample opportunity for him to perform comparative tests.

Certainly the Burkard trap is a fine instrument; superior in virtually every respect to the PVC trap with one exception: it is more expensive. That is the reason why we built the PVC trap. If we had increased the flow rate of the Burkard trap to equal the PVC trap's 15 L/min, the Burkard trap's efficiency may have exceeded that of the PVC trap. When we attempted to do so, the motor of the Burkard trap was damaged (4). Apparently, the failure of the motor was only coincident with the increased flow rate, for Wili (15) reported that the Burkard trap is capable of operating at 15 L/min and Stedman (12) has operated a modified version of the Burkard trap at 17.5 L/min. In retrospect, decreasing the flow rate of the PVC trap to 10 L/min would have provided a better comparison of the performance of the two traps. As we reported earlier (4), we believe that the difference in efficiency between the two traps is a function of air stream velocity and is not due to any inherent superiority of the PVC trap.

We are not in the business of building spore traps. The PVC trap is not patented, and with the exception of a single trap exported to India, we have refused all requests to produce PVC traps. The trap can be built in about 4 hr at a cost of approximately $200 (4). We have always been willing to provide information on construction and operation of the PVC trap and will continue to do so. We would welcome any suggestions from scientists at Burkard Manufacturing to improve the PVC trap.

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