Methodologies for Particle Dispersion Experiments in Plant Canopies

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Abstract

As part of our ongoing work to study the mechanisms of fungal epidemiology in vineyards, the investigation of the transport physics of fungal spores has led to the development of new equipment and methodologies for use in performing and analyzing particle plume experiments. Although these techniques have been used specifically for spore and microsphere transport experiments, they could be tapped for use in a variety of different studies both in vineyards and in other canopy types.

Between the years of 2009 and 2014, five field campaigns were performed by our team in commercial vineyards in Oregon's Willamette Valley. Over the course of those years, many ideas on how to disperse, collect, quantify, and analyze the microspheres used to study plume dispersion in the vineyard were tried and developed. This included the design of new equipment, the novel use of existing technologies, the improvement of ideas utilized by others, and the incremental improvement of all of these from year to year as campaigns continued. Among the methodologies was the use of inert, fluorescent microspheres as a fungal spore analog, the invention of simple rotating-arm impaction traps mounted on low-profile aluminum masts that were deployed in large arrays, and the use of a fluorescence stereo microscope with specific excitation filters and imaging software for use in quantifying the microsphere concentrations. The impaction trap arrays and an array of microsphere release devices were operated using a wireless network, thus allowing for reconfiguration and simple redeployment. This also allowed for independent control for plumes emitted in different directions based on the wind direction. These techniques have enabled for incredibly detailed research into particle plume dynamics in a vineyard.

Particle Plume Releases

Inert fluorescing polyethylene microspheres [1]:

- Cospheric Inc.
- 4 separate colors used
- 10-45 μm diameters => mean $\approx$ 35 μm

Release devices:

- Precision machined vibrating funnels (2010-11]) [1]
  - Vibration allowed flow of dry spheres through tip [2]
  - 3VDC offset-mass motor
  - Inconsistent release rate & total mass
- Ultrasonic Nozzles: Sonaer Inc. (2013-14) [3]
  - Spheres suspended in a 0.05% v/v Tween 20 solution at 0.05 g/ml
  - Suspension in ethanol with continuous stirring will be used in 2016
  - Syringe Pump: Harvard Apparatus
- Simultaneous releases from multiple heights
  - Devices held using 3-finger clamps
  - 2-3 heights from fruiting wire to h

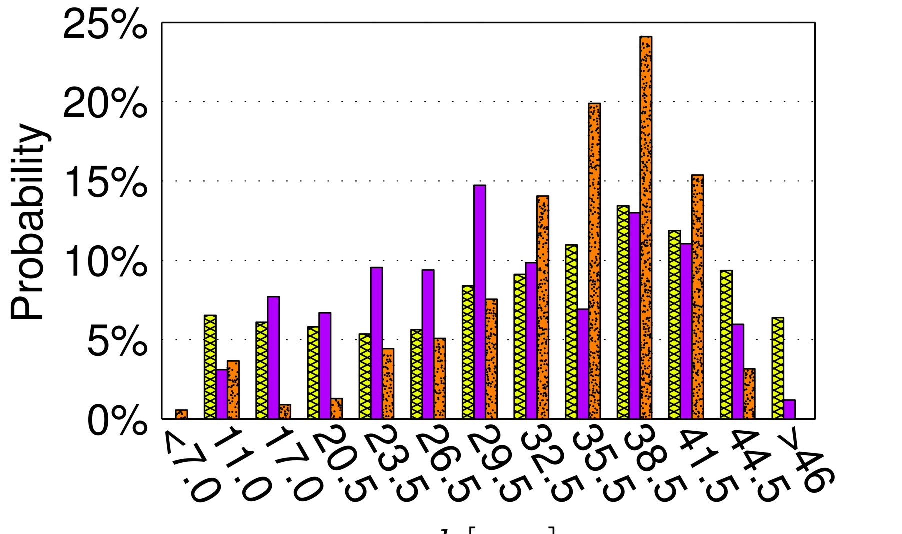

Figure 1: Diameter distributions of the different colors of microspheres

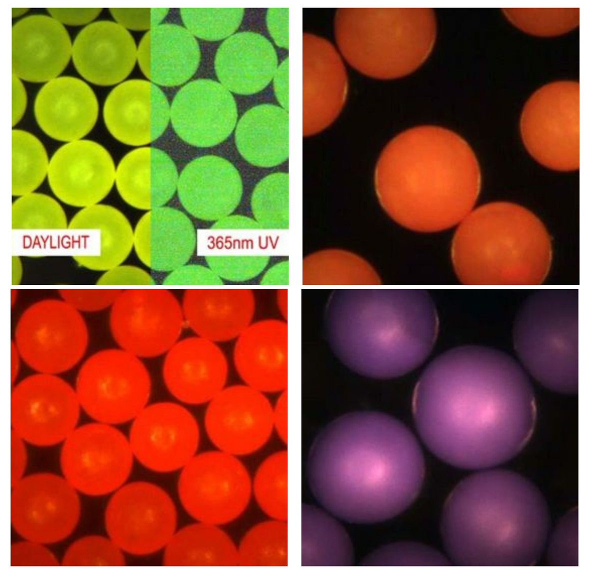

Figure 2: The 4 colors of microspheres from Cospheric LLC

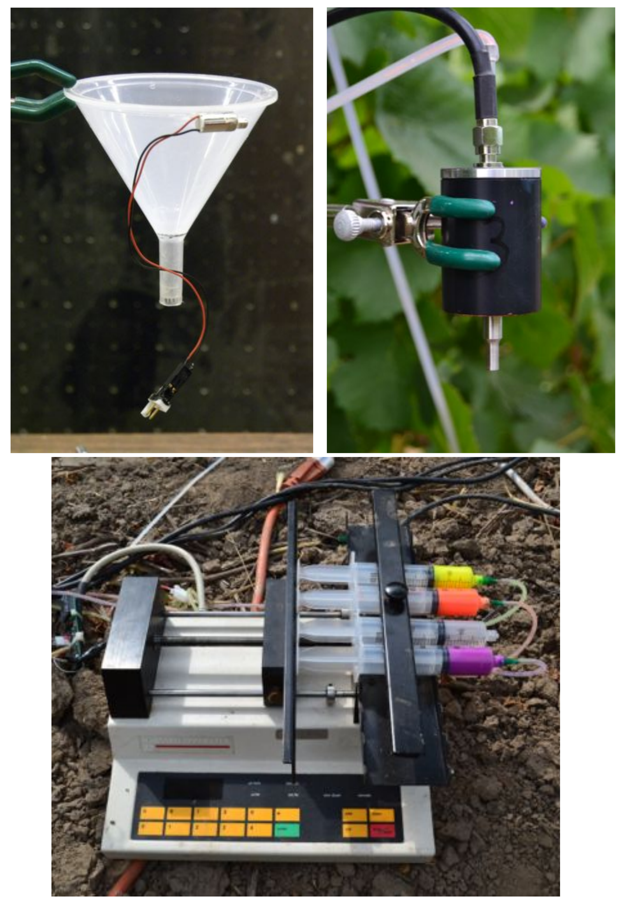

Figure 3: The release devices and the syringe pump used with the ultrasonic nozzles

Microsphere sampling

- Rotating Rod Impaction Traps [1,4]
  - 5VDC pancake motor: 2500 RPM
  - Cross-arm with 4.3 cm radius
  - Rods coated in vacuum grease: applied via hexane bath
- 5 traps mounted to towers
  - 80/20 Aluminum T-channel
  - Highest arm raised via cord & pulley

Figure 4: Rotating rod impaction trap

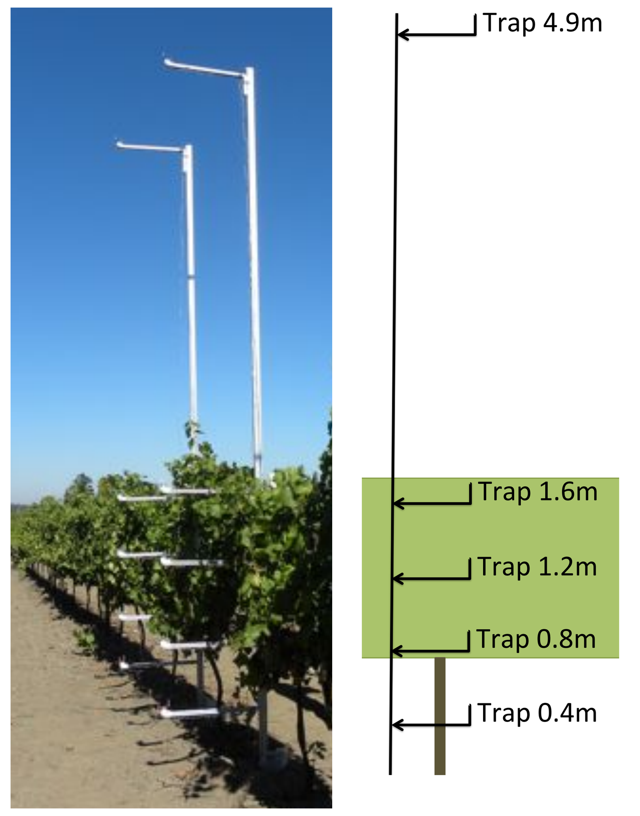

Figure 5: Tower of rotating rod impaction traps in the vineyard

- 42 tower arranged in arrays
  - N winds, 22 used in 2013-14, 20 used in 2011 [1,5]
  - W winds, 23 used in 2013-14 [3]
  - Dual N, 42 used. 22 at north array, 20 at south array on other side of hill crest (2014)
  - LongN = 25 used in 2013 [A]
- Impaction traps, release devices controlled remotely
  - Xbee controller on each
  - Wireless modem used to send commands to Xbees
  - Independent control of groups of trap towers and release devices

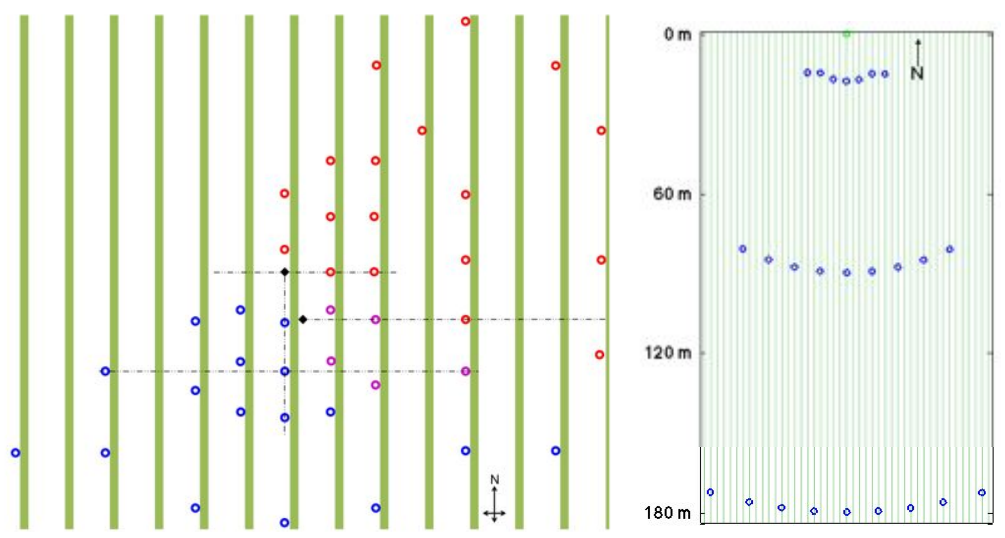

Figure 6: LEFT: Layout of the tower array used for near-source dispersion. Blue+Magenta used for N releases. Red+Magenta used for W releases. Dual N releases used Blue+Magenta at northern array & a copy of that array made from the Red towers at a different southern location. RIGHT: Layout of the tower array used for field-scale dispersion [A]

Meteorological equipment

- Meteorological & energy budget data
  - 10m tower
  - 6 Sonic Anemometers
  - Other sensors (radiation, soil, leaf)
- Low Energy Measurement Stations (LEMS) [6]
  - Anemometer, Temp., Pressure, Humidity, Total radiation, Surface Temp
  - 2 & 14 used in 2013 & 2014
- High resolution temperature gradients
  - Fine-wire TCs: CSATs + Rake
  - Distributed Temperature Sensor: 6" x 1 m resolution down 1 row

Figure 7: The TC rake & 2 LEMS deployed in the vineyard with anemometers above & below h (2014)

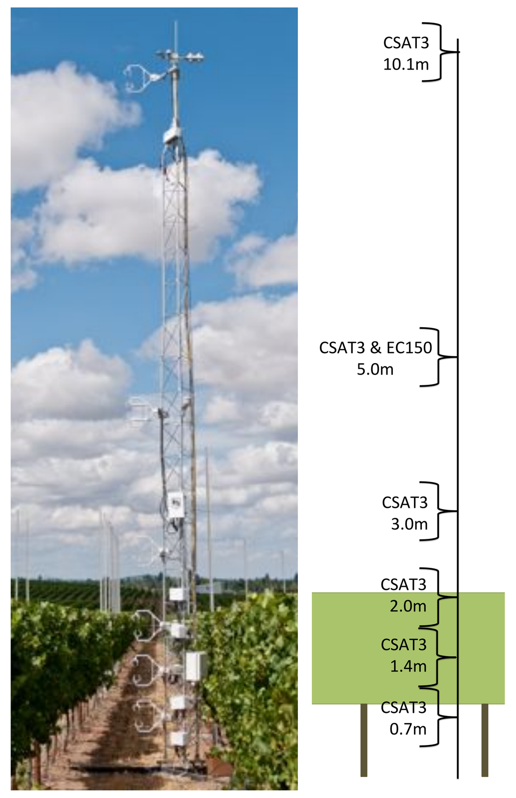

Figure 8: Meteorological tower in the vineyard

Figure 9: SQ110, CNR1, & LI200

Field Sites Used

Figure 12: Google Earth images of the 2 vineyards. Tower location marked in Wildwood (2011). Tower & LEMS locations marked in Lone Star.

- Wildwood Vineyard, Monmouth
  - Flat site used in 2010-2013
  - 44° 49′ 28″ N, 123° 14′ 15″ W
  - N-to-S rows spaced at 2.45 m
  - Canopy height, h = 2.00-2.15 m
- Lone Star Vineyard, Amity
  - Complex site used in 2014
  - 45° 4′ 8″ N, 123° 5′ 48″ W
  - Row spacings, 1.52-2.45 m
  - Canopy heights, h = 1.78-2.0 m

Sample Collection & Processing

- White rods in 2010-13, switched to black for improved imaging in 2014
- Rods color coded by height
- Rods hand collected onto plates labeled for tower & event

Figure 10: Rods collected onto their respective labelled plates.

- Labeled plates examined with a stereoscopic microscope
- Each microsphere color identified with excitation and lens filters
- Microspheres hand counted thus far = very time consuming
- Automated counting being developed

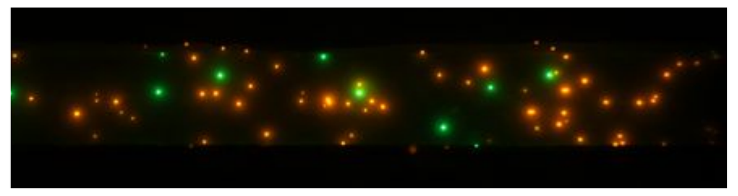

Figure 11: Illuminated microspheres under the stereoscopic microscope

Finalized Techniques & Future Developments

- Microspheres suspended in Ethanol emitted from ultrasonic nozzles
- Collected by inexpensive but effective impaction traps
- Use dark colored rod substrates with thin film of grease
- Automate particle counting in microscope using image processing techniques

References

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[A] The other poster by the same authors at this conference.

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