Sprinkler Drop Characteristics via Weather Monitoring System

B. A. King, Ph.D. P.E, Research Agricultural Engineer
D.L. Bjorneberg, Ph.D. P.E, Supervisory Agricultural Engineer
USDA Northwest Irrigation and Soils Research Laboratory
Kimberly, Idaho

Sprinkler Drop Characteristics: Why?

Sprinkler drop size characteristics affect irrigation efficiency in multiple ways.

- Small drops are prone to wind drift and evaporation loss.
- Large drops promote creation of soil surface seals that decrease infiltration rate leading to run-on and run-off –> application nonuniformity.

Drop Size Measurement Techniques

Numerous methods over the past 50 years.

- Paper stain method. Specially treated paper.
  - Stain diameter is proportional to drop size.
- Flour pellet method. Drops quickly caught in pan of finely sifted flour and oven dried.
  - Dried pellets are sieved and mass is proportional to drop size.

Drop Size Measurement Techniques

High speed photography

- Most accurate due to visual confirmation of drop dimensions.
- Time consuming to analyze.
- Velocity measurement as well.

Drop Size Measurement Techniques

Laser techniques:

- Photodiode array.
  - Shadow of drop passing through a horizontal laser beam is captured on a photodiode array. Width of shadow is measure of drop size.
- Attenuation.
- Scattering.

Laser Sources of Error

Laser techniques have three major sources of error:

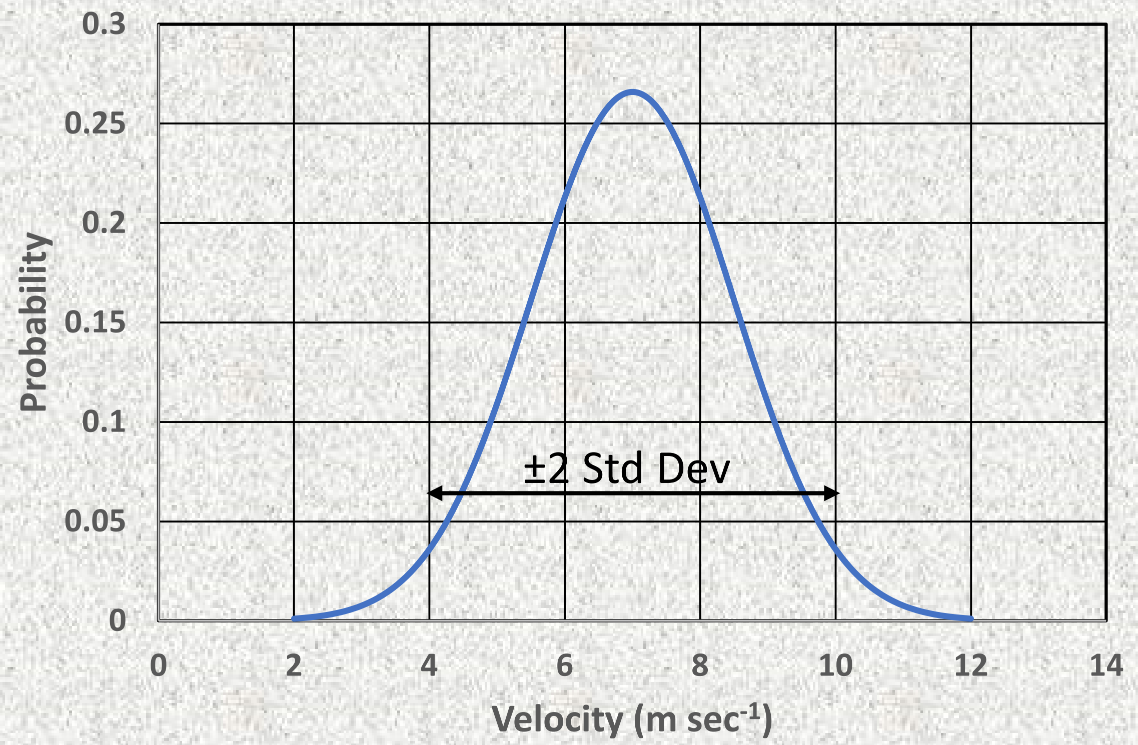
- Coincidence error.
  - Occur when two drops pass through the laser beam simultaneous, projecting overlapping shadows on detector(s).
- Edge effect error.
  - Portion of drop passes through edge of laser beam.
- Splash error.

Physical Error Mitigation Measures

- Coincidence error.
  - Minimize the length of laser beam to reduce the odds of simultaneous drops.
- Edge effect error.
  - Maximize width of laser beam to minimize ratio of edge length to measurement area. Unavoidable.
- Splash error.
  - Cover structural elements with splash reducing material. Unavoidable.

Data Filtering for Errors

- Drop velocity can be used to filter drop size data to minimize measurement errors.



Present Weather Systems

Systems for remote measurement of real-time weather conditions. Basic element is laser-based measurement of precipitation particle size and velocity. Basic data include:

- Drop size distribution
- Precipitation type
- Precipitation intensity

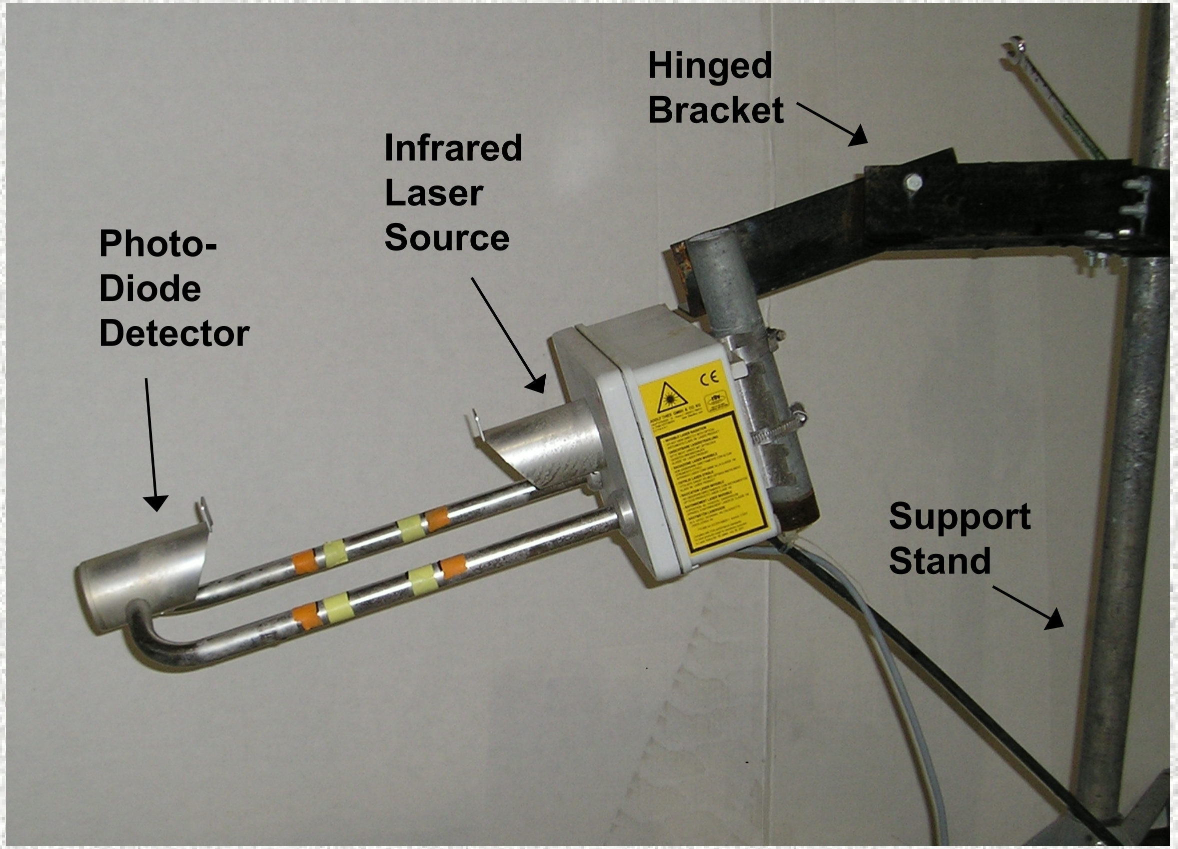
Study Present Weather Systems

- Thies Clima Laser Precipitation Monitor (LPM).
- Campbell Scientific Present Weather System (PWS)

Thies Clima (LPM)

- Parallel laser beam with one photodiode detector. Drop size is based on attenuation of detected laser intensity and velocity is based on time of signal.
- Sample Volume.

Thies Clima (LPM)

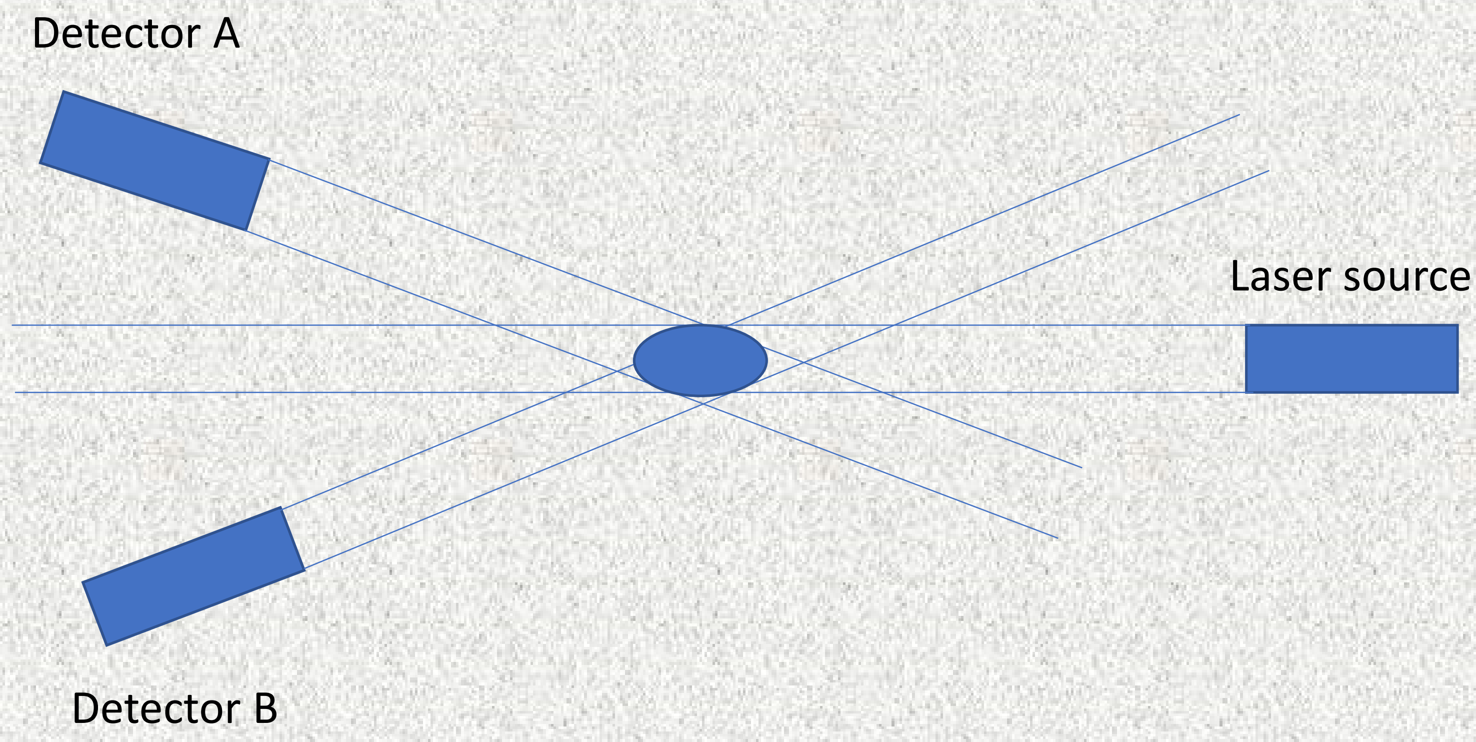


Campbell Scientific PWS

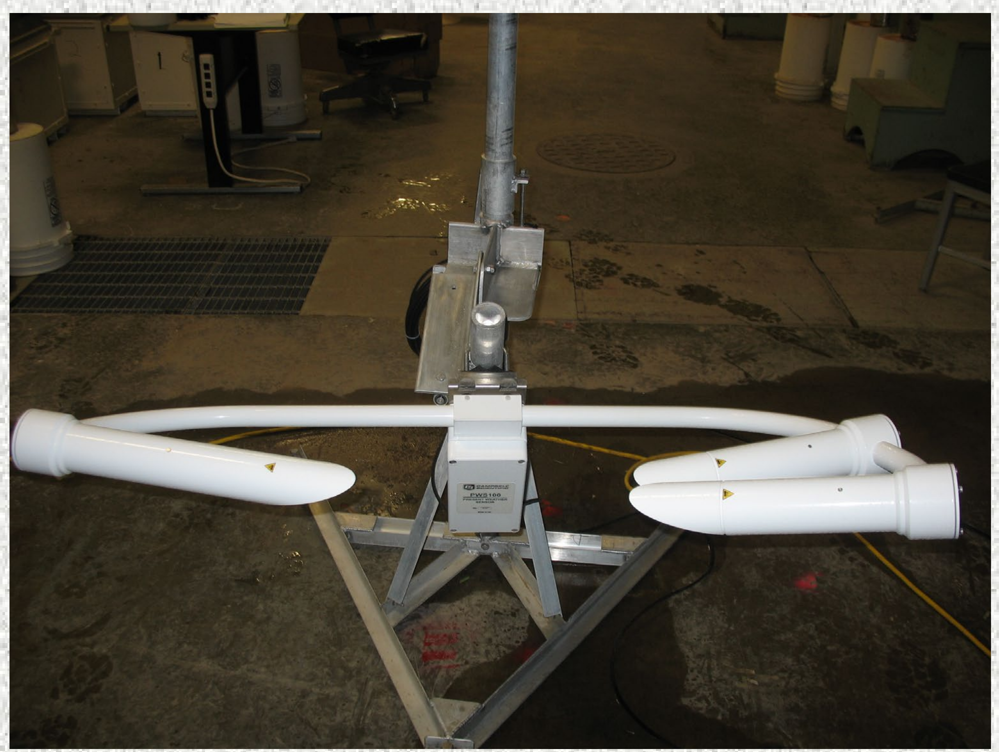
- Phase Doppler Anemometry.
- Four parallel horizontal light sheets spaced 0.8 mm intervals.
- Drop size is estimated by relative time delay between signals of scattered light at differing angles.
- Velocity is estimated by time separation between scattered light intensity.

Campbell Scientific PWS

- Uses one laser with two off-axis detectors.



Campbell Scientific PWS



Comparative Specifications

Parameter	LPM	PWS
Measuring area (cm^2)	nominally 40 to 47	40
Particle size (mm)	0.16 to 8	0.1 to 30*
Size accuracy	±5% by volume	±5% for > 0.3 mm
Particle velocity ($m\ sec^{-1}$)	0.2 to 20	0.16 to 30
Velocity accuracy	not specified	±5% for > 0.3 mm
Maximum Intensity ($mm\ hr^{-1}$)	250	< 999

* Proportion of drops < 0.5 mm decreases significantly.

Objective

Measure sprinkler drop size with Campbell Scientific Present Weather System (PWS100) and compare drop size distributions with results obtained using other measurement methods for the same sprinklers.

Test Sprinklers

Sprinkler	Pressure - psi (kPa)	Nozzle size - 128ths (mm)
Nelson R30 red plate	15 (103)	32 (6.4)
Nelson R30 red plate	20 (138)	40 (7.9)
Nelson R30 red plate	30 (208)	24 (4.8)
Nelson S30 red plate	30 (208)	24 (4.8)

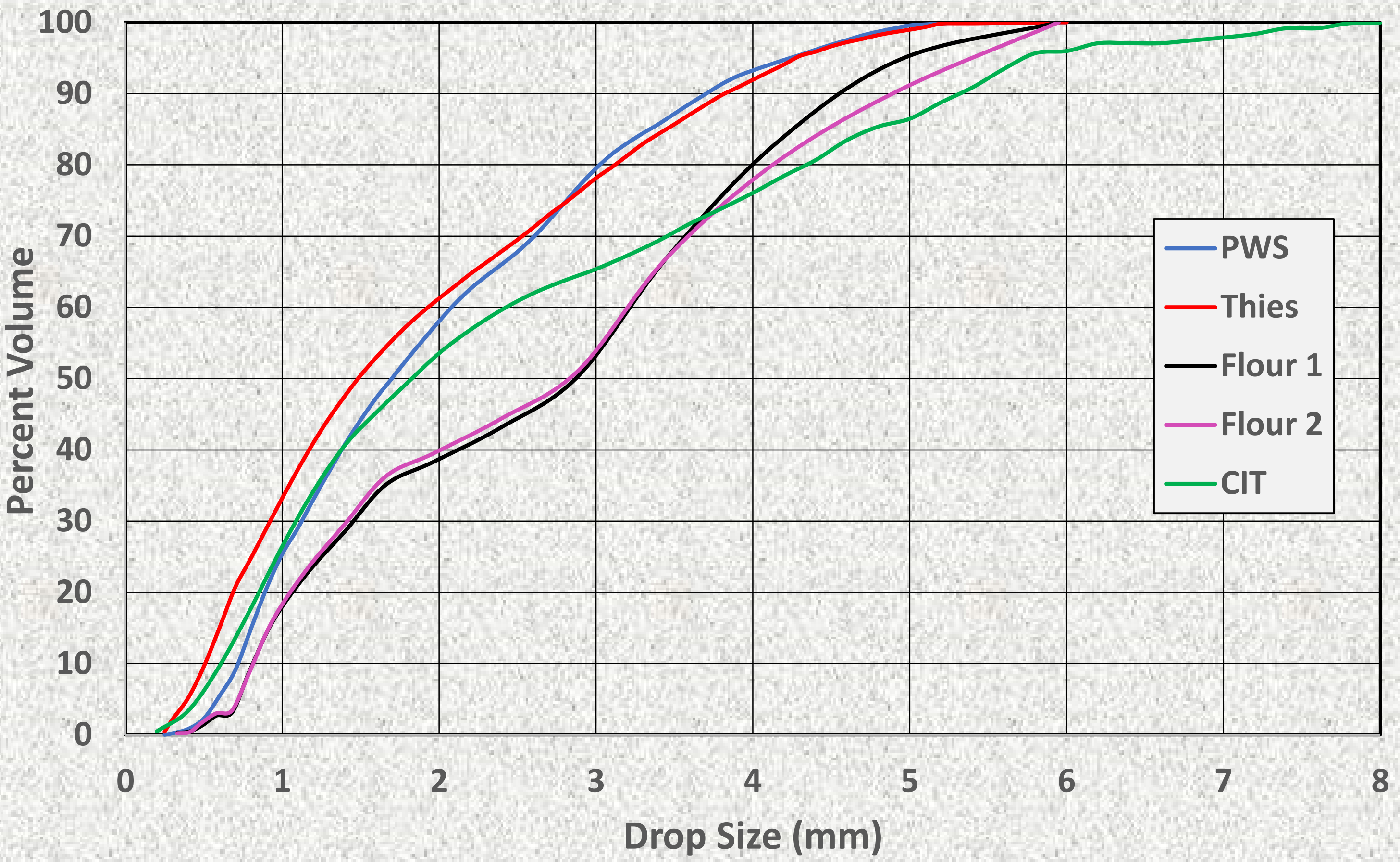
Comparison Data

- Flour Method – DeBoer and Monnens (2001).
- Laser Photodiode method, Center for Irrigation Technology, Fresno State University – Kincaid et al., (1996).
- Laser Thies Clima – King et al., (2010).

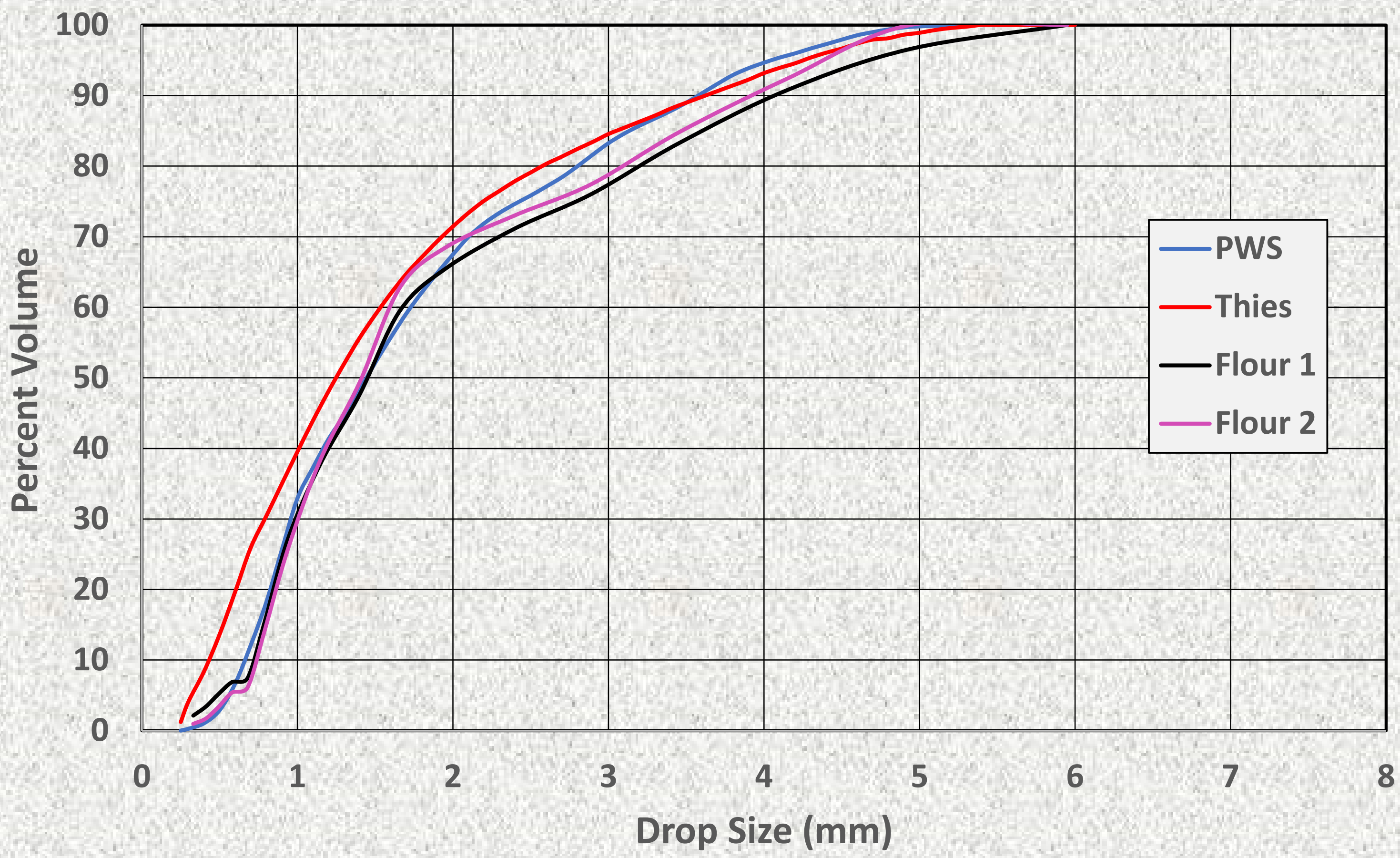
LPM Methods

- 2.5 m (8 ft) sprinkler height.
- Measurements collected at 1m radial increments.
- > 10,000 drops collected.
- Laser sampling area oriented normal to trajectory of bulk drop stream.
- Data filtered based on measured velocity ±2 standard deviations of average velocity.
- Volume weighted drop size distribution based on measured radial application rate pattern.
- Kolmogorov-Smirnov two-sample test ($p = 0.05$).

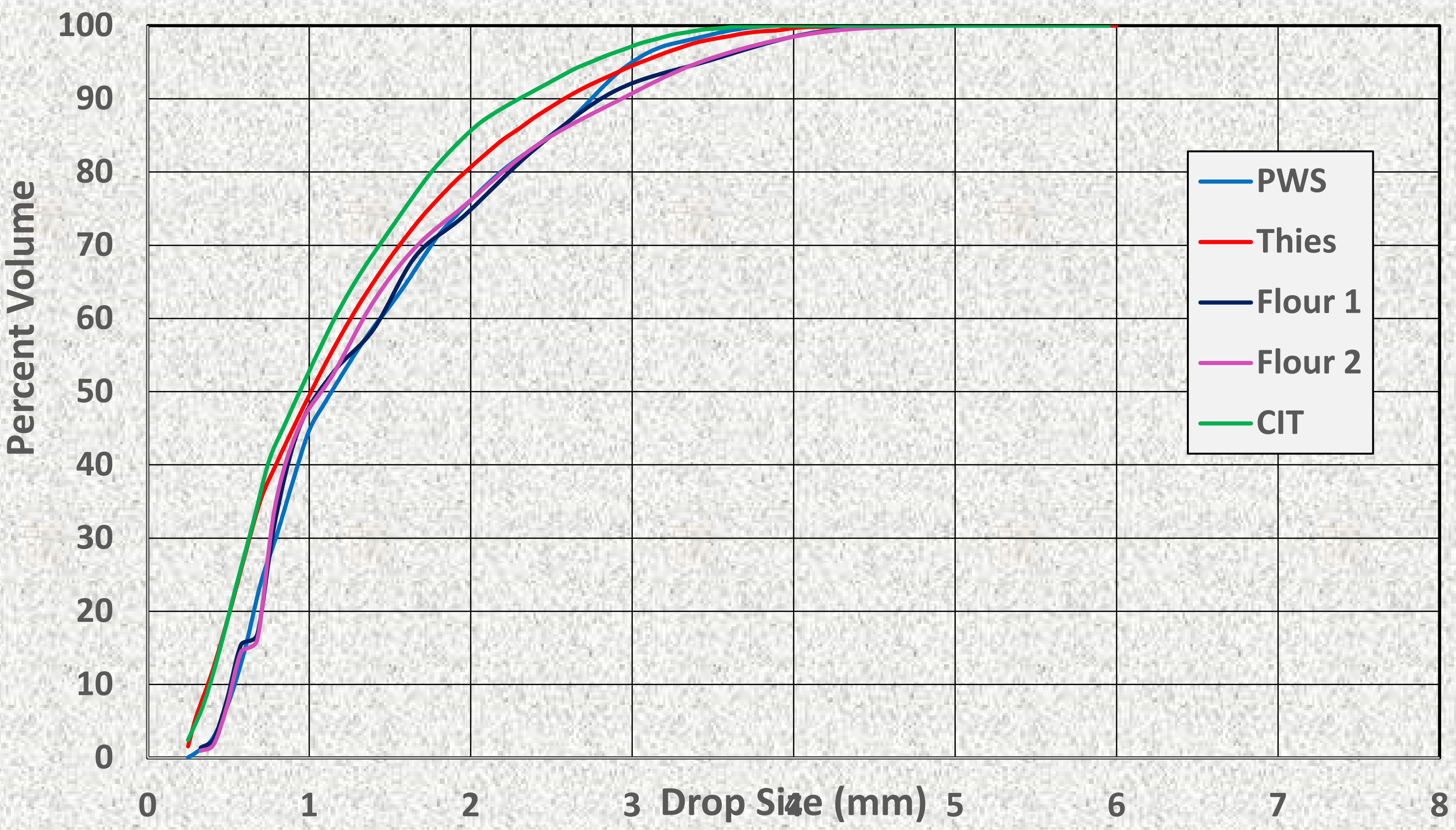
Nelson R30 15 psi #32 nozzle



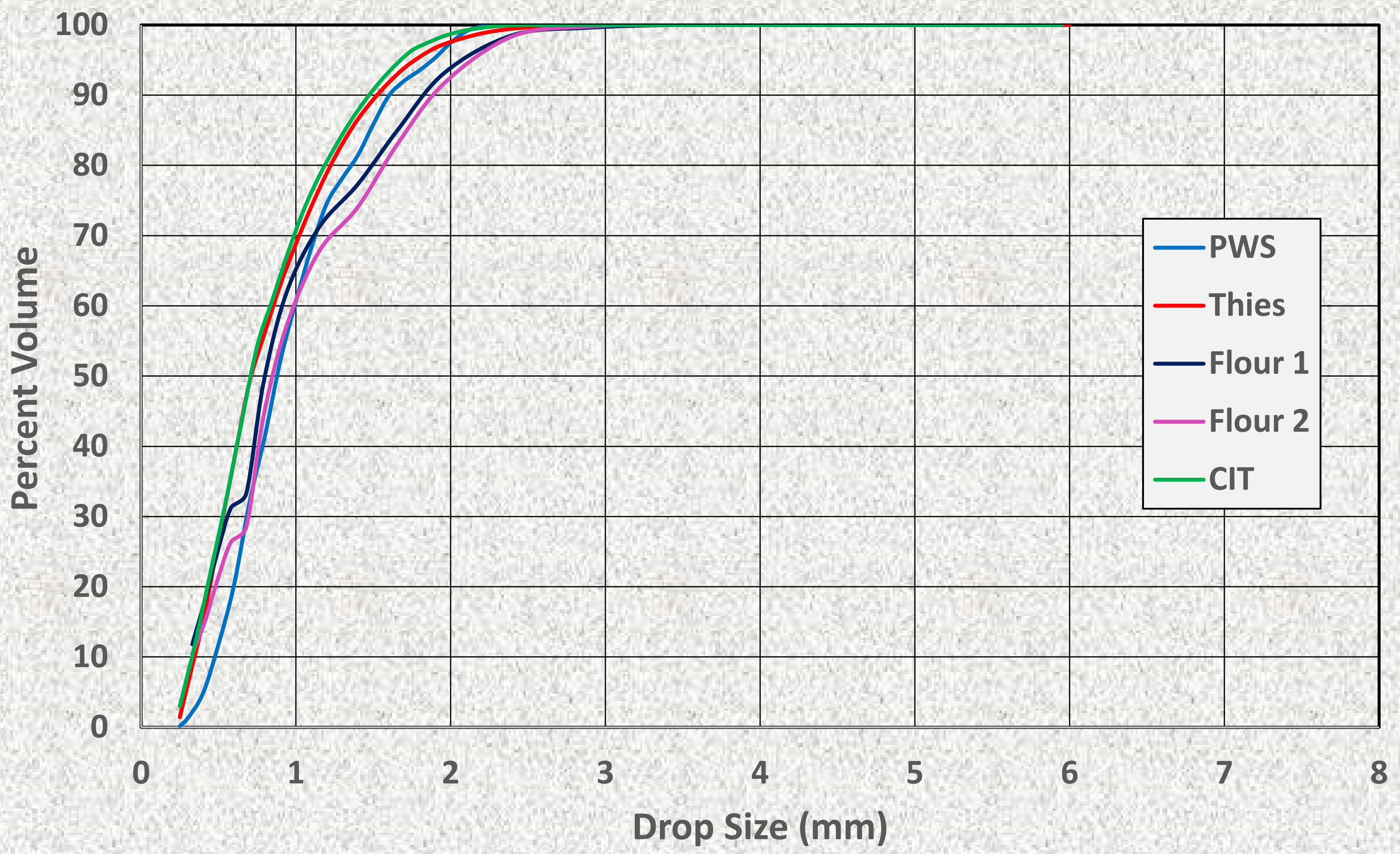
Nelson R30 20 psi #40 nozzle



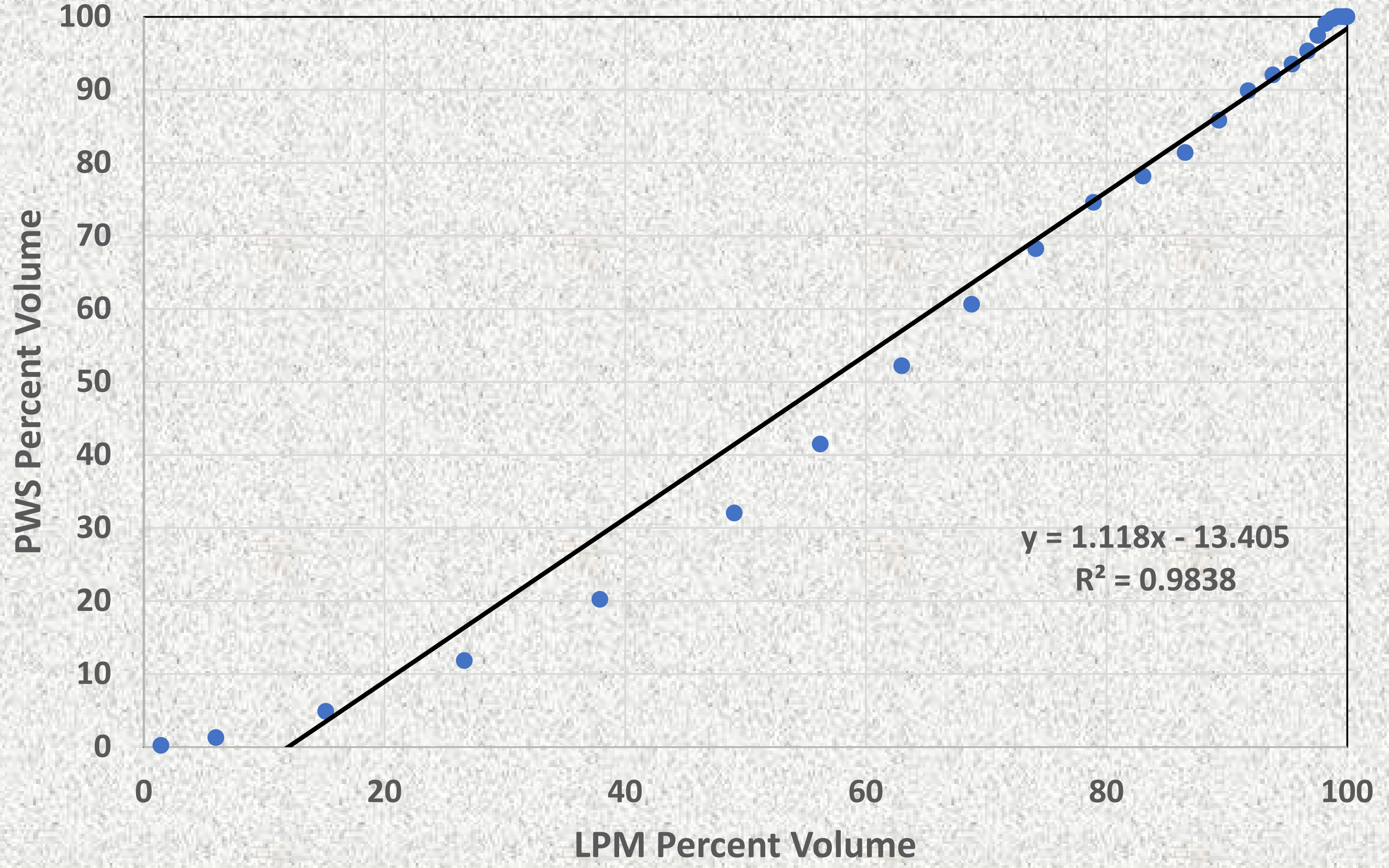
Nelson R30 30 psi #24 nozzle



Nelson S30 30 psi #24 nozzle



Nelson S30 30 psi #24 nozzle

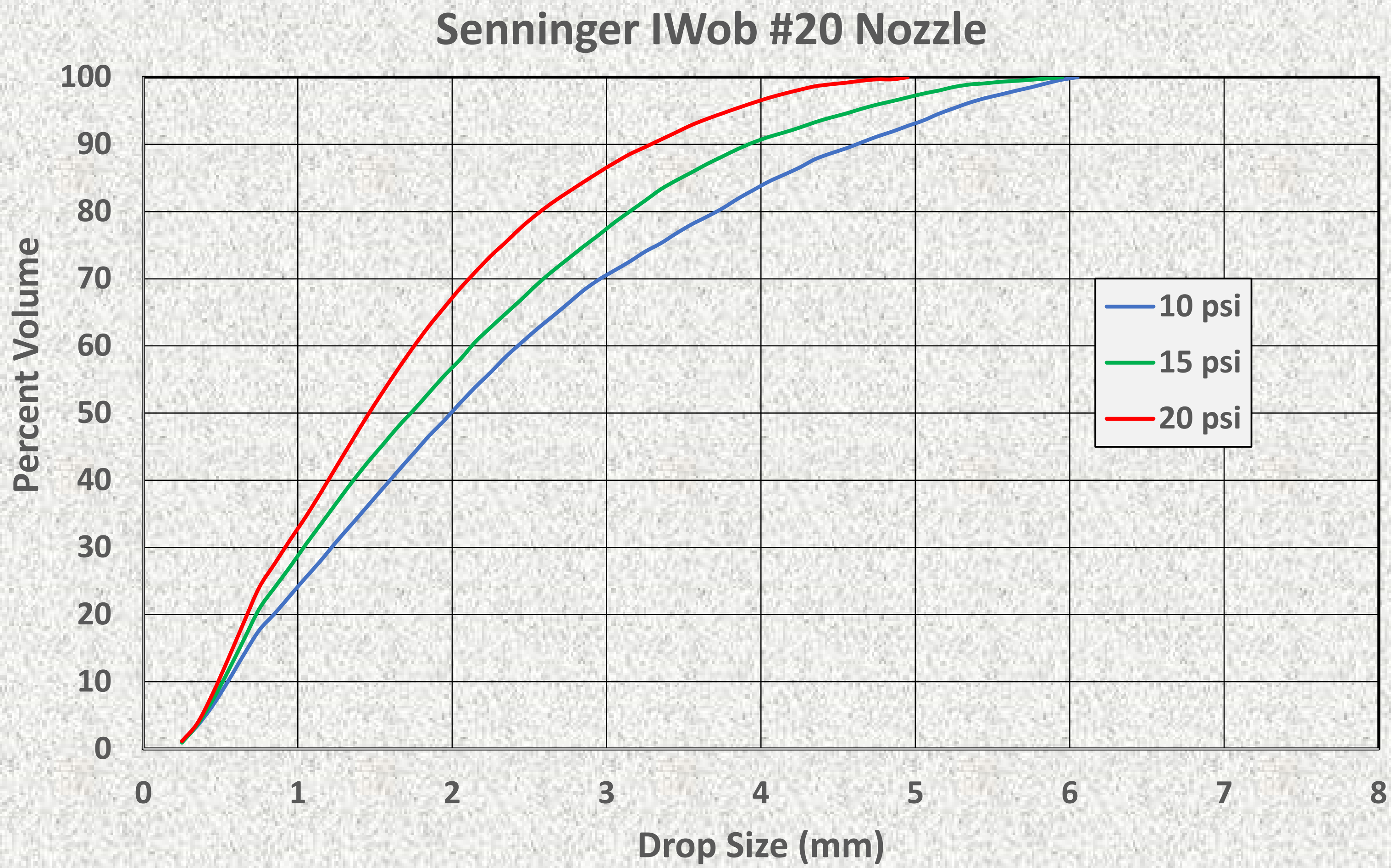


Summary

- Drop size distribution between measurement methods were significantly different ($p = 0.05$).
- For all sprinklers, drop size distributions for the LPM and PWS were very similar $R^2 > 0.98$.
- Reduced sensitivity of PWS for drop sizes less than 0.5 mm biases the drop size distribution and indicates larger drops sizes than the LPM.
- PWS is suitable for measuring sprinkler drop sizes larger than 0.5 mm.

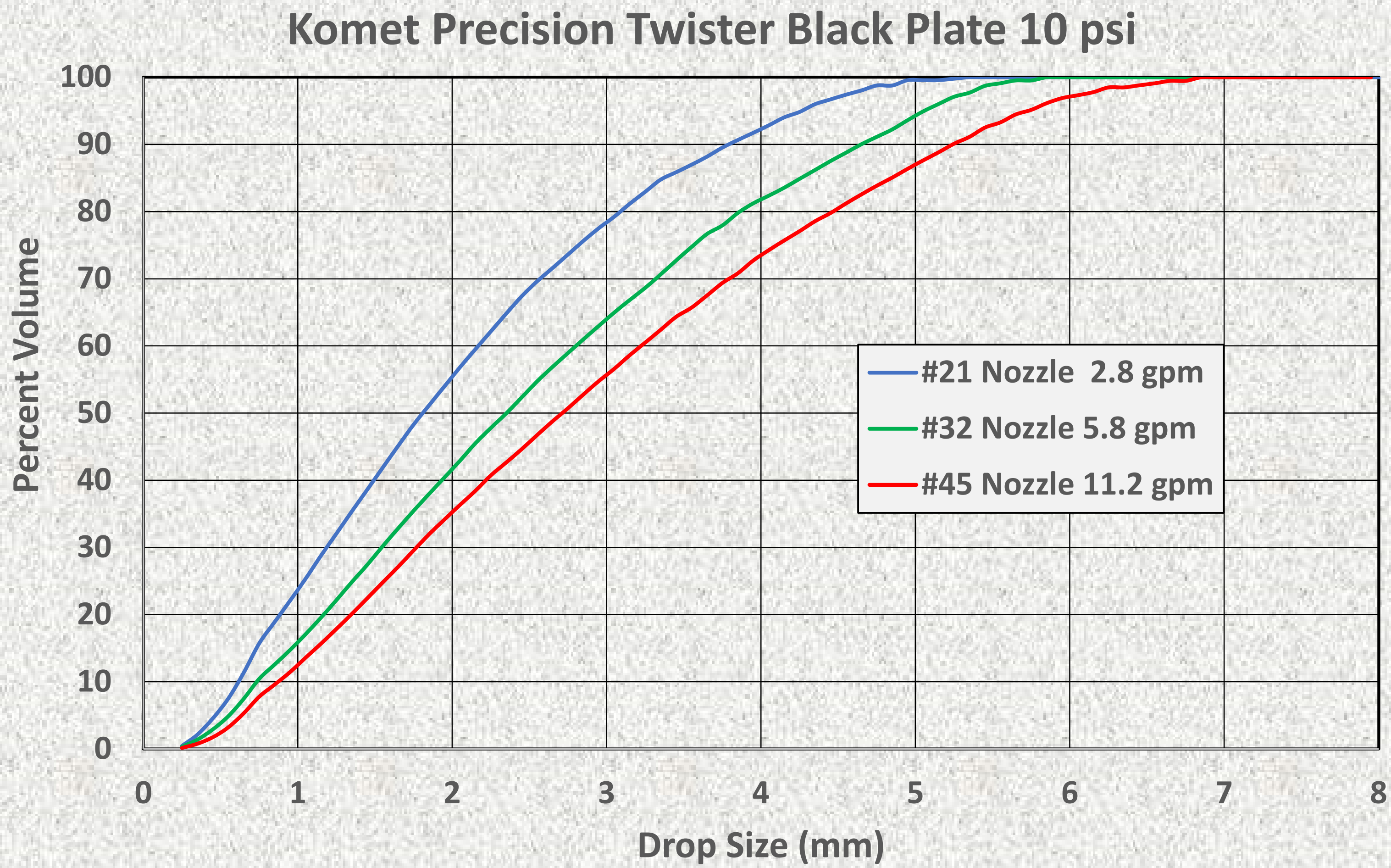
Drop Size Distribution Truths - #1

- Drop size decreases as pressure increases.



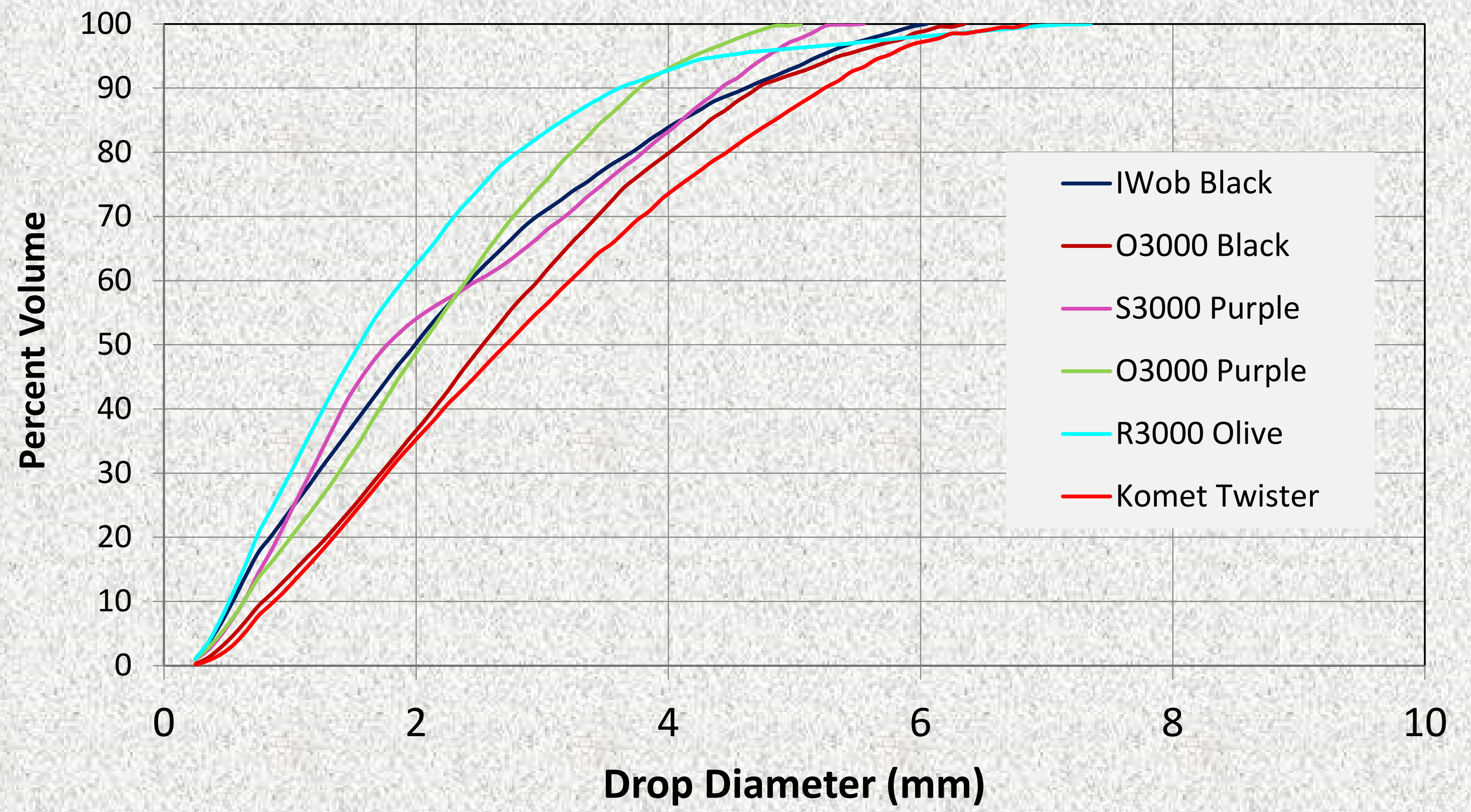
Drop Size Distribution Truths - #2

- Drop size increases as flow increases.



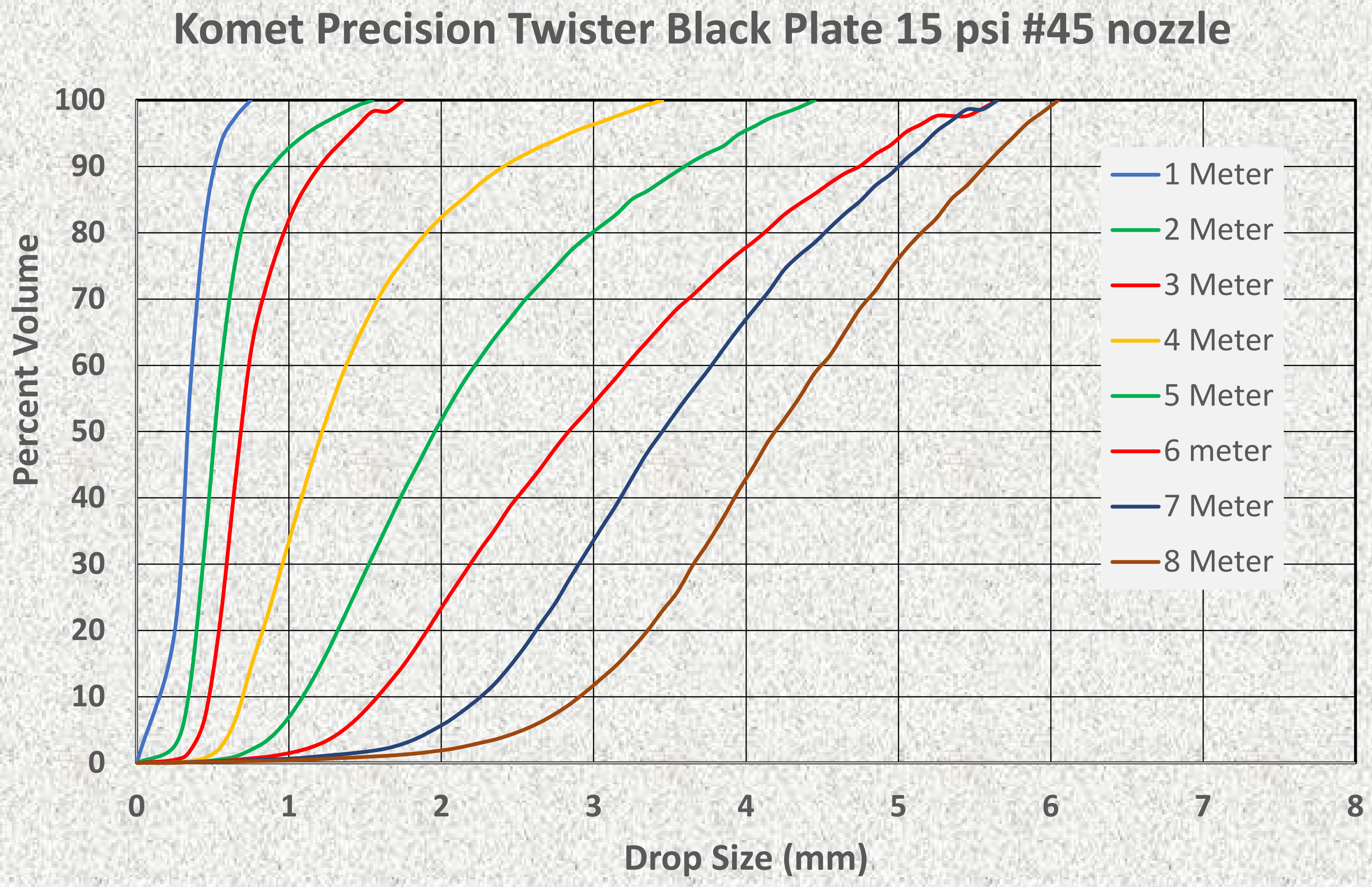
Drop Size Distribution Truths - #3

- Every sprinkler has a drop size distribution.



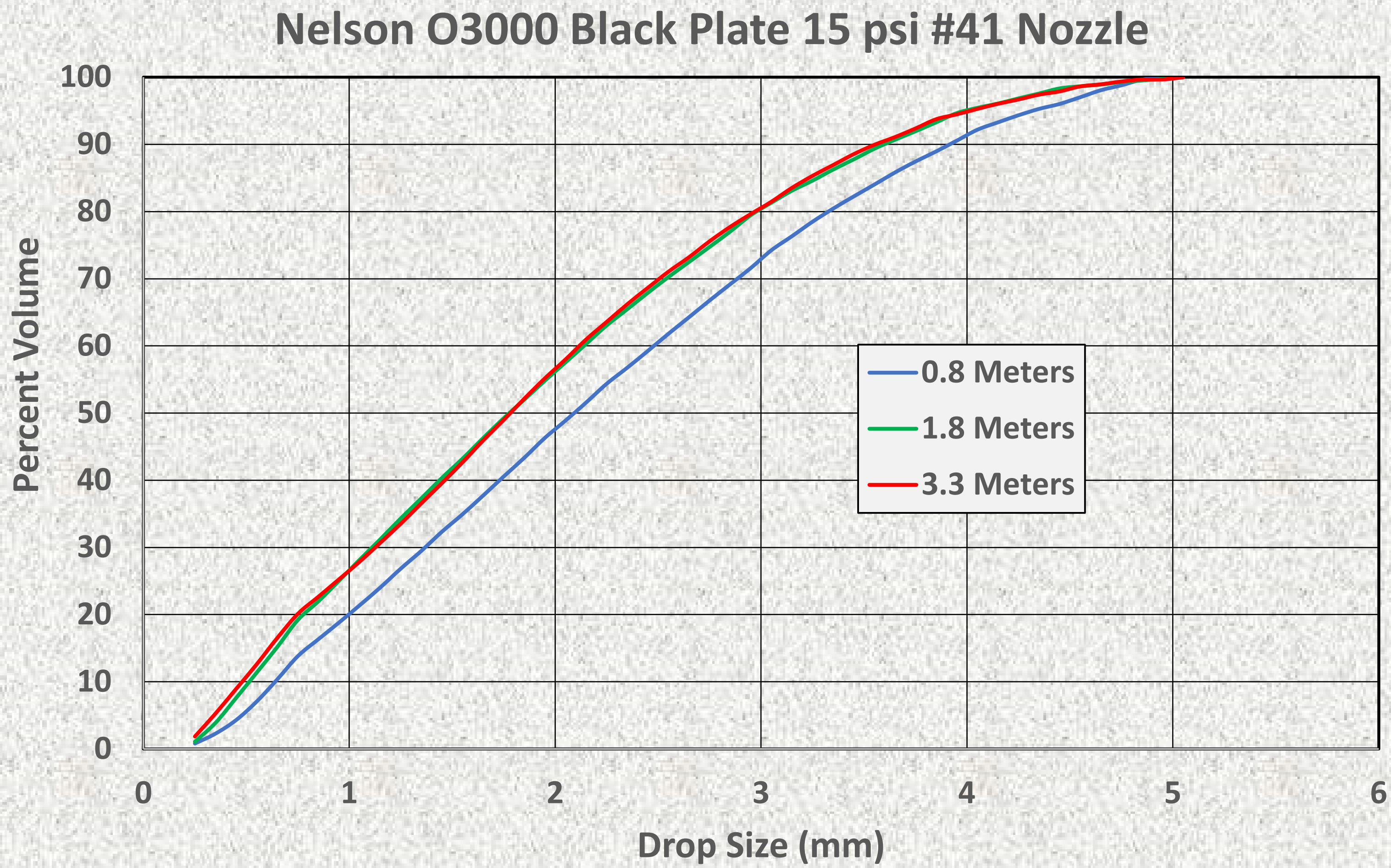
Drop Size Distribution Truths - #4

- Drop size increases with wetted radius.



Drop Size Distribution Truths - #5

- Sprinkler height can affect drop size.



Drop Size Distribution Truths - #6

- Drop Size Governs Application Pattern.