Air-Assisted Electrostatic Crop Spraying Halves Pesticide Total Environmental Load

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The University of Georgia

OVERALL GOAL FOR CROP PEST CONTROL VIA SPRAY-APPLICATION SYSTEMS

- Provide efficacious/economic pest control
- By dispensing into the ecosystem the minimum quantity of control-agent active ingredient
- Efficiently delivered to the intended crop surface
- Thereon deposited uniformly onto both directly exposed & obscured crop surfaces
- While minimizing off-target losses of active ingredient to soil, water & atmosphere.

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Electrostatic Attraction of Charged Spray

ELECTROSTATICS DEFINED

Considers Phenomena and Effects due to the Presence of Electric Charges, either Moving or at Rest, for the Case where the Effects of Interest are Solely due to the Magnitudes and Locations of the Charges and Not due to their Motion.

LORENTZ FORCE ON CHARGED PARTICULATE

$$\boldsymbol{F}_p = q_p\,(\boldsymbol{E} + \boldsymbol{v}_p \times \boldsymbol{B})$$

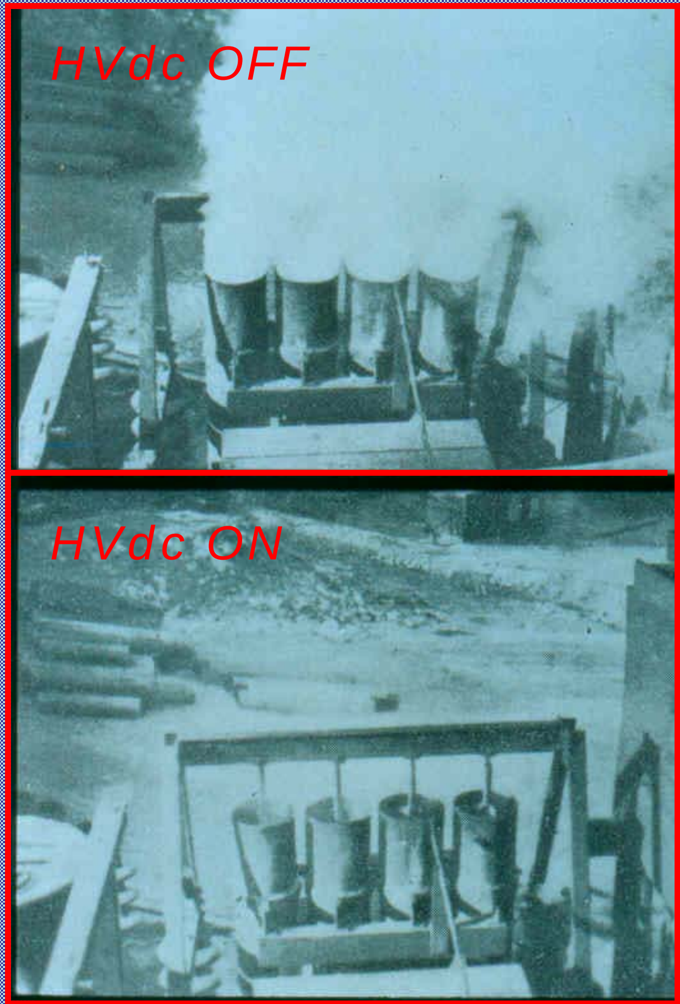
LORENTZ FORCE ON CHARGED PARTICULATE

$$\boldsymbol{F}_p = q_p \boldsymbol{E}$$

ELECTROSTATICS FOR INDUSTRIAL AND COMMERCIAL USES

- Electrostatic Coating
- Electrostatic Precipitation
- Electrostatic Separation
- Electrostatic Flocking
- Xerography
- Ink-Jet Printing
- Nanotechnology Applications

EARLY ELECTROSTATIC SUCCESSES



Electrostatic Precipitation

Xerography

PEST CONTROL FOR CROP PRODUCTION

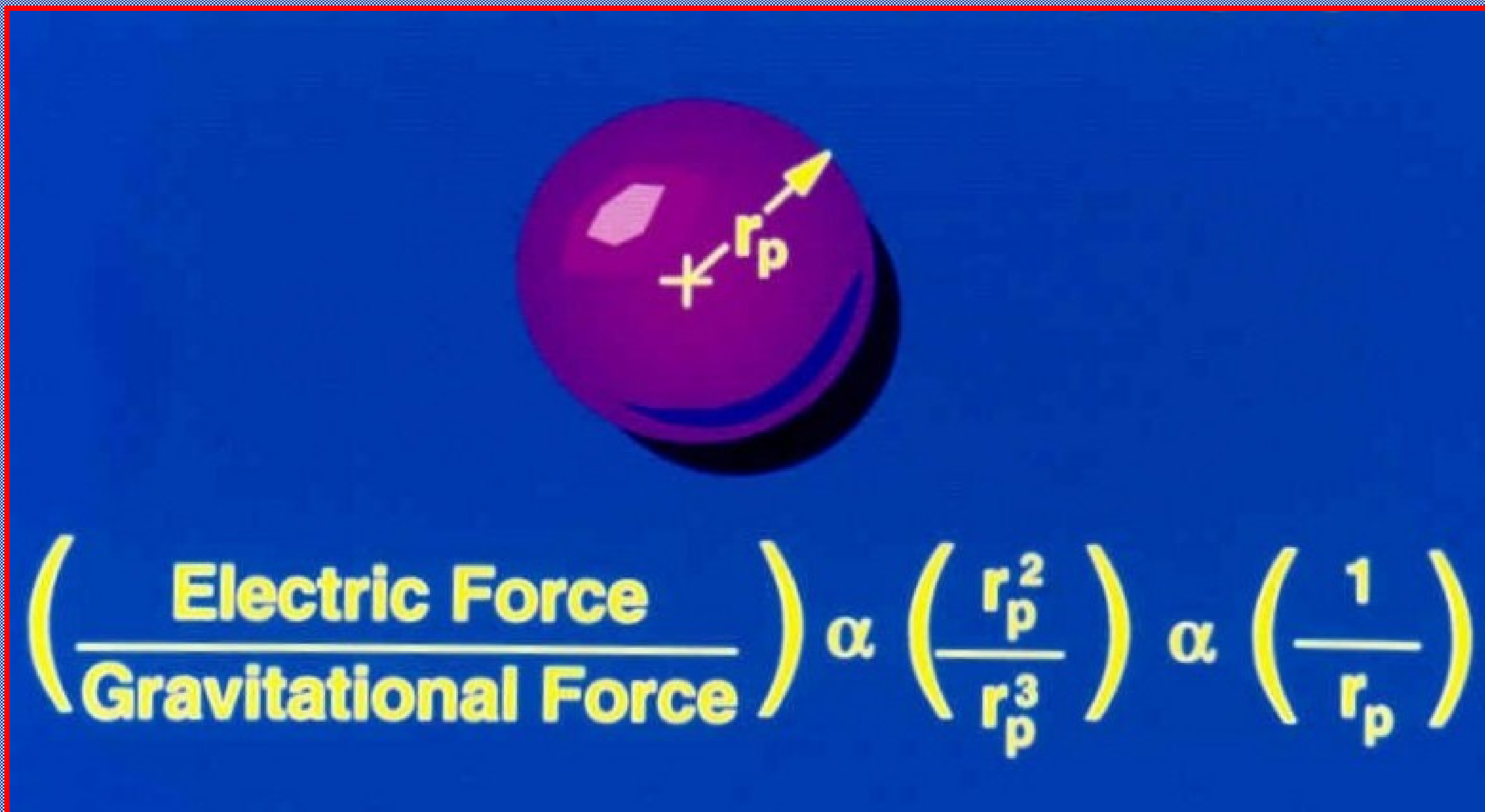
Insecticides

Herbicides

Fungicides

- **Worldwide Usage – • 2.3B kg (a.i.) / Year • $32B**
- **Downside – • Environmental • Energy Sequestered (520×10^{15} J / Year) • Acquired Resistance**

RATIONALE FOR ELECTRIC FORCE

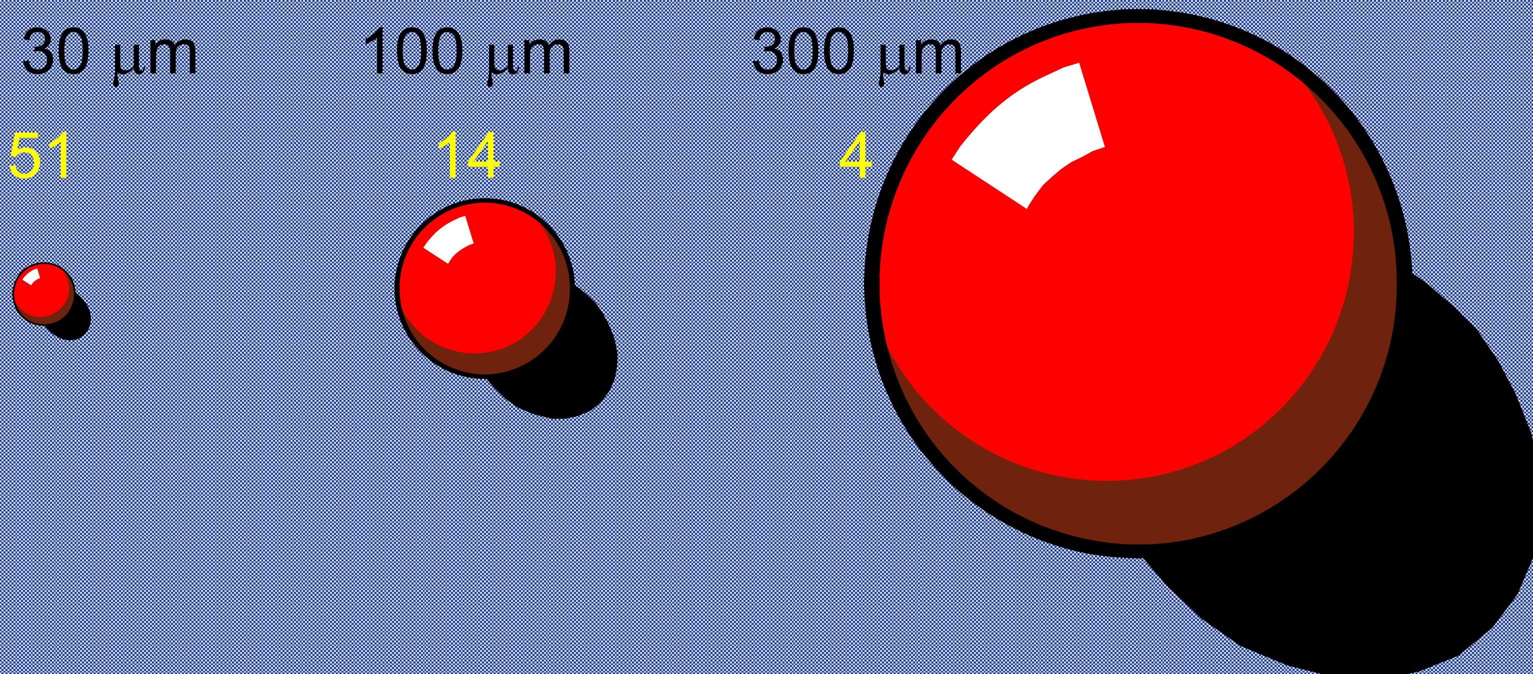


DOMINANCE OF ELECTRIC FORCE VS. GRAVITATIONAL FORCE ON DROPLET

Ratio [$\boldsymbol{F}_{electric} / \boldsymbol{F}_{gravity}$] = [$q_p \boldsymbol{E} / m_p \boldsymbol{g}$] α [$\boldsymbol{E} / d_p$]

where routinely have q_p / m_p = 10 mC/kg & $\boldsymbol{E}$ = ½ kV/cm

dia. d_p =	30 µm	100 µm	300 µm
$\boldsymbol{F}_e / \boldsymbol{F}_g$ =	51	14	4



CRITICAL R&D REQUIREMENTS FOR RELIABLE ELECTROSTATIC SPRAYING

- Spray Droplet Charging – $\boldsymbol{F}_p = q_p \boldsymbol{E}$
- Airborne Charge Retention
- Target Electrical Interactions
- Deposition Field Optimization – $\boldsymbol{F}_p = q_p \boldsymbol{E}$
- Implementation and Efficacy

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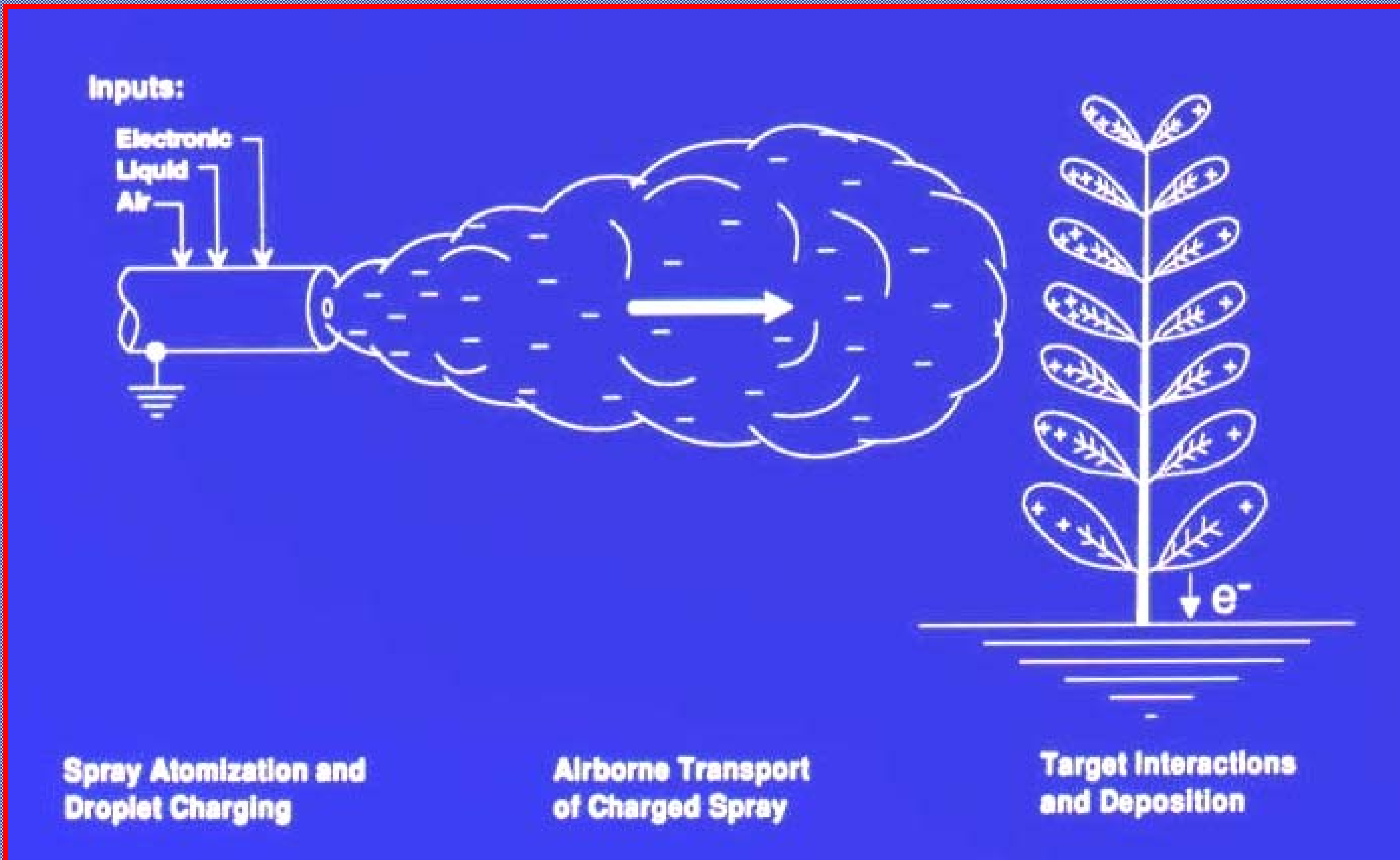
ELECTROSTATIC CROP-SPRAYING PROCESS



PARTICULATE CHARGING METHODS

- Ionized-Field "Corona" – $q_p \alpha (K, r_p^2)$
- Contact
- Electrostatic Induction – $\rho < 10^4$ ohm·m
- Electrohydrodynamic (EHD) – $\rho > 10^7$ ohm·m
- Triboelectrification

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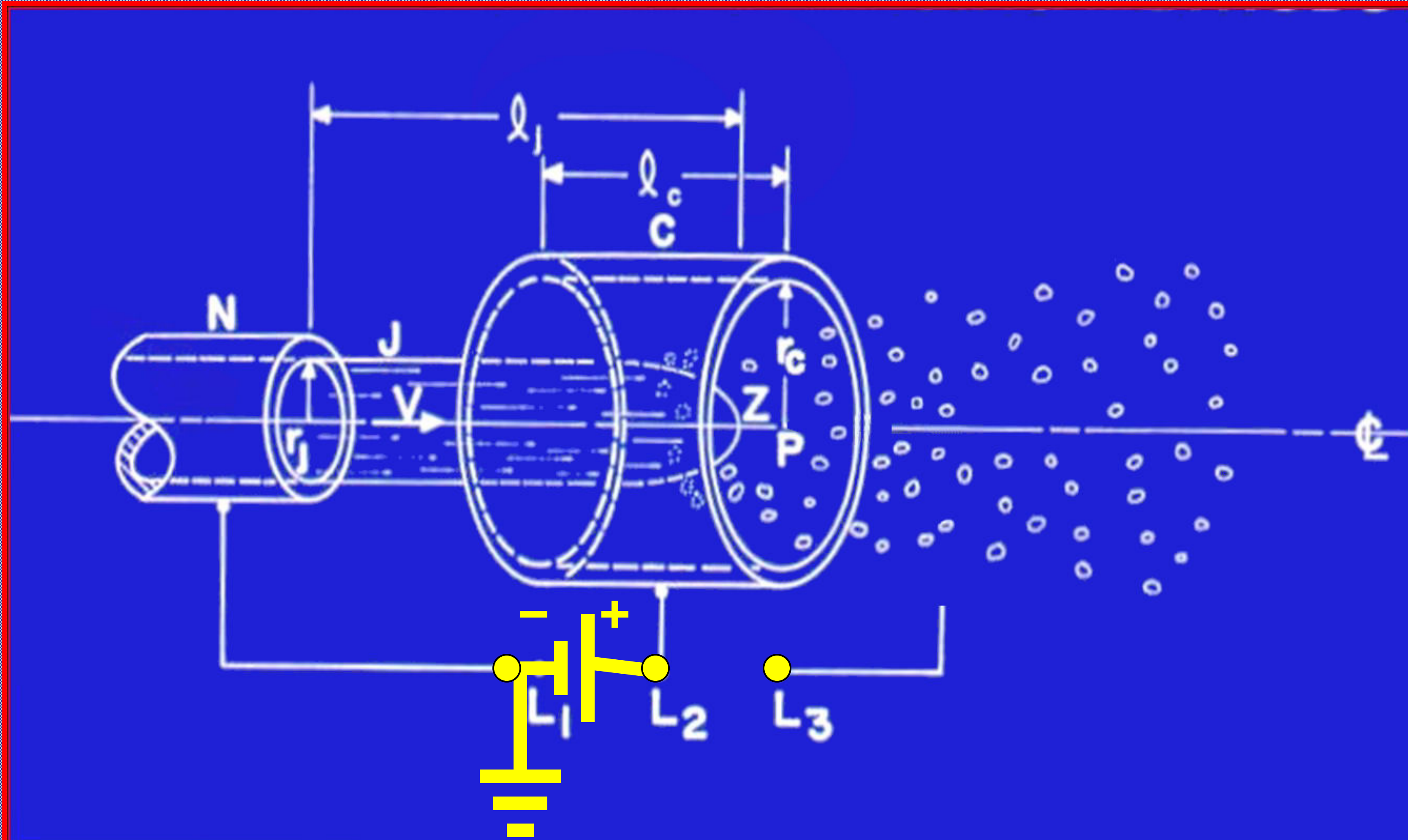
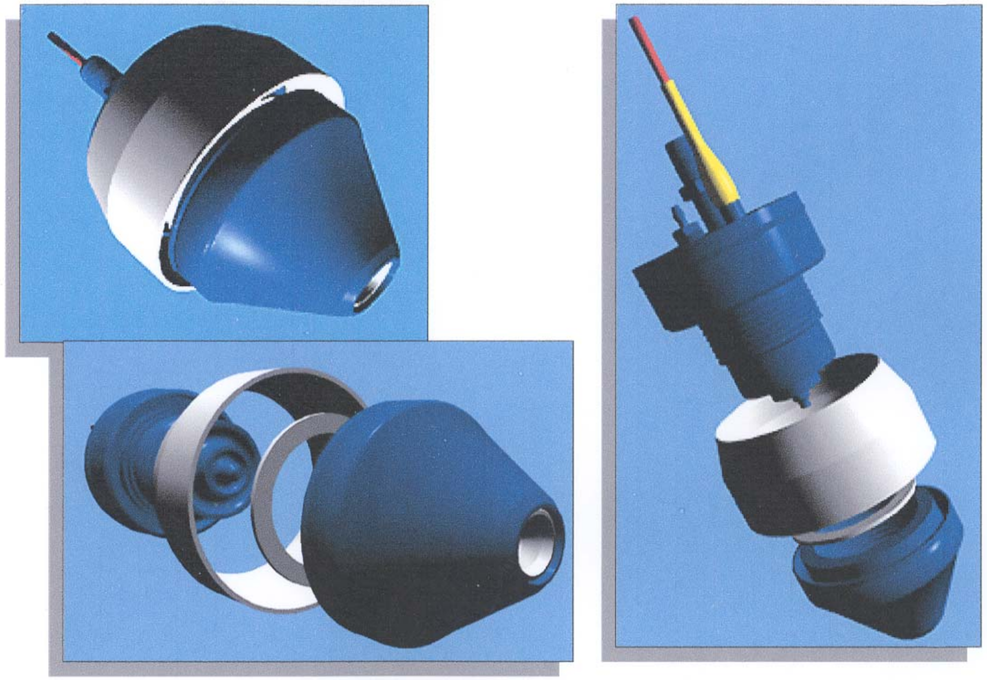
ELECTROSTATIC INDUCTION CHARGING



$$\tau = K\rho\varepsilon_o$$

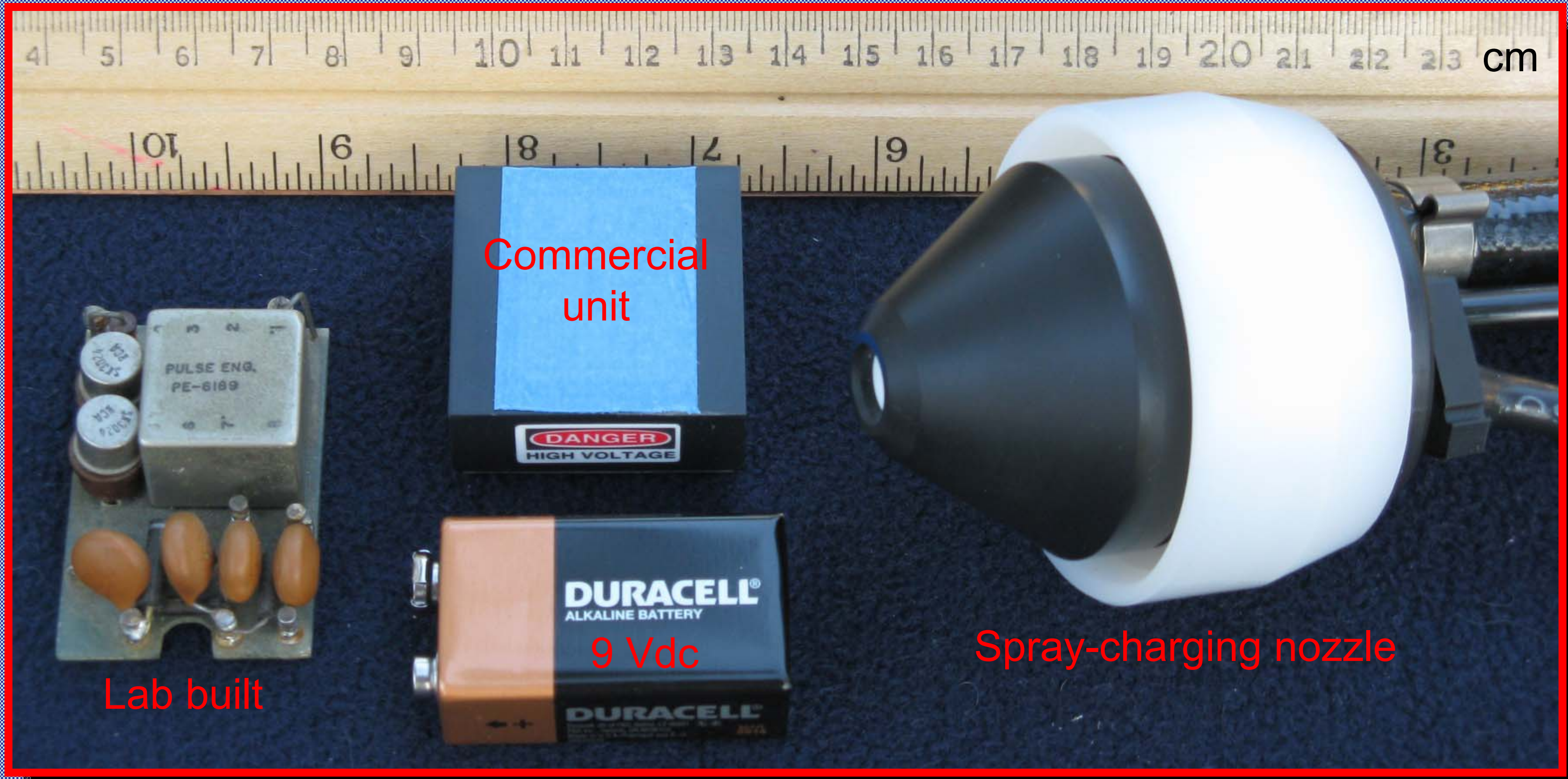
INDUCTION SPRAY-CHARGING NOZZLE



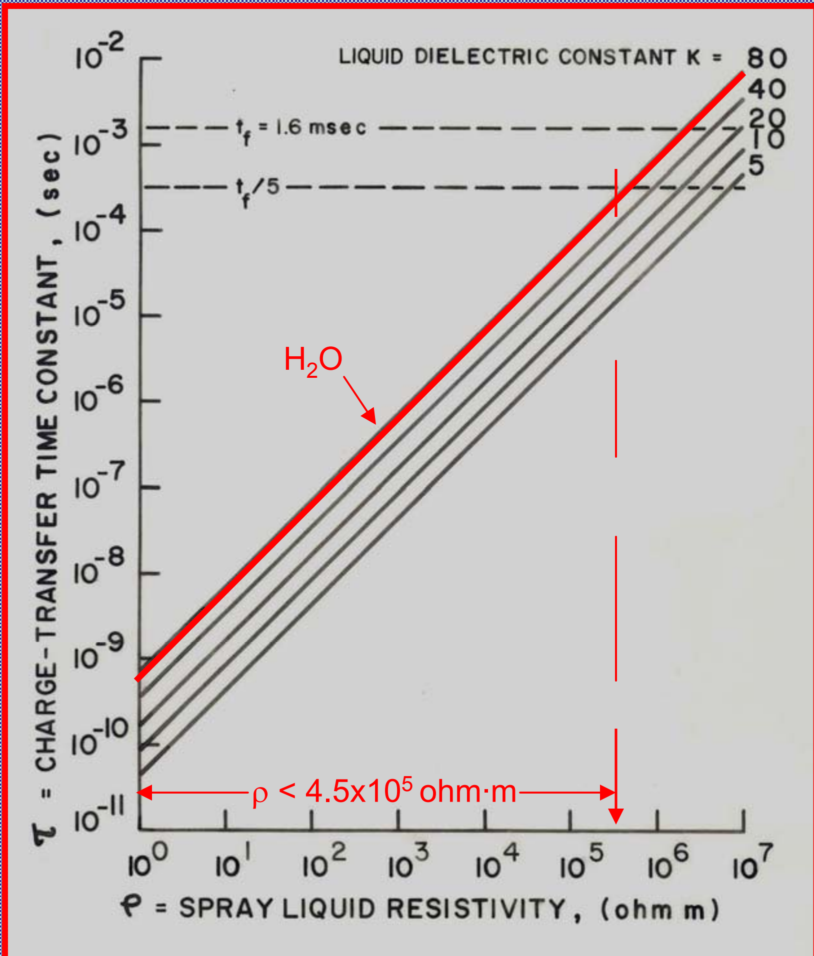
- Pneumatic atomizing ~ 207 kPa
- Spray droplet spectrum ~ 30 μm VMD
- Embedded induction electrode ~ 1.6 MV/m @ 1 kV
- Conductive spray liquids ~ 10^{-1}-10^{4} ohm • m
- Charge-to-mass performance ~ 10 μC/kg • V

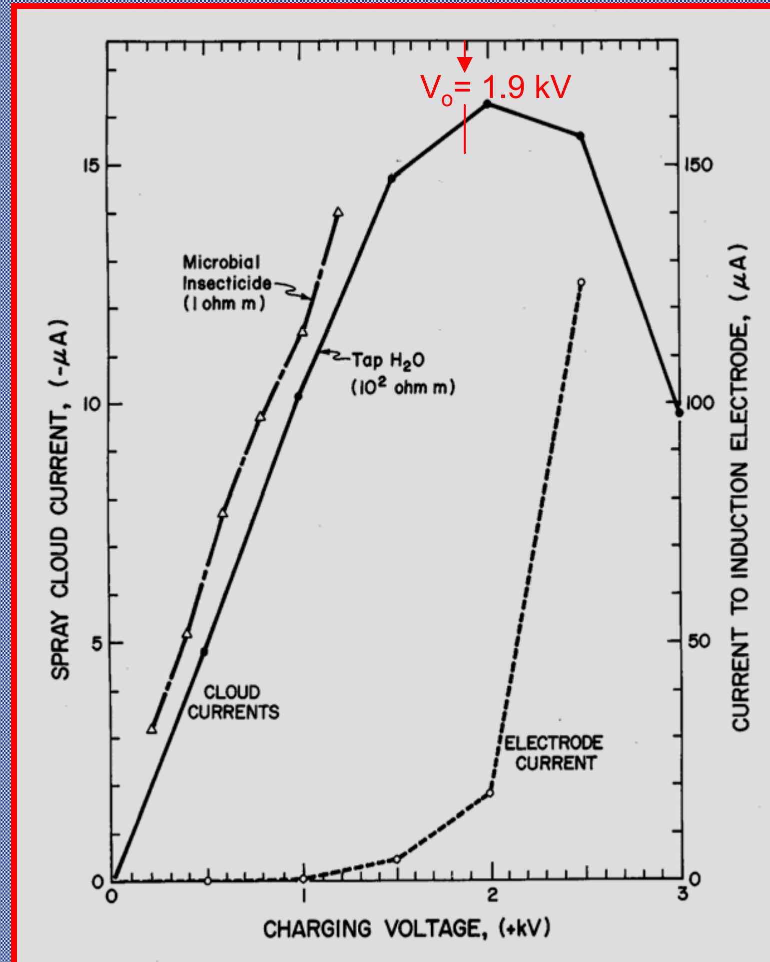
SIMPLIFIED ELECTRONIC VOLTAGE SUPPLY FOR INDUCTION SPRAY-CHARGING NOZZLE

- *Safe* – Input 9-12 Vdc from battery for 1-1.5 kVdc output
- *Low Power / Low Capacitance* – Typically < 100 mW
- *Compact* – < 50 grams permits embedding at each nozzle



DOMAIN OF ELECTROSTATIC-INDUCTION SPRAY CHARGING



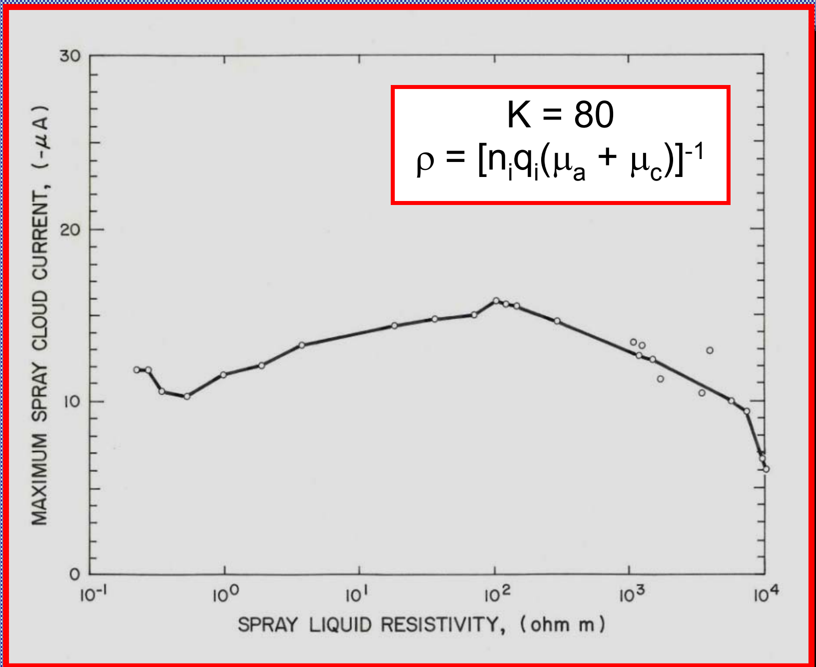


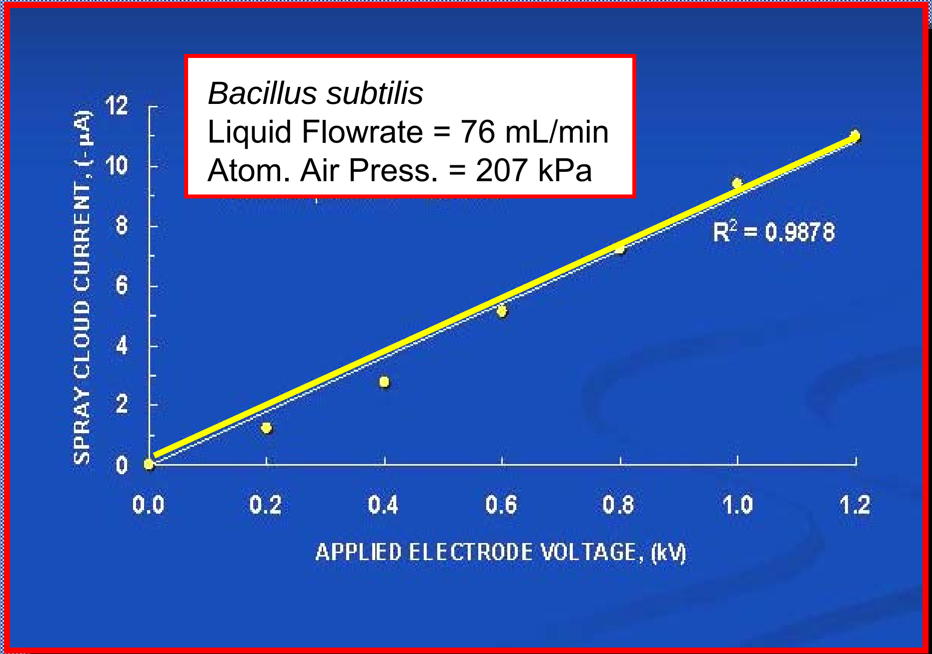
$$\tau = K\rho\varepsilon_o$$

$$E_j = V/r_j \ln(r_c/r_j)$$

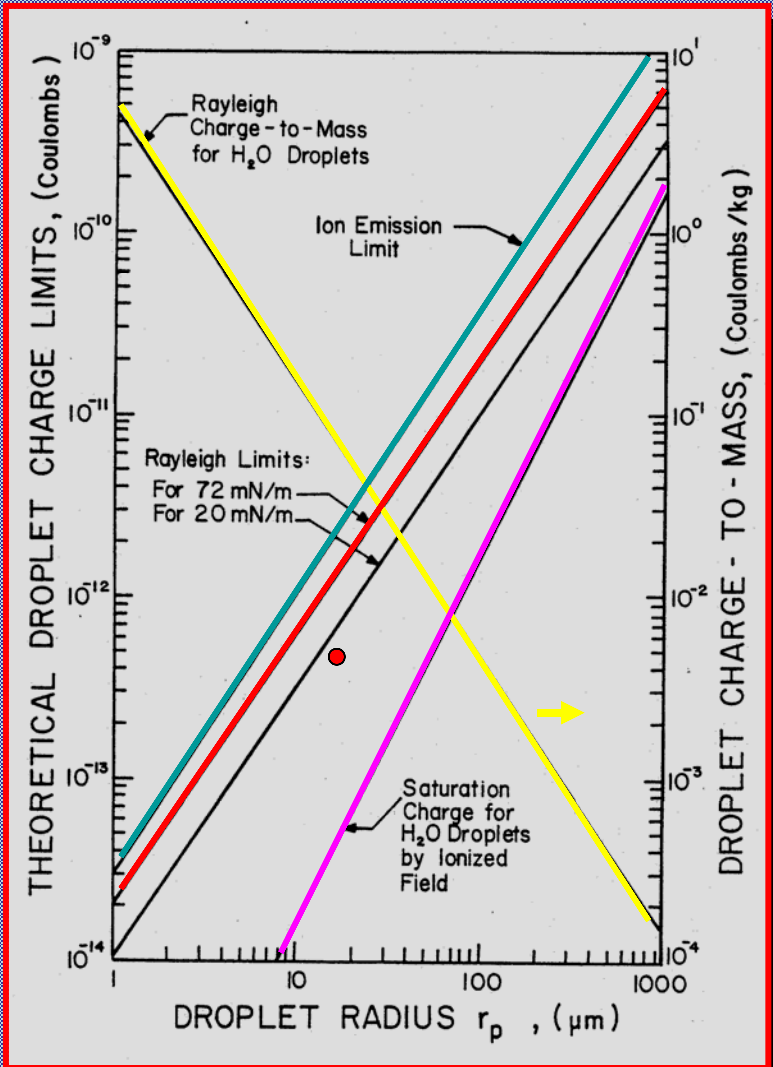
$$V_o = (30 r_j \delta + 9\sqrt{r_j \delta}) \log(r_c/r_j)$$

INDUCTION SPRAY-CHARGING RESPONSE





THEORETICAL MAXIMUM DROPLET CHARGE LIMITS



Rayleigh Charge Limit as Based upon Onset of Hydrodynamic Instability of the Spherical Liquid Surface

$$q_p = 8\pi\sqrt{\varepsilon_0\Gamma}\, r_p^{3/2}$$

Ion-Emission Charge Limit as Based upon Dielectric Breakdown of Air Just Off the Droplet's Surface

$$q_p = 7.35\times10^5\varepsilon_0[r_p^2 + 4.8r_p^{3/2}]$$

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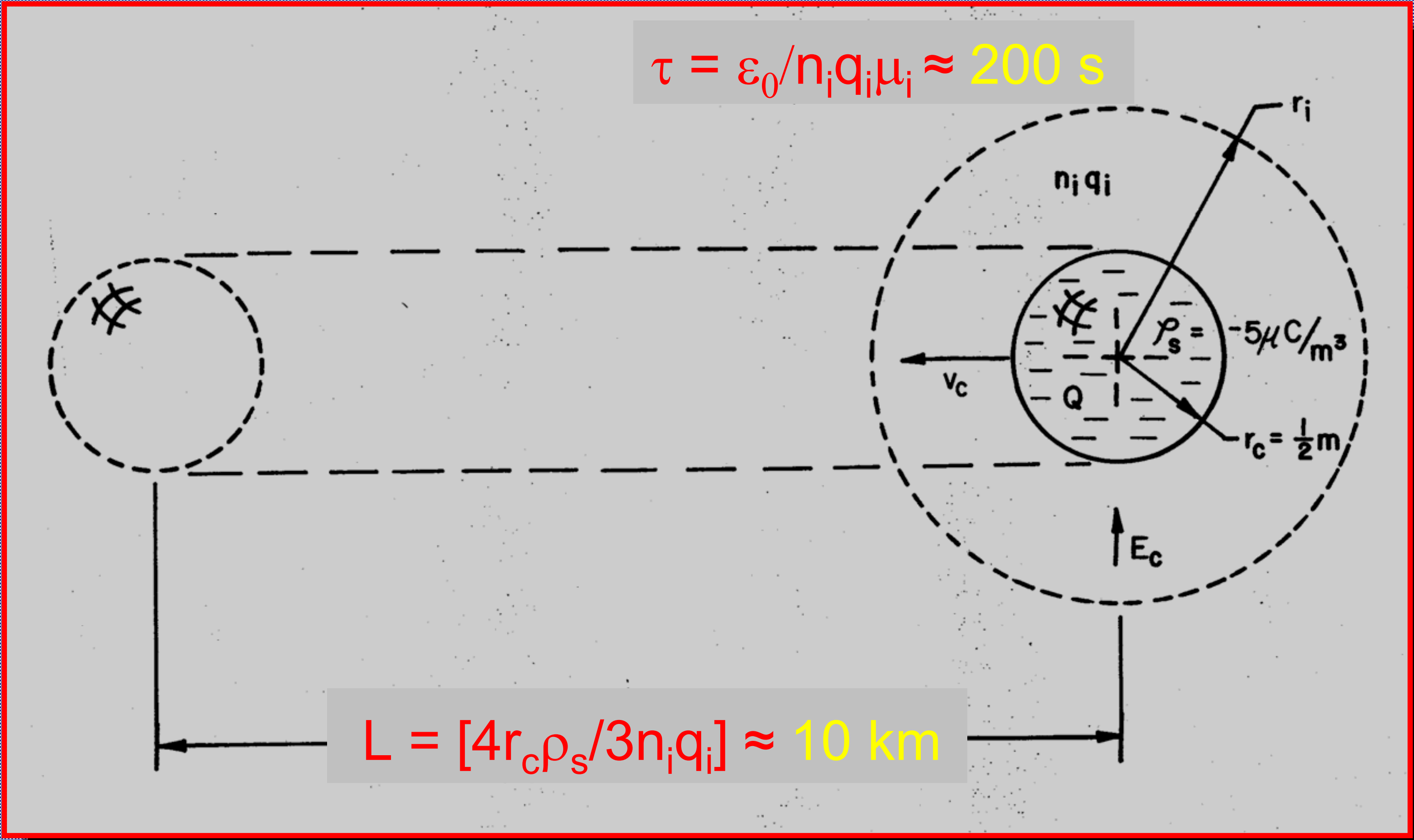
- Implementation and Efficacy

AIR-ION NEUTRALIZATION OF CHARGED SPRAY CLOUD



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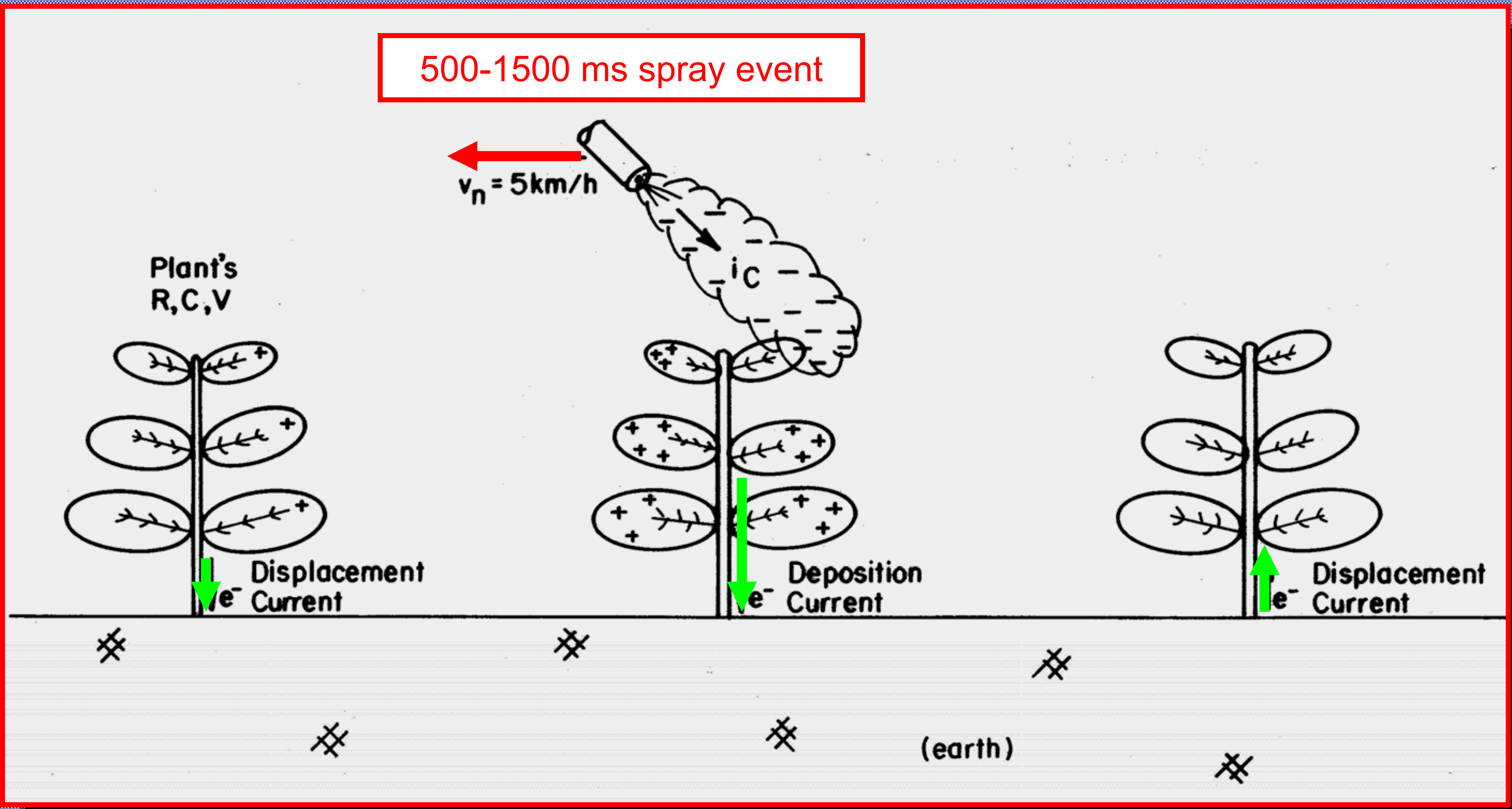
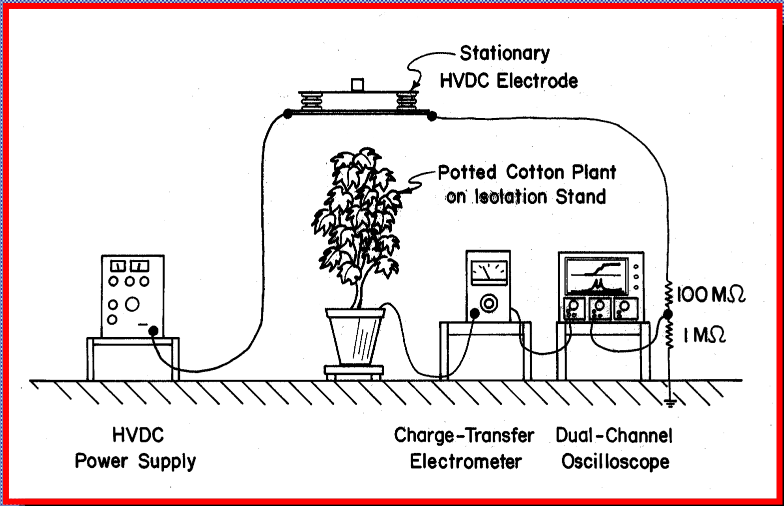
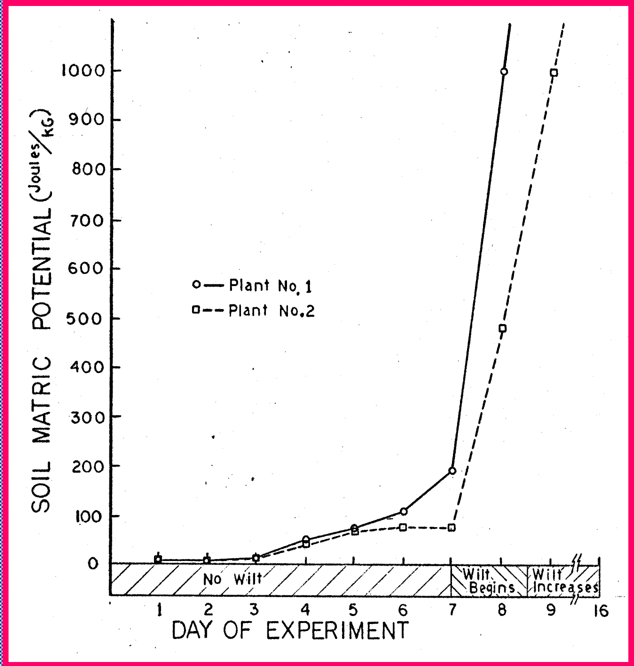
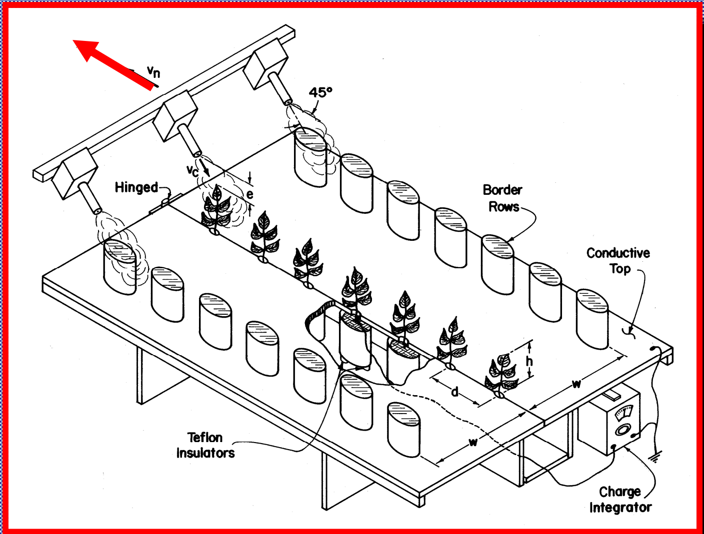
DISPLACEMENT CURRENTS IN TARGETS DURING ELECTROSTATIC SPRAYING



DISPLACEMENT CURRENTS MEASURED IN LIVING PLANTS



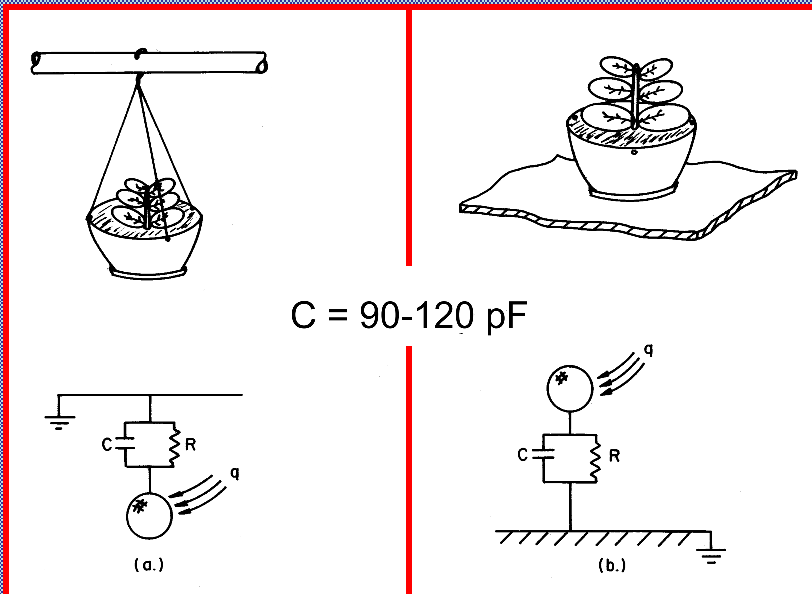


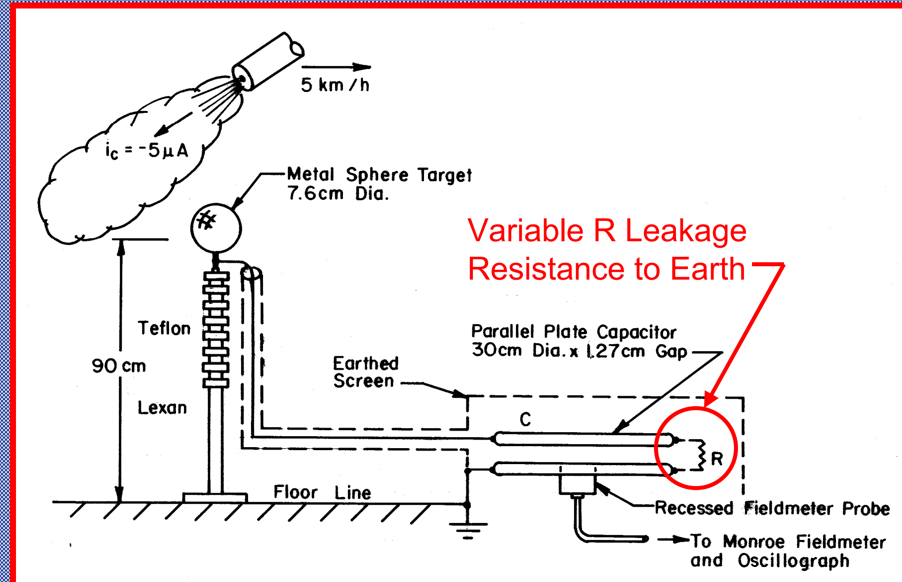


CONCLUSION:

Drought stress does not significantly impede the flow of displacement currents in living plants undergoing electrostatic spray applications.

RC CIRCUIT MODEL OF PLASTIC-POTTED GREENHOUSE PLANTS





$$V_0 = q/C$$

$$V = V_0 e^{-t/RC}$$

Unimpeded Deposition for

$$\tau = RC < 0.1 \text{ s}$$

EXPERIMENTAL EFFECTS OF VARYING GROUNDING RESISTANCE OF TARGETS

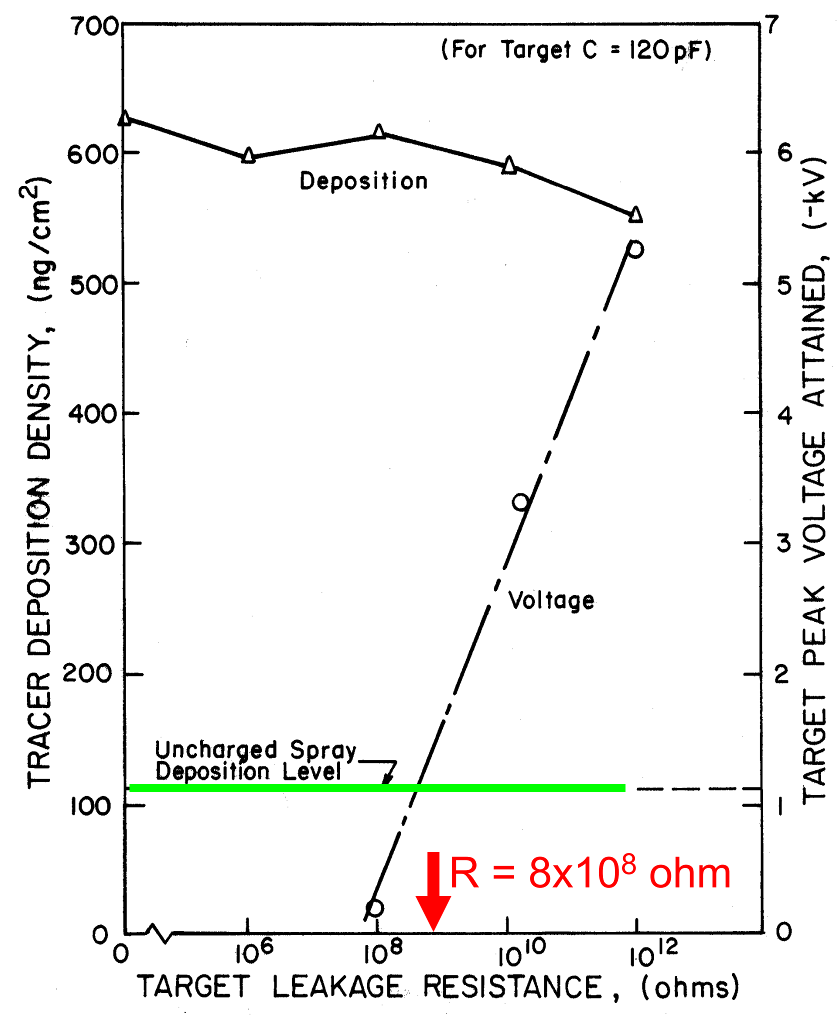
Spraying Event ≈ 500 ms using

-4 mC/kg charge-to-mass spray.

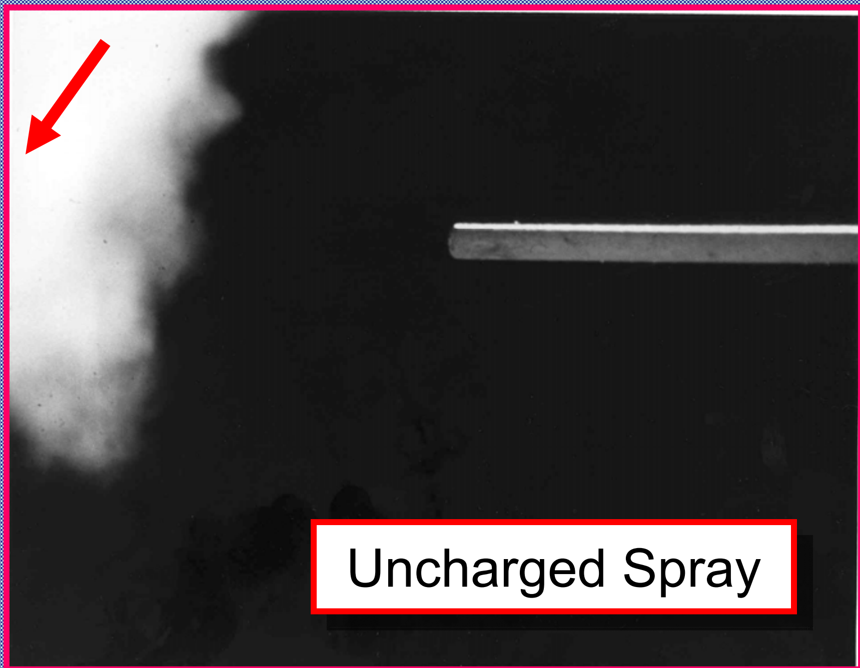
Set τ = 500 ms / 5 = 0.1 s = RC.

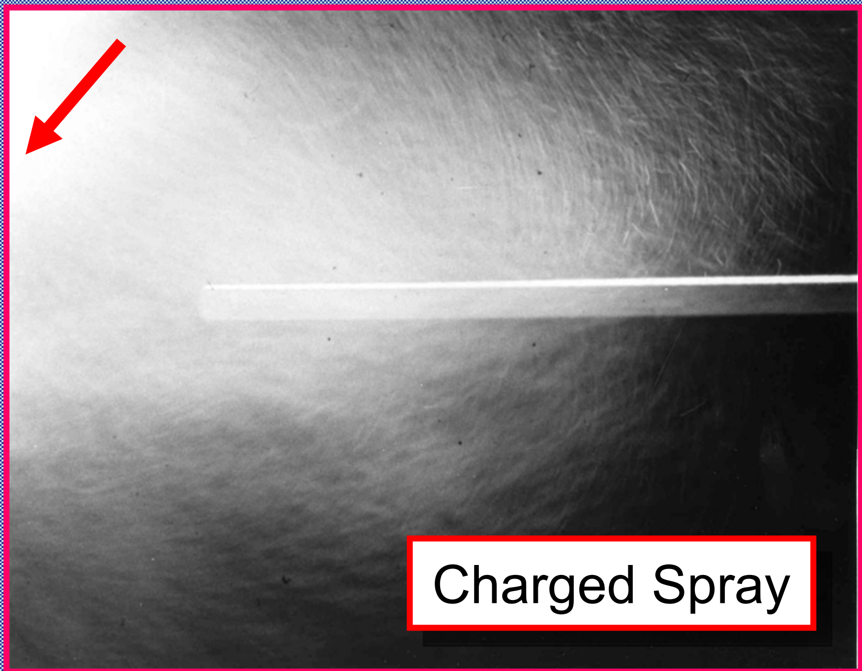
For C = 120 pF, Target R-Value

Must Obey R < 8×10^8 ohms.



ADEQUACY OF TARGET CONDUCTIVITY TO EARTH: WOODEN-DOWEL EXAMPLE





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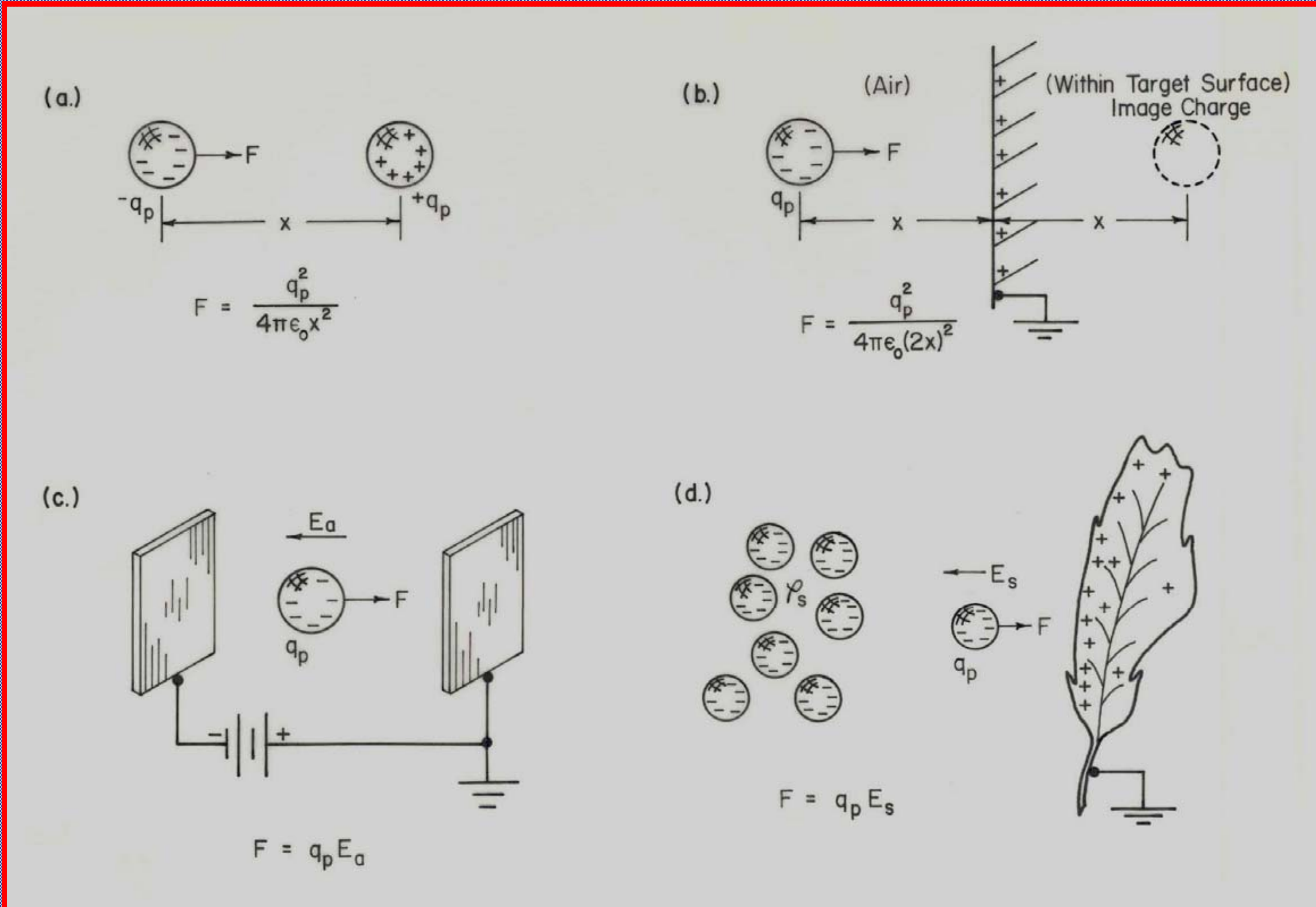
ELECTRIC FORCE OPTIONS FOR AIRBORNE PARTICULATE CONTROL



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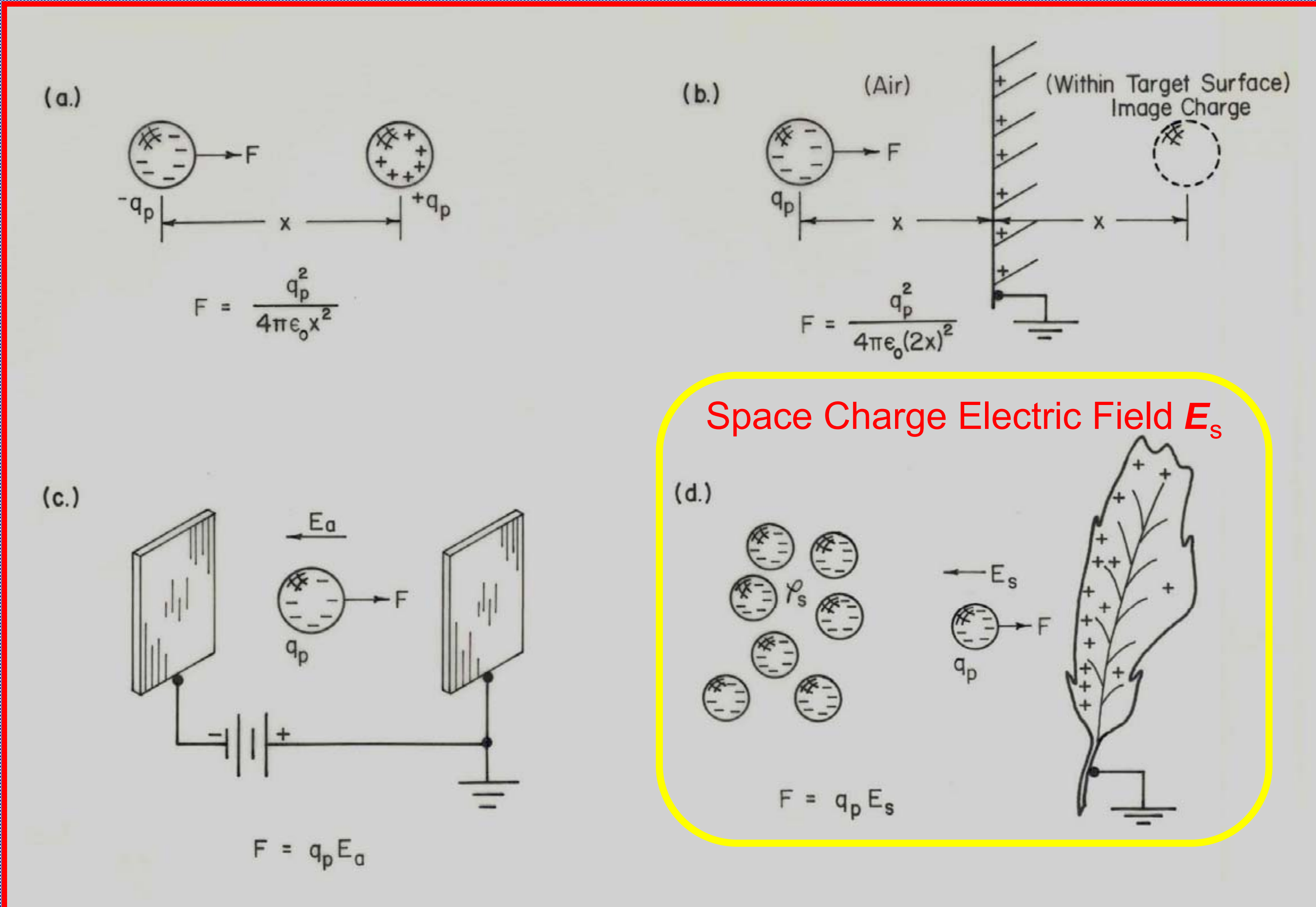
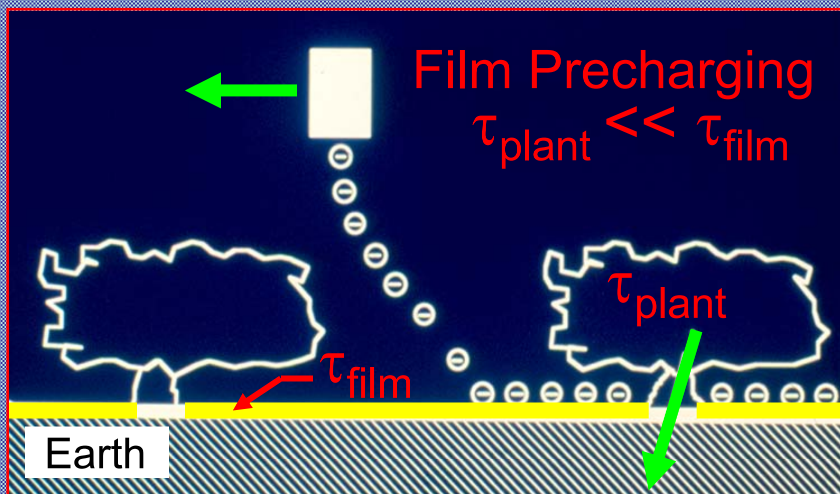
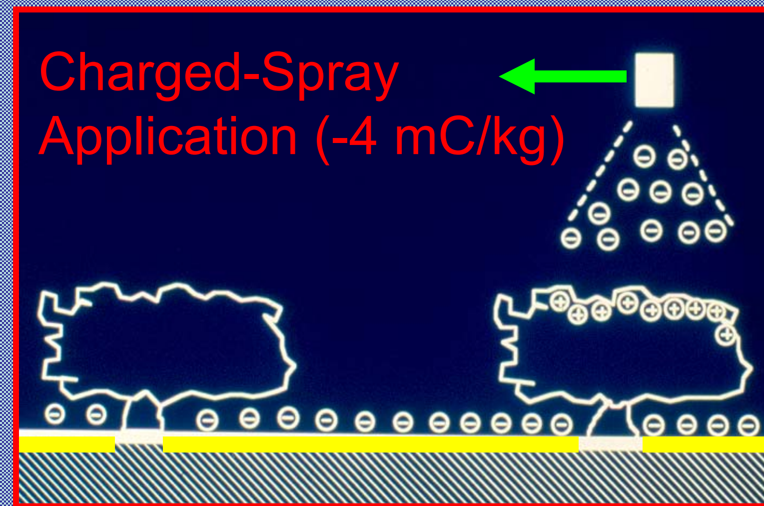


ELECTRODEPOSITION ENHANCEMENT BY PRECHARGING DIELECTRIC BOUNDARY





ELECTRIC FIELD REDIRECTION BY SURFACE PRE-CHARGE CAPTURED ON DIELECTRIC FILM

Film Pre-charge ($-\mu C/m^2$)	Spray Deposition (ng tracer/cm^2)	
	Lower Hemisphere	Dielectric Film
15	277	72
0	137	93
uncharged spray	45	116

Note - Spray charged to -4 *mC*/kg

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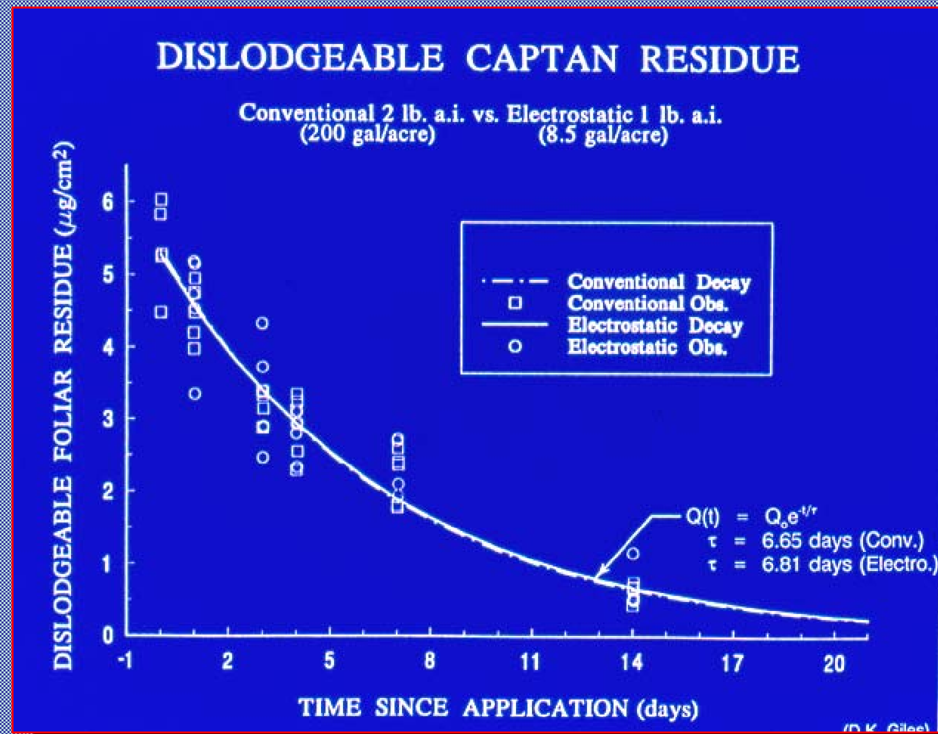
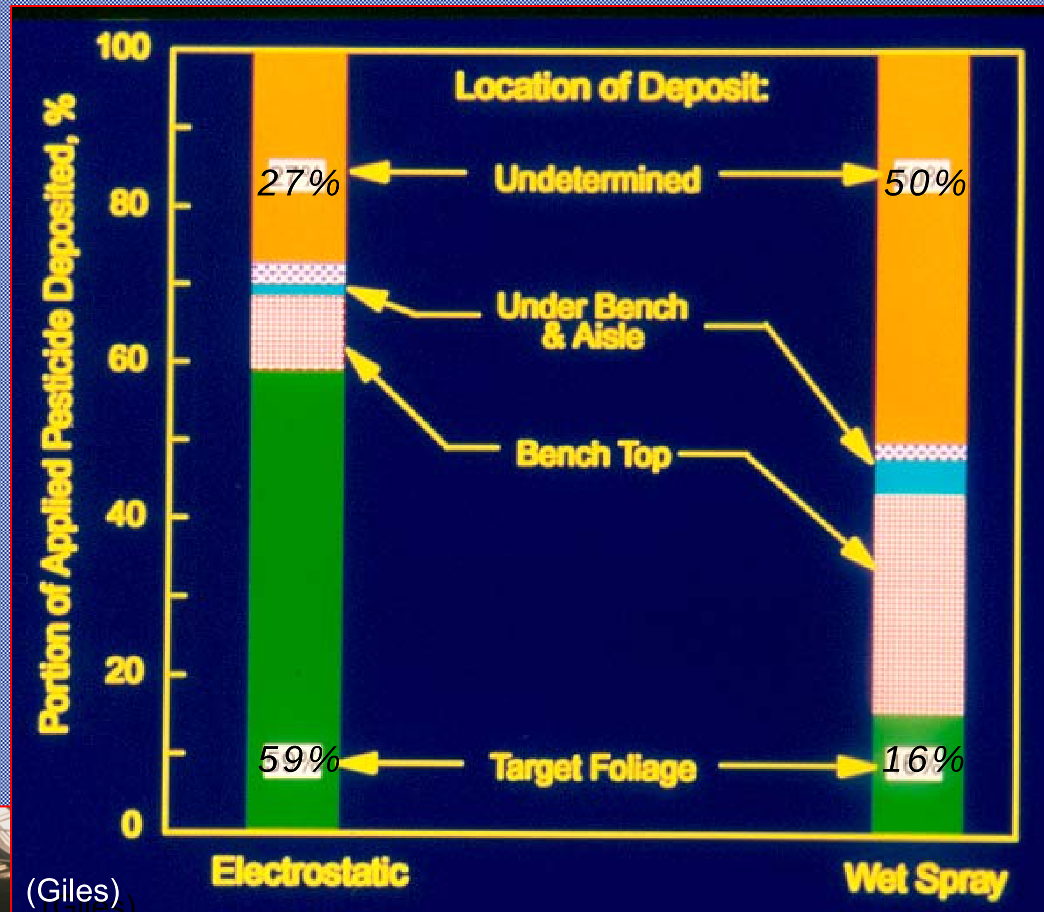
TECHNOLOGY TRANSFER FOR ELECTROSTATIC FIELD SPRAYERS



CALIF. STRAWBERRIES:

ES Foliar Dep.using Half-Rate a.i. = Conv. Dep. using Full-Rate.

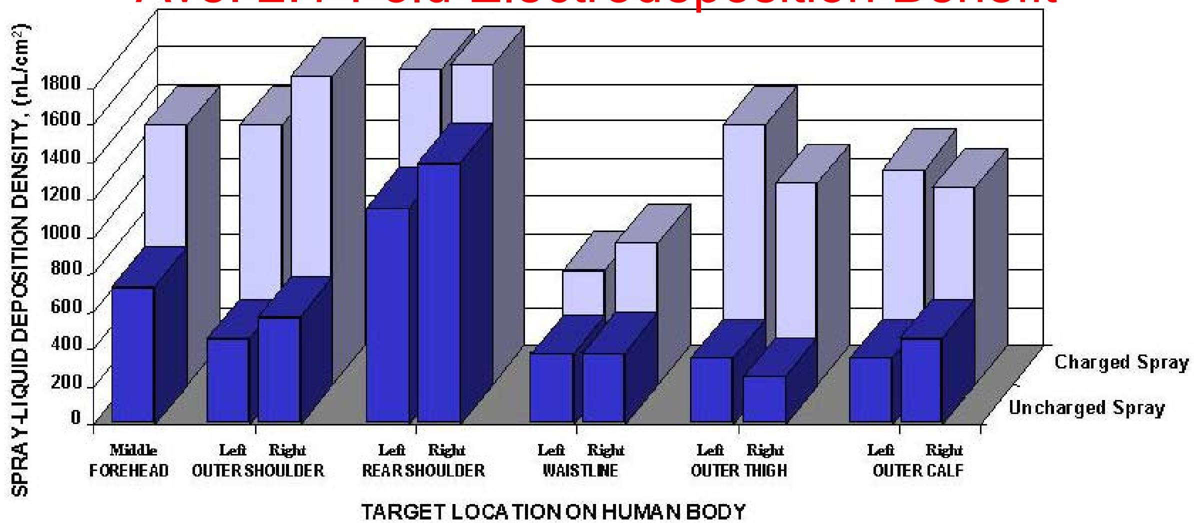
TECHNOLOGY TRANSFER FOR ELECTROSTATIC GREENHOUSE SPRAYERS



Greenhouse Foliage Results:
ES Dep. = 3.7X Conv.

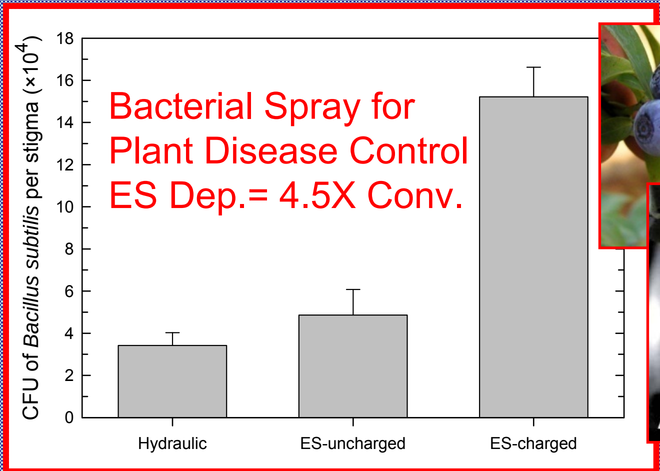
ELECTROSTATIC SPRAY APPLICATIONS TO THE HUMAN BODY

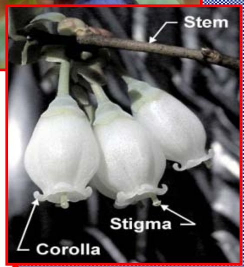
Ave. 2.1-Fold Electrodeposition Benefit

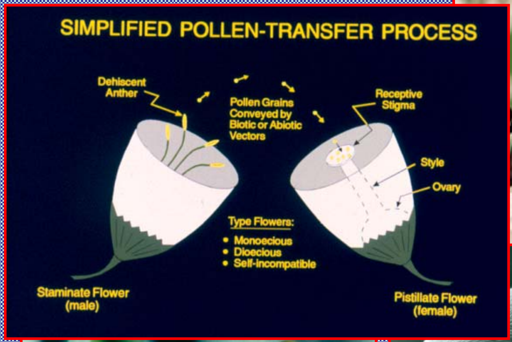


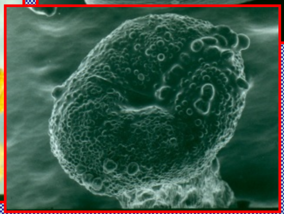
Bioterrorism Countermeasure

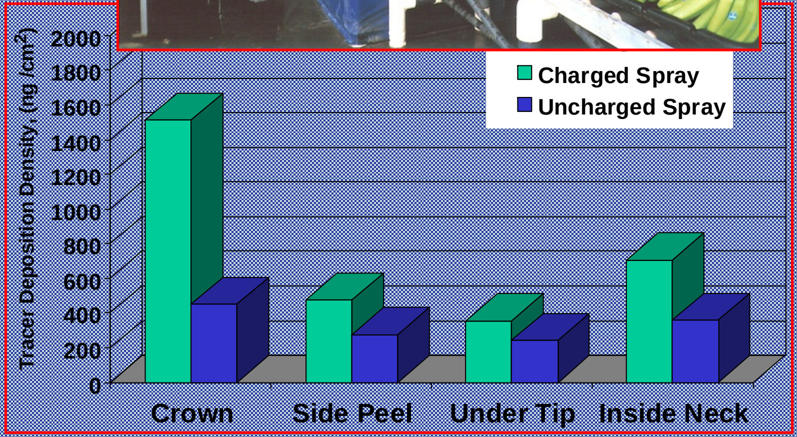
ADDITIONAL ELECTROSTATIC SPRAYS



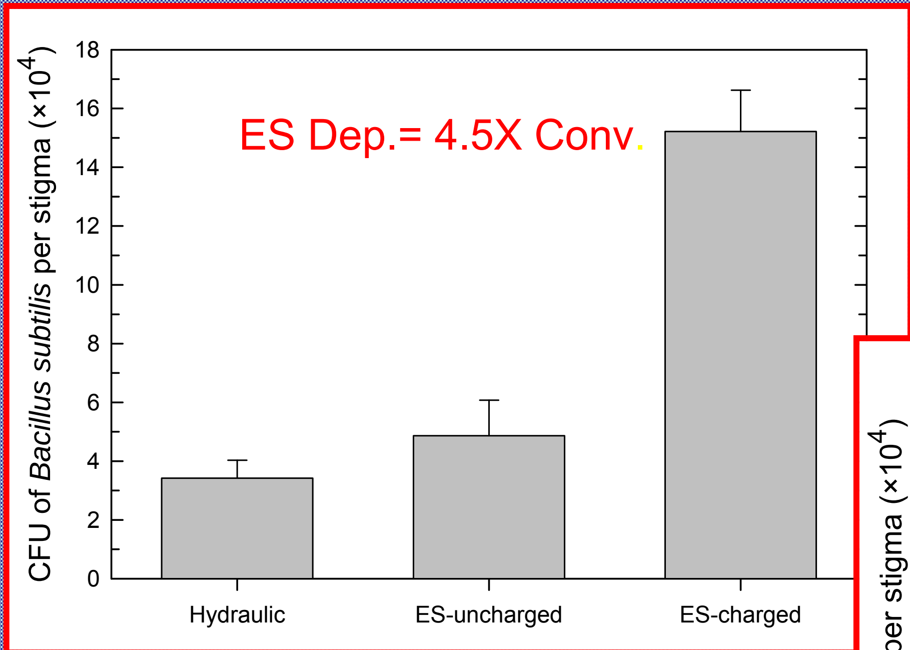




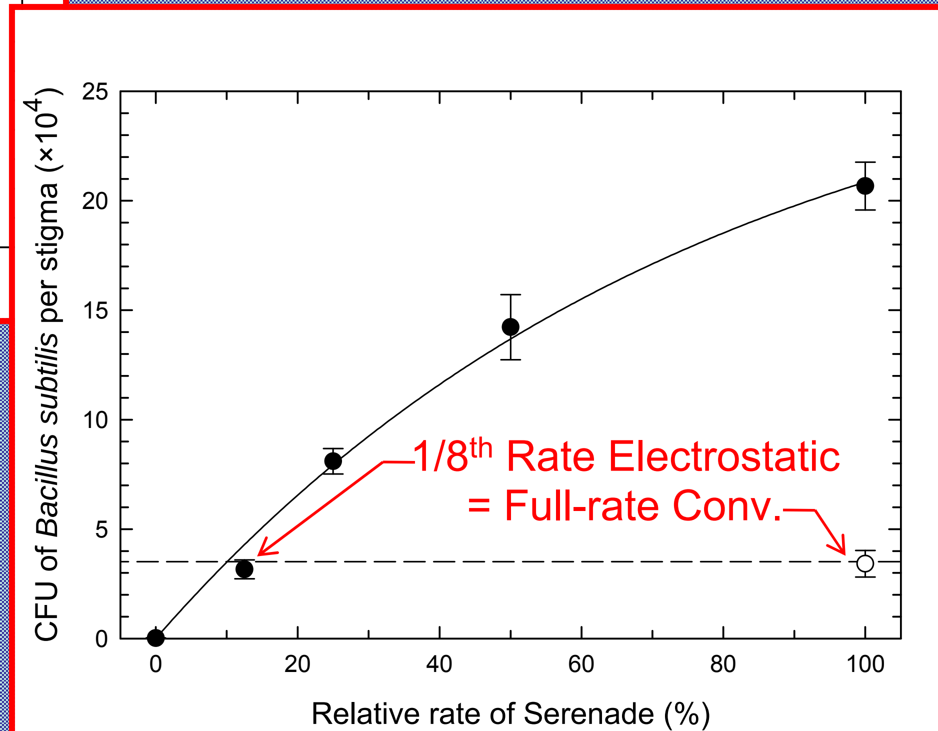




TYPICAL REDUCTION IN TOTAL ENVIRONMENTAL LOAD OF PESTICIDE ACTIVE INGREDIENT

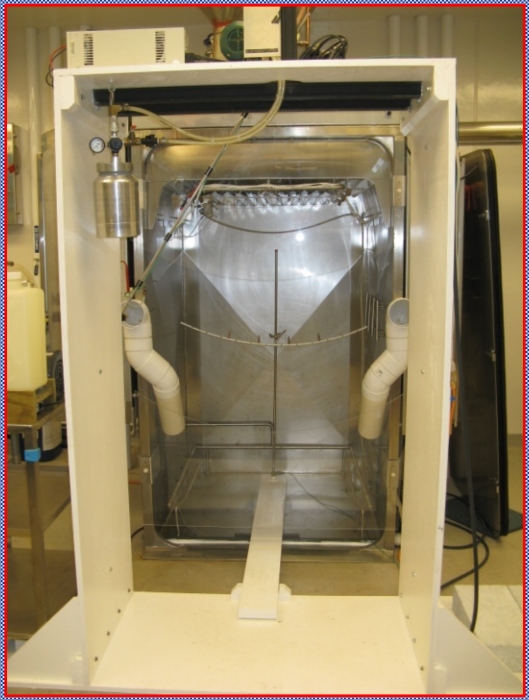


Serenade Biofungicide on Blueberry Plants



ELECTROSTATIC DEPOSITION OF ANTIMICROBIAL SPRAYS FOR SURFACE DISINFECTION

Shawn Lyons – MS FS&T



- *Salmonella enterica*
- *E. coli O157:H7*
- *Listeria monocytogenes*
- H1N1
- SARS
- MRSA

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Electrostatic Attraction of Charged Spray

IMPEDIMENTS TO IMPLEMENTATION OF IMPROVED SPRAY-APPLICATION TECHNOLOGIES

- Well intentioned efforts to address the off-target spray-drift problem of conventional hydraulic-nozzle technology by promulgating "broad-brush" standards (*e.g.*, ASABE, ISO) & pesticide-drift labels (*e.g.*, EPA-OPP-PRN2009-0628) which specify minimum values for:
- Spray-volume dispensed per acre
- Droplet diameter (*e.g.*, 90 μm VMD)
- While giving no "credit" for reducing (*e.g.*, halving) the amount of pesticide a.i. dispensed into the ecosystem… as have UK drift regulations (LERAP) since 2001.

Additional Information

Academic:

- edlaw@engr.uga.edu
- www.engr.uga.edu/people/faculty/law
- www.ael.engr.uga.edu/downloads/ElectrostaticSprayingBlueberry.mpg

Commercial:

- www.electrostaticspraying.com
- www.maxcharge.com