

Development of bioelectrode for electrostatic misting system

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Abstract: Electrostatic spraying has been one of the solutions for the inefficiencies of traditional spraying. However, if the plant target surface is not well conductive or is insulated from the ground, the deposition will occur for only a short period. This study was conducted to determine the effects of the bioelectrode's geometry for efficient flow of electrostatic charge and evaluate its efficiency for electrostatic misting systems. This study utilized a 3x3 factorial arranged using a completely randomized design (CRD). The treatments were divided into two (2) groups: control and experimental. Under the control group are non-electrostatics (NES) and electrostatics (ES). Under the experimental group, nine (9) bioelectrode configurations were used in conjunction with an electrostatic misting system, charging mists at 3 kV and an operational pressure of 540 kPa. A plant sample placed 30 cm away from the nozzle at 25 cm altitude was used. Results show that the use of bioelectrode with a 3 cm coil diameter and 2-4 cm spacing of windings is particularly effective in increasing deposition density, significantly outperforming the control group and other coil configurations. In terms of the area covered, analysis of variance (ANOVA) showed significant differences among the means of different treatments at a 5% level. However, Tukey's HSD test shows that none of the treatments significantly differ. In terms of swath width, 4 cm diameter and 2 cm spacing of windings has the widest swath width, considering the deposition density of 20.7 droplet cm⁻² and 41.2 droplet cm⁻² at 40 cm distance away from the nozzle. The system's unit cost of investment is \$1.47 m⁻².

Keywords: electrostatic spraying, electrostatic misting system, non-electrostatic, bioelectrode, deposition density, area covered, swath width

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1 Introduction

Electromagnetism is one of the four fundamental forces of nature. It has been used in various applications across several industries due to its versatility and efficiency, enabling us to apply known and controllable forces to elements or structures without contact (Saint Martin et al., 2017). As the name suggests, electromagnetism takes two forms: electrostatic and magnetic. The electrostatic force is

the attraction of stationary electric charges. In contrast, the magnetic force is when there is an attraction or repulsion between electrically charged particles that is due to their motion. Utilization of the principle offers a variety of applications, and an example of this is in an agricultural setting, where there is a need for efficient and precise application of plant protection and irrigation through electrostatic spraying.

Foliar application requires enough mist in the plant canopy to be distributed homogeneously with a minimal

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loss. Spraying systems need to efficiently deposit all the water particles into the plant canopy as required by the plant. However, traditional or conventional spraying systems cannot meet these criteria because a fraction of the sprayed liquid falls to the ground by gravity (Campos et al., 2020), while some is lost due to drift (Pascuzzi et al., 2020). Several studies have led to the introduction of electrostatic spraying to address these inefficiencies. The study conducted by Salcedo et al. (2023) has proven to enhance deposition on target surfaces by applying electrostatic field principles. Similarly, Sánchez-Hermosilla et al. (2022) found that an electrostatic hand-held sprayer enhances deposition effectiveness on plant canopies and minimizes ground losses compared to a standard hand-held sprayer. The charges present at the plant canopy greatly influence the movement of the electrostatically charged mists. For the mists to be attracted to the plant canopy, they should be oppositely charged following the principles of Coulomb's Law, like charges repel and unlike charges attract. However, electrostatic spraying technologies generally have several parameters that affect their efficiency, particularly on the deposition properties at the target surface. Studies suggest several external parameters, such as the altitude and the properties of the target plant. According to Law and Cooper (1989) deposition will only occur briefly if the plant's target surface is insufficiently conductive, insulated, or unearthed, as it will accumulate charge from the electrostatically charged mists and be completely charged with the same polarity. Thus, it repels the newly electrostatically charged mists approaching the target plant. Improvement of spray deposition on the plant's canopy involves the manipulation of the charges of the mists and the plant canopy itself, which can be done by electrostatically charging the mists and improving the electrostatic field at the plant canopy, which would entail a supplemental electrode to transfer the ions to the ground.

According to Sánchez-Hermosilla et al. (2022), electrostatic spraying involves subjecting the droplets to a positive electric field, inducing them to become negatively charged. The plant canopy has a neutral

charge, but when the electrostatically charged mists approach, the negative charge in the canopy dissipates, resulting in positively charged leaves that attract the electrostatically charged mists. Enhancing the charge outflow at the plant canopy by allowing the built-up electrostatic charges flow to the ground can avoid neutralization, which would, in turn, attract the mists suspended in air that were not pulled due to the repulsion of neutralized or negatively charged target surface. As evident in the study conducted by Gao et al. (2023), where they investigated the effect of a root core electrode along with several other parameters on the droplet adhesion of charged particles on the roots of aeroponically grown plants, the results show that the root droplet adhesion increased by about using a root core electrode.

Thus, this study aimed to configure a bioelectrode to allow the electrostatic charge outflow at the plant canopy. This aim determines the effects of the variables for configuration on the efficiency of this emerging approach in electrostatic spraying.

2 Materials and methods

The study was conducted at the University of Southeastern Philippines (USEP) Tagum-Mabini Campus, Apokon, Tagum City, Davao del Norte, Philippines (7°25'15"N, 125°49'51"E, at 23 meters asl). The electrode configuration was done explicitly at the university farm shop, and the experimental trials were conducted in laboratory conditions at the designated room in the University Computer-Aided Drafting (CAD) Facility. The study was conducted from January to May 2024. This study was done at three levels of coil diameter at levels 2 cm, 3 cm, and 4 cm and spacing of windings at levels 2 cm, 4 cm, and 6 cm following a 3×3 factorial arranged using a Completely Randomized Design. The design performance evaluation encompasses three (3) experimental replications for each treatment.

2.1 Development of bioelectrode

The electrode material used was copper wire (AWG 12) and was configured and wound up manually. The electrode coil length was fixed at 15 cm

and an extra length of 10 cm to penetrate the ground.

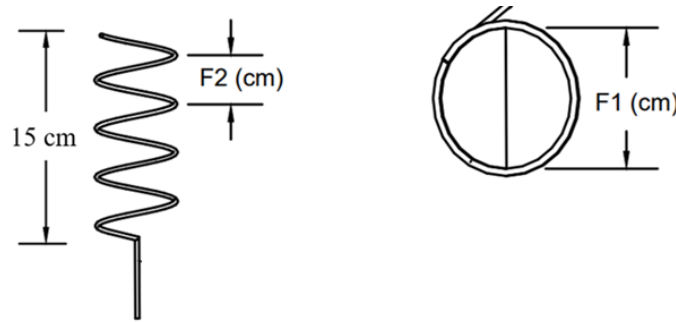


Figure 1 Bioelectrode

The F1 (cm) represents the bioelectrode diameter (inner diameter) in centimeters (cm). This factor enables the electrode to cover a more significant amount of surface area contact in each leaf. The F2 (cm) represents the spacing of the windings in centimeters (cm), which enables the electrode to be physically in contact with as many leaves in the plant canopy as possible. The coil diameter varied at 2, 3, and 4 cm while the spacing of windings varied at 2, 4, and 6 cm. Each coil diameter and spacing of the winding

combination represents the treatment used in the experiment. Treatments 1, 2, and 3 have 2 cm coil diameters that varied at 2, 4, and 6 cm spacing of windings, respectively. Treatments 4, 5, and 6 have 3 cm coil diameters and varied with spacing of windings at 2, 4, and 6 cm, respectively. Treatments 7, 8, and 9 have 4 cm coil diameters, and they also vary with spacing of windings at 2, 4, and 6, respectively. The configured bioelectrode appropriately worked with the misting system, as shown in Figure 2.

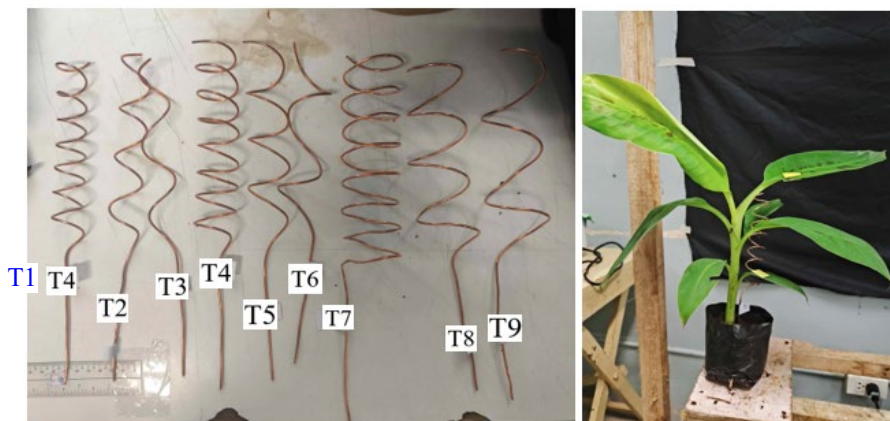


Figure 2 Configured bioelectrode

Table 1 Experimental layout of laboratory tests and laboratory conditions

	Locations	Parameters
Control	Top leaf of the canopy	Deposition properties
Non-electrostatics	Adaxial	Droplet density (DD)
ES electrostatics	Abaxial	Covered (AC)
Experimental	Bottom leaf of the canopy	Swath width (SW)
	Adaxial	
	Abaxial	
Laboratory conditions	Atmospheric temperature (°C)	29 ±0.7
	Relative humidity (%)	77 ±2
	Altitude (cm)	25
	Conductivity of water (µS cm ⁻¹)	0.5
	Density (kg m ⁻³)	999
	Viscosity (kg m ⁻¹ s ⁻¹)	1.00 × 10 ⁻³
	Surface tension (N m ⁻¹)	7.28 × 10 ⁻²
	Permittivity (C ² N ⁻¹ m ⁻²)	708.88 × 10 ⁻¹²
	Dielectric constant of water	80
	Dielectric constant of air	1

2.2 Preparation of experimental setup

The experiment was conducted in the designated room in the CAD Facility laboratory, and the experimental condition shown in Table 1 was gathered before experimenting. The water used in the electrostatic misting system was distilled to ensure that the water was in its purest form and to eliminate the potential effects of impurities.

The system utilizes a water tank to store the irrigation water, a 12 V water pump, and a high-pressure pipe to supply water to the electrostatic nozzle. The position of the electrostatic nozzle is indicated in

Figure 3, where an inductive-type brass electrode was used. The electrode was supplied with an electrostatic high voltage of 3 kV. A wooden frame at a specified altitude of 0.25 m from the plant canopy supported the entire electrostatic misting system. A Cavendish Grand Naine (*Musa acuminata* ‘Grand Nain’) seedling with a height of 0.15 - 0.40 m (approximately two months old) were used in the experiment, and the water-sensitive papers (1” × 0.5”) were affixed at the upper and lower canopy at the adaxial and abaxial surface of the leaves. The seedling was placed at a 30 cm horizontal distance away from the electrostatic nozzle.

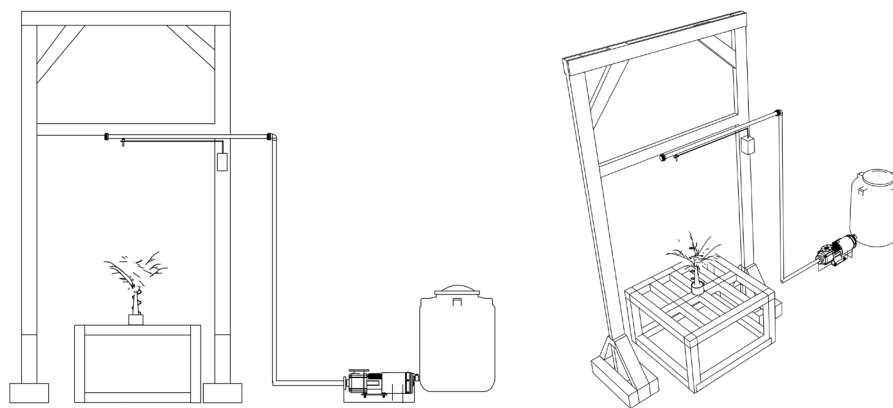


Figure 3 Electrostatic misting system

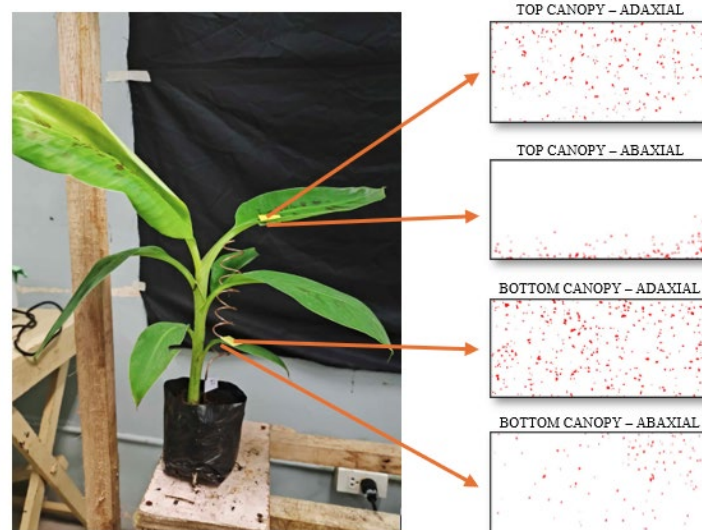


Figure 4 Water sensitive paper placement

2.3 Data gathering

The parameters that were gathered include the responses from the experiment, two (2) deposition properties, which include deposition density (droplet cm⁻²) and area covered (%), and the swath width (cm). These response parameters were used to determine the

effects of the electrode variables. The laboratory and environmental conditions were also gathered as a reference for the results.

2.3.1 Laboratory conditions

The researcher gathered at least five (5) pieces of real-time relative humidity and atmospheric

temperature data. A temperature-humidity meter was used to measure humidity and atmospheric temperature in the experimental area. The target distance was also measured using a measuring tape. The water properties parameters were also declared since the water used is distilled water.

2.3.2 Deposition properties

Deposition properties comprise deposition density (DD) and area covered (AC). These parameters were gathered using a 1" × 0.5" water-sensitive paper. Before the experiment, the WSP was placed at the plant sample's upper and lower canopy adaxial and abaxial leaf surfaces. Each treatment had four WSPs affixed to the plant sample. After the experiment, the water-sensitive paper was collected, stored in a sealable zip lock bag, and labeled according to the leaf surface location and treatment. The WSPs were scanned using a scanner and pre-processed to remove the image noises and other unnecessary captured spots. The image was uploaded in DepositScan™ ImageJ software (USDA/ARS ATRU, Wooster, Ohio).

2.3.2.1 Deposition density and area covered

The pre-processed images were then imported to DepositScan™ ImageJ software for analysis considering the procedures of Salyani et al. (2013). Subsequently, the image was resized accordingly with the actual size of the water-sensitive paper (1" × 0.5") to accommodate accurate measurements. The canvas was then resized to remove the corner where the shadows are visible, which can affect the analysis results. The results were then obtained using the USDA Automatic Paper Analysis Tool Plugin on the software. The average deposition density and area covered were obtained in every sample and were used for the analysis.

2.3.3 Swath width

Using masking tape and a marker, the frame was marked with a 10cm interval distance from the electrostatic nozzle. Two (2) seedlings were placed at each side, ensuring that the leaves covered the marked distance of 40cm. Subsequently, a 1" × 0.5" water-sensitive paper was affixed at each distance interval at the seedlings' top canopy adaxial leaf surface. The

misting proceeded following the group of treatments and conditions shown in Table 1. The water-sensitive paper was then processed and analyzed to get the deposition density, and the data were then recorded for analysis. This method relates to the methodology of Patel et al. (2017), wherein they measured the target coverage and swath width of an advanced air-induced air-assisted electrostatic nozzle. The swath width of the treatment of the control and experimental groups shown in Table 1 was compared for analysis.

2.4 Data analysis

The statistical tool used to analyze and interpret the data is the Two-Way Analysis of Variance (ANOVA) to determine the significance of the quadratic model at $\alpha = 0.05$. It computes the corresponding P-value for the given factor combinations and their interactions. Consequently, a P-value below 0.05 signifies a significant difference, and a P-value below 0.01 signifies a highly significant difference among the different factor combinations.

2.5 Unit cost analysis

Cost estimation was used to determine the cost of the electrostatic misting system. The parameter considered is the depreciation computed using the Straight-Line Depreciation Method (SLD). This approach considers the overall investment cost of the electrostatic misting system, with the salvage value typically set at 10% of the initial investment while considering a standard projected operational lifespan of 5 years. A 500 m² reference area for cost estimation was considered. All materials for the fabrication of the electrostatic misting system that was sourced from the local market and e-commerce platforms were recorded. The individual prices were converted in US dollar currency. Labor costs were based on the local prevailing minimum wage.

3 Results and discussion

3.1 Evaluation of bioelectrode

3.1.1 Droplet density

Results show that the droplet density using a bioelectrode significantly differs from regular and electrostatic spraying. As shown in Figure 5, the

spraying without electrostatic has the lowest droplet density with 0.085 droplet cm⁻² at a 30 cm distance from the nozzle. On the other hand, positive control has relatively noticeable droplet density compared to negative control, suggesting that the system effectively charged the water particles and is working based on the

working principle of electrostatics anchored on Coulomb's Law. Treatment 5, which has a 3 cm coil diameter and four spacing of windings, yields the highest droplet density among all the treatments applied.

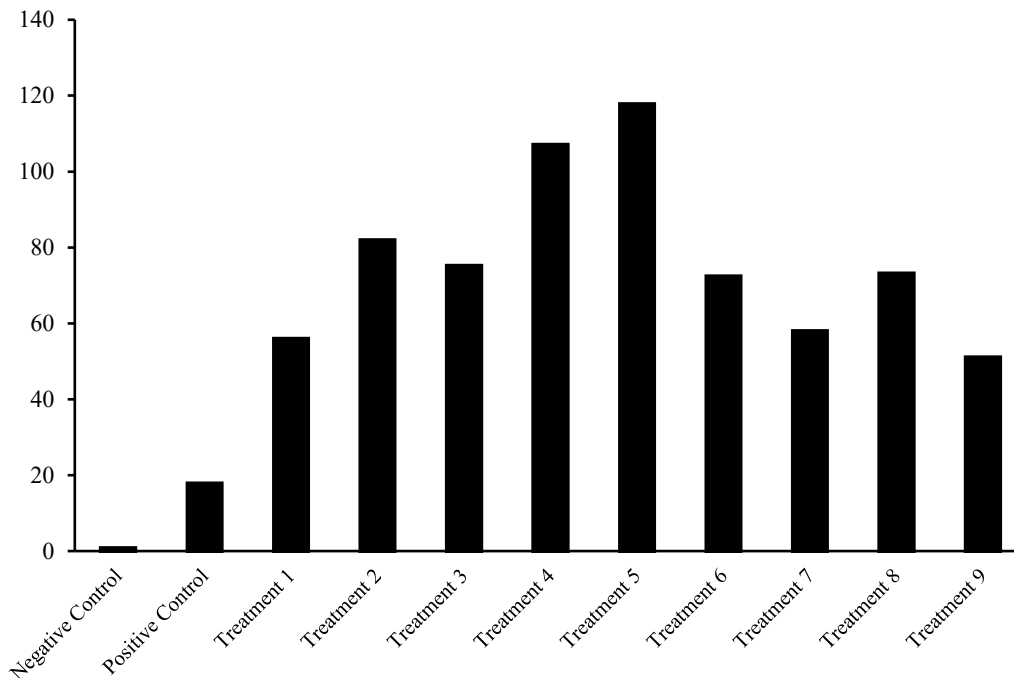


Figure 5 Droplet density of control and experimental groups

The mean droplet density in the plant canopy situated 30 cm away from the electrostatic nozzle as affected by different bioelectrode factor combinations is presented in Table 2.

Statistical analysis shows significant differences among the treatments. The negative and positive control shows a significantly lower droplet density. This means that when compared with traditional and electrostatic spraying methods, spraying with electrostatic and bioelectrode is significantly more effective in depositing mist onto the plant's canopy. It was further validated with the droplet density being highly significant at the 1% level ($p < 0.01$), suggesting strong evidence that the treatments significantly influence the droplet density. On the other hand, treatments 4 and 5 have the highest means but are not significantly different from each other. However, they are significantly different from other treatments and controls. Treatments 1, 2, 3, 6, 7, 8, and 9 are not significantly different from each other but differ from

the highest and lowest means. The moderate coefficient of variance suggests that while there is some variability, the differences observed are likely due to the treatment effects rather than random variation. The result signifies that the use of coil with a 3 cm coil diameter and 2-4 cm spacing of windings (treatments 4 and 5) are particularly effective in increasing droplet density, significantly outperforming the controls and other coil configurations (treatments 1, 2, 3, 6, 7, 8, and 9) which shows moderate effectiveness but are not significantly different from each other. Results suggest that the coil diameter and windings' spacing directly relate to the droplet density.

When the coil diameter and spacing of windings combination are at the lowest and highest level, the deposition density is at the lowest among the treatments, as shown by treatments 1 (2 cm coil diameter and 2 cm spacing of windings) and 9 (4 cm coil diameter and 6 cm spacing of windings). However, when the combinations are at the median level, the

deposition is at the highest level, as shown in treatment 5 (3 cm coil diameter and 4 cm spacing of windings). Furthermore, analyzing the effects of the coil diameter and spacing of windings, it can be seen in the graph that the median level of spacing of windings (4 cm) yields relatively higher droplet density compared to its counterparts (2 cm and 6 cm) in the same coil diameter as shown in treatment 2, 5, and 8. It is also true with the spacing of windings, which results in a much higher droplet density yield at a median level, as shown in treatments 4, 5, and 6.

This result relates to the principle of inductors, wherein inductance and efficiency are of utmost importance to performance. The bioelectrode used can

be seen as an air-core inductor when working. Air core inductors are flexible and can function in various frequencies. A large amount of wire is required to achieve a high inductance, which would require less spaced windings and a wider coil diameter. However, having high inductance equates to less efficiency because the magnetic field generated by the coil disperses, which can lead to interference by inducing currents in nearby wires and other coils. According to Ng et al. (2010), increasing spacing between coil windings improves quality factor but decreases inductance, consistent with the median-level coil configuration described by Johns (1997).

Table 2 Mean droplet density

Treatments	Droplet density (droplet cm ²)**	Sqrt.
1	55.79	6.93 ^{ab}
2	81.72	8.99 ^{ab}
3	74.97	8.51 ^{ab}
4	106.85	10.13 ^a
5	117.62	10.78 ^a
6	72.17	8.4 ^{ab}
7	57.82	7.57 ^{ab}
8	72.93	8.44 ^{ab}
9	50.85	6.99 ^{ab}
Negative control	0.85	0.9 ^c
Positive control	17.63	3.81 ^{bc}
cv (%)	25.16	

Note: ** highly significant at 1% level; *Significant at 5% level; ns- not significant; Same letter superscript means not significant; Sqrt- Square root transformation.

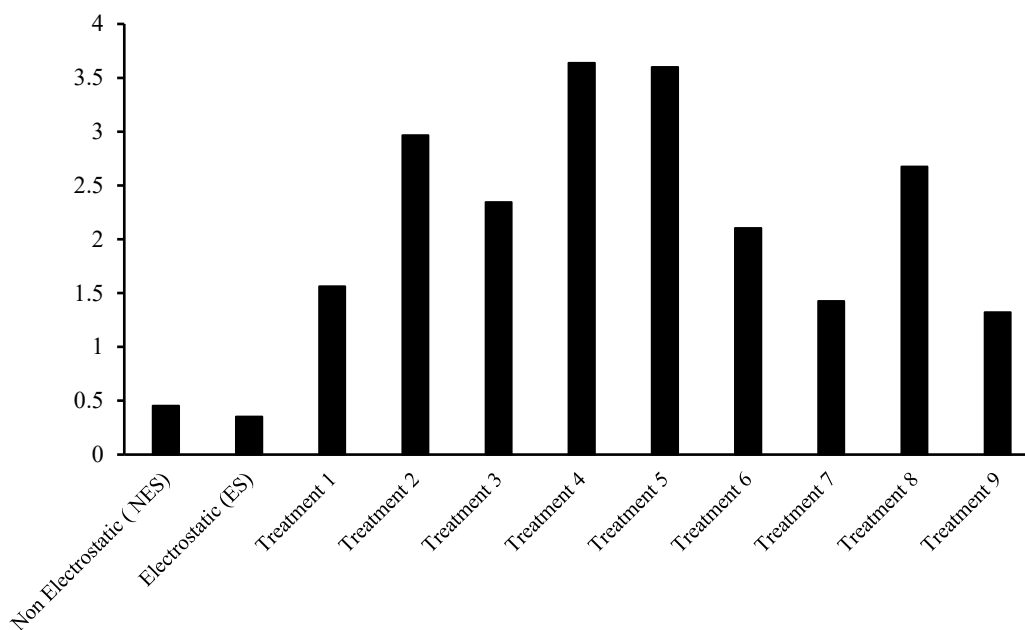


Figure 6 Area coverage of control and experimental groups

3.1.2 Area coverage

Results show a similar trend with the data on droplet density. This suggests that higher droplet

density will also result in increased area coverage. When using a bioelectrode, the area covered significantly increased compared to the traditional

spraying and electrostatic spraying. As shown in Figure 6, treatments 4 and 5 yield the highest area covered among all the treatments utilized, while the positive and negative control group has the lowest area covered.

The mean area coverage in the plant canopy situated 30cm away from the electrostatic nozzle as affected by different bioelectrode factor combinations is presented in Table 3.

Analysis of Variance (ANOVA) showed significant differences among the means of different treatments at a 5% level. The mean area coverage across all treatments is 1.36%, indicating that treatments 4 and 5 significantly exceed the mean area coverage. The results reveal a range of coverage

percentages, with Treatment 4 achieving the highest at 3.64%, closely followed by Treatment 5 at 3.6% and Treatment 2 at 2.97%. On the other hand, negative and positive controls have area coverage percentages below the mean. On the lower end, Treatment 9 showed 1.32% coverage, while Treatment 7 and Treatment 1 had 1.43% and 1.56% coverage, respectively. The control group performed as expected, serving as a baseline with low coverage observed value.

On the other hand, Tukey’s HSD test shows that none of the treatments are significantly different in terms of the area covered. This suggests that all treatments perform similarly in increasing the area covered.

Table 3 Mean area coverage

Treatments	Area covered(%)*	Sqrt.
1	1.56	1.16 ^a
2	2.97	1.71 ^a
3	2.35	1.48 ^a
4	3.64	1.8 ^a
5	3.6	1.89 ^a
6	2.11	1.43 ^a
7	1.43	1.19 ^a
8	2.68	1.56 ^a
9	1.32	1.13 ^a
Negative control	0.68	0.8 ^a
Positive control	0.47	0.59 ^a
cv(%)		32.74

Note: ** highly significant at 1% level; *Significant at 5% level; ns- not significant; Same letter superscript means not significant; Sqrt- Square root transformation.

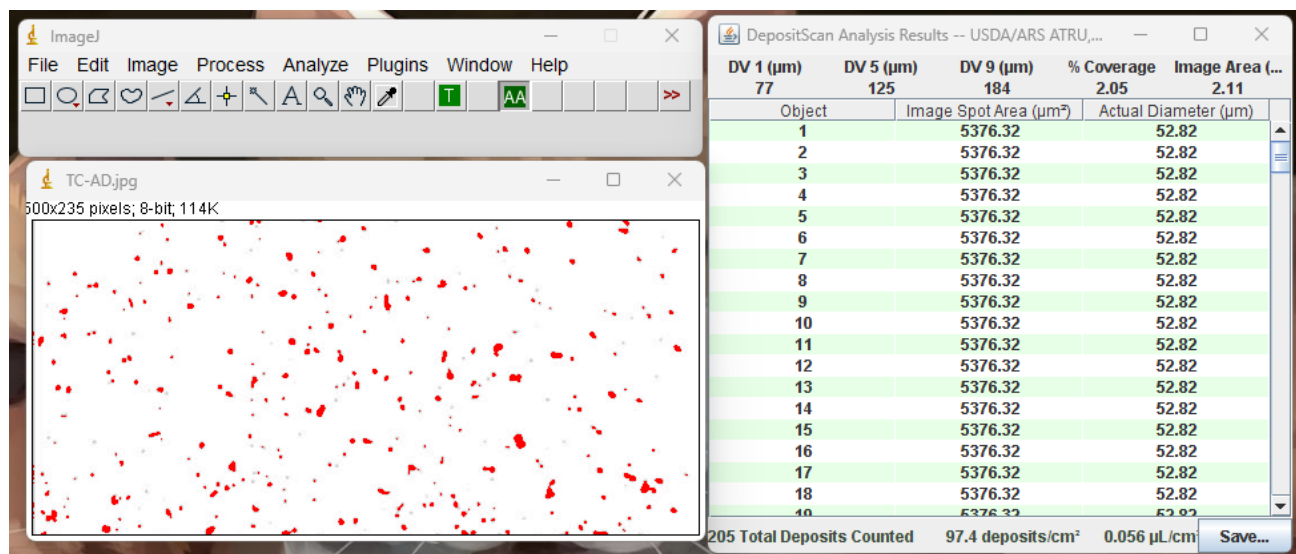


Figure 7 Variations in droplet diameter (treatment 3 – replication 2)

Moreover, Tukey’s HSD test confirms that there is another factor to consider when assessing area

coverage. Although droplet density is a major factor contributing to the computation of area coverage, droplet diameter also plays a significant influence as it may result in a lower or higher area coverage, depending on its value. Larger droplets generally result in lower coverage, while smaller droplets increase coverage (Tadić et al., 2014).

The operating pressure, nozzle configurations, and nozzle height affect the droplet diameter. In this study, these factors were fixed at specified settings. However, the spots registered in WSP still have varying diameters, as shown in Figure 7. The Tukey’s HSD test accounted for this variability, resulting in no observed significant difference among the treatments, contradicting the Analysis of Variance (ANOVA) results.

3.1.3 Swath width

The mean swath width in the plant canopy with a 10cm distance interval away from the electrostatic

nozzle as affected by different bioelectrode factor combinations is presented in Table 4.

As shown in the table, each point distance has varying deposition density in every treatment, represented by green being the highest density, yellow being the medium, and red being the lowest. Non-electrostatic (negative control) has the lowest density in every point distance compared to electrostatic ES (positive control) and the treatments. This suggests that electrostatic spraying generally deposits a significantly higher amount of mists than non-electrostatic sprayers, as evident from the much higher ES values than the NES column. It is also evident in the table that the deposition is much more concentrated at the center, as represented by the green indicator. As the distance from the nozzle increases, the droplet density decreases, forming a gradient. At the farthest point, the deposition is relatively low, and the effects of the bioelectrode are much more noticeable.

Table 4 Mean swath width

Treatment	Left			Right		
	L-40	L-30	L-20	R-20	R-30	R-40
Non-electrostatic (NES)	0.85	3.6	10.65	1.1	4.15	0.85
Electrostatic (ES)	9.4	77.7	523.45	509.5	253.5	28.2
Treatment 1	0.55	10.3	365.7	159.2	30.1	0
Treatment 2	4.25	27.35	392.6	211.4	15.3	5.9
Treatment 3	4.4	18.65	445	231.75	55.8	5.05
Treatment 4	2.75	10.7	334.15	372.95	94.05	6.6
Treatment 5	9.75	76.35	423.4	226.85	49.05	5.95
Treatment 6	31.35	119.05	341.1	372.45	71.9	2.4
Treatment 7	21.3	119.65	414.95	456.05	146.5	42.05
Treatment 8	18.2	85.5	323.25	560.4	202.25	27.8
Treatment 9	3.8	31.7	483.7	422.55	185	34.9

The mean swath width in the plant canopy at 40 cm away from the electrostatic nozzle, as affected by different bioelectrode factor combinations and control groups, is presented in Figure 8.

As shown in the Figure, the bioelectrode with a 4 cm coil diameter has a relatively high droplet density at 40 cm from the nozzle. It is evident that as the coil diameter increases, the deposition at the farthest sample point also increases, which suggests that the coil diameter is effective, particularly in increasing the droplet adhesion, resulting in a wider swath. Treatment 7, with a coil diameter of 4 cm and 2 cm spacing of windings, has the widest swath width considering the deposition density of 21.3 and 42.05 at the farthest

point (40 cm away from the nozzle). The treatments with wider swath widths typically deposit more material at greater distances from the center. Considering the deposition density gradient concerning the distance, positive and experimental treatments will influence the succeeding distance. The difference in the deposition density will be more visible when the distance is not restricted to only 40cm. This phenomenon can also be attributed to the working principle of inductors, which is anchored to the principles of electromagnetism and solenoids. Greater inductance means more energy stored, and it is evident in the results that treatment 7, having the most significant amount of wire utilized (4 cm coil diameter

and 2 cm spacing of windings), yields the highest droplet density at 40 cm distance away from the nozzle. When considering the distance, the inductance of the bioelectrode is a much more critical aspect to consider. Efficiency (minimizing losses) is essential for overall performance. However, it primarily affects how much energy is dissipated rather than stored.

3.2 Unit cost analysis

Based on the cost estimation of the set-up, the total cost of the system for an area of 500m², considering the parameters and assumptions shown in Table 5, is \$735.07. This translates to a cost of \$1.47 per square meter. This cost estimation was based on the standard

spacing of the misting system installed in a typical greenhouse set-up with an addition of an electrostatic mists induction charging system and the installation of a bioelectrode. Compared to a typical misting system, this electrostatic misting system costs \$143.96 more. This accounts for the additional component's total costs, including the electrostatic generator, electrode for the nozzle, and the bioelectrode.

Results show that the system's depreciation cost, which considers the overall investment cost, salvage value of 10% of the initial investment, and a standard projected operational lifespan of 5 years, is \$132.31 per year, as shown in Table 6.

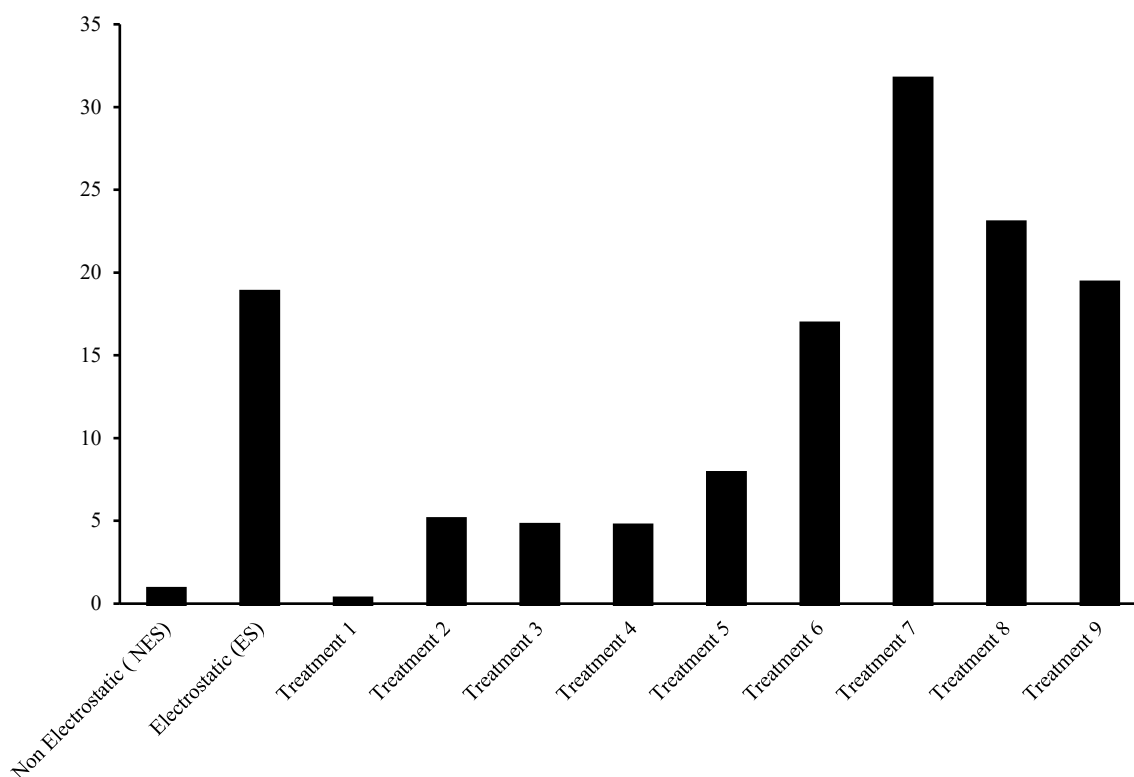


Figure 8 Average deposition at 40cm distance away from the nozzle

Table 5 Reference setup

Area (500 m ²)	Length (m)	25
	Width (m)	20
Spacing (m)	Between sprinklers	1.5
	Between laterals	1.5
	Number of sprinklers per lateral	17
	Number of laterals	13
	Total number of sprinklers	221
Bioelectrode (pcs)	Assumptions: 1 pc per plant	150
	30 cm seedling spacing	

Table 6 Cost estimation

Investment Cost				
Parts	Price (\$)	Unit	Qty.	Total (\$)
Nozzle	0.90	per piece	221	199.90
Pipes	0.45	per meter	325	146.99
Electrostatic generator	27.14	per piece	2	54.27
Electrode	0.04	per millimeter	221	8.28
Bioelectrode	0.54	per piece	150	81.41
Labor	9.05	per day	3	27.14
Water tank	36.18	per piece	1	36.18
Water pump	90.45	per piece	1	90.45
Accessories	90.45	lot	1	90.45
Total cost of the system (Area=500 m ²) (\$)				735.07
Cost per sq.m. (\$ m ⁻²)				1.47
Depreciation (\$ year ⁻¹)				132.31

4 Conclusion

The coil configuration, particularly the diameter and spacing of windings, significantly influences droplet density and coverage compared to traditional and standard electrostatic spraying methods. Specifically, configurations such as a 3 cm coil diameter with 4 cm spacing showed the highest deposition density. Although ANOVA of area coverage showed significant differences among treatments, all configurations performed similarly in terms of Tukey's HSD test, suggesting other factors such as droplet diameter and environmental conditions also have their significance.

Moreover, the study found that electrostatic spraying systems, particularly those utilizing bioelectrodes, show better swath width than non-electrostatic methods, with treatment 7 achieving the most comprehensive and adequate coverage. Despite the significant initial investment required for implementing the bioelectrode-enhanced electrostatic misting system, with a total cost of \$735.07 for a 500 m² area, the increased efficiency and potential savings could justify the expenditure. The long-term benefits of improved efficiency and reduced environmental impact make it a viable option for modern agriculture.

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References

- Campos, S. F. B., J. P. A. R. Cunha, H. H. T. Assunção, T. C. Alves, C. H. S. Zandonadi, and E. M. Lemes. 2020. Efficacy of glyphosate applied using an electrostatic sprayer as affected by adjuvant and carrier volumes. *Planta Daninha*, 38: e020228417.
- Gao, J., Y. Guo, M. H. Tunio, X. Chen, and Z. Chen. 2023. Design of a high-voltage electrostatic ultrasonic atomization nozzle and its droplet adhesion effects on aeroponically cultivated plant roots. *International Journal of Agricultural and Biological Engineering*, 16(2): 30-37.
- Johns, R. 1997. Homebrew your own inductors. Can't find the inductors you need for an antenna, a tuner or amplifier? Build your own-it's easy! Available at: <https://www.ar1.org/files/file/Technology/tis/info/pdf/9708033.pdf>. Accessed 29 May 2025
- Law, S. E., and S. C. Cooper. 1989. Target grounding requirements for electrostatic deposition of pesticide sprays. *Transactions of the ASAE*, 32(4): 1169-1172.
- Ng, D. C., C. Boyd, S. Bai, G. Felic, M. Halpern, and E. Skafidas. 2010. High-Q flexible spiral inductive coils. In *2010 Electromagnetic Compatibility Symposium*, 1-4. Melbourne, VIC, Australia, 8-10 September.
- Patel, M. K., B. Praveen, H. K. Sahoo, B. Patel, A. Kumar, M. Singh, M. K. Nayak, and P. Rajan. 2017. An advance airinduced airassisted electrostatic nozzle with enhanced performance. *Computers and Electronics in Agriculture*, 135: 280-288.
- Pascuzzi, S., V. Bulgakov, F. Santoro, A. S. Anifantis, S.

- Ivanovs, and I. Holovach. 2020. A study on the drift of spray droplets dipped in airflows with different directions. *Sustainability*, 12(11): 4644.
- Saint Martin, L. B., R. U. Mendes, and K. L. Cavalca. 2017. Electromagnetic actuators for controlling flexible cantilever beams. *Structural Control and Health Monitoring*, 25(1): e2043.
- Salcedo, R., E. Sánchez, H. Zhu, X. Fàbregas, F. García-Ruiz, and E. Gil. 2023. Evaluation of an electrostatic spray charge system implemented in three conventional orchard sprayers used on a commercial apple trees plantation. *Crop Protection*, 167: 106212.
- Salyani, M., H. Zhu, R. Sweeb, and N. Pai. 2013. Assessment of spray distribution with water-sensitive paper. *CIGR Journal*, 15(2): 101-111.
- Sánchez-Hermosilla, J., J. Pérez-Alonso, P. Martínez-Carricondo, F. Carvajal-Ramírez, and F. Agüera-Vega. 2022. Evaluation of electrostatic spraying equipment in a greenhouse pepper crop. *Horticulturae*, 8(6): 541.
- Tadić, V., M. Marković, I. Plaščak, M. Stošić, J. Lukinac-Čačić, and B. Vujcic. 2014. Impact of technical spraying factors on leaf area coverage in an apple orchard. *Tehnicki Vjesnik*, 21(5): 1117-1124.