Searching For a Solution to Contain the Increasingly Dangerous Dengue Fever

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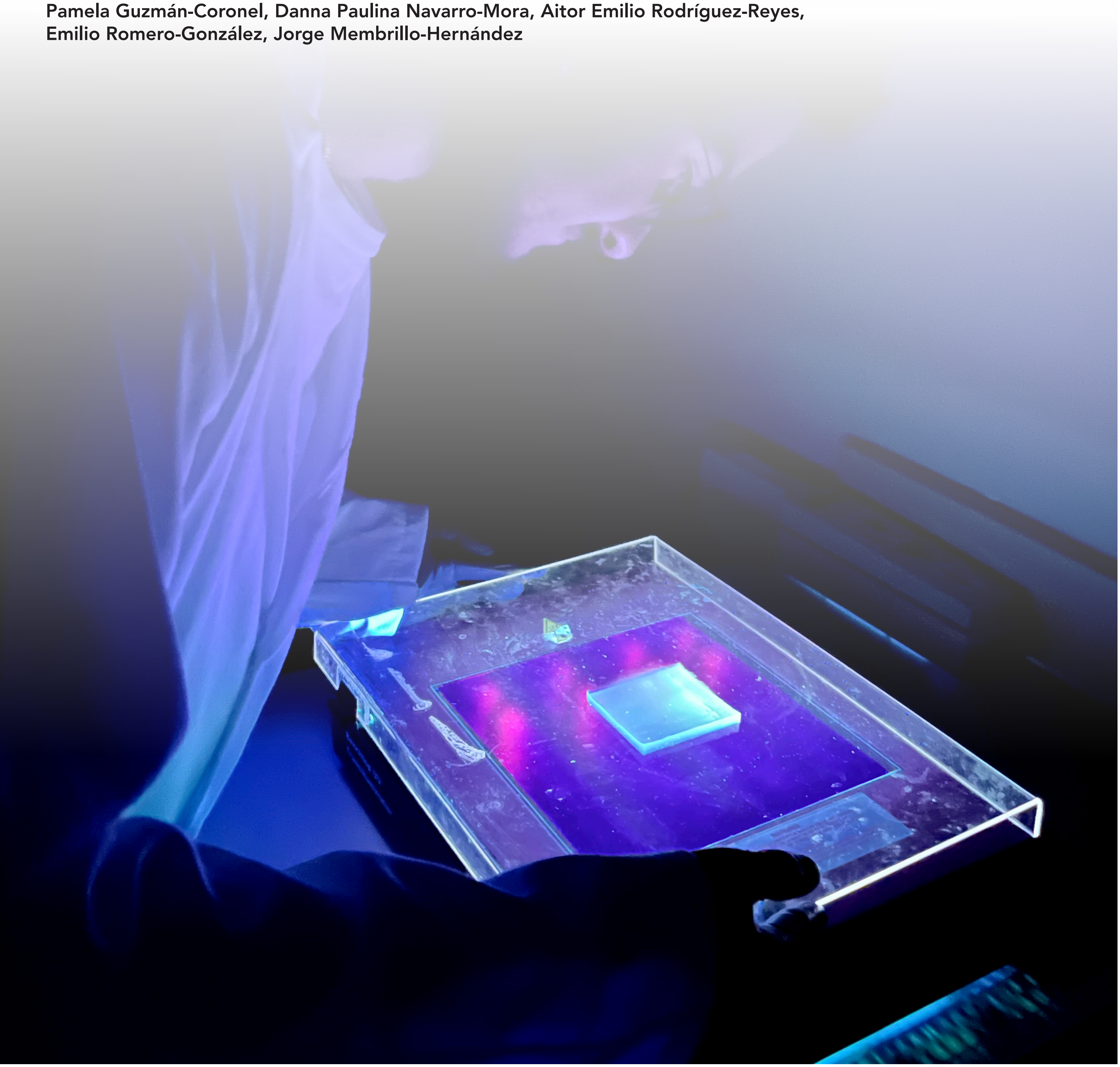

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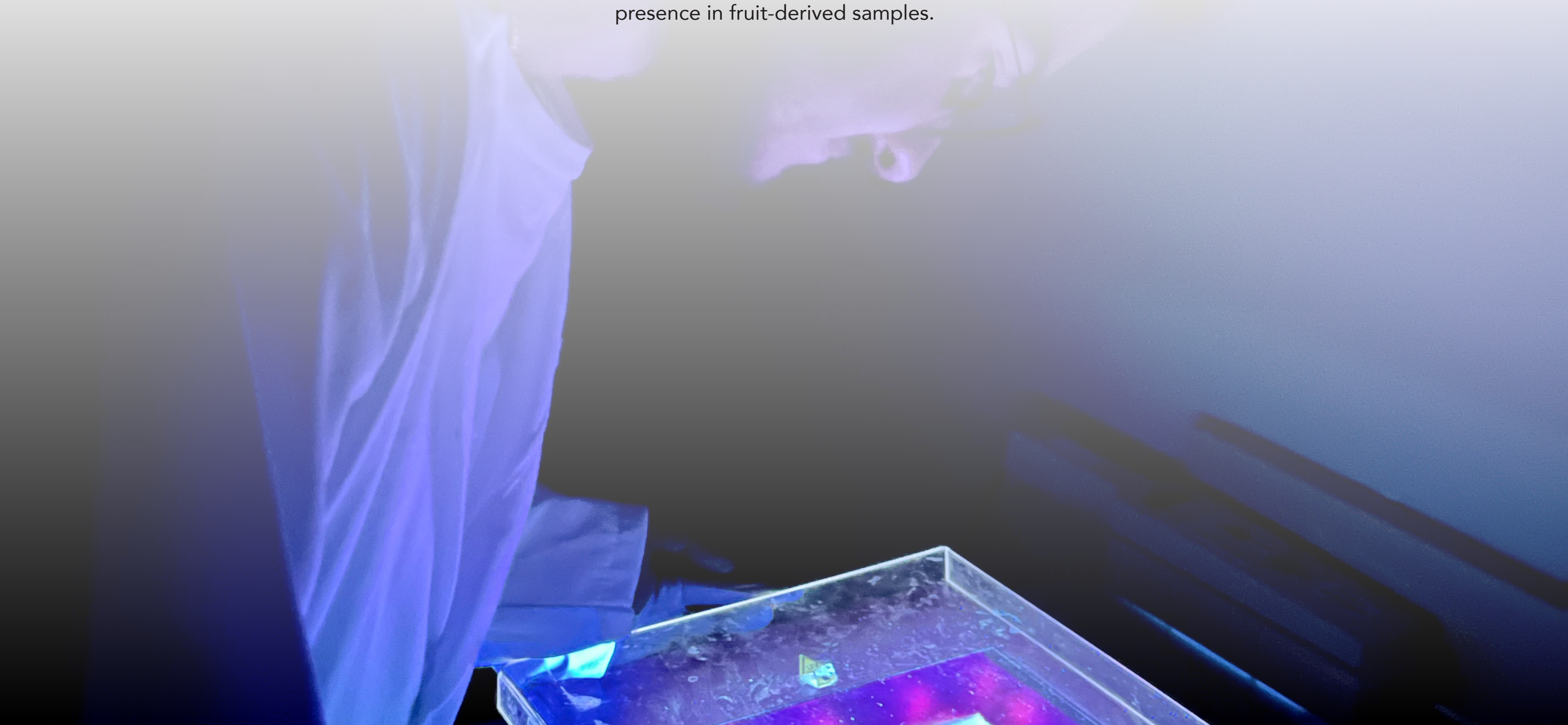
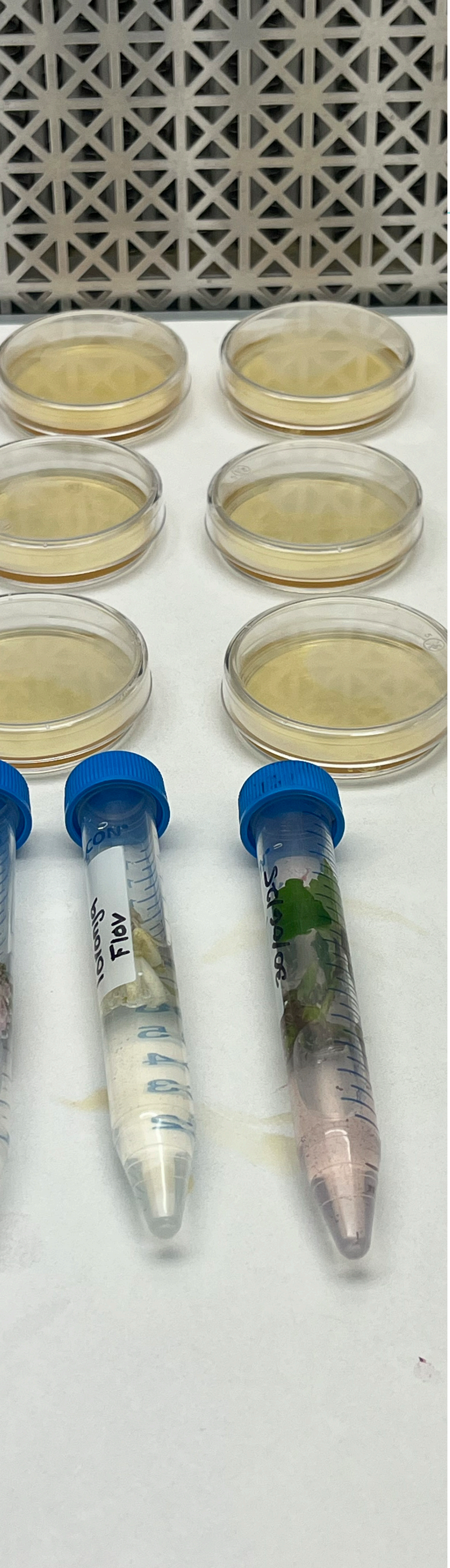
Note: Authors are listed alphabetically with the faculty mentor listed last.

Cover photo: Observation of PCR results to detect *Rosenbergiella nectarea* presence in fruit-derived samples.





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Contribution	Contributor (initials)
Conception or design of the work	PGC, ERG, JMH, DPNM, AERR
Data collection	PGC, DPNM, AERR
Data coding	PGC, ERG
Data analysis and interpretation	PGC, JMH, ERG, DPNM, AERR
Drafting of the case study report	PGC, ERG, DPNM, AERR
Critical revision of the case study report	JMH, PGC, ERG, DPNM, AERR
Final approval of the version to be submitted	JMH, ERG, DPNM, AERR

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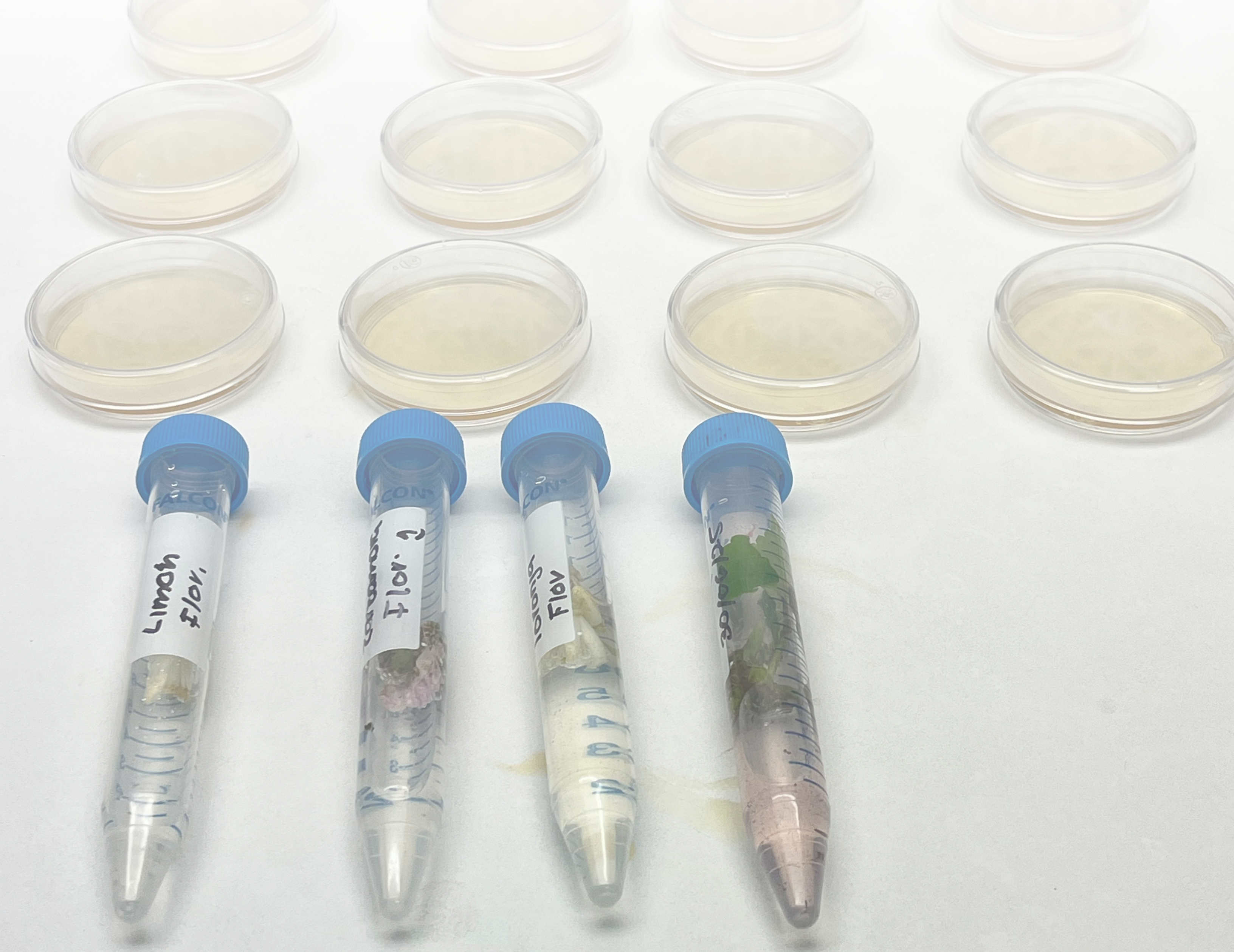

Executive Summary

Dengue fever is rapidly spreading across Mexico. In 2024 alone, there was a staggering 380 per cent rise in cases compared to the previous year. The crisis is especially severe along the Pacific coast, affecting states like Guerrero, Tabasco, Michoacán, and Chiapas. Dengue is more than a medical problem; it is a deep social and structural challenge. Its most serious complications, including hemorrhagic fever, can cause intense pain, internal bleeding, and death. Its burden mainly falls on vulnerable and marginalized groups, especially those living in unstable homes, without access to clean water, or far from medical facilities.

For decades, dengue-control efforts have mainly relied on spraying chemical insecticides. However, these strategies have proven to be unsustainable, unfair, and harmful to the environment. Mosquitoes are becoming more resistant to insecticides, and excessive chemical use endangers other species and entire ecosystems. The shortcomings of traditional methods highlight the urgent need for innovative, community-focused, and environmentally friendly alternatives.

Our research explores a promising biological approach based on natural systems and inspired by previous studies showing that certain bacteria can prevent mosquitoes from being infected by dengue-transmitting viruses. Our team investigated *Rosenbergiella nectarea*, a nonpathogenic bacterium found in the nectar of flowers like grapefruit and dragon fruit. Earlier scientific evidence suggested that if mosquitoes ingest nectar containing this bacterium, the bacteria might colonize their digestive system and interfere with the dengue virus infection, thereby reducing their ability to transmit the virus to humans.

This approach, using a naturally occurring, safe microbe as a method of ecological disease prevention, could transform how we view public health interventions. Importantly, it provides a potentially low-cost, low-risk strategy that communities can adapt and maintain themselves, especially in under-resourced areas.

To start, we posed a simple but essential question: Does *Rosenbergiella nectarea* exist in Mexico's natural environment? If so, we could cultivate the bacteria in a laboratory and spread it in communities with a high incidence of dengue. We gathered nectar samples from flowering plants from different areas of Mexico and analyzed them using molecular detection methods. While we did not detect the bacterium in this sampling, we confirmed that our procedures were effective. Our results align with existing international research, indicating that *Rosenbergiella* is rare and may be tough to find in the wild. Our next steps involve refining sampling strategies, expanding into new regions, and exploring alternative culture methods to detect the bacterium. Ultimately, we aim to contribute to developing community-driven, environmentally grounded solutions to dengue control — solutions that prioritize equity, sustainability, and scientific innovation.

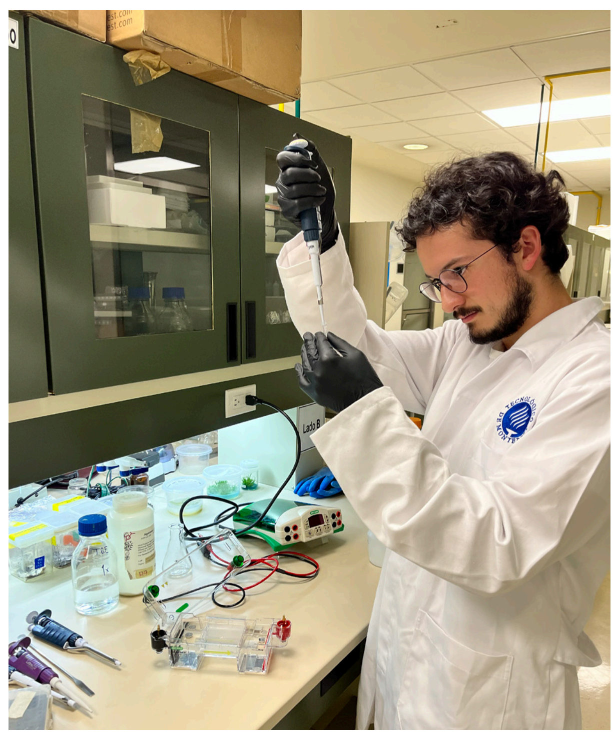

FIGURE 1. Team member preparing reagents and loading components into microtubes for sample analysis

Background: Dengue in Mexico and Issues in Prevention

Dengue is a mosquito-borne viral disease that has become an increasing threat to public health and social well-being, especially in low- and middle-income countries. According to model-based estimates, about 390 million people are infected with dengue each year, with roughly 100 million developing clinical symptoms and 35,000 dying from complications.[1] The disease ranges from mild, flu-like symptoms to severe forms, such as hemorrhagic dengue, which can cause internal bleeding, shock, and death if not treated promptly. These outcomes are not only medically serious but also socially devastating, particularly in communities already facing socioeconomic challenges.

In Mexico, the dengue crisis has worsened in recent years, with a 385 per cent increase in reported cases in 2024 compared to the previous year. The disease mainly affects the country's most vulnerable areas, especially Guerrero, Tabasco, Michoacán, and Chiapas, which are characterized by high poverty levels, poor housing conditions, and limited access to healthcare. A 2023 study found that for every 1 per cent rise in the poverty index, there was a 19.1 per cent increase in severe dengue cases, underscoring the link between socioeconomic hardship and disease risk.[2]

Dengue is primarily transmitted by *Aedes aegypti*, a highly adaptable mosquito that thrives in urban and semi-urban areas. Its tendency to breed in small, stagnant water sources, often found in water storage containers, discarded plastic, or uncovered cisterns, makes the vector especially common in informal settlements where infrastructure is lacking.[3] Climate change, urbanization, and poor sanitation have expanded the mosquito's range and breeding season, worsening the epidemic in regions already facing structural inequalities and environmental stressors.[4]

Significantly, the impacts of dengue extend beyond individual health. The disease imposes a substantial socioeconomic burden on families and communities.[5] Illness leads to lost income, increased healthcare costs, missed school and workdays, and, when complications arise, long-term disability.[6] For vulnerable populations, these setbacks intensify cycles of poverty and marginalization. A randomized controlled trial in Guerrero in 2017 estimated that dengue caused over 412,000 lost work and school days across three coastal regions, underscoring a major impact on productivity and education.

Traditional methods to combat dengue have mainly depended on chemical vector control, such as insecticide spraying and eliminating breeding sites. While these methods can cause short-term reductions in mosquito populations, they are often not sustainable, fair, or environmentally friendly. Mosquitoes are developing resistance to insecticides, and repeated chemical use endangers biodiversity, pollutes water sources, and exposes nontarget species, including humans, to harmful chemicals. Furthermore, these strategies do not address the underlying social and environmental factors of disease transmission, such as poverty, weak healthcare systems, and environmental degradation.[7]

1 Scott B. Halstead, "Dengue," *The Lancet* 370, no. 9599 (2007): 1644–52.

2 Donald S. Shepard, Laurent Coudeville, Yara A. Halasa, Betzana Zambrano, and Gustavo H. Dayan, "Economic Impact of Dengue Illness in the Americas," *The American Society of Tropical Medicine and Hygiene* 84, no. 2 (2011): 200–207.

3 Eduardo A. Undurraga, Miguel Betancourt-Cravioto, José Ramos-Castañeda, et al., "Economic and Disease Burden of Dengue in Mexico," *PLoS Neglected Tropical Diseases* 9, no. 3 (2015): e0003547.

4 Chadapond Seang-arwut, Yupa Hanboonsong, Vithee Muenworn, et al., "Indoor Resting Behavior of *Aedes aegypti* (Diptera: Culicidae) in Northeastern Thailand," *Parasites Vectors* 16, no. 1 (2023).

5 Diarmid Campbell-Lendrum, Lucien Manga, Magaran Bagayoko, and Johannes Sommerfeld, "Climate Change and Vector-borne Diseases: What Are the Implications for Public Health Research and Policy?" *Philosophical Transactions of the Royal Society* B 370, no. 1665 (2015): 20130552.

6 Ibid.

7 Nannan Liu, "Insecticide Resistance in Mosquitoes: Impact, Mechanisms, and Research Directions," *Annual Review of Entomology* 60, no. 1 (2015): 537–59.

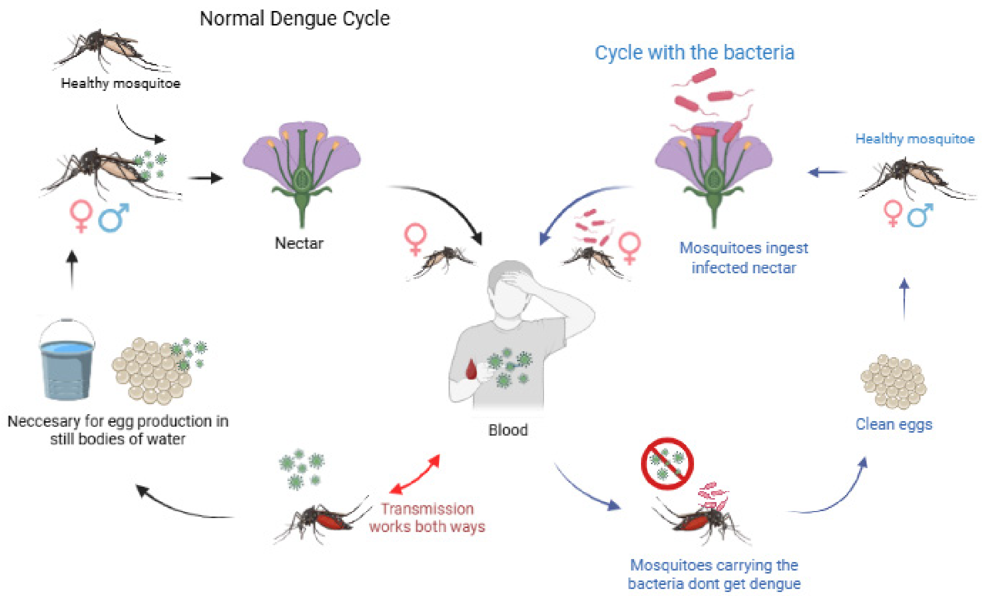

FIGURE 2. Typical life cycle of *Aedes aegypti* mosquitoes, illustrating each developmental stage from egg to adult and their role in dengue transmission compared to life cycle with bacteria-carrying mosquitoes

Consequently, there is an urgent need to develop comprehensive, socially grounded, and ecologically sustainable strategies for dengue prevention. These strategies recognize health not just as a biological condition but as a result of equity, access, and resilience. Research efforts should combine biological innovation, public health equity, and community involvement to create strategies that are effective and adaptable to local social and environmental contexts.

Dengue is not just a biomedical issue; it is a social, environmental, and developmental challenge.

Our research initiative advances this goal by studying *Rosenbergiella nectarea*, a naturally occurring bacterium in floral nectar, for its potential to prevent dengue virus infection in *Aedes aegypti*. This study is not only scientific but also shows a broader commitment to social innovation and ecological health. By using natural systems instead of chemicals, this project aims to provide a safe, affordable, and scalable solution for communities, especially in environmental contexts.

Aligned with three key Sustainable Development Goals, SDG 3 (Good Health and Well-being), SDG 15 (Life on Land), and SDG 17 (Partnerships for the Goals), this research promotes interdisciplinary and cross-sectoral solutions. Supporting Target 3.3 (ending epidemics of communicable diseases), it helps reduce morbidity and mortality in areas with fragile health systems. Under SDG 15, using *Rosenbergiella* provides an environmentally responsible vector control alternative, protecting ecosystems while improving human health. Through SDG 17, the project emphasizes multi-sectoral collaboration, partnering with public health agencies, research institutions, and global organizations such as Médecins Sans Frontières, to build knowledge networks and influence policy for lasting impact.

Our work recognizes that dengue is not just a biomedical issue; it is a social, environmental, and developmental challenge. Addressing it requires more than mosquito control; it demands rethinking public health through the lenses of justice, sustainability, and systemic change in underserved areas.

Dengue and Its Social Impact

Dengue is endemic in over 100 countries across Latin America, Southeast Asia, and sub-Saharan Africa. According to the World Health Organization, nearly half of the global population is at risk, with 100 to 400 million infections occurring each year.[8] Although dengue affects all age groups, its burden disproportionately impacts low- and middle-income countries, where structural inequalities such as limited healthcare access, poor sanitation, and inadequate education increase vulnerability to preventable diseases.

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The social impact of dengue is particularly severe in marginalized urban and peri-urban communities. Rapid, unplanned urban growth has overwhelmed public infrastructure, leaving many without reliable water, waste disposal, or adequate housing. These conditions create ideal breeding grounds for *Aedes aegypti*, the mosquito responsible for transmitting dengue. The Pan American Health Organization emphasizes that water storage in uncovered containers plays a major role in outbreaks — containers that are often a necessity in informal settlements with limited piped water.

Maintaining vector-control programs in these settings involves logistical and financial hurdles. Informal settlements are often difficult to access, lack proper governance, and are excluded from regular public health monitoring. These issues delay response efforts and reduce the effectiveness of national disease-control strategies.

Adding to these challenges is a lack of community engagement and awareness of the risks. In many high-risk areas, people consider dengue a minor illness, which causes delayed medical care and underreporting. This perception hinders early detection efforts and increases the risk of developing severe dengue, which can lead to internal bleeding, organ failure, and death, especially when treatment is delayed. Up to 5 per cent of infections can progress to severe forms, with mortality reaching 20 per cent if treatment is not received promptly.

Educational programs, although helpful, have limited success if they are not adapted to local contexts. A 2013 study in Tapachula (Chiapas, Mexico) found that despite school-based campaigns to prevent mosquito breeding areas, 68 per cent of schools still had mosquito larvae on site due to gaps between knowledge and action. These issues are especially common in Indigenous and rural communities, where low literacy levels and the absence of culturally relevant, multilingual messaging hinder effective public health communication.

Economic barriers further restrict access to healthcare. A study in Mexico found that the average cost of outpatient dengue treatment is USD 451, while inpatient care exceeds USD 1,300, expenses that are unaffordable for low-income families.[9] These costs often lead to delays in

8 Scott L. O'Neill, Peter A. Ryan, Andrew P. Turley, et al., "Scaled Deployment of *Wolbachia* to Protect the Community from Dengue and Other *Aedes* Transmitted Arboviruses," *Gates Open Research* 2, no. 36 (2019):

9 Shepard, et al., "Economic Impact of Dengue Illness in the Americas."

seeking treatment, which can worsen the illness and raise long-term economic burdens. In 2012 alone, dengue cost the Mexican economy about USD 144 million, deepening poverty in affected communities.

Systemic barriers to coordination between local health services and national agencies also hinder intervention efforts. Marginalized groups, such as Indigenous peoples, migrants, and informal workers, frequently lack access to adequate housing, clean water, or waste management services, leaving them excluded from vector-control programs and underrepresented in health policy.

Standard national strategies like fogging or larvicide spraying often fall short in these complex environments. They are poorly targeted, ecologically disruptive, and they create a false sense of security. More importantly, they overlook the social factors that sustain dengue transmission: housing inequality, infrastructure gaps, and political invisibility. Without tailored interventions that consider the lived experiences of vulnerable populations, even well-funded programs may not succeed.

Climate change and globalization are broadening dengue's reach, now affecting areas once seen as safe. However, the developing world still carries the heaviest burden. Rising temperatures, unpredictable rainfall, and increased trade have facilitated the spread of *Aedes* mosquitoes to southern Europe and North America. Yet in resource-limited communities of the Global South, structural vulnerabilities remain the key factors driving exposure and fatalities.

In this context, dengue control must go beyond insect-focused strategies to adopt a socially grounded, equity-oriented approach. Public health efforts should include participatory education, community empowerment, basic infrastructure improvements, and culturally appropriate health services. Sustainable, locally adapted solutions are essential, not only to stop mosquito-borne transmission but also to address the broader social inequalities that allow diseases like dengue to persist and worsen.

About Our Research

This pilot study examined whether *Rosenbergiella nectarea* could serve as a biological method to reduce dengue transmission by *Aedes aegypti* mosquitoes, the primary vector responsible for dengue outbreaks in densely populated urban and peri-urban areas. As insecticide resistance grows and the sustainability of chemical solutions diminishes, our research introduces an innovative, nature-based approach grounded in microbiology and aligned with global public health objectives.[10]

Our approach is inspired by the *Wolbachia* bacteria program, an internationally recognized vector-control effort that reduces the ability of *Aedes aegypti* to transmit Dengue, Zika, and Chikungunya. This program releases *Wolbachia pipientis*, a naturally occurring, nonharmful bacterium, into mosquito populations. *Wolbachia* blocks viral replication within mosquitoes, lowering the risk of disease transmission to humans. Implemented in Brazil, Indonesia, Australia, and now Mexico, this strategy has demonstrated measurable public health benefits while avoiding ecological risks linked to insecticides.[11]

However, the *Wolbachia* method faces some limitations. Environmental factors like temperature and humidity can affect its effectiveness, and it often requires repeated mosquito releases to maintain bacterial presence. Social resistance, caused by misinformation or distrust of biotechnology, has also slowed its adoption in some areas. Despite community concerns about potential health effects, transparent risk communication and community engagement have been key to increasing public acceptance. Luckily,

10 Liu, "Insecticide Resistance in Mosquitoes."

11 O'Neill et al., "Scaled Deployment of *Wolbachia*."

FIGURE 3. Cultivating fruit nectar to search for *Rosenbergiella*

Mexico's 2024 National Plan for the Control of Dengue and Other Arboviral Diseases include *Wolbachia* releases, showing institutional support for biological control strategies.[12]

Our research introduces a complementary microbial approach that could be more adaptable locally and more socially acceptable. Recent studies suggest *Rosenbergiella nectarea*, a harmless bacterium found in floral nectar and mosquito microbiomes, might reduce the ability of *Aedes* mosquitoes to transmit the dengue virus. This bacterium could inhibit dengue virus replication within mosquitoes, providing a potentially low-cost, environmentally friendly method to prevent dengue.

Many people are unaware that mosquitoes feed on nectar in addition to human blood, and primarily only female mosquitoes drink blood for egg production. This dual feeding behaviour leads to our hypothesis: if *R. nectarea* naturally exists in the nectar of certain tropical flowers, mosquitoes might acquire it during feeding, which could alter their microbiome and decrease their susceptibility to the dengue virus. If this is the case, it would represent a socially responsible innovation, supporting ecological sustainability and aligning with community-centred health strategies.

To investigate this in Mexico, we initially identified plant species previously associated with *R. nectarea*, particularly grapefruit (*Citrus paradisi*) and pitaya (*Hylocereus spp.*). We then examined national agricultural and epidemiological data to see if regions with extensive fruit cultivation experienced lower dengue rates. Although we did not establish a clear connection, the study uncovered a gap in data linking ecological resources and health outcomes, emphasizing the importance of integrated strategies for public health and environmental management.

Since no records of *R. nectarea* exist in Mexico, we turned to laboratory testing. We designed tools that can recognize this bacterium's unique DNA and used them to check nectar samples from flowers. These samples were collected in open-air fruit markets and peri-urban neighborhoods in Mexico City, focusing on produce that people commonly consume. In the lab, we carefully prepared the DNA from each sample, made enough copies for

12 Ibid.

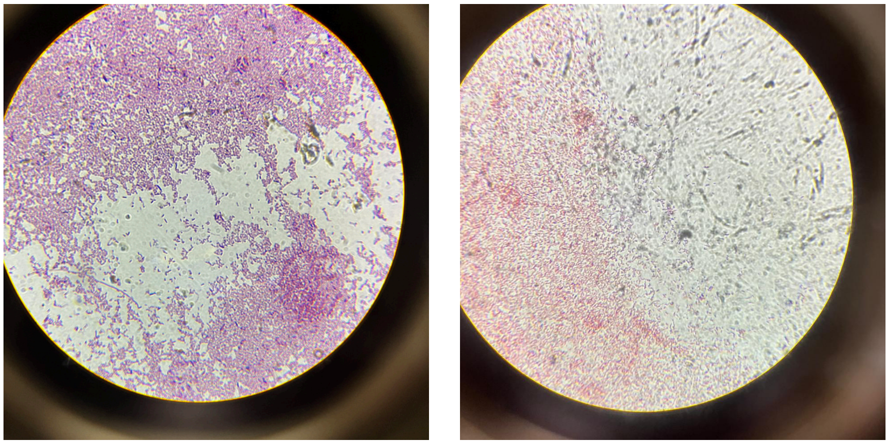

FIGURE 4. Microscopic imaging of various bacteria found in the nectar

analysis, and used a gel test to see if the bacterium was present. Although our tests did not find *R. nectarea* in current samples, the methods proved effective and reproducible, providing a solid technical foundation for future research.

Beyond lab work, the project emphasized capacity-building and scientific empowerment. As students and early-career researchers we were trained in molecular biology techniques, biosafety procedures, and community-engaged science. This infrastructure supports ongoing studies of mosquito–microbiome interactions and provides a platform for scalable, low-risk, biological public health interventions.

We are now refining bacterial enrichment protocols, improving detection methods, and exploring partnerships to access certified microbial strains. These steps will enable us to carry out controlled colonization experiments and evaluate the bacterium's effects on dengue transmission under realistic ecological conditions. Our long-term goal is to integrate microbiome-based vector control into local dengue prevention efforts, especially in underserved communities most burdened by the disease and with limited resources for traditional methods.

In the end, this research merges science, sustainability, and social equity. By exploring solutions rooted in nature and suited to local contexts, we support a global movement toward innovative, inclusive, and environmentally friendly public health strategies to reduce dengue transmission by *Aedes aegypti* mosquitoes, the primary vector responsible for dengue outbreaks in densely populated urban and peri-urban environments. Considering growing insecticide resistance and the limited sustainability of chemical-based interventions, our research proposes an innovative, nature-based strategy grounded in microbiology and aligned with global public health goals.

Governance, Decision Making, and Collaborative Partnerships

This research was conducted under a collaborative governance model that emphasized mentorship, interdisciplinary collaboration, and ethical responsibility. The project received scientific guidance from our mentor Dr. Jorge Membrillo-Hernández, a recognized expert in molecular epidemiology. It was supported by the Instituto de Diagnóstico y Referencia Epidemiológicos (InDRE), Mexico's national reference centre for public health diagnostics and surveillance (the CDC equivalent).

FIGURE 5. Research team working at the INDRE facilities during the development of the project

A participatory, consensus-based framework guided all phases of project design and implementation. This inclusive approach united student researchers, academic mentors, laboratory staff, and public health practitioners in collaborative decision making. By encouraging shared responsibility and peer validation at each stage, from sampling strategy and molecular assay design to biosafety compliance, the research maintained scientific integrity while fostering a culture of ethical co-creation.

Collaboration extended beyond academic and laboratory settings to include meaningful engagement with local health authorities. These partnerships were crucial in identifying epidemiologically significant regions, facilitating access to local data on dengue incidence, and streamlining field logistics for specimen collection. This place-based engagement not only enhanced the relevance and responsiveness of the research but also helped build bridges between academic inquiry and community-centred public health priorities.

Interdisciplinary collaboration was a key element of the project's methodological approach. Expert advisors in microbiology, entomology, molecular biology, and public health provided essential insights during important decision-making points, strengthening the scientific rigour of the study while bringing together diverse disciplinary views.

The study advanced through several iterative phases over ten months. The initial phase concentrated on problem scoping and solution ideation, during which various biological control strategies were explored. After an extensive review of literature and consultation with subject matter experts, the project prioritized *Rosenbergiella* *nectarea* due to its ecological compatibility with *Aedes aegypti* and its promising potential to disrupt dengue virus transmission pathways. This strategic focus enabled an evidence-based, context-aware investigation into innovative public health interventions.

Gender Considerations in Vector-Borne Disease Burden

Although dengue fever is a widespread public health threat, its impact is heavily influenced by intersecting socioeconomic and gender-based vulnerabilities. In low-resource settings, families with limited income and informal or unstable jobs are more affected because illness often leads to lost wages, decreased productivity, and unexpected medical costs.

Gender roles play a vital role in shaping how households respond to disease. In many communities, women take on the main responsibility for caregiving, looking after children, elderly relatives, and sick family members, while also managing domestic chores. This unpaid labour not only adds emotional and physical stress on women but also raises their risk of exposure to mosquito vectors, especially in areas lacking proper sanitation or preventive infrastructure.

Women engaged in outdoor jobs, such as farming or informal street vending, face increased exposure during peak mosquito hours. When combined with limited access to quality healthcare, job insecurity, and lack of formal social protections, these conditions create a cycle of vulnerability. The economic recovery of households after dengue outbreaks is often hindered by these gendered disparities.

By targeting the mosquito vector responsible for dengue transmission, our project aims to reduce not only infection rates but also the broader economic and social burdens disproportionately faced by women and low-income families. Lowering transmission can help minimize household disruptions, maintain income stability, and ease caregiving pressures. In this way, our work supports gender-responsive public health strategies, demonstrating how scientific innovation can address both biomedical and social factors affecting health.

Ultimately, this research emphasizes the need to incorporate gender analysis into vector-control strategies. The approach fosters more equitable health outcomes and strengthens the resilience of marginalized groups, especially the women whose unseen labour maintains household well-being during public health crises.

Impact

This research embodies a multidisciplinary commitment to addressing one of the most urgent global health challenges: the control of dengue fever amid expanding mosquito habitats, climate instability, and persistent health inequities. By investigating the novel potential of *Rosenbergiella nectarea* as a biological control agent, our work advocates for an innovative, sustainable, and socially responsive shift in vector control strategies that aligns ecological integrity with public health imperatives.

At the core of our approach is a systems-thinking framework that reconceptualizes vector control beyond the traditional objective of mosquito eradication. We explored how symbiotic microbial interactions within *Aedes aegypti* could be harnessed to reduce the mosquito's vectorial capacity. The ability of *Rosenbergiella* to alter the mosquito gut microbiome without adversely impacting human or environmental health positions it as a promising candidate for integrated, environmentally conscious disease-prevention strategies, particularly those suitable for resource-constrained settings.

From an applied science perspective, the project's most significant outcome has been the formulation of a replicable, evidence-based methodological framework for biologically driven intervention design. Our experimental roadmap, including rigorous literature synthesis, microbial isolation protocols, and genomic characterization, lays a scientific foundation for future investigations that aim to use insect-residing bacteria to inhibit pathogen transmission. This framework offers a scalable model for research groups exploring biotechnology solutions to global health threats.

Importantly, this study addresses long-standing inequities in the distribution of public health innovation. Populations most burdened by dengue, often located in low-income, Indigenous, and peri-urban tropical communities, frequently remain excluded from the benefits of advanced medical technologies. Because our proposed intervention does not require high-cost infrastructure or individual behaviour change, it holds strong potential for equitable implementation in regions where conventional vector-control measures have repeatedly failed because of structural limitations.

Our participation in this project also prompted deeper reflection on the ethical role of science in advancing social justice. In a global context marked by systemic exclusion and environmental degradation, we believe that scientific inquiry must go beyond elucidating disease mechanisms; it must also challenge the social determinants that allow preventable diseases to disproportionately affect marginalized groups. This belief informed our commitment to co-developing a solution that is not only biologically effective, but socially just, scalable, and ecologically respectful.

Our findings open new pathways for long-term collaboration between academia, public health institutions, and community-based actors. The methodologies and outcomes presented here may inform future pilot programs, field trials, and policy dialogues in dengue-endemic regions, especially those lacking access to vaccination or reliable insecticide distribution. With adequate institutional support, this research could contribute meaningfully to a regional framework for biologically based vector control that is tailored to varied socio-environmental conditions.

Environmentally, the implications of our work are substantial. Unlike synthetic insecticides, which carry risks of ecological toxicity, resistance development, and biodiversity loss, bacterial biocontrol methods such as those involving *Rosenbergiella* are inherently aligned with the principles of ecological balance and environmental stewardship. As global public health discourse shifts toward nature-based, sustainable solutions, our research contributes to a growing scientific consensus advocating for interventions that leverage, rather than disrupt, biological systems

Unlike synthetic insecticides, which carry risks of ecological toxicity, resistance development, and biodiversity loss, bacterial biocontrol methods such as those involving Rosenbergiella are inherently aligned with the principles of ecological balance and environmental stewardship.

Furthermore, the outcomes of this project are aligned with multiple United Nations Sustainable Development Goals (SDGs), notably SDG 3 (Good Health and Well-Being), SDG 13 (Climate Action), and SDG 15 (Life on Land). By bridging microbiological research with global health priorities, we demonstrate the capacity of academic science to produce actionable knowledge that supports both human and planetary well-being.

In sum, this project illustrates the transformative potential of research grounded in interdisciplinary collaboration, social inclusion, and ecological awareness. While our work remains in the early stages, it establishes a critical foundation for a new paradigm of dengue prevention, one where science is not only a tool for understanding but a catalyst for equitable and sustainable change.

FIGURE 6. Team member placing the samples into the electrophoresis chamber which is used to to visualize the PCR test results.

Lessons Learned

This research project has been an important academic and personal journey for all team members, providing valuable insights into both the scientific process and the broader societal responsibilities of research. Working with *Rosenbergiella nectarea*, a relatively little-known micro-organism, presented technical challenges that demanded scientific creativity, persistence, and a solid background in molecular biology. A particularly difficult task was creating the DNA test without having detailed genetic information to guide us. This pushed the team to improve its ability to compare genetic sequences, try out different design strategies, and carefully check its methods with strict controls.

A key insight from this experience is that immediate results do not solely measure scientific progress, but rather the rigour, reproducibility, and transparency of the processes that support knowledge generation. Although we did not detect *Rosenbergiella* in our fruit samples, we developed a replicable, validated experimental pipeline that can inform future research. Our ability to troubleshoot and refine protocols in response to unforeseen outcomes highlights the importance of resilience and methodological adaptability. In this context, setbacks became learning opportunities that catalyzed innovation.

The interdisciplinary nature of our collaboration proved to be another key strength. Our team consisted of students from various fields, including clinical sciences, microbial physiology, electronic systems, and public health diagnostics. This diversity promoted a comprehensive understanding of vector control, where cross-disciplinary views enhanced technical choices. Ongoing dialogue and shared decision making fostered a culture of mutual respect and teamwork, reflecting the cooperative spirit essential to modern global health research.

We also gained a deeper understanding of the structural and operational realities involved in conducting experimental biology in public health settings. Our collaboration with the Instituto de Diagnóstico y Referencia Epidemiológicos (InDRE) provided first-hand insights into how national disease surveillance systems operate. This experience emphasized the importance of designing research with practical applications and policy relevance, reminding us that laboratory science must ultimately serve societal well-being, especially for communities facing systemic barriers to health equity.

Ethical reflection was a key part of the project. Considering the use of a micro-organism in a biological control strategy required careful thought about biosecurity, ecological risks, and the precautionary principle. Conversations with mentors and external experts helped us think about responsible innovation, data stewardship, and the long-term effects of biotechnological interventions. We realized that science must remain accountable to both ecosystems and the communities it aims to serve.

The project also acted as a training ground for developing leadership and project management skills in uncertain conditions. Facing logistical challenges, timeline delays, and technical issues pushed us to share responsibilities, handle stress, and stay connected to a common goal. These experiences showed that successful scientific work depends just as much on adaptability, communication, and empathy as it does on technical knowledge.

Notably, the project also demonstrated a strong commitment to gender equity. We ensured balanced participation across all roles, from experimental design to leadership, in line with Sustainable Development Goal 5 (Gender Equality). This choice was deliberate, based on the belief that inclusive and diverse research teams generate more comprehensive and innovative solutions to complex problems. Our experience challenged traditional gender roles in STEM and provided a replicable model for equity-focused research team structures.

From a social impact perspective, we also recognized the gendered aspects of vector-borne diseases. Women in low-income settings often take on caregiving roles and face increased exposure and limited access to healthcare during outbreaks. By including gender analysis in our research, we found new opportunities for inquiry and action — such as designing biologically based interventions that are sensitive to the needs of female caregivers. For example, gender-responsive delivery models could involve targeted outreach during hours that accommodate caregiving responsibilities or informational campaigns tailored to women's roles in household health management.

Above all, this project reinforced the idea that research is not a straight line toward predetermined outcomes, but a dynamic and reflective process of growth. It taught us to ask better questions, collaborate across disciplinary boundaries, and maintain the highest standards of methodological and ethical integrity. While the lack of a definitive bacterial identification might be seen as a limitation, the technical skills, moral maturity, and collaborative mindset developed during this experience are arguably more lasting and impactful.

Looking ahead, we move forward with improved scientific capabilities and a renewed commitment to the social and ecological aspects of research. This project sets the foundation for future efforts in biological vector control and promotes a research culture rooted in interdisciplinarity, inclusivity, adaptability, and a strong focus on the public good.

Research Team

Pamela Guzmán-Coronel is a fifth-semester biosciences student focused on infectious disease prevention and treatment. Currently, she works as a research assistant at Mexico's National Institute of Respiratory Diseases (INER), where she analyzes gene expression related to COVID-19 and influenza. Her academic path demonstrates a strong dedication to biomedical research with direct implications for public health policy and practice.

Danna Paulina Navarro-Mora is a fifth-semester student in the biotechnology engineering program, known for her deep intellectual curiosity and a resilient, solution-focused approach to research challenges. Her dedication to sustainable development is clear through her work on Consorcia, a student-led project aimed at creating a water purification system that removes heavy metals, tackling critical environmental health issues in underserved communities.

Aitor Emilio Rodríguez-Reyes is a fifth-semester medical student recognized for his strong sense of social responsibility and commitment to advancing public health through scientific inquiry. With a deep interest in evidence-based research, he actively contributes to projects that have a tangible social impact. Beyond his involvement in the Reach Alliance initiative, he plays an integral organizational role in MediTec, an annual multidisciplinary outreach program providing free healthcare services to underserved populations, where he also coordinates the neurology station.

Emilio Romero-González is a fifth-semester biomedical engineering student with a strong passion for translational research and community engagement. Besides his contributions to the Reach Alliance project, he recently completed paramedic training, highlighting his dedication to improving emergency healthcare access and outcomes, especially for vulnerable populations.

Jorge Membrillo-Hernández earned his PhD in biotechnology from King's College London and completed postdoctoral fellowships at the University of Sheffield in the UK and Harvard Medical School at Harvard University, Cambridge, MA. He is currently a professor at the School of Engineering and Sciences and a researcher at the Institute for the Future of Education at Tecnológico de Monterrey. An internationally recognized leader in challenge-based learning (CBL), Membrillo-Hernández specializes in socially oriented STEM education and has played a key role in mentoring interdisciplinary student teams working at the intersection of science, ethics, and social innovation.

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