The Research Station Centro-Altos de Jalisco CIRPAC-INIFAP: celebration of its 50th anniversary

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National Research Institute for Forestry, Agriculture and Livestock (INIFAP by its acronym in Spanish)

INIFAP is a prestigious institution of scientific and technological excellence in México, recognized both nationally and internationally. It was established in 1985 from the merger of the National Institutes for Research in Forestry (INIF founded in 1958), Agriculture (INIA, founded in 1961), and Livestock (INIP founded in 1967), and its primary objectives have been to improve sustainable rural development, enhance competitiveness, and preserve the natural resources. INIFAP achieves these goals through collaborative work with other organizations, either public or private, as well as civil societies involved in the Mexican countryside activities. The institute focuses on generating scientific knowledge and technological innovations in the forestry, agricultural, and livestock sectors, responding to the needs of agro-industrial chains and various types of producers (INIFAP, 2024a).

INIFAP's mission is to develop technological solutions that drive innovation in the Mexican countryside. It envisions itself as a leading institution in creating technologies that benefit producer in the forestry, agricultural, and livestock sectors. The institute relies on 38 Research Stations pertaining to eight Regional Research Centers (CIR) distributed geographically throughout the country. In these locations, specialized researchers work to solve sector-specific and agro-ecological problems.

In addition to research stations, INIFAP manages six National Centers for Disciplinary Research (CENID), each known for a high level of specialization. These include: Water, Soil, Plant, and Atmosphere Relations (RASPA); Conservation and Improvement of Forest Ecosystems (COMEF); Animal Physiology and Improvement (FyMA); Animal Health

Citation: Pérez-Domínguez, J. F., Xelhuantzi-Carmona, J., Ruiz-Ramírez, S., Estrada-Cortés, E., Díaz-Mederos, P., De La Mora-Orozco, C., Bonilla-Cárdenas, J. A., & Rubio-Camacho, E. A. (2024). The Research Station Centro-Altos de Jalisco CIRPAC-INIFAP: celebration of its 50th anniversary. *Agro Productividad*. https://doi.org/10.32854/agrop.v17i9.3023

Academic Editor: Jorge Cadena Iñiguez
Guest Editor: Juan Franciso Aguirre Medina

Received: May 20, 2024.
Accepted: August 16, 2024.
Published on-line: September 20, 2024.

Agro Productividad, 17(9) supplement. September. 2024. pp: 3-13.

and Safety (SAI); Conservation of Genetic Resources (CNRG); and Family Agriculture (CENID AF) (INIFAP, 2024b).

Finally, INIFAP must align with the Convenio de Administración por Resultados 2020-2024. This agreement, following the current analysis, emphasizes the need for an agricultural policy model to address productive inequalities, promote research and technology development, and advance INIFAP's development program with its three main strategic themes: food security, sustainability of natural resources, and technological innovation.

Regional Research Center Pacífico Centro (CIRPAC by its acronym in Spanish)

CIRPAC-INIFAP covers four states in western México: Colima, Jalisco, Michoacán, and Nayarit. This region is known for its agro-ecological diversity, featuring climates that range from arid subtropical to very warm sub-humid tropical, and its outstanding forestry, agricultural, and livestock sectors. CIRPAC focuses on the region's key agrifood chains, which include crops such as corn, avocado, blue agave, sugar cane, vegetables, and cereals, as well as livestock and forestry, including pine, oak, and fir forests. Its mission is to generate and transfer technology and innovations to enhance the competitiveness and sustainability of the agricultural sector.

CIRPAC operates five Research Stations strategically located across its member states, along with two Experimental Sites, one in Jalisco and another in Nayarit. These facilities enable CIRPAC to achieve its objectives which are focused on addressing the region's research and technological development needs (INIFAP, 2024c).

Centro-Altos de Jalisco Research Station (CECEAJAL by its acronym in Spanish)

Altos de Jalisco Research Station was founded in 1974 to address the technological and information needs of agricultural producers in the region of Los Altos de Jalisco (Laborde, 1979), (Figure 1). Initially, research focused on crops such as corn, beans, sorghum, and the

Figure 1. The early days of the Altos Research Station.

corn-beans association. As the infrastructure expanded and more researchers joined, the scope of research widened to include sunflower, flaxseed, soybean, wheat, triticale, oats, and barley.

In 2003, an international evaluation underscored the importance of the Institute for Mexico's agricultural and forestry development. This recognition led to a restructuring that solidified Altos de Jalisco as a Strategic Research Station in the region. The station now covers the "Central" and "Altos" regions of Jalisco and collaborates with other institutions, such as the University of Guadalajara and various higher education centers, to develop research projects and facilitate technology transfer.

Currently, the Research Station is located in Tepatitlán de Morelos, Jalisco, covering most of the state, except for the North Coast and South Coast regions (Byerly, 2006). The facility spans 14 hectares, primarily dedicated to conduct research and extension. The scientific staff includes 30 researchers who work on forestry, agriculture, livestock, and cross-sectoral projects, as well as 10 administrative and support staff members (Figure 2). Forty percent of the researchers are recognized as part of the National System of Researchers from CONAHCYT, enhancing the impact and quality of the research conducted in CECEAJAL.

Forestry Research at CECEAJAL

México has a forest area of 138.7 million hectares, which provides various goods such as timber, food, medicines, and fibers, as well as essential ecosystem services like water and air purification, carbon sequestration, climate regulation, recreation, and landscape services (Torres-Rojo, Moreno-Sánchez, and Mendoza-Briseño, 2016). The state of Jalisco alone has a forest area of 4,850,337.4 hectares, encompassing diverse ecosystems and vegetation, including forests, jungles, mangroves, and arid and semi-arid zones (SEMARNAT, 2013). This diversity underscores the importance of conducting research to understand ecosystem functioning and develop tools to support decision-making by forest owners and managers.

Figure 2. Current staff at the Research Station Centro-Altos de Jalisco.

Currently, Centro-Altos de Jalisco Research Station is involved in three primary areas of forestry research: Sustainable Forest Management and Environmental Services, Plantations and Agroforestry Systems, and Forest Fires (Figure 3). Centro-Altos' research focuses on understanding ecosystem functioning to enhance the management of natural resources, including key timber species. Additionally, this station r has developed tools to better comprehend forest ecosystems and their responses to disturbances, such as fires. This includes studying aspects like forest fuels, fires behavior, fire risk and danger indicators.

In the Forestry Plantations research area, it has been evaluated the establishment and adaptation of various commercial forest species, including tropical species such as cedar, mahogany, parota, and bamboo. Additionally, studies have been conducted on the introduction, adaptation, and timber and latex production of exotic species like teak, melina, and rubber. Growth models for height and diameter, as well as mathematical models to estimate volume, biomass, and carbon for the most relevant taxa have also been developed (Figure 3).

Regarding environmental services, research has been focused on understanding and protecting biodiversity, regulating the hydrological cycle, controlling erosion, producing oxygen, and sequestering carbon, among other services. To advance knowledge on water production and quality, a unique forest basin was established in Tapalpa, Jalisco. This project has provided valuable information on the role of forests in maintaining minimal flow and erosion levels and has enabled the calibration of hydrological models for application to other watersheds. Furthermore, research has been conducted on non-timber products such as resin and oregano, which are integral to these forest ecosystems.

The Research Station has focused on developing, implementing, and transferring new knowledge in forestry, impacting national, regional, and local levels. A key project, the System of Integrated Management of Forest Resources (SIMANIN), was developed for the Sierra de Tapalpa forests and later applied to other regions. SIMANIN, based on a 50-year intensive management plan with five cutting cycles, was designed using producer experience and research from Permanent Silvicultural Research Plots (SPIS) established in the 1980s. The project, launched in 1992, covers 8,000 hectares and includes commercial thinning, regeneration methods with seed trees, and the release of newly established cohorts (Manzanilla *et al.*, 1997).

Figure 3. Research areas in forest sciences at the Research Station.

Another significant project is the National Forest and Soil Inventory (INFyS), which began in 2003 and was developed for the National Forestry Commission (CONAFOR) under the Ministry of Environment and Natural Resources (SEMARNAT). This project established the methodological foundations, sampling design, sample size, and the structure and size of sampling sites, as well as the analysis scheme for obtaining dasometric parameters.

In 2004, SEMARNAT, CONAFOR, the National Institute of Statistics and Geography (INEGI), the National Electoral Institute (INE), and INIFAP formalized the structure of the National Forest and Soil Inventory project and outlined general guidelines in a guiding document. INIFAP was responsible for collecting field data in various states across the country. This data was then statistically processed to generate results and compile state-specific reports.

Currently, several national and regional projects are underway. One notable project is the "Adaptation, Generation, and Integration of Technologies for Sustainable Forest Management in Jalisco and Michoacán". This initiative aims to validate and calibrate growth models for the region and commercially relevant forest species, and integrate these models into user-friendly software, such as ForestSimulator and Shiny applications in Java and R-JavaScript languages, respectively (Figure 4). This will facilitate their use in the forestry sector. Additionally, we are gaining experience in environmental restoration through projects such as identifying priority areas for implementing restoration strategies in ecosystems affected by forest fires. This project will develop methodologies to define priority areas and restoration strategies.

Looking ahead, forestry research at CECEAJAL faces important challenges and opportunities. Climate change, agricultural expansion, and urbanization continue to exert pressure on forests and their biodiversity. Therefore, it is crucial to intensify research in areas such as ecological forestry, precision forestry, ecological restoration, climate change adaptation, and the valuation of ecosystem services.

The incorporation of emerging technologies, such as forest growth simulators, geographic information systems (GIS), and satellite monitoring, presents new opportunities for enhancing forest management and land-use planning. These tools will enable more effective resource management by providing accurate and up-to-date data to support decision-making.

Figure 4. New forestry technologies at the research station.

Currently, there are two laboratories at national level, the forest fire laboratory and another dedicated to integrating emerging technological components for the use, conservation, and restoration of forest ecosystems. However, it is crucial to equip these laboratories with state-of-the-art technology to ensure that the institute remains a leader in research and sustainable forest management at both national and regional levels.

Agricultural Research at CECEAJAL

In the agricultural sector, new varieties of major crops have been developed for the region, along with management recommendations for fertilization, pest control, disease management, and weed control. These efforts aim to enhance or maintain the yield and productivity of local producers. Research focuses on crops including corn, beans, small-grain cereals (such as oats, wheat, barley, and triticale), chickpeas, agave, and forage crops (such as forage corn and pasture), as well as oilseeds (including canola, safflower, soybeans, and amaranth) (CIRPAC, 2008).

The Research Station currently supports agricultural research programs for corn, wheat, oats, and vegetables. Through breeding programs, researchers have continuously developed and promoted new varieties of corn, beans, wheat, oats, barley, and chickpeas. This progress is facilitated by INIFAP's collaboration with national companies and producer associations that focus on the production of certified seeds. These seeds are supplied in a timely manner, meeting demand at accessible prices, and extending their availability to the regional level or the Central Pacific area of influence.

The Research Station is also engaged in research on agave, hibiscus, chia, oilseeds, and small-grain cereals (Figure 5). For agave, research includes integrated management of phytosanitary issues, genetic improvement, and agronomic practices. For hibiscus, studies focus on functional compound content and agricultural mechanization. Oilseeds research (canola, safflower, and soybean) primarily targets agronomic management. In the case of basic grains (wheat, barley, and oats), the research emphasizes agronomic management, genetic improvement, and integrated management of phytosanitary problems.

Since 1979, there has been a genetic improvement program for corn varieties aimed at developing hybrids and improved varieties of white and yellow corn (Ramírez *et al.*, 1996). The program's goal is to produce certified seed for companies and producer groups, targeting grain for the dough and tortilla industry, balanced food, and forage (both fresh

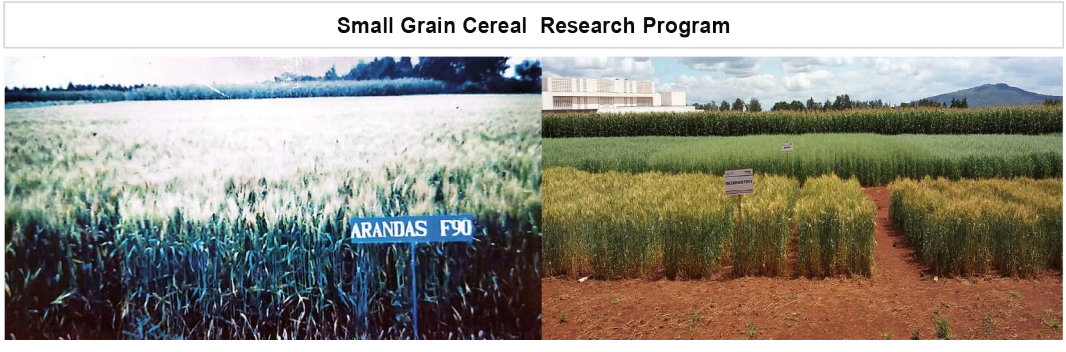

Figure 5. Evaluation and transfer of technology in small grain cereals.

and dry). This initiative has had a nationwide impact, particularly in regions similar to the Central Pacific. Over the past 15 years, CECEAJAL has made over 10 hybrids of white and yellow corn available to producers and seed companies in response to their demands (Figure 6).

The corn research program also includes agronomic management, seed production technology, training for producers and technicians on certified seed production, integrated management of phytosanitary problems, and support for technology transfer. Looking ahead, the Research Station aims to advance towards the agriculture of the future. This vision encompasses the production of food, goods, and ecosystem services that are compatible with natural resource conservation and the use of field by-products as bio-inputs. It also involves generating varieties resilient to climate change, grounded in scientific knowledge, technology, and innovation, while considering national and international trends and developing strategies for their validation and implementation.

Livestock Research at CECEAJAL

The state of Jalisco is recognized as a leading producer of animal protein in México, with notable contributions in bovine milk and meat, pork meat, eggs and poultry meat (Panorama Agroalimentario, 2024). Additionally, Jalisco produces significant amounts of small ruminant meat and honey (Panorama Agroalimentario, 2024). These high production levels reflect the strong commitment of Jalisco's society to primary sector activities (Rostros de Jalisco, 2016). Consequently, animal production systems hold a crucial role in the state from social, economic, and environmental perspectives (Cervantes *et al.*, 2001).

INIFAP has historically engaged in research programs focused on the above mentioned species. Research, training, and technology transfer activities are tailored to the specific socioeconomic, technological, and environmental characteristics of each production system (Programa de Desarrollo del INIFAP, 2018). For instance, in Mexico, bovine milk is produced through various systems: the intensive system predominant in states like Coahuila and Durango, the family or semi-intensive system predominant in Jalisco and Estado de México, and the dual-purpose system found in Veracruz and Chiapas (PNI, 2023).

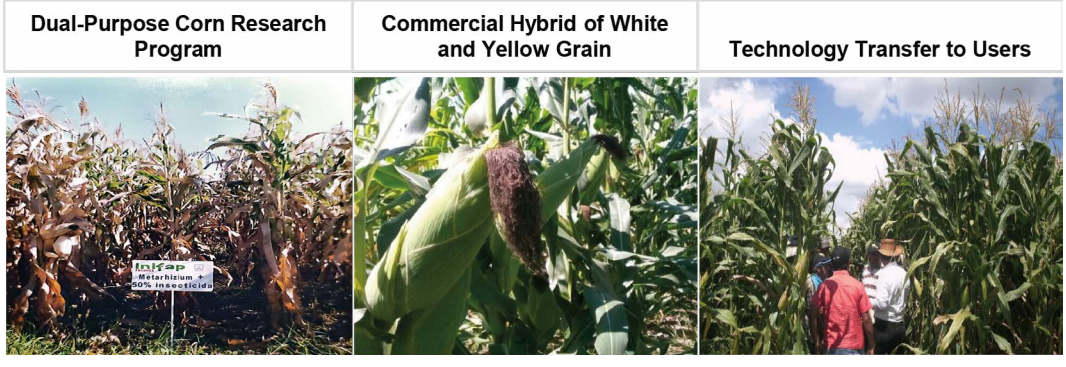

Figure 6. Technology available to producers dedicated to the production of corn seed.

Livestock activities are approached from a process perspective, where products (meat or milk) are transformed from inputs such as fodder and animals through activities linked to a production unit (Núñez *et al.*, 2009). This process approach involves the identification and measurement of indicators generated in each sub-process, including forage production, feeding, reproduction, health, genetics, replacement breeding, and management. This methodology allows the evaluation of whether objectives are being met and tracking progress over time, which is essential for decision-making.

At the Centro-Altos de Jalisco Research Station, the primary research programs focus on dairy cattle managed under the family or semi-intensive milk- production system, beef cattle in the cow-calf system, and swine production. Although the Research Station does not have specialists for every issue within these production systems, it collaborates with specialists from other INIFAP centers across the country to address these challenges. The animal reproduction area constitutes a strength for the livestock sector in this station, since the recent establishment of a laboratory and the integration of researchers with a high specialization in reproductive biology, assisted reproductive technologies, and applied reproductive management (Figure 7). Other strengths include the presence of a module for integrated management of farm waste and swine production (Figure 8) as well as researchers with specialization in forage management and animal nutrition who have extensive experience and tight relations with animal production units and producer organizations.

In terms of research activities, the family milk-production system has seen projects aimed at identifying issues and developing strategies to address them, particularly in forage management, feeding, reproduction, genetics, replacement heifers rearing, and health. For the cow-calf production system, research has primarily targeted feeding and reproduction processes to enhance reproductive and productive performance. In swine production, projects have concentrated on managing farm waste and improving swine health and production (Figure 8).

The knowledge generated from these projects is disseminated through scientific articles and institutional brochures written in accessible language for producers and the general public. Additionally, this knowledge is utilized in courses and workshops designed to train

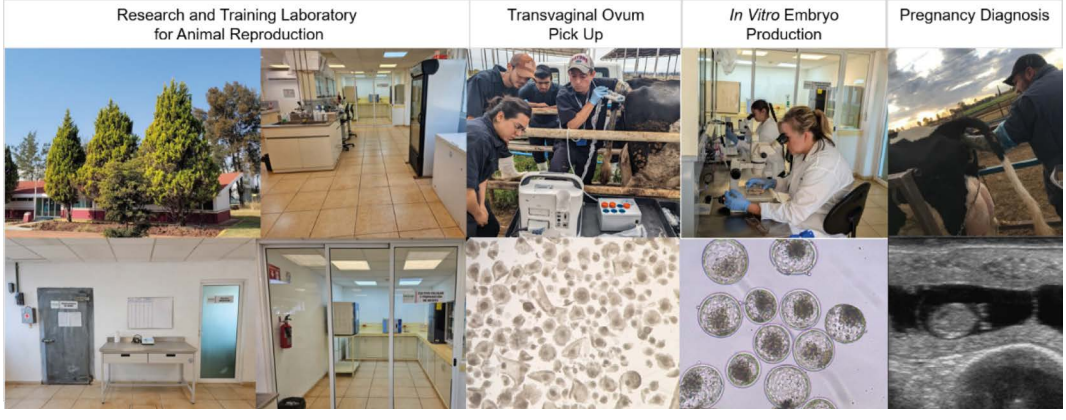

Figure 7. Research and training Laboratory for Animal Reproduction at the Centro-Altos Research Station.

Figure 8. Research and training Module in Managing Farm Waste and Swine Production at the Centro-Altos Research Station.

students, producers, and professionals working in either private sector or government programs related to these animal production systems (Figure 9).

While current projects are aimed to improve the productivity, competitiveness, and sustainability of production systems, there is still progress needed to fully address the research needs of the livestock sector. Environmental changes, such as erratic rainfall patterns, temperature fluctuations, and droughts resulting from climate change, call for the development of strategies that enhance system resilience (Godde *et al.*, 2021). Efforts must also focus on reducing methane emissions and the water footprint per kilogram of protein (milk, meat, or eggs) per animal unit. Improving each sub-process within production units can contribute to these goals.

INIFAP envisions that the adoption of technologies such as automation, artificial intelligence, assisted reproductive technologies, and genomic selection, among others will significantly improve animal production and sustainability. These advancements are essential for meeting the growing global food demands and addressing the challenges posed by increasingly adverse climate scenarios (Agricultura del Futuro, 2024).

Figure 9. Training activities in Beef and Dairy Cattle Production Systems.

Final Remarks

Over its 50 years, INIFAP's Centro-Altos de Jalisco Research Station has been pivotal in advancing forestry, agricultural, and livestock research and development in Jalisco as well as neighboring regions. Its ability to adapt to the evolving challenges and demands of the agricultural sector has established this Research Station as a cornerstone of knowledge generation and technology transfer.

The consolidation of the Research Station as a strategic institution has not only enhanced its infrastructure and human resources but has also broadened its influence. This expansion has significantly impacted sustainable rural development and the competitiveness of the agricultural sector. Strategic partnerships with educational institutions and other organizations have been crucial in expanding knowledge and training new generations of agricultural professionals.

Looking forward, the future of the Centro-Altos de Jalisco Research Station is closely tied to its capacity for innovation and adaptation to emerging realities, such as climate change and the need for more sustainable agricultural practices. Integrating new technologies and scientific methods into its research and development programs will be essential for continuing to address the challenges facing Mexican agriculture effectively.

In summary, the Centro-Altos de Jalisco Research Station has not only observed but actively contributed to the evolution of the agricultural sector over the past five decades. Its achievements reflect the dedication and vision of its researchers and collaborators, who have worked relentlessly to enhance the lives of producers and the sustainability of natural resources. The ongoing challenge will be to sustain leadership in innovation and technology transfer, ensuring that future generations benefit from a thriving and resilient agricultural sector.

ACKNOWLEDGMENTS

We extend our heartfelt gratitude to the following entities for their invaluable support:

- To the Secretaría de Agricultura in Jalisco and the Secretaría de Desarrollo Rural of the State Government: Your continuous support has been instrumental in enabling us to effectively carry out our work in the state.
- To the Consejo Nacional de Humanidades, Ciencia y Tecnología: for funding several research projects and providing INIFAP personnel with the opportunity to be recognized by the National System of Researchers award.
- To Fundaciones Produce: We appreciate your assistance in identifying technology needs and managing financial resources with the relevant entities.
- To Comisión Nacional Forestal: We very thankfull for all your support through these years by using and promoting the research products generated by our researchers.
- To private sector entities in Jalisco, Colima, Michoacán, and Nayarit: many have contributed by providing research funding and services.
- To all researchers from INIFAP-CIRPAC who contributed to this special issue by providing essential information and valuable comments on the final version of this section. Special thanks to Dr. Juan de Dios Benavides and M.Sc. Eduardo Arias for their assistance in correcting the final version. Photographs were provided by M.Sc. David Moreno, Lic. Ruben Chávez, M.Sc. Álvaro Chávez,

M.Sc. Jorge Galindo, M.Sc. Jorge Villareal, M.Sc. Fernando Villaseñor, M.Sc. Eduardo Árias, M.Sc. Gerardo Domínguez, and from archived records.

- Finally, we are thankfull to Agro Productividad Journal, for the opportunity to share our knowledge with the scientific community through this special issue commemorating the 50th anniversary of Centro-Altos de Jalisco.

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