Social Sciences, Rural Sociology and Agrarian Economy

Characterization and functioning of the strawberry innovation system in Salto

Caracterización y funcionamiento del sistema de innovación de frutilla en Salto

Caracterização e funcionamento do sistema de inovação de morango em Salto

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Abstract: In this study, the Strawberry Innovation System in Salto (sis) is analyzed, characterizing its main actors, according to their role and level of involvement. Technological innovations in the sector took place through a process that integrated the information generated by public research with the traditional culture of the region's producers, giving rise to alternative technologies that allowed the sustainable intensification of production. The methodology used in the research was the case study, which belongs to the qualitative paradigm; data collection was based on the conduction of eight semi-structured interviews with qualified informants of different types. Based on the results, it can be pointed out that in Salto, Uruguay, there has been a sis working for decades, whose actors are: the National Institute of Agricultural Research (INIA by its Spanish acronym), the Agronomy College, the General Directorate of the Farm (DIGEGRA), a group of nurserymen, businesses selling supplies and services, the "Salto Hortícola" producer organization, the producers themselves and technical advisers. The synergic functioning of the system is explained by the role of research, which produces knowledge; its interaction with the strawberry nurserymen (primary dialogue network) to validate technologies, and the exchange developed with the rest of the actors to address production problems. It was found that there is a broader dialogue network, in which producers exchange technological proposals, contributing to the sustainability of cultivation in the region.

Keywords: agricultural innovation system, strawberry, social capital, dialogue networks.

Resumen: En el presente trabajo se caracteriza a los actores y se analiza el funcionamiento del Sistema de Innovación de Frutilla en Salto (SIF). Las innovaciones tecnológicas en el sector se dieron a través de un proceso que integró la información generada por la investigación pública con la cultura tradicional de los productores de la región, dando lugar a tecnologías alternativas que permitieron la intensificación sostenible de la producción. La metodología de investigación fue el estudio de caso, perteneciente al paradigma cualitativo; la recolección de datos se basó en la realización de ocho

entrevistas semiestructuradas a informantes calificados de diferente tipo. Según los resultados, puede afirmarse que en Salto, Uruguay, existe un sistema de innovación cuyos actores de mayor importancia son: el Instituto Nacional de Investigación Agropecuaria (INIA), la Facultad de Agronomía, el grupo de viveristas, las empresas comercializadoras de insumos, los productores y los asesores técnicos privados. El funcionamiento sinérgico en el sistema está explicado por el rol de la investigación que genera conocimiento nacional, original, orientado a solucionar problemas limitantes y con mayor facilidad de adopción, su interacción con los viveristas de frutilla en una red primaria de diálogo donde se validan tecnologías, se incorpora conocimiento local e internacional a través de la promoción del intercambio con el resto de los actores para abordar los problemas productivos. Se comprobó que existe una red de diálogo más amplia, en la que los productores intercambian propuestas tecnológicas, contribuyendo a la sostenibilidad del cultivo en la región.

Palabras clave: sistema de innovación agrícola, fresa, capital social, redes de diálogo.

Resumo: No presente trabalho são caracterizados os atores e analisado o funcionamento do Sistema de Inovação de Frutilla en Salto (SIF). As inovações tecnológicas no setor ocorreram por meio de um processo que integrou as informações geradas pela pesquisa pública com a cultura tradicional dos produtores da região, dando origem a tecnologias alternativas que permitiram a intensificação sustentável da produção. A metodologia da pesquisa foi o estudo de caso, pertencente ao paradigma qualitativo; a coleta de dados baseou-se na realização de oito entrevistas semiestruturadas com informantes qualificados de diferentes tipos. De acordo com os resultados, pode-se afirmar que em Salto, Uruguai, existe um sistema de inovação cujos atores mais importantes são: o Instituto Nacional de Pesquisa Agropecuária (INIA), a Faculdade de Agronomia, o grupo de viveiros, as empresas comercializadoras de insumos, produtores e assessores técnicos privados. O funcionamento sinérgico do sistema explica-se pelo papel da investigação na geração de conhecimentos originais, nacionais, direccionados para a resolução de problemas limitantes e com maior facilidade de adopção, a sua interacção com os viveiros de morangos numa rede primária de diálogo onde são validadas tecnologias, o conhecimento local e internacional é incorporado por meio da promoção do intercâmbio com o restante dos atores para tratar de problemas de produção. Constatou-se que existe uma rede de diálogo mais ampla, em que os produtores trocam propostas tecnológicas, contribuindo para a sustentabilidade da cultura da região.

Palavras-chave: sistema de inovação agrícola, morango, capital social, redes de diálogo.

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1. Introduction

The present study aims to analyze the operation of the Strawberry Innovation System in Salto (SIS) and to characterize its participants. The research is carried out in the framework of the main author's thesis, within a Master in Social Sciences of the Agronomy College. In Uruguay, strawberry cultivation (*Fragaria X ananassa Duch.*) is located in the northern coastline's horticultural area, in the surroundings of the city of Salto, and in the southern regions of San Jose and Canelones. According to data from the General Agricultural Census[(1)], the planted area is 127 ha, distributed in 121 production units. Strawberry is one of the most important crops grown in Salto's horticultural area, supplying 50% of the national annual consumption and practically all of the winter and early spring supply. Its production is associated with family units with intensive use of land, labor, and capital[(2)(3)].

Strawberry production technology has been globally inspired by the Californian model, based on annual methyl bromide fumigation for disease and weed control, cultivars obtained by public and private genetic improvement programs and the use of plastic mulching[(4)(5)]. "Frigo" (cold-treated) and fresh (non-refrigerated) plants are used, obtained in high elevation and high latitude nurseries far from fruit production areas, whose cultural practices include localized drip irrigation, among others. This system allowed increasing production per unit area between 30% and 50%[(6)]. In other countries, greater environmental controls were added to the Californian technology using low plastic tunnels and, subsequently, macro-tunnels for higher scale protection[(7)]. The technological bases of the Californian model have also been applied in Argentina[(8)] and the rest of South America[(9)].

Uruguay's southern region (San Jose and Canelones) depends on imported varieties obtained in California and on "frigo" plants imported from nurseries in the USA and Spain[(10)]. Nevertheless, strawberry production technology in Salto's horticultural area has innovative aspects in key factors that differentiate it worldwide, as has been reported by several foreign authors. Plant production is carried out locally in nurseries at sea level, in high-temperature conditions under greenhouses and in the same fruit production farm. Non-refrigerated container plant production is used, in which national cultivars predominate[(11)(12)(13)(14)]. In the Montreal Protocol, governments agreed to eliminate the use of methyl bromide due to its ozone-depleting potential[(15)]. This has created difficulties for production models based on soil fumigation for disease, pest and weed eradication. In this context, new and several previously controlled pathogens that kill strawberry plants have emerged in multiple countries[(16)].

Production in Uruguay has stood out for not adopting annual soil sterilization with methyl bromide[(17)]. In Salto, emerging diseases in the crop are being successfully managed through tolerant cultivars and adjustments in the plant production process[(18)].

Innovations in plant propagation technology, genetics, and disease management arose from a process that integrated information generated by public research with the traditional culture of Salto producers, which involves more intensive use of knowledge than the conventional Californian model[(19)]. Therefore, it is of interest to analyze the participants of this regional and sectoral innovation system, which generated alternative technologies to the predominant systems worldwide and has contributed to sustainable intensification of production.

2. Conceptual framework: Innovation Systems in Agriculture

Starting from the linear technical change paradigm, supported by the diffusion of innovations by Rogers[(20)], theoretical approaches ranged from different angles. It is among the systemic vision of technical change that the contributions of Roling[(21)] can be identified, describing the Information and Knowledge System (IKS)

as "the set of institutions, organizations, and people in the agricultural environment and their relationships and interactions, involved in the generation, transfer, storage, retrieval, integration, dissemination, and use of knowledge and information". For his part, Lundvall[22] describes innovation systems as open, evolutionary, and complex, which accompany relationships within and between organizations, institutions, and socioeconomic structures, creating competencies from learning processes based on both science and experience. This concept evolved into what is currently known as the Agricultural Innovation System (AIS). In essence, an AIS integrates the traditional participants of the IKS (research, Technical Advice and Rural Extension (TARE) and producers) and other relevant actors.

It is important to note, as Arocena and Sutz[23] rightly argue, that the innovation system concept does not describe an existing situation in Uruguay, unlike in other more developed countries. On the contrary, it is an ex-ante approach that is used for its ability to analyze a situation, detecting possible improvements.

In recent decades, the AIS approach has gained popularity as a framework for identifying bottlenecks and improvement opportunities for the innovation capacity of agricultural systems[24][25][26][27]. The two factors that characterize AIS are a broad set of participants and the dynamic interactions between them promoting innovation. Innovation represents a change by which knowledge is applied in a process, product, or service incorporating new advantages for the market or society[28]. The conceptualization of AIS focuses on the interaction between research and TARE (classic in the different paradigms and approaches) while highlighting the importance of synergistic relationships between all relevant actors in the system (beyond research, TARE, and producers), including the private sector and the market.

Technical learning dialogue networks emerge from systemic approaches. Interactions between system actors are mainly channeled through networking[29]. Although these networks may include formal agreements, they basically consist of local groups depending on informal ties and managing a knowledge stock that is under constant transformation[30]. Producers' active participation in the process of identifying problems and improvement alternatives represents a paradigm shift in research, introducing greater producer inclusion in the development of innovations[31].

In participative approaches, innovation is no longer conceived as coming only from external sources, but is developed and designed in its application context involving those in charge of the systems and the decision-making[32].

The ability of a network to effectively operate on an AIS depends on the density and quality of the interactions between the actors (factoring neighborhood, activity type, family ties). Dialogue networks allow knowledge to be the "resulting product of the group's daily exchange of information, experiences, etc., meaning a deeper cooperation level that is not always conscious or intentional"[33].

3. Methodology

A case study from the qualitative paradigm was used in this research. This paradigm aims to consider the studied situation, processes and relationships from the perspective of those being investigated and considering their own contexts, trying to understand the motives and reasons that drive their actions[34]. Several authors manifest that the study of information and knowledge systems (currently innovation systems) cannot be carried out from a quantitative perspective[21][35]. The qualitative paradigm is particularly useful for understanding divergent perspectives whose actors are most likely different in their social, cultural and economic dimensions, and have knowledge and exchange information promoting problem-solving and innovation.

The case study involves the analysis of limited cases to gain in-depth knowledge of these, and is based on the researcher's interests[36][37][38]. As a research design, it is characterized by its adaptability to study

contemporary phenomena in their real context, when the limits that separate the phenomenon from the context that affects it cannot be comfortably established, and there are different opposite visions. It is an always-under-construction creative process, in which the obtained results are studied, based on the established conceptual framework, looking for an emerging logic that links and integrates them[39].

According to its design, this research has a simple case study format. Information was collected through eight semi-structured interviews with different qualified informants. These were conducted in Salto, in the second semester of 2018. The data provided by the interviewees were complemented with a review of the available documentation on the subject and input of the researchers given their related expertise and their experience working in the area.

The semi-structured interview follows a peer conversation model that allows the researcher to understand the perspective that the informants have on their lives and experiences expressed in their own words. It consists of pre-established questions that promote an interaction, where other topics, not previously selected, may arise. This provides the researcher with a holistic view of the situation under study[40].

The interviews collected information on strawberry production innovation systems in northwestern Uruguay, with an emphasis on its participants, their relevance and interaction. In particular, the questions covered the following points: general information, SIS actor survey, knowledge management, existing problems, joints and suggestions for system improvement.

To select the eight qualified informants to interview, knowledge and experience regarding cultivation were taken into account, seeking a balance based on their degree of participation in the process, the task they perform, their training and the degree of involvement within the system. This selection criterion allowed obtaining extensive information about the processes that occurred by comparing different visions. Interviews included people associated with input commercialization, private technical assistance, teaching, research and university extension, public extension of MGAP, nurseries, and producers.

4. Participant characterization and their relevance to the SIS in Salto

4.1 Main stakeholders and their relevance

In this section, each of the participants and their importance within the SIS in Salto are described. They are: the National Agricultural Research Institute (INIA by its Spanish acronym), the General Directorate of the Farm of the Ministry of Livestock, Agriculture and Fisheries (DIGEGRA-MGAP by its Spanish acronym), the Agronomy College (state University -Udelar), a group of strawberry nurserymen, private advisory technicians, input trading companies, associations of horticultural producers of Salto, and horticultural producers of the region.

Actors or stakeholders are people, groups, or organizations that have an interest in a project or program. They are usually considered as those who can have a significant influence, either positive or negative. They are crucial for a situation to manifest in a certain way and for a transformation or change to occur[41].

4.1.1 National Agricultural Research Institute

The activities of INIA in strawberry cultivation technology in Salto are based in Salto Grande regional headquarters and are carried out within the framework of the National Horticultural Production Research Program since 1991. Research has focused on genetic improvement aiming to obtain better quality and agronomic behavior adapted cultivars, tolerant of diseases and pests, improving strawberry plant quality production through propagation technology adjustments and multiplier nurseries development. New protection and management practices have been periodically incorporated into the new cultivar selection

and evaluation process, additionally adjusting some aspects of the production system[42]. Technological proposals are selected considering the likelihood of being adopted by users based on researchers' accumulated experience in the area through interaction with local producers and technicians, in addition to strategies such as validation in farms and critical discussion among nurserymen. An example is the approach used to manage the serious plant mortality problem associated with a new stem and root pathogen complex that emerged in 2015[18]. While recommending the several technological alternatives available within the integrated management and good agronomic practices, innovation focused on adapted tolerant cultivars "combining a high potential to control the sanitary problem in the short term and additionally requiring the lowest implementation cost in terms of time, management, investment or capital"[19]. It should be noted that since 1975 and before the creation of INIA, research work was carried out at the Citriculture Experimental Station CIAAB-MAP (by its Spanish acronym), the Alberto Boerger Agricultural Research Center of the Ministry of Agriculture, adapting technology introduced from reference centers in usa, Europe and Japan in varieties, fertilization, planting distances and in the use of plastics for environmental control[43][44][45].

The interviewees highlight the work of INIA's genetic improvement program, fundamentally enhancing new material adapted to the Salto strawberry production system, allowing to maintain the competitiveness of the crop. "There was a radical change when INIA began with varieties like Arazá; after that, producers did not have to worry about yields or fungi. The investigation and search for better varieties that covered the producer's demand were never interrupted". "Salto is currently producing strawberries due to research. INIA's varieties are the most disseminated". "INIA has been of great importance generating new, increasingly better materials with greater potential".

Both technicians and producers interviewed recognize that "INIA does more than research, it has transferred knowledge and technologies that had a major role in plant production in pots and greenhouses which were fundamental pillars for solving plague problems as soon as they began", "it has always related with producers through different mechanisms", "when major problems arise, INIA is always present, proposing, informing and exchanging knowledge". The Institute has had a key role in generating technologies capable of solving important problems with appropriable proposals; consequently, inventions from technology generation have become innovations in the strawberry production model used in Salto.

The information provided in the interviews matches that reported by Pareja and others[45], concluding that INIA's strawberry integrated production technologies allowed the permanence of producers in the field, by reducing the uncertainty of crop production and the consequent increase in projection possibilities of productive results. Additionally, there was a positive social effect on managing producers' welfare expectations.

4.1.2 General Directorate of the Farm of the Ministry of Livestock, Agriculture and Fisheries (digegra-mgap)

DIGEGRA was created in 2007 with the mission of nationally "executing farming policies that guide the sector towards achieving sovereignty and food security, improving farmers' living conditions through training and extension of production techniques, taking care of the conservation of natural resources"[46]. In 1990, the National Farm Board was created (JUNAGRA), absorbing the functions of the Farmer Plan and the Agro-industrial Projects Advisory Unit (UAPAG). As of 2007, DIGEGRA's regional agency based in Salto stopped engaging in aspects related to technological innovation in farm production (including strawberries), to focus on activities associated with the dissemination, evaluation, and monitoring of projects, participation in the rural development table, surveys and training in good agricultural practices, among others. This has led to the perception that its extension work in the area is not particularly relevant. Its role is perceived as that of gathering information and preparing projects. Some of the interviewees mentioned: "The Ministry is seen

as an office that is there, with few technicians and little presence in the fields". Other interviewees stated: "In DIGEGRA they are focused on completing forms related to commercial matters, but as far as extension, I don't see them participating". "DIGEGRA does fieldwork when there is a catastrophe, its current main role is monitoring the regional situation in terms of production and trade and surveying complex climatic situations, but with little impact on experience and knowledge exchange".

4.1.3 Agronomy College (state University, Udelar)

The Agronomy College, dependent on the University of the Republic of Uruguay (FAGRO, UDELAR, by its Spanish acronyms), has regional presence through the Experimental Station of the Agronomy College in Salto (EEFAS, by its Spanish acronym), and offers courses corresponding to the first years of the bachelor on Agricultural Engineering at the Salto campus of the Regional University Center (CENUR), receiving a one-week stay, dedicated to protected horticultural crops within the bachelor of Horticulture of the specialization in Intensive Plant Production. The time devoted to teaching strawberry production technology is around 8 hours per week between lectures and fieldwork.

Strawberry research began in EEFAS in 1989, targeting issues like nitrogen and potassium fertilization through irrigation, adjustment of transplantation dates and shading in nurseries for plant production. Other studies aimed at improving the analysis of phosphorus in the soil, methods of direct harvest of strawberry and soil rotations and green manures. However, there were two lines of research with greater continuity that aimed at adjusting the techniques of container transplantation and the identification of disease-causing pathogens. Both lines of research were carried out in coordination with INIA and several undergraduate and graduate theses have been developed[47]. The identification of pathogens has been relevant in generating pertinent knowledge, necessary for decision-making on two serious disease events that caused plant deaths in the area, at the end of the 90s and in 2015[48]. The extension has been carried out through talks and field workshops for producers and technicians, in most cases together with INIA Salto Grande, so that the good synergy with INIA stands out: "When the problem of strawberry plant mortality emerged, a meeting was held in which INIA and FAGRO put the extensive research findings they had achieved so far on the table". The interviewees mentioned these are the principal research institutions and entities they go to when problems arise. "The Agronomy College researches and supports crop management although most of their time is teaching-oriented".

4.1.4 Strawberry Nursery Group

Salto's strawberry nursery operators are horticultural producers who multiply cultivars obtained by INIA for the north coastline horticultural area, contributing to supply plant material of better genetic, physiological and sanitary quality[49]. In 2001, when the first variety of strawberries produced in Uruguay was obtained, it was necessary to promote agents that began the activity of producing plants for producers, since there were no nurseries in the area[3]. Therefore, producers interested in both using the new genetics and collaborating in its dissemination to others were selected as licensees and multipliers.

The nursery operators are five producers who represent different scales of production, technological levels, and areas within Salto, they have been linked to producer associations and give different priority to nursery within their activities. They produce mother plants to supply their own nurseries and those of other producers, given that strawberry producers in Salto create their own nursery in a traditional model. In this way, the Salto nursery operators play a role that is more similar to that of livestock breeders, selling plants every year for producers' own fruit crop production. Producers and technicians agree that "most producers get their mother plants from nursery operators". "Regarding the renewal of mother plant material, nursery

operators play an important role in spreading innovation, making micro propagated plants and selling them to producers, transmitting information and guiding communication between technicians".

Nursery operators group activities are promoted by INIA, seeking to improve plant production, validating new cultivars before their release, discussing new local and introduced technologies, relieving problems, and anticipating needs. Information exchange is also facilitated through a group chat in WhatsApp messaging app. Joint bidding and commercialization of the latest varieties released have been milestones in the nursery operators group consolidation process. Thus, this group can be considered as a primary network for technical dialogue based on relatively structured contacts and having a certain degree of formality. "In production problem cases, such as plant death due to different pathogens, generated information is disseminated on account of interdisciplinary work among institutions, private technicians, INIA technicians, FAGRO teachers, producers, nursery operators, having common goals and contributing from their specific role".

4.1.5 Private advisory technicians

Technical advice in Salto's horticulture was associated with protecting crops under greenhouses that replaced old protection structures called "quinchos" in the late 1980s and early 1990s. At that stage, according to Piñeiro, two-thirds of Salto's surveyed horticultural producers did not have technical advice(50).

In 2001, records show 56% of horticulturists received some sort of advice, through the Group Technical Assistance Program of PREDEG-JUNAGRA and from independent advisors. predeg's technical assistance combined individual farm visits with group meetings allowing technical advice access to many small producers. In 2006, the horticultural survey carried out by DIEA-DIGEGRA reported that 46% of producers started having some type of technical assistance on a weekly basis. In 2020, the Salto Horticola Union and the Municipal Administration of Salto revealed that 61% of producers received individual technical assistance, half of them through weekly visits(51). It should be noted that technical advice given by agronomists and agricultural technicians in Salto has mainly focused on pest and disease control and crop nutrition. According to the technicians and producers interviewed, "the existing articulation between institutions and technical advisors facilitating information is relevant, demanding and adds value to innovation". "The role of technical advisors is to disseminate technological innovation information to producers". Some indicate a tendency to resolve temporary situations. "Different advisory types coexist, the most common is short-term hiring to address specific problems; hiring technical support with an integral approach is unusual."

Nonetheless, it has been registered that popular opinion among producers and technicians is that "producers always try to get technical advice and most of them count on it", and that "60-80% of producers in Salto receive some type of technical assistance", which is inconsistent with the survey data. Despite the fact that for some interviewees "technical assistance is available for producers to access through various channels and on different modalities", there are uncertainties about why some producers still do not receive technical assistance.

4.1.6 Input trading companies

Salto's horticultural activity generates an input demand that stimulates the presence of local suppliers of technological products such as seeds, phytosanitary treatment inputs (chemical and biological), fertilizers, irrigation equipment, plastics, machinery, and wood, among others. Additionally, local representatives from national firms visit production farms with their offers. Some trading companies have specialists in their teams. The interviewees agree on the importance of trading companies in cultivar innovation, adapting exogenous knowledge about imported technological inputs, and their inclusion in the production system (chemical and biological inputs, irrigation equipment, and plastics for crop protection). To develop or

validate a new, imported product, companies encourage some producers and consulting technicians to use it and, by trial and error, evaluate its benefits and the necessary adjustments to implement. Once validation is completed, the product is disseminated to the entire producer community through direct communication, social media and talks. The interviewees commented that this information should be taken with caution, since companies aim is to sell: "Importing and commercial companies participate in innovation systems. However, sales pressure exists. Companies representatives organize events at producers' houses to offer their products, influence their decisions and do business. It must be clear those are commercial events and one needs to be objective". In any case, producers expressed that "another way to receive technical advisory is through trading companies' agronomists. Producers go to stores and consult agronomists who sell products through their technical advice". "All commercial companies in Salto are a source of information; if producers need information, they have it available, it is within their reach and they know where to go look for it".

4.1.7 Associations of horticultural producers of Salto

Most of Salto's producer associations are oriented to union activities, seeking to improve commercialization, services, security, and mitigate problems caused by severe weather. Currently, union affiliation rate is 64% according to data released by Salto Horticola and the Municipal Administration of Salto in 2020[51].

Communication with national and local governments and with public institutions has been channeled through the unions. However, the Salto's Horticulturists Movement (SHM), an organization that operated between 1988 and 2002, used to manage these activities while working towards improving crop production technology, particularly for strawberry cultivation. The SHM impacted strawberry production positively by advising horticultural producers through its technical department. Additionally, it created nurseries to supply quality plants and experimental export experiences for its members.

Currently, Salto's producers are grouped in the Salto Horticola Union, established in 2012 as a civil association bringing together seven trade unions of horticultural producers of varied seniority and experience. These are: "Grupo Parada Viña", "Asociación Granjeros de Salto", "Mesa Hortícola de Salto", and the Rural Development Societies of Salto (SFR by their Spanish acronym) "Colonia 18 de Julio", "Presidente D. O. Gestido" and "Osimani y Llerena". Salto Horticola's goal is to consolidate an associative strategy to promote horticultural activity in the region, contributing to local and national development.

The interviewees do not recognize Salto Horticola as a relevant participant of the SIS, particularly when comparing its contribution with the major impact the Salto's Horticulturists Movement had in the past. Instead, they value its "work on business management, infrastructure, human resources, and financial management. Its interaction with producers and contribution towards development is permanent; there is a lot of coordination and weekly work, both formally and informally". Union affiliation rate is 64% according to data released by Salto Horticola and the Municipal Administration of Salto in 2020[51].

4.1.8 Horticultural producers of Salto

The number of strawberry farms registered in Salto ranged between 67 and 107 according to annual surveys carried out by DIEA-DIGEGRA[52][53][54][55]. Although it represents less than half of the strawberry producers in Uruguay, it produces more than half of the national production, as northern-coastline producers achieve higher average yields and possess increased technology[56].

Salto's horticultural producers have generated relevant tacit knowledge based on cultivation accumulated experience. Strawberry plantation dates back to the end of the XIX century and was led by Harriague, who brought seeds into the country and invited an expert farmer from France[57]. Fruit, vegetable, citrus, and

vine production development was generated in the surroundings of the city of Salto at the end of the XIX century mainly by Italian immigrants[58]. Portuguese immigration also contributed, in the first half of the XX century[59].

Salto's horticulture was developed by seeking to supply the main consumption center of the country, entering "Mercado Modelo" of Montevideo with off-season products, taking advantage of certain favorable natural conditions and the application of crop weather protection techniques. This probably generated the need to develop trial-and-error adjustments in the production practices, intensive use of knowledge, and a technology-driven mindset.

Another peculiarity is that in Salto, unlike in other parts of the world, producers cultivate strawberries within a diversified scheme. Strawberries are regularly cultivated in production units that also grow other vegetables, sometimes intensively. Combining strawberry with tomato and pepper in greenhouses and with onion and sweet potato in open-field cultivation facilitates knowledge extrapolation from one item to another as well as the possibility of sharing resources such as infrastructure. In general, Salto's horticultural producers have a very positive attitude towards technology and are prone to innovate and communicate their experiences to other stakeholders in all kinds of informal instances. This feature has enabled information and knowledge transmission, consolidating expanded dialogue networks which have compensated for the lack of official services of technical assistance and rural extension. Strawberry producers in Salto can be considered to be a secondary network for technical dialogue, integrated by different actors and based on unstructured interactions, aiming to disseminate technological content to broad audiences. Opinions reinforcing this concept were collected during interviews mentioning that "producers are sources of information but, at the same time, they are demanding", "they generate information and exchange their ideas and experience with other producers". According to Freiría, northern horticulturists have positive expectations where generational change and new producers are welcomed[60]. There is innovation and rapid adoption of technology, investments, and willingness to grow. Furthermore, it is highlighted that successful production units are associated with direct market access and a series of soft skills based on tacit knowledge, which is difficult to systematize, document, and transmit.

4.2 Overall system performance

Through the testimony of the interviewees, personal observation and related documentation review, it can be concluded that the general performance of the SIS in Salto is synergistic. The elements supporting this assertion are listed below.

4.2.1 Articulation

It is highlighted that over the years INIA has had a central role in facilitating synergy between the different participants of the SIS. INIA Salto Grande has developed an approach for strawberry production technology generation in Salto, considering it has to be oriented to solve limiting problems and must be easily "adoptable" and "appropriate" in order to become innovation. Undoubtedly, TARE's services play an important role. However, in terms of technological innovation, it is necessary to take into account producers' "adoptability" and their contribution to improving technology design to mitigate energy waste risks. Moreover, INIA focused on generating knowledge and original technological products in high impact factors (genetics and propagation), based on the fact that "adaptive research" of imported inputs and practical adjustments are, in general, rapidly carried out by producers, technical advisors, and trading companies. Examples of these are new products, fertilization adjustments, types of nylon, and irrigation equipment, among others, which are issues that research cannot address at the moment due to lack of resources. The group of nursery operators

has essentially assembled, integrated, and discussed knowledge generated in the area by research institutions, imported technologies, and producers' continuous adjustments. This enabled a continuous articulation between the different actors, strengthening ties, coordinating tasks, seeking to achieve a form of networking where trust and exchange have determined the sustainability of the innovation system.

According to the opinion of producers and technicians interviewed, "there is a good relationship between research and extension", "interactions with institutions are productive and in good terms", and "public and private institutional openness" was emphasized. It was expressed that "the innovation system works; it is receptive to well-founded demands and there is an intention to provide answers and promote exchange". Testimonies reveal that "the existing articulation between institutions and technical advisors, who are information facilitators, is relevant, demanding and adds value to SIS in Salto". Some indicate that among the "different advisory types that coexist, short-term hiring to address specific problems is the most common one, while hiring technical support with an integral approach is unusual". Regarding producers' attitude towards technical advice, it was indicated that "producers always try to receive technical advice, most of them count on it." For their part, the producers interviewed agree that interaction is strengthened as problems emerge, since "specific problems encourage the exchange even more". They mentioned that "when problems arise, people come together and work towards making a contribution because there is commitment."

Although articulation between actors exists, the operation can be improved. An interviewee indicated that "there is a good relationship, but there is room for improvement. Ideally, at least one annual meeting should be held to check crop status, identify possible contingencies and define responsibilities, deadlines and courses of action for the achievement of the objectives and goals that might be set".

4.2.2 Information availability and access

It is recognized that there are several ways to access information in the area: "INIA's crop-specific workshops, FAGRO workshops, presentation of theses and projects' results, communication between producers, private technicians and institutions and input suppliers". It is understood that "information flows through INIA", according to the comment of a technician who highlights new material generation, with greater potential and resistance capacity, as the key for crop sustainability in the region.

The interviewees mention demonstration farms, producers' group meetings and INIA's workshops as good tools to disseminate information.

It is important to mention that problems regarding technology access for small-scale producers can be identified. The lack of periodic technical assistance, with an integral approach, is pointed out as an impediment. It is believed that "technological information flows with difficulty, or is hard to access for small producers who sometimes do not even have technical assistance", "they are one step behind".

Producers indicate some improvements needed regarding technical advice: i) a more integral technical advice, taking into consideration that problems are related to property management; and ii) greater coverage through the presence of technicians in the territory. In other words, although information is available to the vast majority and there is significant adoption of national cultivars and improved plant production techniques, technology adoption degree requiring greater investment or greater control of processes fluctuates according to different economic, cultural and technical advice variables that producers receive.

Furthermore, the existence of a secondary network, a system of families that provides knowledge and information flow in the region is recognized. An interviewee describes it stating that "if a producer is doing good with a certain variety, the rest find out right away because every Sunday people meet, either at the agrarian league game or at gatherings. Family dialogue networks are valuable circuits". Salto's horticultural producers generally communicate their experiences directly to other producers or to the groups they are part of. Communications have been enhanced with the use of social networks such as Facebook or

WhatsApp, which some interviewed technicians mention as other alternative channels for the dissemination of technologies. In this secondary dialogue network, private technicians and trading companies also interact, constituting a meeting place for different actors, fostering frequent informal interactions.

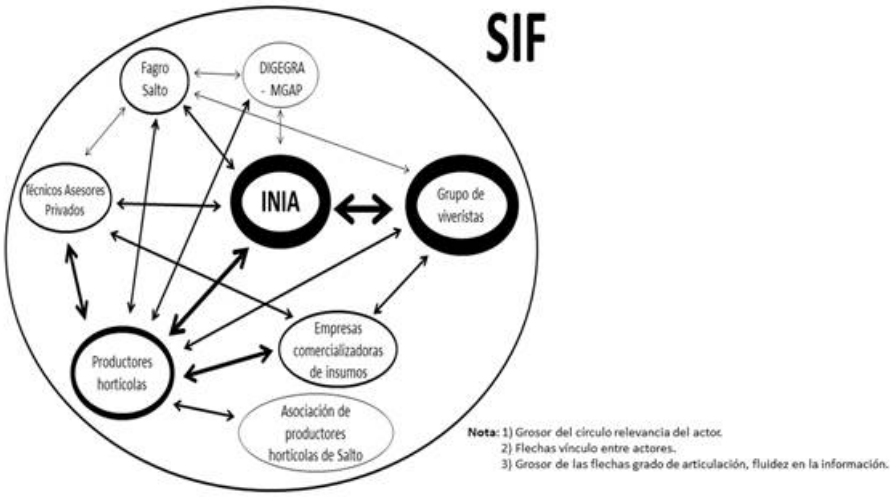

FIGURE 1
Salto's SIS participants and their level of interaction

Figure 1 shows the relative importance of the participants within Salto's SIS, their degree of interaction and information flow regarding the innovation of strawberry technology.

As can be noted in the diagram, there are actors with greater relative weight within the SIS (represented with the thickness of each circle) according to their role and level of involvement. At the same time, all the actors are linked to each other, although the degree of interaction and the flow of information exchanged vary, represented by the thickness of the arrows.

5. Conclusions

In this study, the strawberry innovation system (SIS) in Salto was characterized by analyzing its participants and operational performance. Firstly, the actors involved in the SIS were determined: INIA, the Agronomy College, DIGEGRA, Nursery operators Group, input trading companies, Salto Horticola, producers and technical advisers. Not all participants have the same weight in this system.

Salto's SIS has prioritized the generation of local knowledge in key production factors over other model types (imported knowledge). This particularity constitutes a strength that explains why the SIS provides successful responses to specific emerging problems.

From the interviews, three types of actors according to their relevance can be identified. The first group has great relevance and is constituted by: i) INIA Salto Grande, ii) the group of nursery producers (licensees of INIA's cultivars) that make up a primary network of technical dialogue, and iii) Salto's horticultural producers who represent a secondary technical dialogue network.

INIA's vegetable genetic improvement program stands out, having among its roles the creation of new materials adapted to the regional strawberry production system and the generation of technologies capable of solving specific problems with easily appropriated proposals, allowing to maintain crop competitiveness in the area.

Nursery operators have a very important role in the SIS, representing a primary network of technical dialogue that validates technology. This cooperation has an institutionalized interaction basis. For their part,

horticultural producers are also relevant actors of SIS in the dissemination of information on a less structured interaction basis (face-to-face informal mechanisms often based on kinship or friendship).

A second group of intermediate relevance is constituted by: i) input trading companies, ii) technical advisers and iii) FAGRO. The first two provide technical information and advice, mainly on issues related to pest and disease control and plant nutrition. FAGRO's work in Salto is teaching about crop technology and investigating plant pathology and propagation.

The third group is constituted by low-relevance actors in SIS, which are: i) DIGEGRA (MGAP), and ii) producer associations. Despite both participants in this third group had a greater impact on strawberry technology in the past, their role has changed.

Results indicate that the SIS presents a synergistic operation, explained by:

i) INIA's predominant role, stimulating the participation of producers in all stages of the knowledge creation process and encouraging the demand for more knowledge, contributing to system sustainability. This participation is structured in two levels: a) through a primary network of producers (nursery operators), who are referents in cultivation, for validation, discussion of problems and solutions, both the promoted by INIA and those generated by producers themselves (giving value to local knowledge) and input suppliers; and b) through a broad network of producers who contribute to the dissemination of previously developed proposals in the region.

ii) An operational framework in which technological proposals are selected by assessing, a priori, their ease of use and their potential to solve problems.

iii) The role of technical advisers and input trading companies in disseminating information and their direct work with producers. Among producers, consultation with technicians is considered to be the main channel of information access, although this access is inequitable and depends on the production scale.

iv) The significant presence of networks among SIS actors, compensating the lack of technical assistance and rural extension services. On the other hand, producers have been expanding their access to information due to advances in new communication technologies. These aspects stimulate a synergistic functioning, favoring the flow of information, experiences, or tacit knowledge exchange between the different actors through formal interactions, mainly in the primary network as well as informal relations in the secondary network. These two networks promote information socialization generating linear or creative imitations that expand the adoption rate and strengthen social capital, promoting a local culture that favors technical change.

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