Chapter 6
Management of Tephritid Fruit Flies in Argentina

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Abstract The Medfly, *Ceratitis capitata* (Wiedemann), and the South American Fruit Fly, *Anastrepha fraterculus* (Wiedemann), are the only economically important tephritid fruit fly species found in Argentina. Both species harshly affect production, marketing, and export of fruit and vegetable owing to their damage incidence and economic losses and their quarantine restrictions. The exotic species *C. capitata* is distributed throughout Argentina, while the native *A. fraterculus* is restricted to Northern Region. Since 1994 in Argentina, the National Agri-Food and Animal Health and Quality Service (SENASA) has implemented the National Fruit Fly Control and Eradication Program (PROCEM). The first fruit fly control strategy applied through PROCEM has been based on the integrated use of the sterile insect technique (SIT), cultural and air/ground chemical controls, and a quarantine system. Nowadays in the Patagonia and Cuyo regions, fruit fly area-wide integrated management led to the establishment of Medfly free areas and reduction of postharvest treatments. Augmentative biological control in central-western Argentina was

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currently added into biorational strategies of PROCEM-San Juan as a complementary tool in environmentally friendly way. This chapter reviews the current threat status of fruit fly pests in Argentina by reporting on the progress in their management and emphasizing control strategies that should be deepened.

Keywords *Ceratitis capitata* · *Anastrepha fraterculus* · Integrated fruit fly management · Area wide · Eco-friendly control strategies · Fly-free and low-prevalence areas

6.1 Introduction

Argentina is a relevant world producer of different species and varieties of fresh fruits and vegetables due to the wide variety of ecosystems prevailing in the country between 24°S and 40°S latitude, from the northern province of Jujuy (Bolivia border) to the southern one of Rio Negro (Patagonian Region). The fruit and vegetable sector contributed 3183 million US$ to the country in 2019, accounting for almost 5% of total exports. Fruits accounted for 72% and vegetables for 28% of the sector's exports. Therefore, it is the seventh most important sector in Argentina, slightly below livestock (Ernst 2020). The economies of important Argentinean provinces (Entre Ríos, Corrientes, Mendoza, Neuquén, Río Negro, San Juan, and Tucumán) are directly linked to the evolution of fruit production. Therefore, fresh fruits and their by-products are important sources of income, both in the domestic and foreign markets (Ernst 2020; Sánchez 2020). In this regard, Argentina's exports of fresh fruit were nearly 800,000 tons in the first 10 months of 2020 (Campos 2020). In addition to export revenues, fruit farming plays a fundamental social role in terms of job opportunities, as it is a labor-intensive activity (Ernst 2020).

As for cultivated fruits, citrus cover 150,000 ha in areas with ideal ecological conditions for growing oranges, tangerines, grapefruit, and lemons. Citrus crops are focused in both northwestern and northeastern subtropical regions, known locally as "NOA" and "NEA," respectively. In the first one, oranges, grapefruit, and lemons are produced, the latter mainly in the province of Tucumán, whereas in the second fruit-growing region countless varieties of oranges and mandarins predominate, which are harvested and exported practically all year. In addition, the province of Entre Rios ("NEA" region) accounts for 33% of the country's blueberry production (Invest-Argentina 2017). Tucumán is also an important producer and exporter of small-soft fruits, such as blueberries, strawberries, raspberries, and blackberries (Kirschbaum 2011; Funes et al. 2017). An important fruit-producing microregion in the "NOA" is the Calchaquíes Valleys in the province of Salta, which are located at 2000 m, and where wine grapes, peppers, and stone fruits are produced on a small scale (Ramirez 2017; Salta 2021). Around 62% of Argentina's fresh fruit exports come from two dry-climate fruit-producing regions known locally as "Cuyo" and

"Patagonia." The first one is located in central-western Argentina and involves the provinces of San Juan and Mendoza, whereas the second one is located in southern Argentina and mainly involves the northern microregion of extra-Andean Patagonia locally known as "Alto Valle del Río Negro," from provinces of Río Negro and Neuquén. Both Argentinean regions are characterized by intensive artificially irrigated fruit farming, with the production of temperate fruits such as stone fruits (peaches, plums, cherries, and apricots), pome fruits (apples, pears, and quince), berries (mainly grapes and blueberries) and also figs (Invest-Argentina 2017; Ojer 2019; Ojer et al. 2019; Ernst 2020). With regard to pears and apples, Argentinian production comes almost exclusively from the "Alto Valle del Río Negro" fruit-growing microregion (Agrositio 2018). Another fruit-growing region is located in the northeast of the province of Buenos Aires, with the city of San Pedro as its central production area. In this small region, there are currently 4600 ha cultivated, mainly with citrus and peaches, and to lesser scale blueberries, figs, kiwifruit, and persimmons (Angel et al. 2016).

Tephritid fruit flies are one of the main fruit pests that strongly affect the production, marketing, and export of fresh fruits in all Argentinean fruit-growing regions, which has a negative socioeconomic impact on fruit production systems (SENASA 2017). These pest dipterans are currently represented in Argentina by only two species of economic and quarantine importance: the Mediterranean fruit fly or medfly, *Ceratitis capitata* (Wiedemann), and the South American fruit fly, *Anastrepha fraterculus* (Wiedemann) (Ramirez 2017). Both tephritid species cause economic losses either by direct damage to fruits or by indirect losses. Direct damage involves the presence of larvae inside fruit or oviposition activity of female flies, which leads to a decrease in fruit production in the cultivated area where the pest is active, to a drop in the quality of the infested fruit. Indirect damage involves export restrictions imposed by purchasing countries, which require quarantine treatments or other measures that increase marketing costs (Guillén and Sánchez 2007).

Given adverse effects of both fruit fly species increased as Argentina's fruit growing expanded and diversified, the National Agri-Food and Animal Health and Quality Service of Argentina (SENASA, Spanish acronym) implemented the "National Fruit Fly Control and Eradication Programme" (PROCEM, Spanish acronym) to fight against these pests (Ramirez 2017). Applied current actions by PROCEM involve area-wide integrated fruit fly management (AW-IFFM) approaches, particularly adapted to both ecological–geographical characteristics and the incidence of the pest in each fruit-growing region. Therefore, this chapter provides an informative overview on the following: (1) the economically important tephritid fruit fly species found in Argentina, (2) early methods to control fruit fly pests in Argentina, (3) the history and current status of PROCEM, (4) different suppression and eradication strategies implemented against both *C. capitata* and *A. fraterculus* by PROCEM, and (5) challenges and future development to the *C. capitata* and *A. fraterculus* management in Argentina.

6.2 Economically Important Tephritid Fruit Fly Species in Argentina

Among the tephritid fruit flies, *C. capitata* is the most polyphagous species known (Copeland et al. 2002) and one of the most damaging on a global scale for fruit production and trade (USDA 2016). This exotic pest was introduced to Argentina, probably via Buenos Aires, where it was found infesting peaches in 1905 (Turica and Mallo 1960) or did so naturally from Brazil (González 1978). However, in 1937, it was recognized as a pest in Argentina (Vergani 1952). Numerous alternative exotic fruit species made *C. capitata* propagation possible throughout the country. Currently, *C. capitata* infestations have been reported in 58 commercial and wild, exotic fruit species grown in fruit-producing regions and a wide diversity of native fruits throughout the country (Ovruski et al. 2003a; Segura et al. 2006; Guillén and Sánchez 2007; Bouvet and Segade 2015; Funes et al. 2017). *Ceratitis capitata* populations mainly thrive in highly disturbed urban and rural environments, with an abundance of exotic host plants usually not exploited by the Neotropical-native *A. fraterculus* (Schliserman et al. 2014). However, fruit-producing areas of the Patagonian Region and the Central and Southern Oases of Mendoza are nowadays fruit fly-free areas (Ramirez 2017).

Anastrepha fraterculus, a native of the Neotropical region, has long been regarded as one of the most polyphagous species of the *Anastrepha* genus attacking many economic importance fruits (Norrbom 2004). In Argentina, 46 fruit species, including commercial and wild species, were recorded as suitable hosts (Bouvet and Segade 2015). Nevertheless, *A. fraterculus* is a cryptic species complex (Vera et al. 2006; Cladera et al. 2014) possibly consisting of eight identifiable morphotypes (Devescovi et al. 2014), distributed allopatrically from Mexico to central Argentina (Hernández-Ortíz et al. 2012). Their status as a pest varies geographically within the American continent. Some morphotypes cause serious economic damage to several *Citrus* species in Argentina, Brazil, and Colombia, whereas the species described as *A. fraterculus* is not recognized as a pest for *Citrus* crops in Mexico (Aluja et al. 2003). In Argentina, *A. fraterculus* populations are mainly found in the most humid and warmest areas of central, northwestern, and northeastern Argentina, where it coexists with *C. capitata*. However, *A. fraterculus* may sometimes be detected in other areas of the country because of sporadic introductions due to human activity, that is, commerce and migration (Alberti et al. 2002). Molecular evidence and mating compatibility tests (Rull et al. 2012; Cladera et al. 2014) pointed out that only one morphotype is present in Argentina (Gómez-Cendra et al. 2016), which is consistent with *Anastrepha* sp.1 aff. *fraterculus* but renamed Brasil-1 by Hernández-Ortiz et al. (2012). Although *A. fraterculus* attacks several commercial fruit species in Argentina (Guillén and Sánchez 2007), it is mostly found in association with native Myrtaceae and Juglandaceae species, and exotic feral fruit species such as *Psidium guajava* L. and *Prunus* spp. in slightly disturbed wilderness areas from northern Argentina (Schliserman et al. 2010, 2014, 2016).

6.3 Background of the Earliest Methods of Monitoring and Control Pest Fruit Flies in Argentina

Cultural practices and biological control strategies have historically been in use since the early 1930s in Argentina. The first ones mainly involved the removal of heavily infested fruit from both the tree and the soil (Hayward 1944). Any fallen, waste, or ripe fruit (not suitable for marketing) were deposited in 1-m deep wells into which they were covered with lime and then with local soil (Domato and Aramayo 1947; Vergani 1952; Turica et al. 1971). This procedure kills the fly larva as it leaves the fruit or prevents the adult emergence from puparia already formed inside the fruit. Other important cultural measures used were the control of weeds and the soil raking to remove newly buried puparia, which will die from desiccation or predation (Turica and Mallo 1960; Rosillo and Portillo 1971; Turica et al. 1971). Pruning of unproductive trees or parts of trees has extensively been used in the past as it is today. In terms of biological control, the first steps involved activities focused on increasing indigenous fruit fly parasitoids in the citrus-producing areas of northern Argentina. The methods used were modest and rustics. For example, pits were dug under commercial fruit plants, and then these pits were filled with infested fruit and covered with wire netting. This mesh allowed adult parasitoids to get out but not adult flies, as they were larger than parasitoids (Ogloblin 1937; Schultz 1938). Another method was wooden crates with small wire mesh lids Hayward (1940a, b). These crates housed the infested fruit and were placed under fruit trees. The wire mesh allowed only adult parasitoids to escape. Another method was to collect infested fruit and take them to the laboratory to retrieve adult parasitoids, which were placed in 30 × 25 × 30-cm wooden cages with a detachable glass door in the front (Hayward 1940b; Rosillo 1953; Turica and Mallo 1961; Nasca 1973). These cages were taken to the fruit farm where their doors were opened for native parasitoids to release. The introduction of exotic parasitoids into Argentina for fruit fly biological control began in 1947 and continued until the late 1980s. These early projects aimed to develop a classical biological control strategy. Several parasitoid species were introduced from other Latin American countries (Turica 1968; Ovruski et al. 2000; Ovruski and Schliserman 2012). However, these parasitoids were originally from Hawaii's innovative, pioneering fruit fly control program.

Between the late 1950s and the early 1990s, control of *C. capitata* and *A. fraterculus* in Argentina was mostly attempted through the use of a mixture of synthetic organophosphorus insecticides, usually malathion, parathion, or fenitrothion, and food attractants, mainly sugarcane molasses, yeast extract, corn protein alone or with trimedlure, commonly known as bait sprays in an aerial and terrestrial application (Turica et al. 1971; Aruani et al. 1996). For soil application, chlorinated insecticides like dieldrin, Aldrin, and HGH were used. Mc Phail-type traps, originally made of glass, or plastic traps known as Portici, both baited with liquid food attractants containing either 25% wine vinegar or fruit/sweetcorn protein and carbohydrates diluted in water, were widely used (Turica and Mallo 1960; Turica et al. 1971; Marchese et al. 1975). In addition, dry traps such as plastic Steiner traps were baited with liquid trimedlure as a sexual attractant only for males and were later deployed although less frequently than liquids traps. These trap types were used in the first monitoring system or to suppress the pest population in some particular crops (Turica and Mallo 1960; Turica et al. 1971; Vattuone et al. 1999). These control actions were carried out, particularly by provincial entities, such as Agro-industrial Experimental Stations, and national institutions, such as the National Institute of Agricultural Technology (INTA, Spanish acronym) in collaboration with the Directorate of Plant Health of the Secretary of State for Agriculture and Livestock of the Nation (Marchese et al. 1975). However, there was no national coordination to articulate fruit fly control strategies at the regional level.

6.4 History and Status of the PROCEM

The PROCEM was created in 1994 by the Argentine Institute of Plant Health and Quality (IASCAV, Spanish acronym) to achieve the integration of the control actions against both *C. capitata* and *A. fraterculus* carried out by different provinces at a regional level in Argentina. Then in mid-1996, the IASCAV was merged with the SENASA. This was done to improve sanitary guarantees for exports of raw materials from Argentina and incorporated agri-food production with federal transit destined for the domestic market, including family farming (SENASA 2010). Thus, the PROCEM was placed under the jurisdiction of SENASA because this national institution designs, organizes, and executes specific programs focused on the production of safe food for human and animal consumption. The new paradigm involved integrated fruit fly pest control/eradication systems with the active participation of the national, provincial, and municipal states with private farmers and/or fruit growers' associations. This structure continues to date.

In order to achieve this new share scheme, the country was initially divided into five fruit-growing regions based on environmental conditions, geographical and ecological characteristics, soils, distances, and isolation among fruit-producing areas, in addition to local traits of fruit farming sector, as follows (Aruani et al. 1996): (1) region "I," the southernmost region, from 36°S downward, included the Patagonian region covering the south of La Pampa and Buenos Aires provinces; (2) region "II" located in central-western Argentina, approximately between 29°S and 36°S, and bordering the Andes Mountains; (3) region "III" involved the southernmost province of northwestern Argentina (La Rioja province) and two from the central area (San Luis and Córdoba provinces); (4) region "IV" included four provinces of northwestern Argentina (Catamarca, Jujuy, Salta, and Tucumán provinces) located approximately between 22.5°S and 28.4°S; and (5) region "V" enclosed the rest of the country, covering a wide geographical area with differences in weather and natural vegetation conditions, such as north-central, northeastern, central, south-central, and east-central regions. Regions "I" and "II" cover about 500,000 ha of fruit production in irrigated valleys isolated from native xerophytic vegetation. They are two of the most important Argentinean fruit-growing regions with a spare export capacity. Region I, which mainly involves provinces of Neuquén and Río Negro, consists mostly of valleys producing pome and fine fruits which are located on the Patagonian plateau between 361 and 185 m. Region II, with varied natural landscape, has highland valleys at an altitude between 700 and 2100 m where fruits are grown commercially in irrigated oases (Alós et al. 2014) surrounded by vast semi-desert plains and high mountains without native host plants for fruit flies. This region, known as Cuyo, involves provinces of San Juan and Mendoza, mainly produce grapes for export winemaking, table grapes, must, raisins, and stone fruits. In Region I and in almost everywhere in Region II, *C. capitata* is the only tephritid species, while *A. fraterculus* is found in isolated populations throughout the north of Region II. Region "III" covered areas of low fruit production, mainly dedicated to the national domestic market. This region is dominated by *C. capitata*, but isolated populations of *A. fraterculus* can also be found in areas with microclimates characterized by higher annual rainfall. The region "IV," known as NOA, involves one of the most relevant citrus-growing areas of the country, as well as one of the major berry production areas. It is one of the main Argentinean fruit-exporting regions. Both tephritid species' pests are abundant in this region, but *A. fraterculus* populations are mainly distributed throughout the subtropical Yungas rainforest, with null, low, or medium environmental disturbance levels (Schliserman et al. 2014). This region, with an extremely varied natural landscape, has highland valleys at an altitude between 1600 and 2100 m surrounded by vast semi-desert plains and high mountains devoid of native fruit fly host plants, but the fruit is grown commercially in irrigated oases (Funes et al. 2017). These western mountainous areas, locally known as Calchaquí valleys which spread from Tucumán to both Catamarca and Salta provinces in the north, mainly produce grapes for export winemaking, berries, and stone fruits for jams, and quinces for jellies and jams. The large and diverse region "V" included the second most important Argentinean citrus-growing region, known as NEA, which involves the provinces of Corrientes, Entre Ríos, and Misiones, and the fruit-producing area of San Pedro, in the northeast of Buenos Aires. Both, *C. capitata* and *A. fraterculus*, are found throughout this region, but the former is more prevalent in crops. The characterization of the country based on regional fruit farming allowed PROCEM to set as its main objective to reduce the socioeconomic impact caused by tephritid fruit fly pests on fruit and vegetable production chains at national level (Quiroga et al. 2010). However, the PROCEM in its early phase was more focused on main fruit-growing areas of Patagonia and some of the highland valleys of the Mendoza and San Juan provinces (Cuyo). In these regions, weather conditions and landscape structure limit medfly spread, whose populations are restricted to areas with artificially irrigated fruit hosts. In this context, control/eradication actions for *C. capitata* were based on the integrated use of SIT, chemical and cultural control methods, and quarantine systems. This combination of strategies proved to be very effective in achieving fruit fly pest-free or low-prevalence areas (Aruani et al. 1996; De Longo et al. 2000; Alós et al. 2014). Nevertheless, during this first phase of PROCEM, a monitoring system for both tephritid pest species was set up in the provinces of La Rioja (Frissolo et al. 2001) and Entre Ríos (Aruani et al. 1996; Putruelle 1996; Bouvet and Vaccaro 2009), using trapping nets with McPhail with food baits and Jackson traps with a male lure. This monitoring system was deployed in those areas with high fruit and vegetable production efficiency levels.

Later, the expansion of PROCEM's actions to other fruit-growing regions, especially the citrus-producing areas of NEA, NOA, and northern Buenos Aires, renews the integration of strategies for fruit fly pest control at the national level under a wide-area approach (Guillén and Sánchez 2007). This implied a change of strategy in the NEA, which led to a shift from chemical control by air or ground sprays focused on the crop to integration with eco-friendly methods, such as SIT, at a regional scale. The new strategic approach encouraged PROCEM to provide both Patagonia and Cuyo regions with more tools to keep fruit fly-free- and low-prevalence areas, as well as the expansion of actions to nonproductive areas, but with the presence of medfly host fruits, such as urban areas. Therefore, the strategy adopted from around 2010 to the present has emphasized the use of chemical treatments on foliage integrated with other control approaches. These techniques are as follows: (1) aerial releases of sterile medfly males in large areas, (2) mass trapping focused mostly in urban areas, (3) cultural control in combination with soil chemical control in "hot" areas with high pest density (Quiroga et al. 2010; Alós et al. 2014), and (4) the use of biological control through augmentative releases of an exotic larval-pupal parasitoid (Suárez et al. 2014; Sánchez et al. 2016). In addition, there was a strengthening of the quarantine protection system and the implementation of phytosanitary emergency programs for pest outbreaks in free- or low-prevalence areas (Quiroga et al. 2010, 2016; SENASA 2018). These actions enacted by the SENASA are framed in a scheme of fruit fly exclusion and detection program. In this context, the national PROCEM provides technical support to provincial or regional fruit fly programs in meeting its goals for domestic and international activities to prevent the establishment and spread of economically important fruit flies.

Five sub-programs in operation on an ongoing basis, namely, "Patagonia," "Mendoza," "San Juan," "NEA," and "Valles Calchaquíes-Salta" currently constitute the national PROCEM. Those provincial or regional programs are actively implementing fruit fly pest monitoring and specific integrated management measures nowadays. In this regard, the Fundación Barrera Zoofitosanitaria Patagónica (Funbapa), the Instituto de Sanidad y Calidad Agropecuaria de Mendoza (ISCAMEN), and the Dirección de Sanidad Vegetal, Animal y Alimentos del Gobierno de San Juan (DSVAA-San Juan) are currently implementing PROCEM's actions in the Patagonia region (Villarreal et al. 2018), Mendoza province (ISCAMEN 2022), and San Juan province, respectively, all under SENASA coordination. The PROCEM-NEA was put into operation on a collaborative basis between SENASA, governments of the provinces of Corrientes and Entre Rios, and private producers (Ramirez 2017). Similarly, the government of the province of Salta, SENASA, and the INTA regional NOA Norte, with the participation of farmers, is implementing the PROCEM-Valles Calchaquíes-Salta (SENASA 2015).

In general terms, all PROCEM sub-programs involve three main components, namely, detection, phytosanitary control, and communication. The detection system consists of a trapping network to determine the density and population dynamics of the pest in each province or region and to provide a diagnosis that would allow phytosanitary control actions to be drawn up. The detection system reached about 10,000 operational traps, and the trained personnel performs 572,000 trap checks per year (SENASA 2018). Fruit sampling is also performed, to determine the susceptibility of the different species and varieties, sequence, and percentage of infestation, and identifying possible wild hosts. A targeted sampling by symptomatology is carried out on fruit that has fallen on the ground or those still on the tree. The phytosanitary control system entails a control strategy by area or region, at the right time according to the target pest dynamics, and by combining different management tools. The communication and broadcast system involves informative meetings and training workshops mainly aimed at producers, to inform them about the characteristics of the pest and control strategies. Monitoring data is also shared with provincial government authorities, and workshops are also held with students from agro-technical and secondary schools to raise awareness of the scope of the program and the importance of controlling the pest.

The updated phytosanitary status related to fruit flies in fruit-growing areas covered by those sub-programs is as follows (Ramirez 2017): (1) fruit fly pest-free areas in Andean-Patagonian Valleys (Alto Valle del Río Negro and Neuquén, Middle Valley of the Colorado River, General Conesa Valley, interior of the Patagonian Plateau and Lower Valley of the Chubut River) and in both central and southern oases of Mendoza; (2) *A. fraterculus*-free area and *C. capitata* low-prevalence areas in both northern and eastern oases of Mendoza; (3) *C. capitata* low-prevalence area in the highland Calingasta Valley of San Juan; (4) areas under *C. capitata* and *A. fraterculus* control in the remaining fruit-producing valleys of San Juan; (5) areas under *C. capitata* and *A. fraterculus* suppression in the citrus-growing sector between Monte Caseros (Corrientes province) and Colón (Entre Ríos province) (NEA region); and (6) areas under *C. capitata* and *A. fraterculus* monitoring in the Valles Calchaquíes from Salta province (NOA region).

The PROCEM has been ranked by SENASA as one of the most successful Argentinean phytosanitary programs, mainly because of its public–private partnership model under national supervision, and with close involvement of provincial governments, non-governmental corporations, and national scientific-technological research institutions, which facilitated the successful implementation of an AW-IFFM system (Quiroga et al. 2016; Ramirez 2017; SENASA 2018).

6.5 Strategies Implemented for Fruit Fly Integrated Management in Argentina

The set of strategies implemented by each currently operating sub-program depends on several factors, such as the achieved phytosanitary status, prevalence of one or both pest tephritid fruit fly species, environmental and landscape conditions of areas under production, the infrastructure required for the use of specific fruit fly management methods, and also the logistical and operational capacity of the program. In this context, "Patagonia," "Mendoza," and "San Juan" programs are structured in a system of interlinked components that facilitated the current phytosanitary status of fruit fly free- and/or low-prevalence areas in highly productive fruit-growing valleys. These components can be outlined as pest detection or monitoring networks, control/eradication strategies, insect production for biological and autocidal use, quarantine protection, and data processing, administration, maintenance, and communication systems (Quiroga et al. 2010; Alós et al. 2014; Llera et al. 2016; Ramirez 2017). In an overall outline, fruit fly mitigation integrated strategies currently implemented in Argentinean fruit-producing areas are SIT, mass trapping, cultural, biological, air and ground chemical controls, and phytosanitary barriers as a quarantine protection method.

6.5.1 SIT

In Argentina the SIT has been intensively using against medfly since the late 1980s, and from the early 1990s onward, this eco-friendly technique 90s has been overseen through the national PROCEM (Guillén and Sánchez 2007). The SIT was initially used in the province of San Juan in 1986 (Llera et al. 2016), and then, at the beginning of 1990, it began to be applied in the province of Mendoza (De Longo et al. 2000). Later, the SIT was mainly extended to Patagonia (Sánchez et al. 2001; Villarreal et al. 2018; PROCEM-Patagonia 2018) and partly to both La Rioja province (Frissolo et al. 2001) and the NEA region, more precisely in citrus-growing areas of Entre Rios and Corrientes (Quiroga et al. 2010, 2016). The implementation of the SIT was feasible through the establishment of insect mass-production biofactories in the provinces of San Juan and Mendoza. This is because to develop SIT, the target pest insect must massively be multiplied. Male individuals are sterilized by radiation and released in areas with low pest presence, where they mate with wild females, which will not generate offspring and thus the pest population decreases over time (IAEA 2019; Liedo et al. 2020).

For sterile medflies production, the national PROCEM oversees two biofactories built by provincial government support, one located in the province of San Juan (named "Bioplanta San Juan") and the other in the province of Mendoza (named "Bioplanta Multipropósito Santa Rosa Km 11"). Construction of the Bioplanta San Juan began at the end of 1982 and was concluded at the end of 1985 (Escobar et al. 1998). This biofactory located in the district of Rivadavia, south-central San Juan, in the Tulum Valley, has a surface area of 1200 m^2 with a production capacity of 40 million medfly sterile pupae per week of optimum quality (DSVAA-SJ 2012). In 1991, the biofactory known as the "Bioplanta Piloto Km8" was built in Mendoza for *C. capitata* mass rearing, but after 16 years dedicated to the production and release of sterile males, a new biofactory, the Bioplanta Multipropósito Santa Rosa Km 11, was inaugurated in 2007. This biofactory, located on Provincial Route 71, KM 11, in the district of Santa Rosa, eastern Mendoza, is the largest of its kind in South America, with a covered surface area of 16,000 m^2 (ISCAMEN 2022). Through production at this biofactory, the PROCEM Mendoza is releasing 220 million sterile males every week (ISCAMEN 2022). The biofactories of both provinces started with the SIT using a native biparental *C. capitata* strain. In 1995, the ISCAMEN replaced the native medfly strain with the white pupae strain SEIB60/96 at Bioplant Km8 (De Longo et al. 2000; Gómez-Riera et al. 2000). Both biofactories produce currently sterile medfly males of the temperature-sensitive lethal (tsl) genetic sexing Vienna-8 strain without inversion (hereafter: "tsl" Vienna-8 strain w/i). In addition to their use in Mendoza and San Juan, sterile medflies were shipped from both provinces to Patagonia in 2011, 2012, and 2015–2016 (Beltrachini, "unpublished data"). Nowadays, sterile medflies produced in Mendoza are released in Patagonia (Ramirez 2017; PROCEM-Patagonia 2018).

The outstanding results of the continued use of SIT in a wide-area framework, as the main component of the Patagonia and Cuyo regions' fruit fly programs, led to the establishment of fruit fly-free areas and consequently to the reduction of production costs by limiting postharvest treatments (Ramirez 2017; Rendón and Enkerlin 2021; ISCAMEN 2022). These achievements made possible the international market opening by enabling fresh fruit and vegetables to be exported (Borges et al. 2016; Villarreal et al. 2018; SENASA 2018). Based on SENASA's data published in 2018 (SENASA 2018), monitoring and control actions carried out by PROCEM covered 1,000,000 hectares in the Patagonian region, Mendoza, San Juan, and in the citrus-growing areas of the NEA, where around 400 million sterile medflies were weekly released. In those regions, 5.5 million tonnes of fruits are annually yielded. In this regard, the production of pears and apples stands out, with 330,000 tonnes exported from the Patagonia Free Area and 3500 tonnes of grapes exported from Cuyo (SENASA 2020; Ernst 2020). Another success indicator is the fact that in 2019 and 2020, Argentina exported 5600 tonnes of cherries grown in these regions, which represented 27.2 million US$ in revenue to the country (Willis 2020).

The SIT is a successful strategy in Patagonia and the provinces of Mendoza and San Juan, especially due to three factors: (1) orographic features of cropped areas, such as isolated irrigated valleys surrounded by mountainous highlands and arid plains deprived of medfly hosts, (2) dry and cold weather conditions, low annual rainfall and average annual temperatures between 10 and 16 °C, and (3) the distribution of medfly populations focused on areas with microclimates created by both artificial irrigation and fruit tree cultivation that provide food and shelter to the pest. The above features greatly limit the medfly natural spread to other cropped areas (Díaz et al. 2008; Quiroga et al. 2010; Rial et al. 2010; Villarreal et al. 2018).

Advances in research and technological development have enabled SIT to be optimized through enhancements in the rearing process and releasing more effective sterile insects. Hence, the development of genetic sexing strains, improved management of "mother" colonies, more nutritious artificial diets, the production process mechanization, and improvements in packaging and release methods have reduced the costs of SIT application (Liedo et al. 2020). The AW-IFFM programs incorporating the SIT have developed manuals on quality control tests to evaluate precopulatory and copulatory success, and male post-copulatory performance of mass-reared sterile males (Abraham et al. 2020). In this context, laboratory trials with medfly males of tsl Vienna-8 strain produced at the Bioplanta San Juan were performed to improve SIT's effectiveness implemented by PROCEM-San Juan. Results verified that sterile males of tsl Vienna-8 strain were better able than wild males to inhibit female remating on the same day of first copulation and as able as wild males 1 day after first copulation (Abraham et al. 2020). In addition, a decrease in radiation dose from 140 to 100 Gy did not influence both copulatory and post-copulatory events of sterile medfly males (Abraham et al. 2020). This is an interesting point because in a field-competition context with fertile males to monopolize copulation with wild females, males irradiated at lower doses may be more successful. Field studies were also promoted by PROCEM-San Juan through the DSVAA-evaluated artificial devices to estimate in field conditions the induction of sterility in wild medfly females after the application of SIT in San Juan. Those egg-laying devices were useful to measure sterility induction and can be further improved by refining long-distance attraction and deployment schemes (Suárez et al. 2019a).

Regarding the use of SIT for *A. fraterculus* control in Argentina, studies on optimal gamma irradiation doses and pupal age have been carried out since the early 2000s (Allinghi et al. 2007). However, there has been significant progress in many fields toward achieving the SIT for *A. fraterculus*, which is currently in the preliminary stages (Cladera et al. 2014).

6.5.2 Mass Trapping

The implementation of mass trapping and attract-and-kill strategies is globally encouraged in integrated pest management because of increasing restrictions on synthetic pesticides (Cook et al. 2007). Based on the foregoing, mass trapping is a mostly targeted strategy in urban areas where there is a great diversity of host fruits scattered in backyards and in rural areas with records of high adult captures because it does not leave chemical residues on the fruit, and therefore it is safe for animals and humans (Hafsi et al. 2020). It is a technique mainly adopted by Patagonia, Mendoza, and San Juan (Alós et al. 2014; Taret et al. 2014; Llera et al. 2016; ISCAMEN 2022), although in the NEA region, particularly in the province of Entre Ríos, it was also used in areas surrounding both blueberry and citrus crops for *C. capitata* and *A. fraterculus* control (Putruelle and Petit-Marty 2000; Bouvet and Vaccaro 2009, 2012; Mousqués 2016; Trupiano and Roncaglia 2019). Urban areas have higher average temperatures than rural areas, and Citrus trees, which are common in backyards, provide protection to the medfly and serve as bridges between winter and spring when environmental conditions are more suitable for reproduction and host search. For that reason, mass trapping is advisable in highly disturbed areas. Different trapping devices can be used for this fruit fly control technique, with either dry or liquid attractants, or lures. Interesting trials on mass trapping effectiveness were carried out in San Juan, which showed two interesting findings: (1) the liquid protein-baited trap was considerably more effective in population suppression than the dry trap and (2) one trap per host plant would be an appropriate density to achieve high control levels (Taret et al. 2014). A subsequent study in a *Citrus* crop of Concordia (Entre Ríos, NEA) performed to evaluate the mass trapping effectiveness using the food attractant Cera Trap®, a protein biological formulation with great attractive power on *C. capitata*, revealed a significant suppression effect on the pest population (Mousqués 2016). However, the high cost of both traps and attractants is a limitation of using mass-scale trapping in AW-IFFM programs (Aluja and Pinero 2004; Flores and Montoya 2020). A comparative study between mass trapping with McPhail and Jackson traps and conventional chemical spraying methods also carried out on citrus crops affected by *C. capitata* in Concordia showed a high effectiveness of mass trapping, but at a higher economic cost, ~50% on average, than chemical control (Trupiano and Roncaglia 2019). Therefore, low cost and effective traps and attractants, locally available, are imperative for the development of mass trapping as a sustainable management strategy for small backyard orchards. In this regard, studies were carried out in producing irrigated valleys spread in semi-arid areas of San Juan to evaluate the effectiveness and advantages or disadvantages of using disposable plastic bottle traps baited with natural fruit juice-based lures for catching medflies for monitoring and controlling wild populations at the orchard level (Guillemain et al. 2021; Suárez et al. 2021; Rull et al. 2022). Results showed two interesting scenarios: (1) interaction between attractant efficacy and season, as the highest values of medfly, catches recorded in both spring and autumn was achieved with traps baited with orange juice and (2) the use of fruit juices as attractants and disposable bottles as traps decrease the impact on non-target insects and reduce fruit fly management costs.

6.5.3 Biological Control

The augmentative biological control was added in 2008 into the integrated management tactics of PROCEM-San Juan as a potential complementary tool with both the SIT and the mass trapping to control medfly populations in a more effective and environmentally friendly way (Suárez et al. 2012). Before this event, sporadic releases of introduced and native parasitoid species were made between the 1930s and 1990s, mainly in the citrus-growing regions of northern Argentina. These actions were particularly carried out by provincial or national agricultural institutions or by scientific research laboratories (Ovruski and Schliserman 2012).

At present, biological control is a strategy used by PROCEM-San Juan as a consequence of three successful initiatives, which are outlined as follows: (1) development and permanence over time of four research and technology cooperative agreements between a national research institution, such as the National Scientific and Technical Research Council (CONICET-Argentina, Spanish acronym), and the government of the province of San Juan; (2) establishment and optimization of a mass rearing of the South Asian-native, larval parasitoid *Diachamimorpha* *longicaudata* (Ashmead) (Hymenoptera: Braconidae) using irradiated larvae of the medfly tsl Vienna-8 strain w/i as host at the Bioplanta San Juan (Suárez et al. 2019b, 2020; Carta Gadea et al. 2020); and (3) evaluation of the *D. longicaudata* performance as a biocontrol agent against medfly in open-field through both sporadic releases in fruit-growing valleys (Suárez et al. 2014) and systematic augmentative releases in a commercial fruit crop (Sánchez et al. 2016). Interestingly, post-augmentative release data showed up to 75% of wild medfly population mortality only due to *D. longicaudata*. Based on those promising results, mass releases of *D. longicaudata* in urban and rural areas are currently being implemented by PROCEM-San Juan.

Diachasmimorpha longicaudata, a synovigenic, solitary, larval endoparasitoid of several pest fruit fly species feeding on a wide variety of host plant families (Montoya et al. 2011), is one of the candidate exotic species for use in augmentative biological control in Argentina (Ovruski et al. 2011), as in many other Latin American countries (Garcia et al. 2020). This braconid parasitoid was introduced into Argentina for the first time during the 1960s (Ovruski and Schliserman 2012), but its establishment on *Anastrepha fraterculus* has only recently been verified in the citrus-growing regions of northern Argentina as a direct result of sporadic releases (Schliserman et al. 2003; Oroño and Ovruski 2007). In 1999, *D. longicaudata* was reintroduced into Argentina via Mexico coming from the Biological Control Laboratory at the Moscamed-Moscafrut National Programme (Ovruski et al. 2003b). Initially, *D. longicaudata* was successfully colonized at the Insectary of the Research Centre for the Regulation of Harmful Organisms Populations (CIRPON, Spanish acronym) on larvae of a wild *C. capitata* strain. In 2005, the *D. longicaudata* colony was transferred to the Biological Control Department of the Pilot Plant of Industrial Microbiological Processes and Biotechnology (PROIMI, Spanish acronym), and the second colony of *D. longicaudata* was established on *A. fraterculus* larvae. Shipments of individuals from the *D. longicaudata* colony held at PROIMI to other institutions of technological development in Argentina occurred between 2005 and 2008. The first shipment of parasitoids was sent to the INTA in Castelar, Buenos Aires province. At this institution, the genetic sexing Cast-191 strain of *C. capitata*, based on a mutation in the "sw" gene, which affects fly development rate, was successfully evaluated as a potential host for rearing *D. longicaudata* (Viscarret et al. 2006). However, the feasibility of rearing *D. longicaudata* on X-irradiated larvae of a biparental *C. capitata* strain was tested at the INTA-Castelar (Viscarret et al. 2012), as well as the use of X-irradiated larvae of *A fraterculus* as host (Bachmann et al. 2015). The last shipments of *D. longicaudata* individuals were made to the BioPlanta San Juan facility at the end of 2008 (Suárez et al. 2012), where the parasitoid is currently reared on irradiated medfly larvae of the "tsl" Vienna-8 strain (Suárez et al. 2020).

In addition to *D. longicaudata* augmentative releases in fruit-producing valleys of San Juan, detailed studies on the bioecology (Segura et al. 2007, 2012, 2016; Ovruski et al. 2011; Núñez-Campero et al. 2016) and on its potential as a biocontrol agent of both pest species infesting several fruit species (Ovruski et al. 2007, 2012; Suárez et al. 2019c; Buonocore Biancheri et al. 2022a) were carried out in Argentina.

An ongoing research field in Argentina is the use of Neotropical-native parasitoids in augmentative biological control against both economic importance fruit fly tephritid species. Some indigenous species may be used in combination with the exotic *D. longicaudata* in Argentina (Van Nieuwenhove et al. 2016; Buonocore Biancheri et al. 2019; Núñez-Campero et al. 2020, 2022). In this regard, experimental-scale rearing of two Neotropical-native parasitoid species that attack both *C. capitata* and *A. fraisculus* are developed at PROIMI's insectary in agreement with PROCEM-San Juan (Núñez-Campero et al. 2012, 2014, 2020; Buonocore Biancheri et al. 2022b).

6.5.4 Chemical Control

Chemical control of fruit flies traditionally involved the use of toxic baits made by mixing an insecticide and a food attractant, usually a vegetable protein. Chemical applications can be carried out both by ground and aerial means and have long been the main control tactic for pest fruit flies in Argentina. The most widely used insecticide in Argentina's fruit-growing regions, as in other countries, has been the organophosphate pesticide malathion, mixed with hydrolyzed protein plus water (Marchese et al. 1975; Putruele et al. 1993; Aruani et al. 1996; Vaccaro and Mousqués 1996; Guillén and Sánchez 2007). This mixture has been very effective in controlling medflies at very low lethal doses before the use of SIT in Argentina (Guillén and Sánchez 2007), as well as against other pest fruit fly species around the world (Flores and Montoya 2020). However, despite Malathion's efficacy, its use has been widely restricted due to its low selectivity to non-target organisms, high residual action, environmental pollutants, and high harmfulness to human health (Mangan 2014). In light of that, from 2010 onward, Spinosad (0.024 g/100 cm^3, CB) bait ground treatments on full foliage cover and/or in spots, as well as aerial treatment as an alternative to Malathion to control both *C. capitata* and *A. fraterculus* were encouraged in the various operating programs in Argentina (Quiroga et al. 2010, 2016; Rial et al. 2010; Alós et al. 2014; Ramirez 2017). The Spinosad, a contact bio-insecticide, is a more environmentally friendly pesticide with very low toxicity to mammals and is classified by the U.S. Environmental Protection Agency as a low toxicological risk product (Ramirez 2017). In the target area, the most effective form of application is to carry out aerial chemical treatments, covering as much area as possible. This modality of work has been implemented by PROCEM-NEA since 2011 and has made it possible to cover large areas in short periods, providing synchronized control of the target pest. In this sense, aerial application overcomes the operational disadvantages of ground application (Ramirez 2017). As a complement to chemical control at plant level, soil treatments aimed at controlling fly puparia under fruit trees are also carried out through the use of chlorpyrifos 48 E at 2.5‰ (Quiroga et al. 2010). These treatments are useful for lowering infestation in heavily attacked pots and can be carried out at any time of the year. In addition, chemical soil treatments are essential in those urban homesteads and rural commercial orchards that keep crop residues, especially during the winter as citrus fruits remain in this season of the year. However, chlorpyrifos, a broad-spectrum organophosphate insecticide, has been considered harmful to human health since late 2021 and the gradual elimination of formulations containing the active ingredients (pa) chlorpyrifos ethyl or chlorpyrifos-methyl was established, until its total prohibition for agricultural use on all crops in Argentina (Kulczycki Waskowicz and Hermida 2021). In this context, soil applications of pyrethroid insecticides such as cypermethrin and lambda-cyhalothrin, which have low toxicity to mammals, have also started to be used (Alós et al. 2014). The Diazinon or Dimpilate is another organophosphate pesticide that has often been used successfully to control tephritid fruit fly puparia in soil, mainly in the citrus-growing region of northeastern Argentina (Vaccaro and Mousqués 1996) but has the same fate as chlorpyrifos.

6.5.5 Cultural Control

Cultural control mostly involves fallen fruit collection and remnants of the harvest for subsequent destruction. It is one of the earliest phytosanitary measures implemented in any Argentine fruit fly control program. For example, in 2017, 535 tonnes of fruits were destroyed as a cultural control measure in the Patagonia, Cuyo, and NEA regions (SENASA 2018). Another example is that in 2018, in several localities of the Patagonian region, such as Alto Valle, 25 de Mayo/Catriel, Rio Colorado, the south of the province of Buenos Aires, and the locality of General Conesa, areas involved in the highest traffic of people, movement of host fruits, and/or in the vicinity of uncontrolled zones, which involves a higher risk of pest introduction, 28,529 kg of fruits were destroyed from 1500 households (PROCEM-Patagonia 2018).

6.5.6 Domestic Quarantine Strategy

This approach involves regulations promulgated by local governments but supervised by SENASA in the framework of a national fruit fly exclusion program, to regulate the introduction of infested host fruit, planting materials, soil, or living organisms into the country, and/or province or region under an operational fruit fly control program. In this regard, two quarantine procedures have been implemented by the national PROCEM, such as the quarantine protection system and the quarantine treatment facilities system (Quiroga et al. 2010, 2016; Ramirez 2017). The first quarantine system consists of phytosanitary control posts at international and national airports and on interprovincial roadways. There are 16 and 25 quarantine checkpoints at airports and interprovincial routes, respectively, which operate 24 hours throughout the year. Actions involve inspection and disinfection of vehicles, luggage screening, and verification of quarantine treatments, which is performed by phytosanitary inspectors, scanners, and sniffer dogs. The main terrestrial quarantine control posts in the Argentine territory are located in the fruit-growing provinces/regions currently under operational programs, such as San Juan, Mendoza, Patagonia, and NEA (Entre Ríos and Corrientes provinces) (Rial et al. 2010; Quiroga et al. 2016; Ramirez 2017). An example of the importance of quarantine controls to protect fruit fly-free areas is the extensive phytosanitary barrier effectively operated by Fumbapa in Patagonia (Rendón and Enkerlin 2021).

The second quarantine system comprises methods of phytosanitary postharvest treatment using methyl bromide (Willlink et al. 2007a) and a cooling regime (Willlink et al. 2007b). The phytosanitary measures are carried out in 11 quarantine treatment facilities throughout the country. Three of these installations are located in the northwest (2 in Tucumán and 1 in Jujuy), 4 in the northeast (3 in Entre Ríos and 1 in Corrientes), 1 in the central west (San Luis province), and 3 in the central east (1 in the north and 2 in the south of Buenos Aires). These phytosanitary stations carry out quarantine treatments of fruits mainly addressed to the following: (1) fruit fly-free areas (Patagonia region and southern Mendoza), (2) *A. fraterculus*-free area and *C. capitata* low-prevalence area (northern Mendoza), (3) *A. fraterculus* control area and *C. capitata* low-prevalence area (southwestern San Juan), and (4) *A. fraterculus* and *C. capitata* control areas (the remaining San Juan). Approximately 100,000 tonnes of fruits have annually undergone quarantine treatment to supply protected areas (SENASA 2018).

In addition to quarantine treatments to facilitate the movement of fruit within Argentina, some of these establishments have carried out quarantine-based research to export fruit. An example of the above is the work carried out for 10 years by the Obispo Colombres Agro-industrial Experimental Station (EEAOC, Spanish acronym) in Tucumán, concerning the quarantine cold treatments for *C. capitata* and *A. fraterculus* for *Citrus* export, mainly different varieties of lemon, grapefruit, orange, and tangerines (Gastaminza et al. 2007). Cold sensitivity trials mostly showed that third instars larvae of both *C. capitata* and *A. fraterculus* are the most tolerant immature stage, any cold treatment developed for *C. capitata* is effective for *A. fraterculus*, and *Citrus* varieties tested had the same effect on different immature stages of both economic importance fruit fly species (Gastaminza et al. 2007; Willink et al. 2007b, 2008).

6.6 Challenges and Future Development

The set of integrated actions carried out by provincial regional PROCEMs, with the supervision of SENASA, so far has brought benefits for the country, such as reduced fruit losses, improved health, and food safety, and the possibility of exporting without quarantine treatments, as well as the possibility of opening international markets. The latter has happened thanks to the uninterrupted drive of the Patagonia and Cuyo (Mendoza and San Juan) fruit fly programs, aided by very harsh winter conditions in those regions, semiarid and arid environments with native xerophytic vegetation, and artificially irrigated fruit-growing oases that focus medfly populations, the only pest tephritid species existing in those regions. However, among the difficulties faced by Argentina is that the medfly is widespread in the remaining fruit-producing regions, particularly in the warm and humid citrus-growing areas of northern Argentina. In these regions, the medfly is not limited to commercial crops, family orchards, or urban environments but also to wild vegetation surrounding cultivated areas, where there is an abundance and continuity of alternative native and feral host fruits over large areas. Added to this problem is the presence of the Neotropical-native *A. fraterculus* which coexists with *C. capitata*. However, cold quarantine treatments have been effective in facilitating *Citrus* export from northern Argentina. This fact does not detract from the need for further integrated control measures against both tephritid fruit fly species. Therefore, it is expected that the recent implementation of an AW-IFFM approach in the NEA and the already operational actions in Patagonia and Cuyo will serve as an example for neighboring regions, such as the NOA. This will provide a knowledge base on fruit fly management that should further broaden interest in the use of complementary control strategies. In this framework, it is important to underline that *A. fraterculus* has already colonized the cold, semiarid environments in the highlands of the Calchaquí Valleys from Tucumán, Catamarca, and Salta (Ovruski et al. 2010; Funes et al. 2017), and the fruit-growing irrigated valleys of the northern dry highlands of the Jujuy province (northwestern Argentina) (Manero et al. 1989). This has led to the development of a comprehensive phytosanitary plan for the Calchaquí Valleys with the creation of PROCEM-Valles Calchaquíes de Salta (SENASA 2015). In this context, the *A. fraterculus*' current dispersal to irrigated fruit-growing areas in dry semiarid to arid conditions, coupled with the fact that the SIT application to control *C. capitata* in overlapping areas would induce *A. fraterculus* to occupy the gap left by the exotic pest species, is a scenario to consider in the nearest future. Consequently, integrated eco-friendly tactics to control it, such as the complementary use of SIT, biological control, and mass trapping, need to be considered straight away at once.

On the basis of PROCEM's achievements and taking into account the actions that remain to be undertaken, the challenges it should face can be summarized as follows: (1) deepening the use of the wide-area strategy, as well pest-free places of production and pest-free production sites strategies within the framework of risk mitigation system (FAO 1999); (2) strengthening national surveillance and response capacities to ensure early detection and timely mitigation of infestations, (3) enhancing exclusion activities in entry sectors, (4) supporting preventive, targeted, and effective release programs of sterile flies and parasitoids; (5) reinforcing AW-IFFM actions favoring complementary use of eco-friendly strategies based on previous trials on integration of both SIT and augmentative biological control carried out in San Juan (Sánchez et al. 2018); (6) encouraging operating programs through infrastructure improvements, provision of inputs and inter-institutional collaborations with scientific and technological entities; and (7) achieving the development of SIT for *A fraterculus* to have another eco-friendly control method complementary to biological control and mass trapping.

6.7 Concluding Remarks

The SENASA, through the national PROCEM, acts in response to the threat caused by the two economically important fruit fly species present in the country with an integrated management action system. This modality incorporates provincial and regional operational programs for control and/or eradication of pest tephritid fruit flies in the main fruit-growing regions with surveillance activities through monitoring, phytosanitary control strategies, and producer outreach. In addition, the supervision of control tasks, interpretation of exclusion risk data to apply port-of-entry mitigation, and regulatory actions are also carried out. This multifaceted approach is the result of close collaboration and consultation between SENASA, provincial governments, national and provincial agricultural research and technology development institutions, and private producer associations, as well as other stakeholders in the PROCEM. Because of this, SENASA needs to keep up the innovative approach of AW-IFFM in the fruit-growing regions of Argentina. Efforts should focus on improving the facilities and monitoring tools available in these provincial or regional programs, as well as the ongoing training of human resources. However, the objectives and initiatives pursued in each operational program or in regions close to implementing a fruit fly control program are limited by economic, fiscal, scientific, and operational realities. Notwithstanding the foregoing, there is a particular need to focus efforts on identifying ways to improve the efficiency of actions undertaken by SENASA to enable the continued success of currently operational programs, while optimizing resources. Collaboration and communication must remain an overall component of PROCEM. As an example, the successful application of SIT in combination with other eco-friendly control tools, such as biological control (Cladera et al. 2008; Liedo et al. 2021) and/or mass trapping, is an integrated strategy that, to be implemented on a large scale, requires continuous cooperation and consensus within the national PROCEM.

In overview, PROCEM's strategic objectives encompass overall protection against the pest from exclusion at entry points, early detection through effective surveillance in free areas, prevention of outbreaks in low-prevalence areas, and eradication or management, as most appropriate.

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