## Introduction

The human population in 2050 will require an additional 60% in agricultural food production (Fischer, 2014). Plant pathogens threaten food security in both developed and developing countries, as 20-40% of all current crop production is lost to disease (Oerke, 2006, Savary *et al*., 2012). The losses from plant diseases worldwide amount to more than US $ 220 billion annually (Sarokozi, 2019). Agricultural production has been a central objective of research, especially as there has been a diminishing of the availability of natural resources such as arable land, water, energy, labor, fertilizers, and seeds certified free of pathogens (Savary et al., 2012).

Plant viruses are especially a problem in Colombian agriculture and horticulture. A program for the distribution of virus-free seeds and plant material is not available in the country. There is a need for a survey of the viruses threatening the country's agriculture, and in South America in general. This thesis presents the need for a certification program for virus-tested plant material in Colombia. In a cooperation project that has been carried out over the last fifteen years between Colombian and German stakeholders, certification programs have been proposed with the following goals:

- Detection of viruses that pose problems for farmers, and development of molecular and serological tools for routine diagnosis and monitoring
- Production of virus-tested material, and best practices in handling and propagation of healthy material for distribution to growers as a solution to viral diseases.

The program addresses improving productivity and competitiveness by offering tangible solutions to the agricultural sector through knowledge transfer and advanced technologies. The alliance between German and Colombian partners aims to establish and implement a coherent, efficient, and multidisciplinary program with a measurable impact on food security (Figure 1.1). Operationally, this alliance, made up of ministries, universities, private companies, farmers, and additional stakeholders, aims to use the great research potential represented in the human capital of the participating national and international institutions, to address the complex problem of dealing with the losses caused by viruses within the context of food security, including the promotion of healthy consumption. A certification of virus-tested plant material would benefit the country as a whole and protect the quality and quantity of domestic products and exports. The distribution of tested plant material among grower associations and farmers, monitored by the department of agriculture, is an important part of a country's plant protection program.

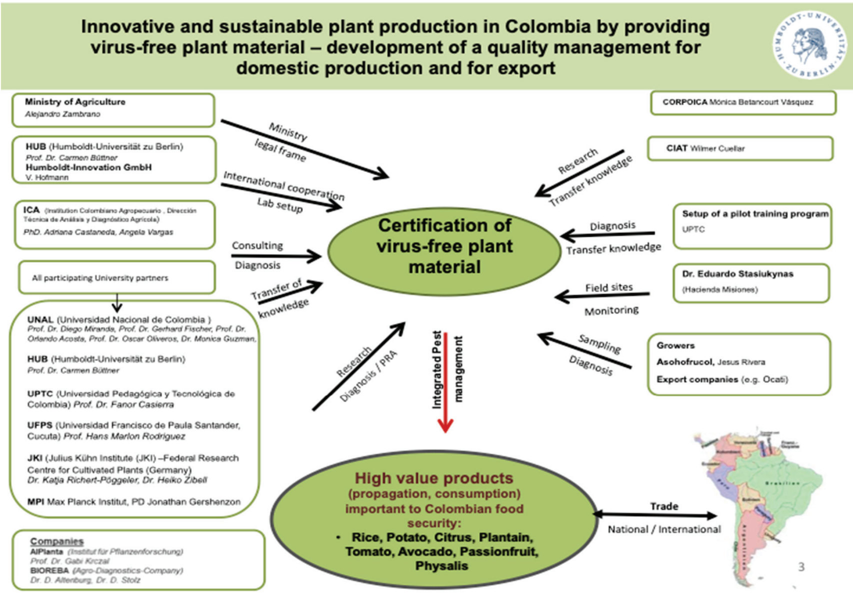


**Figure 1.1** Organogram of the components and Colombian and German partners of the certification project (Developed with Buettner, Bandte, Langer)

## *1.1 Background: Colombia as producer of value exports*

Due to its biodiversity and geographic location, Colombia is a country capable of producing quality and quantity agricultural products. The horticultural and agricultural export sectors are growing at a rapid rate over the last few decades, as production has increased. Due to various factors such as increased trade and distribution of plant material for these exports, plant viruses have become a major problem in the country. The German/Colombian consortium created a priority list of crops that would be the focus of such a collaborative project including citrus, avocado, potato, tomato, rice, passion fruit, physalis, and plantain.

## *1.2. Selection of the cultivars*

Three plants were chosen as model experimental cultivars, due to their ease of use in the greenhouse, and importance as exports from Colombia. The plants chosen were cape gooseberry (*Physalis peruviana),* ornamental rose (*Rosa sp.*), and purple passion fruit *(Passiflora edulis* Sims.).

### *Physalis peruviana*

*Physalis peruviana L*, also known as cape gooseberry, is one of Colombia's largest exports, reaching 29 countries, especially the European market, where 97% of the cape gooseberry is imported. Germany, the Netherlands, the United Kingdom, and France are the countries that account for 86.47% of the total volume imported (Piñeiro, 2007).

The source of origin of *Physalis peruviana* is the South American Andes. The Physalis genus is part of the Solanaceae family, including about 100 species (Legge, 1974).

The small and sweet fruit that emerges from an inflated calyx offers vitamins A and C (Fischer et al., 2005), as well as functional alkaloids, flavonoids, carotenoids and bioactive compounds (Chaves, 2006). The plant is a perennial, growing upto 2 meters high, with heart-shaped leaves 5-15 cm in length and 4-10 cm in width (Fischer, 2000). Its 10-15 cm branches are sustained by a herbaceous main stem of 8-12 nodes, and by roots growing as deep as 80 cm (Angulo, 2005). The ideal soil type is sandy clay with a pH between 5.5-6.8 with organic matter of at least 4% (Fischer et. al 2005) and annual temperatures between 13-18°C (Angulo, 2005). Average rainwater should be between 1000 to 1800 millimeter and relative humidity should reach between 70 to 80% (Popova et al., 2010). The typical harvest time in Colombia is around six months (Fischer et. al, 2005). Figure 1.2 shows a map of producers of physalis for export that are registered with the Colombian Department of Agriculture.

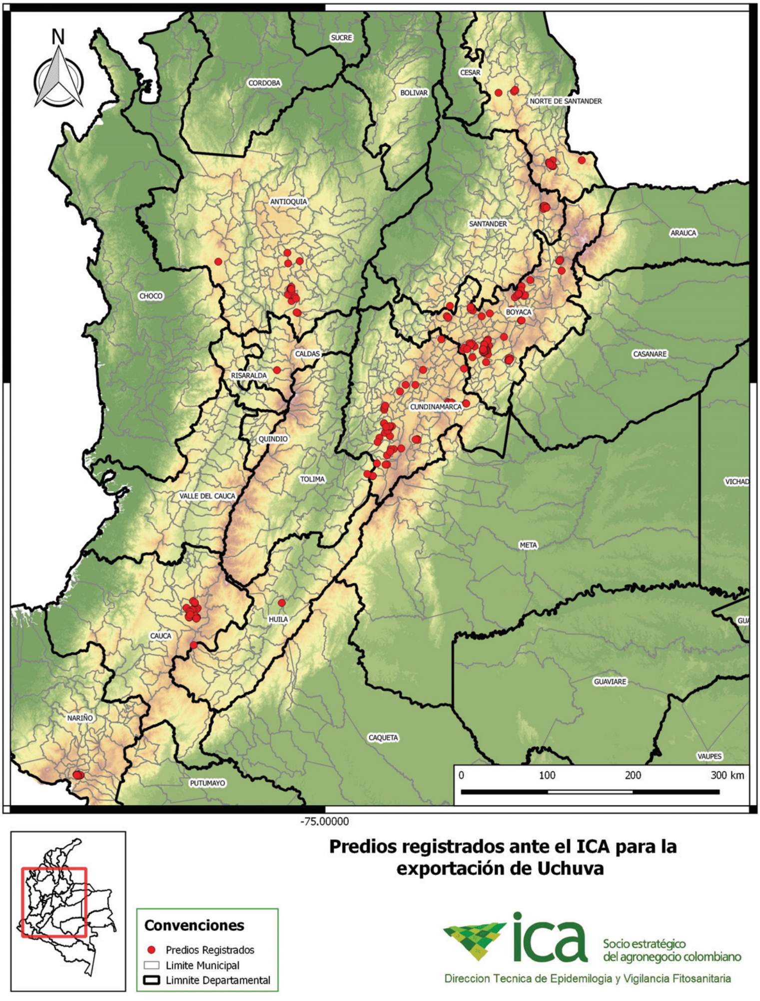


**Figure 1.2** ICA (Colombian Agricultural Department) registered parcels of exportable physalis

In Colombia, the cape gooseberry crop comprises a total cultivated area of 952 ha with an estimated yield of about 13,260 tons per year; the departments of Boyacá, Antioquia and Cundinamarca are the main producers, accounting for 58.4, 17.4 and 17.5 percent of the national production (Agronet, 2019). Recently, the production of cape gooseberry (Figure 1.3) has declined from 13,760 tons in 2010 down to 9,810 tons in 2014 (Agronet, 2016). This drop has been attributed to several factors, which include climate change, the increase in the incidence and severity of fungal diseases caused by *Fusarium oxysporum* and *Phoma sp*. (Fisher et al., 2014, Osorio-Guarin, 2019, Miranda et al., 2021) and the infection by several viruses inducing chlorosis, mosaics, leaf deformation, dwarfism and greening of veins (Zapata et al., 2005; Aguirre-Ráquira, 2014; Gutiérrez et al., 2015; Rodríguez et al., 2016).

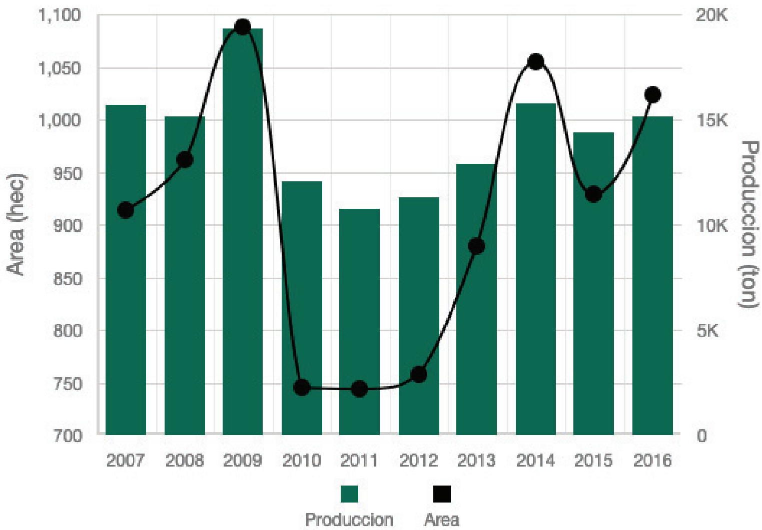


**Figure 1.3** Physalis production and area in Colombia (Agronet, 2019)

Fruit that is not exportable due to its size is sold in the domestic market or processed as dehydrated food (Castro *et al.,* 2008). The quality of the domestic and exportable cape gooseberry is significantly correlated with the pathogens that affect it, which include fungi, bacteria, insects and other pests. Until now there has been little research on the viruses that infect it. The production of cape gooseberry is part of the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO) program aimed at intensifying the production and consumption of fruit and vegetables to prevent chronic and degenerative diseases such as cardiovascular disease, diabetes and some types of cancer.

*Passiflora edulis* Sims.

*Passiflora edulis* belongs to the *Passifloraceae* family, which includes 530 species (Joy and Sherin, 2016). Passion fruit is a perennial, vigorous, climbing, woody vine that produces an edible round or ovoid fruit and has a tough, smooth, waxy dark purple hued rind with faint, fine white specks (Joy and Sherin, 2016). Effective production takes place at 1,800 to 2,600 meters above sea level, temperature between 15-20°C, a relative humidity between 70-80%, and between 900 and 1,200 mm of rain per year (Fischer et. al, 2021). Passion fruit is filled with an aromatic mass of double-walled, membranous sacs containing orange colored pulpy juice and small, black-pitted seeds (Joy and Sherin, 2016). *Passiflora edulis* grows well in tropical and subtropical regions, where the climate is hot and humid (Joy and Sherin, 2016). Passion fruit can be grown on a range of soils, sands to clay loams. Generally, these vines are grown on deep, relatively fertile and well-drained sandy clay soil (Joy and Sherin, 2016).
In 2016, Colombia produced over 15,000 tons of purple passion fruit as shown in the figures 1.4 and 1.5 below (Agronet, 2019).

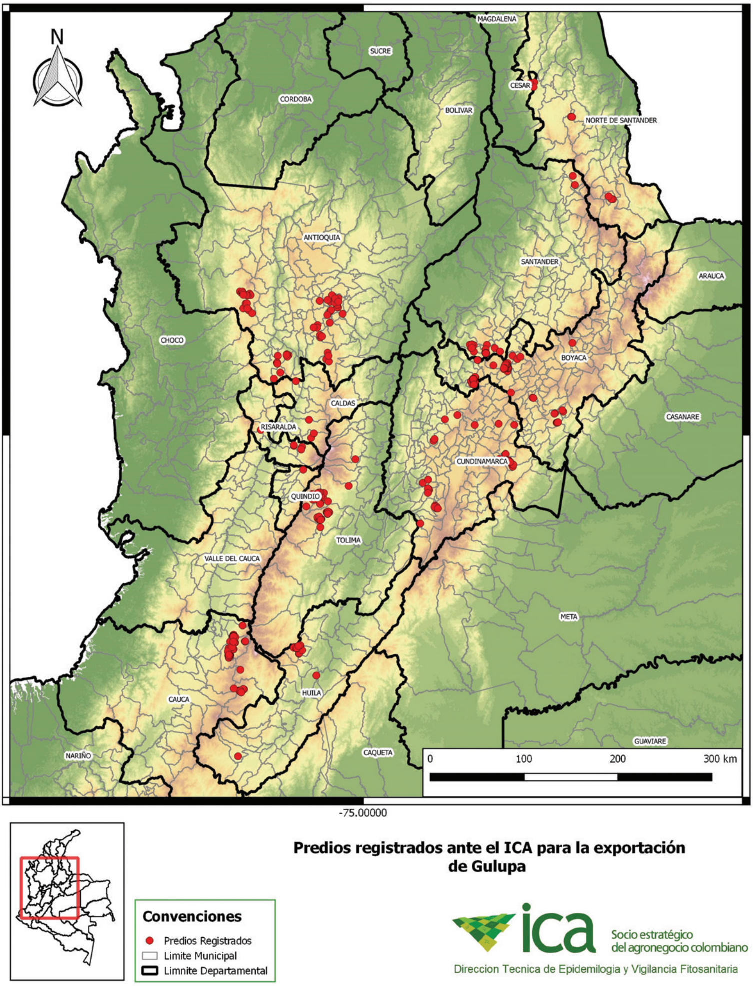


**Figure 1.4** ICA (Colombian Agricultural Department) registered parcels of exportable passion fruit

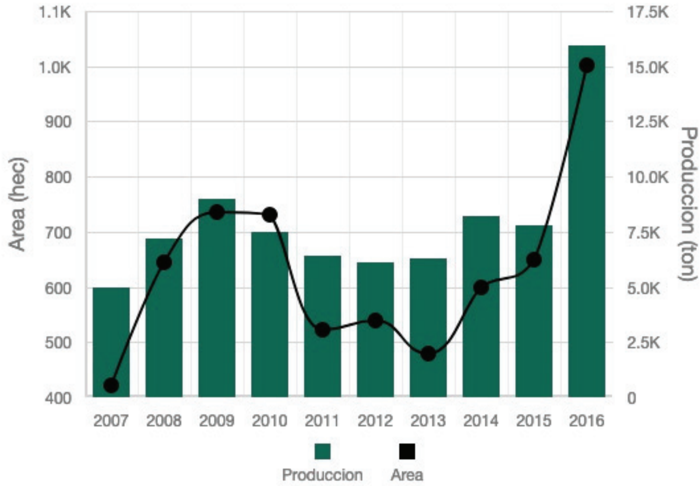


**Figure 1.5** Passion fruit production and area in Colombia (Agronet, 2019)

*Rosa L.*

The global export of cut flowers has grown since 2011 from 8.5 to 20.6 billion USD in 2013 (Conlon, 2015). The floral industry is dominated by Holland, which produces 83% of the world's cut flowers, followed by Colombia, the second largest exporter worldwide (Rabobank, 2016).

80% of carnations and 30% roses produced in Colombia are imported by the United States (Rabobank, 2016). The history of the Colombian flower industry has witnessed a partnership with the US since the development of John F. Kennedy's Alliance for Progress which began in August 1961, which was developed to enhance economic cooperation between the US and Latin American countries to combat communism (Conlon, 2015).

Colombia exported more than two billion flower stems and 50 types of flowers to the US in 2006 totaling 418 million USD (Conlon, 2015). By 2012 this figure rose to 1.188 billion USD. In 2013, 65 percent of all cut flowers imported into the U.S. were from Colombia, up from 55 percent a decade earlier (Conlon, 2015). Roses were the primary export flower, at 365 million USD, followed by carnations at 156 million USD and chrysanthemums at 147 million USD (Rabobank, 2016). The U.S. imports 70% of its cut roses, 98% of its chrysanthemums and 99% of its carnations and alstroemerias from Colombia (Conlon, 2015). Colombia ships 15% of total cut flower exports by sea, loading 700 forty-foot containers of 150,000 chrysanthemum stems to the UK in 2013 (Conlon, 2015). In Colombia, 73% of production is found around the Bogota Savannah, 24% surrounding the Medellin Rionegro Valley, and 3% distributed throughout western and central parts of Colombia (Agronet, 2019). Colombia grows 8,000 hectares: 90% in greenhouses (Conlon, 2015). 75% of the 300 farms producing flowers for export are represented by Ascoflores (the Colombian Association of Flower Exporters), 50% of which are between 20-50 hectares, and represented by the association Fedeflores (Agronet, 2019). In 2016, Colombia produced over 15,000 tons of roses (Agronet, 2019). In Figure 1.6 the location of registered parcels of exportable rose are presented, as well as the production and area statistics in Figure 1.7.

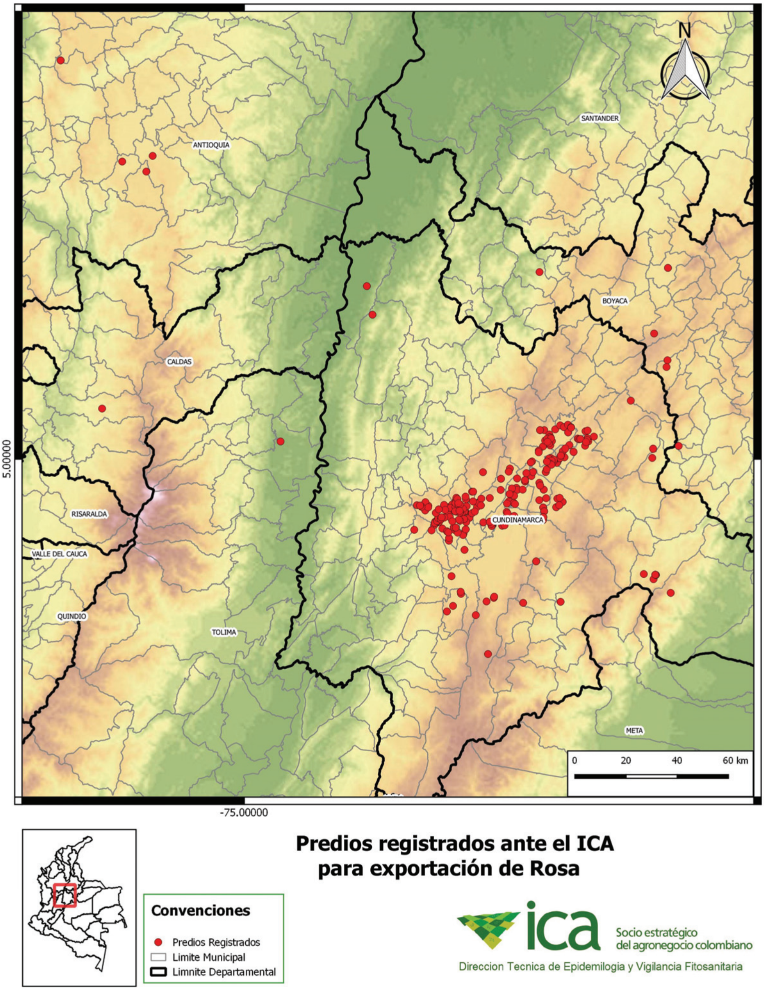


**Figure 1.6** ICA (Colombian Agricultural Department) registered parcels of exportable rose