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Citrus Cultivation in Venezuela

**Gustavo Fermin[1*] • Armando Briceño[1] • Francisca Ely[1] •
Luis Cedeño[2] • Yani Aranguren[1] • Carle Valecillos[1]**

[1] Centro Jardín Botánico, Facultad de Ciencias, La Hechicera. Universidad de Los Andes, Mérida 5101, Venezuela
[2] Instituto de Investigaciones Agrícolas y Pecuarias, Facultad de Ciencias Forestales, Santa Rosa. Universidad de Los Andes, Mérida 5101, Venezuela

Corresponding author: * fermin@ula.ve

ABSTRACT

This short review focuses on a few aspects related to the citrus industry that have received attention in Venezuela. From a well, culturally speaking, established citrus industry, consistent efforts have been made to study the main pests and pathogens that cause diseases and economic losses in citrus orchards across Venezuela. Despite the knowledge gathered from almost a century of phytopathological studies, however, very few advances have been attained in the improvement of citrus germplasm in Venezuela. In the same way, postharvest management of the produce has not shown a successful history of accomplishments. The marginal increase of production and yield in recent times that seems to be decelerating the tendency of the last fifteen years to accumulate losses, however, have yet to demonstrate that the industry is experiencing a renewal of its cultural practices and an increase in financial and technological inputs. Increases in the consumption of fruits have also been recorded in the last few years, but consumption has not yet reached the recommended levels set by international standards. The citrus industry in Venezuela has still much to do, despite being one of the most important in the country, to contribute to food security and to offer the producers an attractive source of personal and professional satisfaction as well as financial reward.

Keywords: citriculture, fruit crops, orange

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INTRODUCTION

Aside from tasting good and being one of the most refreshing fruits, citruses are high in vitamin C content. Members of this important group of fruit plants are ubiquitously found in Venezuela. Citrus trees constitute the first perennial, woody fruit crop in Venezuela; it has also been favored as a domestic ornamental plant and may be found almost everywhere in the country, with exception of the cold, high altitude regions. Citrus fruits are among the favorite fruits for fresh consumption and juice processing in the country. In fact, they run only behind bananas and pineapple as fresh produce (Mora and Rojas 2007), and they are also the ones preferred by the juice industry, which is particularly important in a country where fresh fruits, but more importantly fruit juices, are a traditional and obligate part of the daily diet. Yet, fruit consumption in Venezuela still lags behind the recommended daily intake (Machado-Allison 2007). For the year 2004, for instance, the availability of fresh fruits in the diet of Venezuelans was 123.8 g per person, of which 16.7 corresponds to oranges (Ministerio del Poder Popular para la Salud 2007). From all the statistics analyzed so far, it is clear that all of citrus production is consumed locally, except for a marginal exportation of 'Tahiti' lime (Laborem *et al*. 1996). Nonetheless, the perspectives of an increasing demand for food, and particularly fresh fruits, and governmental plans to increase production, might revert the negative figures associated with the citrus agroindustry in Venezuela over the last 15 years. A marginal increase in production, if sustained or improved, might permit a recovery of the production to levels similar to those reached in the early 1990s.

The citrus industry, however, faces many challenges, with pests and pathogens ranking as the main obstacle that medium to high income growers must confront. From viroids and viruses to higher eukaryotes, citrus plants in Venezuela must coexist with a myriad of potential, and actual, enemies, as reflected in **Table 1**. In this short review emphasis will be given to phytopathological aspects of citrus cultivation in Venezuela, since improvement of the germplasm currently being exploited in the country is still in its infancy – despite the fact that citrus plants have been

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Invited Review

Table 1 Main pests, weeds and pathogens of citrus plants reported in Venezuela.*

Viroids	*Citrus exocortis viroid*
	Citrus xyloporosis viroid
Virus	*Citrus leprosis virus*
	Citrus psorosis virus
	Citrus tristeza virus
Bacteria	*Spiroplasma citri*
	Xylella fastidiosa
Fungi and oomycetes	*Aschersonia placenta*
	Alternaria citri
	Alternaria sp.
	Ascochyta citri
	Ascohyta sp.
	Aspergillus niger
	Botryodiplodia theobromae
	Botryosphaeria rhodina
	Camarosporium sp.
	Capnodium citri
	Capnodium sp.
	Cercospora penzigii (= *aurantia*)
	Cercospora citrigrisea
	Cercospora sp.
	Chaetothyrium sp.
	Diaporthe citri
	Diplodia natalensis
	Elsinoe fawcettii
	Fusarium lateritium
	Fusarium sp.
	Gloeosporium limetticolum
	Glomerella cingulata
	Metarhizium anisopliae
	Microxyphium sp.
	Mycosphaerella citri
	Mycosphaerella horii
	Pellicularia koleroga
	Penicillium digitatum
	Penicillium italicum
	Phomopsis citri
	Phyllosticta sp.
	Physcia sp.
	Phytophthora citrophthora (= *parasitica*)
	Phytophthora palmivora
	Phytophthora nicotianae
	Phytophthora terrestris
	Rhizopus nigricans
	Septobasidium alni
	Septobasidium pseudopedicellatum
	Septoria aurantiicola
	Septoria citri
	Sphaeropsis tumefaciens
	Sphaerostilbe coccophila
	Sphaerostilbe flammea
	Sporotrichum citri
	Stenella citri-grisea
	Strigula elegans
	Strigula sp.
	Trametes scabrosa
	Tripospermum sp.
	Tubercularia sp.
Algae	*Cephaleuros virescens*
	Trentepohlia sp. (Incertae sedis)
Nematodes	*Criconema demani*
	Criconemoides sp.
	Gracilacus aculenta
	Helicotylenchus crenacauda
	Helicotylenchus microcephalus
	Helicotylenchus multicintus
	Hemicriconemoides cocophillus
	Hemicriconemoides communis
	Hoplolaimus seinhorsti
	Meloidogyne exigua
	Mesocriconema sphaerocephalum
	Paratrichodorus minor

Table 1 (Cont.)

Nematodes	*Paratylenchus elachystus*
	Paratylenchus minutus
	Peltamigratus holdemani
	Peltamigratus macbethi
	Pratylenchus brachyurus
	Pratylenchus hexincisus
	Pratylenchus scribneri
	Pratylenchus zeae
	Radopholus similis
	Rotylenchus caudaphasmidius
	Rotylenchulus reniformis
	Scutellonema brachyurum
	Trichodorus sp.
	Tylenchorhynchus acutus
	Tylenchorhynchus annulatus
	Tylenchohrynchus capitatus
	Tylenchulus semipenetrans
	Tylenchus costatus
	Xiphinema americanum
	Xiphinema brasiliense
	Xiphinema brevicollum
	Xiphinema krugi
	Xiphinema peruvianum
	Xiphinema simile
	Xiphinema vulgare
Mollusks	*Orthalicus maracaibensis*
	Oxystiyla pulchella
	Polymita sp.
Insects and arachnids	*Acromyrmex octospinosus*
	Aleurocanthus woglumi
	Aleurothrixus floccosus
	Alabama argillacea
	Anastrepha fraterculus
	Aphis citricola
	Aphis craccivora
	Aphis gossypii
	Aphis nerii
	Aphis spiraecola
	Atta sexdens
	Brevipalpus obovatus
	Brevipalpus phoenicis
	Chrysomphalus aonidum
	Coccus viridis
	Cratosomus punctulatus
	Crematogaster spp.
	Dialeurodes citri
	Diaphorina citri
	Diaprepes abbreviatus
	Dysdercus maurus
	Eutetranychus banksi
	Epitragus fuscus
	Frankliniella sp.
	Glyptoscelis fascicularis
	Gonodonta clotilda
	Gonodonta nutria
	Gonodonta pyrgo
	Gymnandrosoma auriantanum
	Heliothrips haemorrhoidalis
	Icerya purchasi
	Lampetis cacica
	Lepidosaphes beckii
	Lepidosaphes gloverii
	Litostylus juvencus
	Oligonychus peruvianus
	Orthezia sp.
	Panonychus citri
	Papilio anchisiades
	Papilio thoas
	Parabemisia myricae
	Paraleyrodes sp.
	Parlatoria ziziphi
	Phobetron hipparchia
	Phyllocoptruta oleivora

Table 1 (Cont.)

Insects and arachnids	*Phyllocnistis citrella*
	Pinnaspis aspidistrae
	Platynota sp.
	Platytylelus costalis
	Polyphagotarsenomus latus
	Pseudococcus sp.
	Saissetia hemisphaerica
	Saissetia nigra
	Selenaspidus articulatus
	Solenopsis geminata
	Tetranychus trinidadensis
	Tetranychus tumidus
	Toxoptera aurantii
	Toxoptera citricida
	Trigona amalthea
	Trigona tridinadensis
	Trigona spp.
	Unaspis citri
Weeds	
Dicots	*Acmella radicans*
	Clibadium surinamense
	Cuphea melvilla
	Dioclea guianensis
	Fleischmannia microstemon
	Galinsoga quadriradiata
	Gamochaeta americana
	Hyptis atrorubens
	Irlbachia alata
	Jacobina boliviensis
	Justicia pectoralis
	Mikania micrantha
	Odonellia hirtiflora
	Physalis angulata
	Prestonia acutifolia
	Ruellia geminiflora
	Salvia tiliifolia
	Sipanea pratensis
	Solanum americanum
	Vismia baccifera
Monocots	*Cipura paludosa*
	Trimezia martinicensis
Other plants (parasitic)	*Langsdorfia* sp.
	Phoradendron sp.

*The bibliographic source for the organisms listed here is multiple, and they are available upon request. However, we recommend the following references that have shown to provide the most useful and complete information: for general references, Fundación Shell (1966), Ordosgoitty *et al*. (1971), Díaz and Salas (1973), and Junta del Acuerdo de Cartagena (1996); for phytopathogenic nema-odes, Crozzoli (2002); fungi and Chromista, Chardon and Toro (1934), Müller (1940), Spaulding (1961), Dennis (1970), Urtiaga (1986), Rondón (1990, 1992), Erwin and Ribeiro (1996), Pretorius *et al*. (2003) and Farr *et al*. (2008); weeds, especially from Monagas state Lárez (2007a, 2007b); and insects, Fernández *et al*. (1957), Arnal *et al*. (1993), Briceño (2007) and Cermeli (2007).

amongst us for at least 400 years –, and plant protection is the aspect of citrus production that has received the utmost attention in the country.

Besides their natural enemies, as mentioned before, citrus cultivation in Venezuela has been historically characterized by some positive, but also negative factors that conspire against a successful degree of accomplishment. Fruit cultivation has a long tradition in the country as a cultural practice that has received careful attention from phytopathologists, entomologists and agronomists. Citrus cultivation in Venezuela, however, is characterized by: 1) being almost exclusively devoted to cope with local demands, although insufficiently; 2) a lack of rational plans to improve or develop cultivars adapted to our conditions; 3) low yield values mostly due to inappropriate cultural practices, mismanagement of pests and pathogens, and an almost non-existent improvement of the germplasm employed to sustain both fresh consumption and industrial processing; 4) currently used post-harvest practices (inadequate selection, improper transportation) that render a poor performance; 5) being severely affected by a low level of technical support and an almost inexistent evaluation of production means and practices; 6) absence of a concerted relation between research and production; 7) a consuetudinary instability of official support policies, particularly demonstrated by erratic measures regarding agriculture broadly speaking, and citriculture in particular; 8) in general, quality of the products is low and phenotypes are heterogeneous.

Production of combined citrus is mainly managed in the central-northern states of the country (Yaracuy, Carabobo and Aragua), Monagas and Sucre to the east, and Táchira and Zulia in western Venezuela (**Fig. 1**), but minor producing units are also present in the rest of the country, with exception of south to Orinoco River. Although other states of the country apparently also show appropriate conditions for citrus production (Rudolph 1944), diverse economical, social and political reasons have precluded the extensive use of citrus species in areas recommended for their cultivation. For a comprehensive agroecological zone description of orange production in Venezuela, however, we encourage the reader to consult an excellent monograph by Benaccio *et al*. (1985) in which the authors describe the physical and climatic characteristics of promising areas were citrus might be cultivated, state by state.

It has already been mentioned that citrus species have been present in Venezuela for almost 400 years; but commercial production at great scale, however, is a recent development that can be traced back to the 1960s. In this regard citrus cultivation in Venezuela is still a nascent industry that, when considering its short life, has been somewhat successful. Attempts to increase yield, for example, has responded to the need of increasing value and financial return, but also, contradictorily, to pest management. When citrus plants succumbed to tristeza in the early 1980's, not only more appropriate rootstocks were used to substitute susceptible ones, but crop density also increased, and hence, production – as demonstrated by the golden years of citrus production during the next decade. Effective density from 156-204 plants/ha increased to 319-408, or even to 1283 plants/ha when using dwarfing germplasm (Citrumelo 'Swingle'), as reported by Avilán and Ruiz (1999). Increase in crop density, as well as the application of effective phytosanitary measures, should help producers sustain and increase production; the latter, however, has always been the weakest point of Venezuelan fruitculture, although successful cases of biological control, however, will be presented later. On the other hand, it has been shown that plants bear fruits during 7-11 months, and studies to determine best time of harvest, under Venezuela conditions, have also been performed (Laborem *et al*. 1993). Despite these efforts to study some factors related to crop management (crop density, plant fertilization, time of harvest, etc.), and to apply them to the limited cases in which producers are willing to take the risk, citriculture in Venezuela is still characterized by an almost permanent low productivity.

Low yield (less than half of what is potentially achievable) is attributed to the low technical input of the agroindustry, as well as to the reasons mentioned in preceding paragraphs. If the citrus industry, then, is to contribute to the long aspired goal of food security in the country, at least four objectives must be pursued: 1) Careful selection of a germplasm that will allow for extensive studies related to improvement, exploitation, production, processing and diffusion among consumers in order to offer to vulnerable groups an easy access to macro, micronutrients and other compounds (e.g., vitamins and antioxidants) that might positively impact their health and wellbeing; 2) Complete assessment of the totality of chemicals in citrus plants that might be useful to attain the previous goal of germplasm improvement. These include, of course, historical uses of citrus chemicals that, perhaps due to lack of study, have not been exploited adequately, but that might contribute to an increase in the possibilities of a wider use and consumption of different citrus species. In the long term, the identifica-

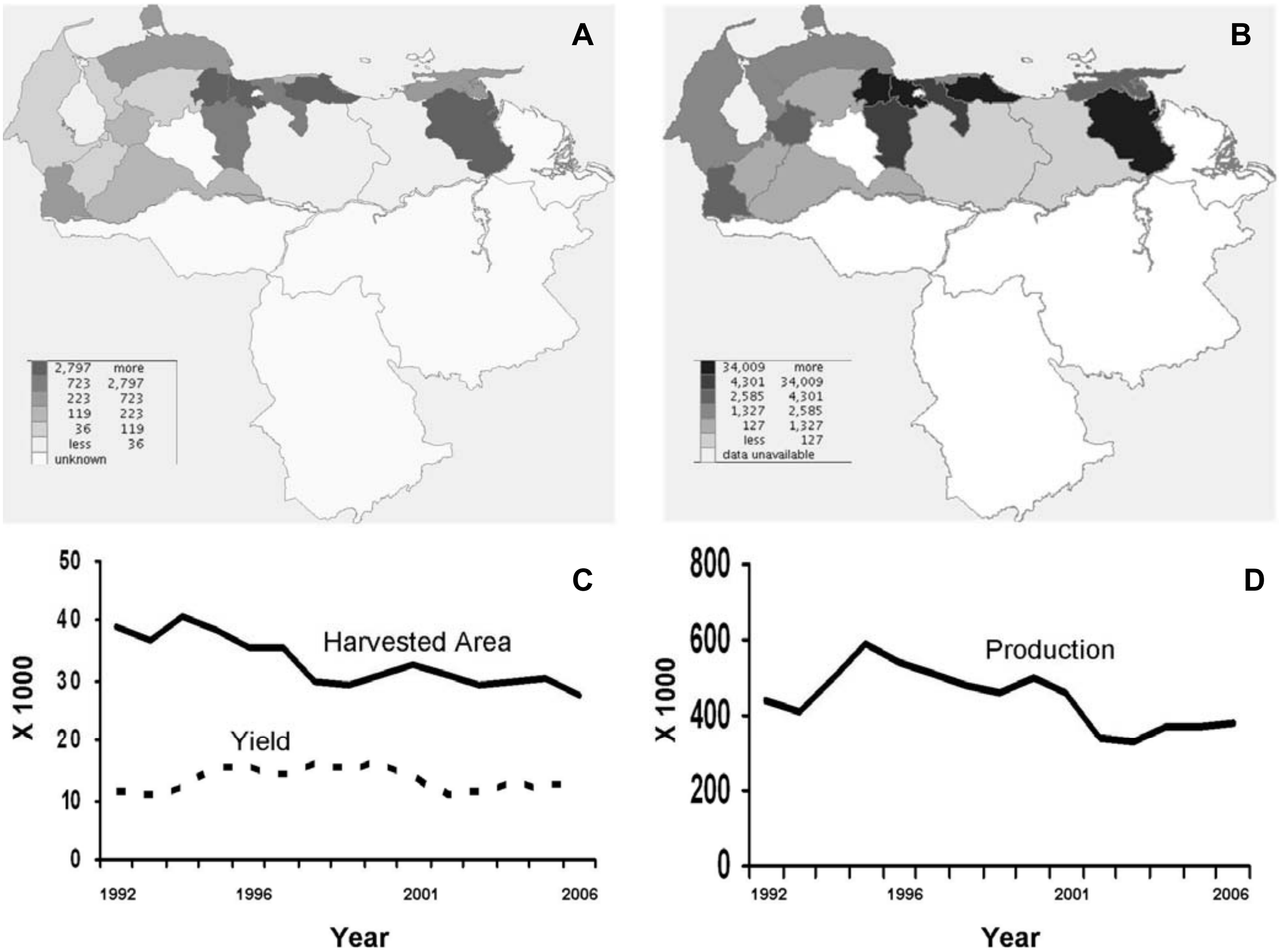

Fig. 1 Data of orange production in Venezuela. (**A**) Map of harvested area for oranges, shown by state. (**B**) Map of oranges production, shown by state. (**C**) Area devoted to the cultivation of oranges (in Ha), as well as yield (in Kg/Ha) during the last 15 years. (**D**) Orange production in Venezuela during the last 15 years. Maps were generated by the FAO on-line interactive service (http://www.fao.org/landandwater/agll/agromaps/interactive/page.jspx), and data for graphs C and D were taken from the statistical database of Fedeagro (http://www.fedeagro.org/).

tion of major germplasm, as well as the weak points that need a more conscious action, will indicate which genetic features, biosynthetic pathways, and resistance performance determinants need to be genetically altered in order to improve and strengthen the citrus industry in Venezuela; 3) A sustained increase in the use of different techniques and strategies based on molecular markers to characterize old and new varieties and assess their purity, as well as a detailed description and catalogue of the main pathogens and their population structures. Additionally, the mastering of molecular knowledge and techniques will allow engineering changes in composition and physiology of the produce during maturation, harvesting, transportation, either by classical genetic improvement practices or by transformation by different means; and 4) a concerted action between researchers, producers and governmental representatives which will permit to establish a coherent set of regulations concerning all aspects related to the citrus industry, including germplasm manipulation and phytosanitary measures.

HISTORICAL BACKGROUND AND CULTURAL ADOPTION

All first accounts from the conquerors that first visited and described the newly discovered country (1498, and later) indicate that the diet of native Venezuelans was rich in fruits that included guava (*Psidium guajava*), papaya (*Carica papaya*), diverse Annonaceae, a few of the genus *Spondias*, several palms and pineapples, as well as other minor fruits (Patiño 1963; Cunill *et al*. 2007). Although the first conquerors found difficulty in swallowing most of the native fruits, other fruits, like pineapple, where quickly adopted. Nonetheless, the Spaniards introduced, as soon as they could, those fruits that were familiar to their diet. Among the first fruits introduced by Spaniards and Portuguese to tropical America were oranges, along with other *Citrus* species that included lemon and lime. The entrance of citrus trees to Venezuela, in particular, took place at different times. At the beginning, it was part of the first attempt to implant in the newly discovered land the agricultural goods and means they knew in Spain; years later, some citrus fruits were introduced again by slaves brought to America by the Europeans. In either case, the origin of citrus plants in Venezuela is the same: from Asia, by way of adoption in Europe and Africa, and their subsequent cultural implantation in our land (Patiño 1969).

First historical references, from different sources, to citrus fruits adopted early in Venezuela include *C. aurantiifolia* (1573), *C. medica* (1579), *C. decumana* (1578) and *C. aurantium* (1578). Other citrus plants, such as *C. grandis* and *C. reticulata*, arrived later (XIX century), but were readily accepted, especially since the first adopted citrus created a culture of sour fruit consumption. However, it is likely that citrus cultivars were introduced earlier, since by 1535 some varieties were already reported in the Caribbean (Vila 1981). In fact, according to Patiño (1969), citing different sources, Columbus brought seeds of orange, lime, cider and lemon as early as 1493, during his second journey to America.

Citrus plants are not only an integral part of the modern Venezuelan agriculture; these were readily adopted from the very moment natives were acquainted and used to their consumption, even at present, by diverse ethnic groups that maintain their indigenous identity. Among the Hiwi in Venezuela, for example, *C. aurantium* is one of the common seasonal fruits included in a diet where mangoes, and other less well-known fruits, can also be found (Hurtado and Hill Kim 1990). None of these two fruits are autochthonous, and yet, they constitute an integral part of the nutritional culture of indigenous people, that blend well with their traditional background derived from nature and their ancestors. Among the Yanomami, inhabiting the Brazilian and Venezuelan Amazon, on the other hand, several autochthonous Rutaceae, although not *Citrus*, are used for different medical purposes (Milliken and Albert 1997). Finally, in various agriculture-based societies, mainly in the Andean states, citrus was also easily adopted, among other crops that enriched the cultural practices of the conquered natives (Clawson and Raymond 1982).

Citrus fruits have a wide variety of traditional uses worldwide, and very recently have gained additional public interest due to their high content in ascorbic acid, flavonoids, lycopenes, carotenes and lemonoids (Ferguson 2002). Although the fruits are mainly consumed as fresh fruits in Venezuela, juices or desserts are prepared domestically or industrially. Citrus fruits and different organs of the plant are used in ethnomedicine, as any Venezuelan is familiar with at least one of their various beneficial properties or uses, particularly in the case of oranges and lemons. Customarily, Venezuelans believe in the health-promoting effects of vitamin C, which they believe is mainly found in orange and lemon; the latter being preferred for the treatment or alleviation of cold symptoms, especially if mixed with honey (Vit *et al*. 2006). However, the studies concerning the medical uses of Rutaceae in Venezuela are scarce (Játem *et al*. 1997), which is surprising considering the amount of people familiar with the use and commerce of herbs and plant parts used in popular pharmacopoeia, yet they are unaware of the exact health promoting properties of citrus plants.

Leaves, flowers and fruits are used, alone or in combination with other natural products, in beauty treatments and in the relief of ailments of the respiratory, digestive, endocrine, cardiovascular and muscle-skeleton systems; also as analgesic, and for the cure of infectious and parasite-derived diseases (Jones *et al*. 1964; Keshava 1985; Caballero 1995; CONAPLAMED 2000; Bermúdez and Velásquez 2002; Gil and Carmona 2003; Lárez 2004; Carrillo-Rosario and Moreno 2006), or as disinfestant in the control of poultry coccidiosis (Tamasaukas *et al*. 1997).

C. aurantiifolia and *C. limon* are used as respiratory antiseptic, gastric protectant, antiemetic, diuretic, spasmolytic, antidepressant, antifungal, wound healer, to improve digestion and blood circulation, and for the treatment of diarrhea, the alleviation of cold and coughing, and for insect bites (Jones *et al*. 1964; Keshava 1985; Hoyos 1994; CONAPLAMED 2000; Bermúdez and Velázquez 2002; Carrillo-Rosario and Moreno 2006). In addition, they are also used in beauty treatments of skin and hair (Keshava 1985). *C. aurantiifolia* has also been used as an antihemorrhagic to treat snake bites (Lárez 2004).

C. sinensis is employed in the treatment of asthma, coughing, hypertension, spasms, pain, diabetes, and also as an alternative for the management of obesity, malaria and some other hepatic and cardiac problems (Hoyos 1994; Gil and Carmona 2003), and as a febrifuge and antiflatulent (Lárez 2004). For most of the 1930s, orange leaves mixed with baking soda was the only dental care product available in eastern rural Venezuela (Muñoz de Fermin, pers. comm.). *C. reticulata* and *C. reshni* are preferred for the health and care of the skin, control of hormonal disorders, and as a diuretic (Keshava 1985; Hoyos 1994). *C. medica*, on the other hand, has been reported as an efficient alternative as antiemetic, antiseptic, and vermifuge (Hoyos 1994), while *C.* x *paradisi* is also popular for the control of hypertension (Lans 2006).

Pulp and flour, made of seeds and peel as subproducts of the juice industry, are used in the concentrate food for bovines, poultry and fishes (Pérez *et al*. 1975; Moreno *et al*. 2006), whilst essential oils from *C. reticulata* have showed an efficient antimicrobial activity (Martínez *et al*. 2003), and those derived from lemon as an effective insect repellent (Rojas and Scorza 1991). Some varieties of citrus and a few other Rutaceae are popular as ornamental plants in domestic gardens, or as live fences, including *C. aurantium*, *C. sinensis*, *C. madurensis*, *C. lansium*, *Fortunella margarita* and *Triphasia trifolia* (Serpa 1965; Hoyos 1994).

Finally, of the autochthonous Rutaceae, some are preferred for wood, while others, like *Pilocarpus goudotianus*, are popular for its renowned properties in the treatment of glaucoma (Hermoso and Escala 2002). Another non-indigenous Rutaceae, *Ruta graveolens*, or common rue, is employed as a carminative and for menstrual pains (Lans 2007).

Citrus was not only well accepted after their introduction; they are now an integral part of Venezuelan consumption and pharmacopeia, as they blend well with the fruits of the neotropics, forming a rich assortment of fruits uncommon to many regions of the world.

Production, varieties and native Rutaceae species

The Rutaceae family is a group of mostly woody, very fragrant plants, comprised by 155 genera and 930 species, both tropical and subtropical (Judd *et al*. 2002). The best known and representative member of this family is the genus *Citrus*, whose species are of great economic importance due to their fruits and essence oils (Mabberley 2000). Citrus are original from tropical and subtropical Asia, specifically China (Gmitter and Hu 1990), although the taxonomy of the group is very confusing (Scora 1975). However, molecular markers are helping elucidate relationships among different *Citrus* species (for an example in oranges and lemon see Moore 2001). In Venezuela there are 25 native genera of Rutaceae plus one exotic genus (*Citrus*), with 84 native or naturalized species, including 16 that are endemic (Ricardi 1991; Hokche *et al*. 2008). Among these endemics are the genera, *Apocaulon*, *Galipea*, *Pilocarpus*, *Rutaneblina*, and *Zanthoxylum* (Taylor 1989; Reynel 1995). *Pilocarpus* and *Zanthoxylum* have some potential for their medical uses and for their wood, respectively (Patiño 1982).

Citrus is the most important plants from the Rutaceae family in Venezuela. Currently, the main producing areas comprise the states of Carabobo, Yaracuy, Aragua and Miranda, in the central region of the country, the states Monagas and Sucre in the east, and Táchira (**Fig. 2**) and Zulia in the west (Moreno *et al*. 2006), as shown in **Fig. 1**. However, it is fair to say that citrus became so well adapted and was adopted from the very beginning of the colonization that they ended up being ubiquitous in the country, to the point that the nascent colonial industry of cattle considered guava and citrus trees as real pests (Patiño 1969).

As mentioned previously, citrus fruits comprise the second group of fruits produced in the country, which employs 30-40,000 Ha for an annual production that oscillates around the half million tons per year (**Fig. 1**). The most important citrus varieties, in terms of production, are oranges (60.05%), tangerines (26.72%), limes (11.91%), and others including grapefruits. Yield has been estimated at 13.3, 16.4, 16.3 and 9.6 $TM.Ha^{-1}$, respectively. In general, there is an ample variation in crop density, with a predominance of the low ones, with modern irrigation practices limited to few orchards, a heterogeneous use of fertilizers and infrequent weeding, either manual or mechanical.

There is considerable controversy and confusion regarding the taxonomic designation of the species and varieties of citrus cultivated in Venezuela (Serpa 1965). For this reason, aside from the lack of an organized citrus industry and deficient germplasm conservation in Venezuela, the actual and current genetic citrus resources present are not well known. However, in Venezuela diverse species of *Citrus* are cultivated: *C. sinensis*, *C. aurantium* L., *C. maxima*, *C. reti-*

Fig. 2 Citrus cultivation in Táchira, western Venezuela. (**A**) A tangerine tree from an orchard close to La Tendida, in one of the most efficient citrus producing areas of the Táchira state. (**B**) Flower of *C. latifolia*, at a different orchard in the same area. (**C**) Tangelo fruits grown nearby La Tendida. (**D**) Typical symptoms of tristeza, in an adult orange tree. (**E**) Symptoms of (treated) gummosis in orange. (**F**) Symptoms of an unidentified virosis in tangelos.

culata, *C.* x *paradisi*, *C. grandis*, *C. limon*, *C. aurantiifolia*, *C. taiwanica*, *C. sunki*, *C. latifolia*, *C. reshni*, *C. jambhiri*, *C. volkameriana*, *C. madurensis*, *C. limetta*, and C. *medica* (Serpa 1965; Hoyos 1994; Quijada *et al*. 2002). In addition, there are non-*Citrus* citrus plants of other related genera, such as *Fortunella margarita*, *F. japonica*, *Poncirus trifoliata*, *Clausena lansium* and *Triphasia trifolia* (Serpa 1965; Hoyos 1994). Despite the lack of a historical register concerning the many occasions citrus have been re-introduced in Venezuela, during the first half of the twentieth century the favorite donor countries of citrus germplasm were Puerto Rico and Florida, especially for research purposes (Pacheco 2003).

Due to crop decline caused by phytosanitary, cultural and environmental problems, it has been customary to use rootstock grafting which has permitted, with a varying degree of success, to save the production by means of increased use of plants that are more resistant, better adapted or more productive (Rondón *et al*. 1993; Monteverde *et al*. 1996; Laborem *et al*. 1998). Nonetheless, despite the advantages that this germplasm offers, new problems have emerged that require the search and development of new species and varieties able to cope with pressing challenges (Rondón *et al*. 1993). By the year 1982 and later, preferred rootstock for commercial production in Venezuela included, for example, 'Citrange Troyer', 'Citrange Carrizo', 'Citrumelo Swingle', 'Mandarina Cleopatra', 'Limón Volkameriano', *Citrus taiwanica* and 'naranjo criollo', aimed at dealing with main citrus diseases that included tristeza, exocortis, xyloporosis and gummosis. There has also been a growing interest dealing with vigor, drought resistance, productivity and fruit quality (Leal and Trujillo 1970); however, no consistent effort has been made to improve germplasm regarding these factors.

C. aurantium is known in Venezuela as sour orange, box orange or 'naranja cochinera', and is represented by three subspecies, *amara*, *bergamia* and *myrtifolia*. The most common of these subspecies is *amara*, which is extensively used as a rootstock (Serpa 1965; Monteverde *et al*. 1996).

C. sinensis, or sweet orange, is probably the most popular of all citrus in Venezuela. Many varieties of early, medium or late maturation have been cultivated, like 'Valencia', 'California' (Washington Navel), 'Pineapple', 'Parson Brown', 'Mediterránea dulce', 'Luegim-Gong', 'Puerto Rico', 'Frost Valencia', 'Cutter Valencia', 'Campbell Valencia', 'Frost Navel' 'D. Joao', 'Rotuna Island', 'Salustiana', 'Hamlin', 'Criollo Montero', 'Natal', 'Pera' and 'Parson Brown' (Serpa 1965; Monteverde *et al*. 1996; Laborem *et al*. 1998).

Tangerines are represented in the country by *C. reticulata* and *C. reshni.* Among the cultivated varieties, 'Willow Leaf', 'Algeria', 'Dancy', 'Cleopatra', 'Nova', 'Cravo', 'Kinnow', 'Kara', 'Poncan', 'Parson Special', and the clementines 'Fina', 'Marisol' and 'Oroval', are the most popular (Laborem *et al*. 1998; Serpa 1965). On the other hand, grapefruit *C. x paradisi* is available in varieties of white or pink flesh, and the most cultivated varieties include 'Marsh', 'Foster' 'Reed G.F.T.', 'Reiking Pomelo', 'Duncan', 'Star Ruby' and 'Thompson' (Serpa 1965; Avilán *et al*. 1982; Laborem *et al.* 1996).

Varieties of *C. limon* are few and include 'Eureka', 'Verna', 'Lisboa', 'Villafranca' and 'Génov' (Cañizarez and Salcedo 1994). This species, however, has lost commercial value since it has been substituted by varieties of *C. aurantiifolia*, *C. latifolia*, *C. volkameriana* and *C. jambhiri* (Valbuena 1996; Ojeda *et al*. 1998; Quijada *et al*. 2002).

The hybrids cultivated in the country include tangors (*C. sinensis* x *C. reticulata*), with at least three different varieties, 'Ortanique', 'Temple' and 'Minneola' (Laborem *et al*. 1998), and citranges (*C. sinensis* x *P. trifoliata*), with the varieties 'Carrizo', 'Troyer' and 'Uvalde' (Reyes and Ruiz 1984). Other hybrids cultivated in Venezuela include *C. reticulata* x *C. paradisi*, *C. reticulata* x *Fortunella* and *P. trifoliata* x *C. paradisi* (Reyes and Ruiz 1984; Serpa 1965). *C. grandis*, *C. maxima*, *C. medica*, *F. margarita*, *F. japonica*, *P. trifoliata*, *C. lansium* and *T. trifolia*, are species that are not extensively cultivated, yet can be found in small orchards and gardens (Hoyos 1994; Serpa 1965).

Finally, many rootstocks have been assayed, of which the most popular ones are those that show a certain degree of resistance against pathogens, like *C. reshni* (rootstock 'Cleopatra'), *C. aurantium* or *C. sinensis* x *P. trifoliata.* Scions are very diverse, but the most commonly found are those that are commercially attractive, such as the orange varieties 'Valencia', 'California' (Washington Navel) and the lemon *C. latifolia* (Serpa 1965; Reyes and Ruiz 1984; Valbuena 1996; Laborem *et al*. 1998; Quijada *et al*. 2002).

PATHOGENS AND PESTS

A diseased plant is incapable of completing its life cycle, due to unfavorable environmental factors, a compromised physiology or due to pathogenic agents. Fruit crops do not escape this situation, and perhaps the high sugar content of their fruits makes them an easy and attractive target of different pathogens. The list of enemies of commercially cultivated citrus is long. The list shown in **Table 1** clearly reveals the broad diversity of pathogens and pests of citrus present in Venezuelan orchards. Some of them are restricted to specific areas of the country, whilst others are found ubiquitously wherever citrus species are grown. The main challenging pathogens and pests of citrus plants in Venezuela will be shortly described below; however, some readers might like to consult the references given in **Table 1** for more comprehensive information. Diseases of unknown etiology will not be covered here, e.g. citrus blight (EPPO 2004), unless the nature of the agent is at least suspected (viruses, for example).

Viroids and viruses

Probably the most prevalent disease of citrus is tristeza, caused by the *Citrus tristeza virus* (CTV, Closteroviridae), which causes tree decline, stem-pitting and yellowing of the seedlings. At least two different genotypes, derived from the analysis of three different isolates of CTV, are present in the country as molecularly established by Hilf *et al.* (2005), yet a more comprehensive analysis is needed to characterize the population structure of the virus present in the country. The disease was first described, or identified, in Venezuela by Ciferri in 1950, and was later corroborated by Knorr in 1960 in lemon trees, *C. aurantiifolia*, and lemon 'Meyer' *C. meyeri* (Ciferri 1950; Knorr *et al.* 1960, cited by Rangel *et al*. 2000). In 1983, two conditions in Venezuela became highly conducive for the virus disease: first, that 90% of orange orchards consisted of a highly susceptible rootstock-scion combination (sweet orange/sour orange); and second, the presence of the efficient virus vector *Toxoptera citricida*) (Monteverde 1983), which was first identified in the country in 1976 and was widespread by 1979 (Mendt 1992). It has been argued that CTV has caused the loss of 10 million citrus trees in Venezuela (Anonymous source, 1995, cited by Gianessi *et al*. 2002), yet we have found no references or statistics that support this assumption. Finally, cross protection has been claimed to be (successfully) used in Venezuela to control tristeza (Ochoa *et al*. 1993), yet no further information to sustain this assertion has been found.

Another viral disease of importance in Venezuela is citrus leprosis, which became a phytosanitary problem in the early and mid 1990s when prevalence of the disease increased dramatically. Restrictions imposed by neighboring countries on the importation of fresh fruits produced in Venezuela is an example of the many challenges the citrus industry faces in this country, especially when phytosanitary measures are less than adequate. The disease is caused by the *Citrus leprosis virus* (EPPO 2007), a rhabdovirus, which in Venezuela seems to be transmitted by the mites, *Brevipalpus obovatus* and *B. phoenicis* (Knorr and Denmark 1970; Garnsey *et al*. 1988). Although a protocol for the phytosanitary certification of citrus, based on RT-PCR using the viral RNA, has been standardized in the country (Rangel *et al*. 2006, unpublished), no official adoption has been followed.

Among the diseases attributed to undescribed viruses is *impietratura* (tissue hardening). During the early stages of infection, the disease can be detected by the appearance of very small fruits. Diseased fruits are extremely hard, gum pockets are formed on the fruit albedo, and over the fruit itself hard protuberances are also evident; production is diminished and immature fruits frequently fall (Ortega 1986). The former was reported for the first time in 1970 by Rondón on sweet orange (*C. sinensis*) varieties 'Valencia' and 'Puerto Rico' (Rondón *et al.* 1970; Monteverde *et al.* 1992). Another disease whose etiological agent is an undescribed virus, reported for the first time by Monteverde *et al*. in 1983 (Monteverde *et al*. 1992) in Venezuela, is concave gum, mainly on sweet orange. This pathogen leads to the production of scales on the cortex of the trunk and main branches, accompanied by chlorosis and diminished production (Ortega 1986).

So far, only two diseases caused by viroids have been described in Venezuela. The first, exocortis, is caused by *Citrus exocortis viroid* (Pospiviroid), which mainly attacks lime 'Tahiti', leading to a reduction in trees growth. Also, affected plants produce gum exudates, exhibit longitudinal cracks and a reduced production (Ortega 1986). The disease was reported by Estrada and Malaguti in 1972 (Monteverde *et al.* 1981, 1992). The second, xylosporosis, or cachexia, is caused by the *Citrus cachexia viroid* (Hostuviroid) that mainly attacks tangerines. Diseased plants show pits on the trunk, gum pockets, yellowing of leaves and reduced production (Ortega 1986). It was reported by Monteverde *et al.* in 1985.

Bacteria

Few articles and scientific printed material have been published regarding the presence of phytopathogenic bacteria on citrus cultivated in Venezuela. In some cases, the presence of a vector has prompted some researchers to warn on the potential presence of the harbored bacteria; yet no conclusive evidence has been presented of the bacteria themselves. For instance, *Candidatus* liberibacter americanus, vectored by the psyllid, *Diaphorina citri*, (Cermeli *et al*. 2000; Halbert and Nuñez 2004) and causal agent of huanglongbing, has been actively pursued although not even preliminary data has currently been published that demonstrate its presence in Venezuela. Truly identified bacteria include *Xylella fastidiosa*, the causal agent of citrus variegated chlorosis (Hernandez *et al*. 1993), and potentially *Spiroplasma citri* (EPPO 2003a). Venezuela has been acknowledged to be free from all strains of *Xanthomonas* pathogenic to citrus (Kyprianou 2006), but some controversy exists, since several Venezuelan researchers have suggested that *X. citri* may be present in some of the citrus orchards. Yet again, there is no published data to support these claims.

Fungi and oomycetes

Amongst the most important citrus diseases reported in the phytopathological literature in Venezuela are those caused by fungi and oomycetes. Damage caused by, and the presence of the fungi, *Rhizoctonia solani*, *Pythium* sp., *Fusarium* sp., and the oomycete, *Phytophthora citrophthora* (= *parasitica*), are frequently observed in seedling beds; while in nurseries, diseases like wilting caused by *P. parasitica* and *Fusarium* sp., leaf spot by *Cercospora penzigii* (= *aurantia*) (Díaz and Salas 1973; Urtiaga 1986), scab by *Sphaceloma fawcetti*, anthracnose by *Colletotrichum gloeosporioides*; areolate leaf spot by *Pellicularia filamentosa* and diplodia gummosis and stem-end rot by *Botryodiplodia theobromae* (Rondón 1992), are fairly common. The latter, reported in 1992 by Cedeño and Palacios-Prü, is also considered the causal agent of cortical lesions and gummosis in lemon (*C. aurantiifolia*) and orange (*C. sinensis*).

In adult plants, premature drop of flowers and young fruits, especially in *C. latifolia*, are induced by fungi like *C. gloeosporioides*, *C. acutatum* and *Rhizopus* sp. (Rivas *et al.* 2006). These three pathogens have been consistently isolated from infected flowers and fruits. Another disease common in adult trees, includes leaf spot, which leads to foliage drop as observed in *C. aurantium* and lemon (Rondón 1967, cited by Contreras and Rondón 1980). Controlled infection assays performed on *C. jambhiri*, *C. aurantiifolia*, *C. volkameriana*, *C. reshni* and *P. trifoliata* x *C. sinensis*, Contreras and Rondón (1980) demonstrated that the causal agents of the disease were *Alternaria citri* and *C. gloeosporioides*; the former as a primary agent of the disease, and the latter as a synergistic factor of infection.

According to Rondón (1990), among the frequent and economically important diseases found in citrus orchards are gummosis or root rot, caused by *P. citrophthora*, dieback by *B. theobromae*, leaf-spot by *C. penzigii* and *C. citrigrisea*, anthracnose caused by *C. gloeosporioides*, and fumagine by *Capnodium citri*. Another disease affecting leaves and fruits is the greasy spot (*Mycosphaerella citri*, as reported by Rondón 1990 and Pretorius *et al*. 2003). Although it is not known when the pathogen appeared in the country for the first time, it has been clearly established that it is present in citrus production areas characterized by an elevated relative humidity, abundant rain and temperatures ranging from 24 to 30°C, especially in the case of sweet orange, grapefruit and tangerine orchards. Another citrus disease of certain importance in Venezuela is citrus scab, caused by the fungus *Sphaceloma fawcettii*, the anamorph of *Elsinoe fawcettii*, which can infect true lemons, and to a lesser extent, tangerines and grapefruits (Urtiaga 1986). The disease is characterized by protruding, corky lesions, which in most cases can deform or diminish the size of affected plant organs. Finally, *Septoria citri* has also been reported in Venezuela, which is reputedly the causal agent of lesions in the form of concentric rings (the fungus fruiting bodies), or septoria spot, on diverse varieties of orange, lemon and grapefruit (Dennis 1970; Rondón 1992).

Nematodes

There are many nematodes that are considered to be etiological agents of important diseases in fruit trees, particularly of citrus, worldwide (Baines *et al.* 1978; Cohn 1972; Ducharme 1969, cited by Petit 1990a). Besides fungi, nematodes are the best studied plant pathogens in Venezuela, particularly those affecting fruit trees.

First reports of nematodes on citrus in Venezuela date back to 1955, when they were collected in orchards located in the central part of the country at La Victoria, Aragua state (McBeth 1956, cited by Petit 1990a). In the late 1960s, Yepez and Meredith (1970) report on the most important nematodes that affect fruit trees including citrus, Musaceae, mangoes, avocado, pineapple and papaya. Years later, based on a systematic sampling on the main citrus producing areas of the country Petit (1990a, 1990b) reported that the most important nematode associated with *Citrus* cultivation in Venezuela is *Tylenchulus semipenetrans*. This nematode was found associated with the cultivation of orange (*C. sinensis*) 'Valencia' grafted on tangerine 'Cleopatra' (*C. reshni*) rootstocks, lemon 'Volkameriano' (*C. volkameriana*) and citrange 'Carrizo' (*P. trifoliata* x *C. sinensis*) (Petit 1990a). Other nematodes present in soil samples, yet in lower densities, are those belonging to the genus *Helicotylenchus*, *Paratylenchus*, *Peltamigratus*, *Pratylenchus*, *Rotylenchus* (*R. reniformis*), *Trichodorus*, *Tylenchorhynchus* and *Tylenchus* (*T. costatus*) (Petit 1990b).

More recently, Crozzoli (2002) presented an excellent review with a very comprehensive list of phytoparasitic nematodes in Venezuela, responsible for the majority of the losses of the fruit industry in the country, including citrus.

Insects

Geraud (1983), after performing a comparative analysis between different pests of tomato and citrus, reports that during the 1950s–1960s, the most important insect pests of citrus plants in Venezuela were aphids (*Homoptera*: *Aphidae*) and the scales (*Homoptera*: *Diaspididae*, *Coccidae* y *Margarodidae*). Later, the mite causing the disease known as 'bronceado de los frutos', and identified as *Phylocoptruta aleivora* (*Acarina*: *Eriophiydae*), was added to the list. However, it was only by the end of the 1960s that advances in entomological studies and direct technical assistance to growers allowed for an increase in knowledge of the main insects that affect citrus plants in the country. Not surprisingly, however, aphids and scales continued to be among the most important pests afflicting this crop.

During the years 1965-70, *Aleurocanthus woglumi* (Angeles *et al.* 1971; Geraud and Doreste 1977, cited by Geraud 1983; EPPO 2003b), the citrus black fly, is reported for the first time in the most important citrus producing areas of Venezuela. It is worth recalling that by the end of the 1960s the use of insecticides was almost inexistent in citrus orchards, and that it was precisely the emergence of *A. woglumi*, as an important citrus pest, that stimulated its reappearance. But on the other hand, it was also critical in motivating studies on the natural enemies of *A. woglumi* (parasites, predators and pathogenic fungi) as potentially useful for establishing strategies of biological control (Ferrer 2001). It was a parasite wasp, *Prospaltella opulenta* (*Hymenoptera*: *Aphelinidae)* that allowed for successful and almost complete control of the citrus blackfly (Geraud *et al*. 1977, cited by Geraud 1983). In 1985, the Japanese white fly, *Parabemisia myricae* (Kuwana), was also reported as an important pest on different citrus cultivars (Chávez and Chávez 1985).

Interestingly, in 1976, Geraud reports for the first time in Venezuela the presence of the insect vector of CTV, the citrus black aphid, *T. citricida* in the region known as Mene Grande, Bolívar District, state of Zulia (Geraud 1976, cited by Geraud 1983).

Particularly in the Venezuelan Andes, in an excellent review, Briceño (2007) describes a series of insects that causes considerable damage on different species of *Citrus*. Among them, the causal agent of 'red scale', *Crysomphalus aonidum*, is a cosmopolitan insect that infests any citrus plant under virtually any environmental condition and drastically reduces plant foliage resulting in decreased plant vigor and fruit quality. *Lepidosaphes beckii*, etiological agent of 'comma scale', attacks all parts of citrus trees, causes defoliation and produces yellowing around the scale. In the case of the 'white snow scale', or citrus 'queresa', caused by *Unaspis citri*, the damage is not as severe since it is also a target of a naturally occurring parasitism. Only the males feed on citrus plants during their immature stage. Therefore, it is only in old trees where layers of scales accumulate. The insect may impair tree respiration.

'Citrus moth', the leafminer *Phyllocnistis citrella*, was reported on oranges, tangerines and lemon in Venezuela for the first time in 1995, in Maturín, Monagas State and in the Andes in 1997. Damage is mainly caused by serpentine galleries, which in turn causes deformations and curling of the leaves. 'Orange moth', *Ecdytolopha* (*Gymnandrosoma*) *aurantiana*, on the other hand, is widely distributed in South America. In the Venezuelan Andes, it is mainly found on 'Naranja criolla' and late varieties. The lepidopteran perforates fruits, making them unmarketable and susceptible to attack by opportunistic fungi (Bricceño 2005).

Among the aphids, *Aphis craccivora* has been reported to cause feeding damage on different species of citrus plants, while *A. gossypii* and *A. nerii* cause leaf deformation in *C. aurantium*. On the other hand, *A. spiraecola*, although not an efficient virus vector, does cause severe deformations on diverse species of citrus plants. However, it is *Toxoptera. citricida*, known as the 'citrus black aphid', that is the most damaging of the aphids affecting citrus crops in Venezuela. As an efficient vector of CTV, has led to the decimation of citrus plants in Venezuela killing over 6 million trees with the disease. This pest can cause severe deformations, when it is not viruliferous. Another species of the genus, *T. aurantii*, has also been reported in the country (Cermeli 2007).

To conclude with this section, it is important to emphasize the profound, positive impact that entomologists have caused in the citrus industry in Venezuela, and in fruitculture in general (Pacheco 2003, 2006). Aside from increasing our knowledge of important pests, many Venezuelan entomologists have ventured to use biological control from the very beginning of this scientific discipline in the country, with notable success. We have already mentioned the case of *A. woglumi*; however, prior examples have paved the way to biological control in Venezuela. During the years 1939-41, for example, C. H. Ballou (1941) introduced *Rodolia cardinalis*, a coccinellid, to control the cottony cushion scale, *Icerya purchasi* in citrus (Ferrer 2001). More recently, Linares *et al*. (2001) reported on the use of *Ageniaspis citricola* for the control of the aforementioned psyllid, *P. citrella*.

Others: weeds, algae and mollusks

Other pests can affect citrus production, without causing economical impact comparable to that caused by viruses, fungi and nematodes. A good account of weeds present in citrus orchards, and other crops, is presented by Lárez (2007a, 2007b), but restricted to Monagas state, in eastern Venezuela. A comprehensive study of weeds in other areas of the country is not available. Regarding algae, there are episodic reports of the Chlorophyta, *Chepaleuros virescens* and *Trentepohlia* sp., but they are not considered major pests. Few reports also mention the parasitic plant *Langsdorfia* sp., which is not considered to be of relevance or economical importance.

Of the mollusks present in citrus orchards, the most prominent is *Orthalicus maracaibensis*, which can cause severe damage on the trunk and the cortex of young branches, leading to total loss of leaves (Fuentes 2006).

IMPROVEMENT AND PERSPECTIVES

It can be argued that research in Venezuela related to *Citrus* species in particular, and Rutaceae in general, has been scarce and devoid of continuity. Most of the studies regarding citrus have been oriented to horticultural management of the crop and limited to evaluations of the grafting potential rootstocks, and evaluation and control of diseases in commercial species and varieties (Laborem *et al*. 1993; MARNR 1996; Avilán *et al*. 1998; Laborem *et al*. 1998; Wagner *et al*. 1998; Cañizares and Rojas 2001; Ojasti 2001; Wagner *et al*. 2002; Quintero *et al*. 2004). Few ethnobotanical (Delascio 1985; Bermúdez and Velázquez 2002; Carrillo-Rosario and Moreno 2006), anatomical (Avilán *et al.* 1982, 1986; Laskowski 2006; Cañizares *et al.* 2007), germination (Leal 1970), phenological (Perez *et al*. 2004) and phytochemical studies have been carried out with citrus (Ojeda *et al*. 1998; Rincón *et al*. 2005). The more prominent findings have already been mentioned, or will be shown in the following paragraphs, but it is worth mentioning the persistence of a divorce between the research performed at universities and other governmental research institutes, and producer problems and needs. This fact, however, is not an exclusive feature attributable to citrus cultivation; neither is it a recent development. From 5,822 references of a Venezuelan agriculture bibliography (Badillo and Bonfanti 1957) only 14 were devoted to citrus (with eight of them only to citrus diseases). For the years ahead, matters did not change: the subjects of research on citrus are the same and research is still much needed, although the number of articles had increased steadily in the last 40 years. In the following lines a brief summary of several important findings on citrus plants in Venezuela in recent years are presented.

All edible species of the genus *Citrus* are very rich in ascorbic acid, flavonoids and essential volatile compounds, lisigen oils in the parenchimatous tissues of leaves and branches (Rincón *et al*. 2005; Cañizares *et al.* 2007). They also contain coumarins of the bergapten group, which are frequently added to tanning preparations since they promote skin pigmentation. In Venezuela, Ojeda *et al*. (1998) identified a total of 51 chemical constituents of the essential oil from *C. limon*. The most abundant compound found was the monoterpene, limonene (65.65%), and the main aldehydes were geraniol (1.43%) and nerol (0.87%). Among the remaining hydrocarbons, they also identified β-pinene (11.0%) and γ-terpinene (9.01%) in elevated proportions. Besides, the authors reported on the presence of 3.79% of oxygenated compounds, of which 2.70% were composed of aldehydes, 0.53% alcohols and 0.56% esters. In another study, Rincón *et al.* (2005) focused on the composition and concentration of bioactive compounds of the citrus flour that is widely consumed in Venezuela (*C. sinensis*, *C. reticulata* and *C. paradisi*). High concentrations of ascorbic acid, magnesium, carotenoids, diet fibers and abundant polyphenolic compounds were reported. The latter showed high antioxidant efficiency, and since they are more abundant in tangerine peels, they are recommended for the prevention of cardiovascular diseases and other health threatening conditions related to lipid oxidation.

One of the first and persistent systematic attempts made to improve citrus cultivation and productivity was a study evaluating different rootstocks for pathogen resistance (Rondón *et al*. 1993) and tolerance to diverse sources of abiotic stress. Regarding planting materials, micrografting was proven to be valuable in the generation of germplasm free from exocortis and psorosis (Monteverde *et al*. 1986), and yet no attempts have been made to produce citrus plantlets free from virus and viroids on a greater scale. In the same vein, in a study on pollen germination, Leal (1970) concluded that *P. trifoliata* and some oranges and tangelos (*C. reticulata* x *C. paradisi*) are appropriate germplasm for improvement programs. However, there is no evidence that these findings have ever been put in practice.

In a technical report on the use of biotechnology in Venezuela, García (2005) mentions the application of clonal micropropagation and the production of clean seeds, the advances in the use of molecular markers to citrus and their pathogens. She also touted an increase in the number of scientists in the country with proficient skills in molecular biology and predicts an increase in the technological input to citriculture in Venezuela. For example, the detection of viruses by multiplex polymerase chain reaction (Roy *et al.* 2005) has been proven an effectiveness method of detecting CTV, which remains the prevalent viral disease in citrus in Venezuelan orchards (unpublished). On the other hand, the control of *Papaya ringspot virus* by a transgenic approach (Fermin *et al*. 2004), set an example for the application of modern techniques for the control important pathogens in fruit crops, but the country does not appear to be ready for the acceptance and commercialization of genetically modified crop plants (Fermin *et al*. 2005).

Few attempts to improve *Citrus* germplasm by Venezuelan researchers using *in vitro* technologies in hybrids have been applied, in some cases with notable success (Viloria *et al*. 2005). This valuable effort represents another example of scientists already prepared to assume the challenge of modernizing Venezuelan citriculture since, although *in vitro* tissue culture techniques have been widely used in the country, citrus species might be considered so far a neglected target in this regard.

In 2007, the Interamerican Web on Citrus held a meeting in Venezuela, where members of three different countries, as well as producers, gathered to discuss pressing issues related to citrus cultivation. It is expected that the reactivation of the working group might lead to a concerted effort to assist producers in designing a modernized strategy that might help increase citrus production. Some governmental efforts aimed at providing technical and financial assistance to citrus growers are under way in different parts of the country, but it is still too early to predict the final outcome of what seems to be a serious attempt to recover citrus production.

CONCLUDING REMARKS

The citrus industry in Venezuela, including production and processing, seems to be recovering from a decade of low productivity, low technical input, scarce research and poor financial support. Additionally, there are certain aspects of the Venezuelan society, as a whole, that provide an optimistic view for the future of the citrus industry: First, a well formed group of phytopathologists showing a renewed interest in the main pathogens that attack fruit trees, including the diverse species and varieties of *Citrus* cultivated in the country; second, by all measures, the economic situation of the vast majority of the inhabitants of the country has improved, which has led, and will continue doing so, to an increase in food availability and consumption, including fruits; third, although still very low, exports of citrus might stimulate an increase in production for both local and external markets. However, the country needs a renewal of its citrus genetic material. The main obstacle for a rational, comprehensive and realistic genetic improvement program is the absence of previous experience in this field for this particular important crop. To our knowledge, the limited citrus germplasm in the country (Pérez *et al*. 1998; Rincón *et al*. 2006) is not sufficient to support an improvement program (for example, there are only 93 entries for citrus species at CENIAP, according to Pérez *et al*. (1998), of which less than 15 have been characterized), nor is the almost inexistent experience in tissue culture or transformation of citrus species enough to sustain an improvement program adapted to modern biotechnology.

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