PROJECT TITLE: MANGO ROOTSTOCKS. LITERATURE REVIEW AND INTERVIEWS.

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INDEX

ANNEX 1. MANGO ROOTSTOCK SURVEY
ANNEX 2. LIST OF INTERVIEWED PEOPLE

Background and Introduction

Despite the notorious potential impact of rootstocks on quantitative and qualitative yield of mangoes, rootstock and cultivar/rootstocks interaction studies are considered among the most important pending subject for mangoes and scarcely covered by research (Galán Saúco, 2015a). As an example, only one paper on mango rootstocks (Hermoso *et al*., 2015) has been presented in the last two International Mango Symposium of the International Society of Horticultural Science (ISHS) held in the Dominican Republic (2013) and Australia (2015).

The main global objective of this project is to review and update the existing information about mango rootstock for commercial cultivars, as well as identifying rootstock research lines and find the availability and interest of the main world research institutions for future collaborative projects on the subject all over the world. Due to the scarce existing available printed and electronic sources about the subject, interviews (by email, telephone, and/or in person) with people, either researchers or producers, involved in the mango industry of different mango producing countries of the whole world, will serve us, both for getting information about the desired characteristics of a rootstock demanded by the industry and as complementary information. An important source of information will also be a mango rootstock survey sent to the main producing mango countries (see Annex 1). This project will be focused mainly on mango cultivars that are marketed in the United States ('Tommy Atkins', 'Ataulfo', 'Kent', 'Keitt' and 'Haden') but other worldwide commercial cultivars will also be included as well as relevant information about mango rootstocks.

Worldwide commercial cultivars.

According to the recent review made by Galán Saúco (2015b) presented at the XIth ISHS International Mango Symposium held at Darwin, Australia, Floridian cultivars 'Tommy Atkins', 'Kent', 'Keitt' and to a minor scale 'Palmer', 'Haden', 'Edwards' or 'Irwin' dominate the global fresh-fruit export market, particularly when destined to the European Union (EU) and the United States (USA). In the USA market the offer is reduced almost exclusively to Floridian cultivars plus 'Ataulfo', from Mexico and 'Madame Francis' from Haiti and completing the spectra of commercial cultivars with few newcomers like the Australian 'Calypso' entering recently this market. On the EU market the offer is much wider and besides the mentioned Floridian cultivars includes the Israeli cultivars with 'Maya', 'Aya', 'Omer', 'Shelly' and 'Kastury'. Other less coloured and different-tasting cultivars, like 'Alphonso', 'Chausa' and 'Sindhri' from India and Pakistan are also marketed especially in England. 'Amelie', an early cultivar produced by African countries like Ivory Coast or Mali has been marketed traditionally in the EU, but it loses competitivity when 'Kent' from Peru starts to appear in the market. 'Valencia Pride', originated in Florida origin and also produced in some African countries together with 'Amelie', receives some years a good reception in the EU market at the beginning of the season due to its excellent colour and typical mango shape but suffers from rapid maturation that reduces its market potential. Finally, the offer is completed with another Floridian cultivar 'Osteen' from Spain, selected 'Carabao' fruits from The Philippines, the sweet 'Nan Dok Mai' from Thailand and 'Cavallini' from Costa Rica.

Green (unripe) mangoes, especially those of the Thai cultivars 'Khieo Sawoei', 'Nongsang', 'Pim Sem', 'Rad' and 'Saifon' are preferred by many Southeast Asian consumers but the main Eastern markets look for cultivars exhibiting a special feature, rather than just colour

- except in China and Japan where red colour, particularly of ‘Irwin’, produced in greenhouse is also much appreciated - such as the sweetness of ‘Keaw’ ‘Nan Dok Mai’ or ‘ ‘Maha Chanuk’ from Thailand or the excellent tasting quality of the cultivars ‘Chausa’, from Pakistan, ‘Alphonso’, ‘Dasheri’, ‘Kesar’, ‘Langra’ and others in India and the ‘Carabao’ in Philippines, or the hint of turpentine in ‘Kensington Pride’. In fact, none of the cultivars mentioned in this paragraph, except ‘Maha Chanuk’, exhibit red colour.

The processing sector uses either rejected fruits or less well known Floridian cultivars, such as ‘Brooks’ or ‘Lippens’ in African countries like Burkina Faso, and even polyembrionic types, like ‘Criollo de Cholucanas’, ‘Chato de Ica’ and ‘Rosado de Ica’ in Peru or the cultivar ‘Ubá’, a small but highly sweet fruit (Brix >20º) cultivated specifically for juice in Brazil. The Indian cultivar ‘Panchadarakalasa’ is also grown for processing in India.

From the additional information about commercial mango cultivars extracted from the Mango Rootstock Survey composed by the author specifically for this work (See Annex 1) it can be seen that not many other cultivars different from those mentioned so far are important in the mango fresh trade. Exceptions may be some South East Asian, Chinese or Egyptian cultivars - those mainly as pulp - much restricted to regional trade-, and in the processed market the role of South Africa exporting mainly dried mangoes to the European Union, the Middle and Far East and the nearby African countries as well as the important contribution of Colombia exporting mango puree and juice to the Middle East, Europe, Africa, Oceania, South America, Central America and the Caribbean Region. In the particular case of Latin-American countries (see table 1a). which are the main suppliers of the North American continent all the exported cultivars for the fresh market, with the exception of the Thai cultivar’ Nan Doc Mai’, some local Dominican Republic and Cuban cultivars, are Floridian types. These Floridian cultivars also dominate the export trade for the African mango producing countries and Spain, having also importance in Israel although new bred cultivars are increasingly planted in this country (table 1c). On the contrary, the Floridian cultivars, with the exception of ‘Irwin’ in Taiwan and Japan, have no relevance as commercial cultivars in South East Asia or (table 1b), but are being planted in the Pacific, particularly in New Caledonia and Hawaii and ‘Keitt’ also’ in Australia.

A recent review of the world mango market in 2015 (Gerbaud, 2016) shows no other new commercial cultivars except the growing irruption of some cultivars from the Dominican Republic (‘Banilejo’, ‘Gota de Oro’, ‘Crema de Oro’, ‘Mingolo’ or ‘Puntica’) in the European markets.

Summary of interviews on the influence of rootstocks in quantitative and qualitative aspects of mango production.

To obtain updated information about the actual use of rootstocks in different countries 66 people, including researchers, nurserymen and producers or producer associations from 40 countries (Annex 2), where interviewed first by sending them through email the mentioned mango rootstock survey (Annex 1) and later, when necessary, by phone or personal contacts. The selection of the contacts was based mainly on the knowledge of the mango world acquired by the author through the many years, from 1996 till 2015, serving to the International Society of Horticulture Science (ISHS), first as Chairperson of the Section of Tropical Fruits and then as Chairperson of the Mango Working Group. A summary of these interviews is given on table 2 (Rootstocks used in different countries, grouped by geographic zones, a) Latin America, USA and the Caribbean; b) Asia and the Pacific and c) Africa, Middle East and Europe), table 3 (Desired characteristics of a rootstock by countries) table 4 (Ongoing trials and interest on international cooperation in rootstocks work, again grouped by geographical zones) and table 5. Yield of Floridian and other selected cultivars on different rootstocks reported as estimated for different researchers.

The main general findings that can be extracted from these interviews are the following:

1) In practically all the countries, **rootstocks are chosen because of the facility of obtaining seeds** without paying especial attention to the benefits for the scion. In countries like Egypt or China seeds are obtained from the processing plants.
2) **Generally, they are polyembryonic types** coming from local and well adapted trees long before introduced in the area. The only exception lies in India, Pakistan, Bangladesh, Oman, China and Hawaii where monoembryonic seedlings and even some *Mangifera* spp compatible with mango in Hawaii and Indonesia are also used as rootstocks. The explanation for the use of monoembryonic rootstocks in the area of origin of mangoes in South East Asia may be that the majority of orchards are old low density plantings where uniformity of the rootstock is not as important as in modern plantings and that for China and Hawaii deriving from the scarcity of available seeds. A particular case is that of Australia where sometimes 'Kensington Pride' is cultivated on its own roots because of the polyembryonic characteristics of this cultivar.
3) **The same rootstock is normally used for all cultivars.** Only in a few cases there has been reported specific recommendation for some cultivars. Among them the following indications has been given for, 'Kent', 'Tommy Atkins', 'Keitt' orsome other Floridian cultivars:
    a) 'Coquinho' is not recommended in Brazil as rootstock for 'Tommy Atkins' and 'Van Dyke' because gives great vigour to the grafted plants.
    b) 'Mameyito' is not recommended as rootstock for 'Keitt' in the Dominican Republic because this cultivar grafted on it shows iron chlorosis in alkaline soils.
    c) 'Van Dyke', but also 'Irwin', 'Kent' and 'Tommy Atkins' appears to be more resistant to dry conditions when grafted on seeds of the 'Arauca' than when grafted in the rootstock 'Hilacha' in Colombia.

Besides availability of seeds and other obvious reasons, not always mentioned in the surveys like rapid growth in the nursery compatibility with the cultivars, high percentage of taking and, of course, increase of yield, this last mentioned by 24 countries, the most desired characteristics for a mango rootstock were the following:

A) Tolerance to salinity, desired by 24 countries from practically all the mango producing areas of the world.
B) Dwarfing, preferred by 21 counties also from the different mango producing areas.
C) Good nutrient absorption, particularly iron absorption chosen by 12 countries.
D) Tolerance to pest and diseases (anthracnosis, *Ceratocystis* and others) desired by 12 countries.
E) Tolerance to flooding, desired by 11 countries.
F) Tolerance to dry conditions, demanded by 10 countries.
G) Improve of fruit quality, including increase or reduction in fruit size mentioned by 7 countries.
H) Adaptation to problematic soils mentioned by 4 countries, 3 for calcareous soils and one for acid sulphate soils.
I) Altering cultivar vigour and tree architecture indicated by 3 countries.
J) Improving flowering, also mentioned by 3 countries.

K) Resistant to strong winds or increasing root depth mentioned only for Reunion Island and Taiwan, both in the area of incidence of hurricanes and typhoons.

L) Shortening of the juvenile phase, mentioned only by two countries.

M) Low incidence of internal fruit breakdown (IFB) indicated only for Spain.

N) Adaptation to greenhouse cultivation and to subtropical climates with cold winters and very hot summers, also reported only by Spain.

A few comments about these results are worth to be mentioned here:

It is not a surprise that tolerance to salinity and dwarfism are the more demanded characteristics for a mango rootstock and that tolerance to flooding and dry conditions as well as tolerance to pests and diseases are also among the most cited as good characteristics for a rootstock. With the expected world climatic change several, if not all climatic variables, will be affected (IPPC, 2007), The expected rise in temperature and changes of precipitation in the tropics and the subtropics will cause more frequent and unpredictable episodes of precipitation or drought and dry scorching conditions and the elevation of the sea level will cause an increase of soil and water salinity because of the intrusion of salty water in water tables (World Bank, 2012). These climatic changes may also accentuate the pests and diseases problems affecting mangoes (Normand *et al*., 2015). It is also obvious that dwarfism or semi dwarfism in the subtropics is a requirement for modern mango high density plantings already established in countries like Mexico, Egypt, India and South Africa among other countries (Galán Saúco, 2015c). Altering tree vigour and modification of mango architecture, as well as shortening of the juvenile phase and with profuse flowering may be ascribed also to the idea of producing more compact and early yielding mangoes required for high density cultivation. It is evident that a deep rooted rootstock will be better prepared to support the more frequent and intense hurricanes ad typhoons also expected in the scenario of predicted global climatic changes and that the adaptability to problematic soils and its ability to absorb soil nutrients is a good characteristic for a rootstock. Improve of fruit quality by using a particular rootstock and specially to reduce or increase fruit size is more problematic since these characteristics are more linked to the cultivar and to the fruit load but, as it will be seen in the literature review, there is possible to influence on fruit quality through an appropriate rootstock. It is a surprise to note that only one country, Spain, mentions as a good characteristic for a rootstock the low incidence of IFB, although this problem, linked to a disequilibrium in the Ca/N relationship (Galán Saúco, 2008), may be reduced either by rootstocks with good capacity to absorb nutrients, particularly calcium or through a reduction of nitrogen application. The actual recommendation of increasing calcium applications and keep foliar nitrogen concentration below 1.2 % (Galán Saúco, 2009) may perhaps be the cause of a lower incidence of this problem and, in consequence, of the fact that low incidence of IFB was mentioned as a desired characteristic only by Spain.

As a conclusion from these interviews it is evident that **the best rootstock must have the main following characteristics**:

Heavy and uniform annually producer to guaranty availability of seeds, a high degree of polyembryony to guarantee uniformity, good compatibility with the cultivars, tolerance to salinity, dwarfing characteristics, good ability to absorb nutrients, particularly iron and calcium, tolerance to flooding, tolerance to dry conditions and favouring the improve of fruit quality. If adapted to problematic soils, tolerant to pests and diseases and deep-rooted, better.

It should, of course, **not** be **detrimental to yield** or even better it should **improve yield and/or yield efficiency** (yield by canopy unit area).

Obviously, practically all the rootstocks used in the different countries meet, as much as possible, the requirement of being <u>’Heavy and uniform annual producer to guaranty availability of good seeds, a high degree of polyembryony to guarantee uniformity and good compatibility</u>

with the cultivars that are grafted on them', but not all of them have the other characteristics mentioned above.

In fact, examining table 2 it can be seen that:

Tolerance to salinity is reported only for 'Criollo de Cholucanas' (Peru), 'Hilacha' (Colombia), 'Piqueño' (Chile), *Mangifera kasturi* (Indonesia), 'Bau 6, 7 and 8' (Bangladesh), 'Gomera 1'(Spain), 'Sukkari' (Egypt) and '13/1' (Israel).

Dwarfing effect is only indicated for 'Banilejo' and 'Piñita' (Dominican Republic) 'Piva' (South Africa and Florida), 'Saigon 119' (Indonesia) and 'Kom' (Hawaii).

Good ability to absorb nutrients is reported only for 'Criollo de Cholucanas', 'Kaew' and 'Ta-Lub-Nak' (Thailand), 'Tsar-Swan' (Taiwan) and '13/1' (this last particularly iron).

Tolerance to flooding is indicated only for Criollo de Cholucanas', 'Hilacha', and 'Sabre' (South Africa).

Tolerance to dry conditions is reported only for 'Criollo de Cholucanas', 'Jamaica' (Costa Rica), 'Mango de racimo' (Guatemala), 'Arauca' (Colombia), 'Kaew' and 'Ta-Lub-Nak', 'Bau 6, 7 and 8', 'Tsar-Swan', 'Kohuamba' (Sri Lanka), 'Cat head' and 'Long mouth' (Ivory Coast) and '13-1'.

Influence on fruit quality has not been indicated for any rootstock in any of the interviews.

This bring us to another important conclusion: **Not any of the rootstocks used commercially exhibit all the desired characteristics and furthermore there is not even a single rootstock which combines the two attributes more demanded for a rootstock by the mango industry, tolerance to salinity and dwarfing effect**

We will not finish this section without commenting about the effect of rootstock in the yield of mango in general and, particularly, for the Floridian cultivars, based in the information also obtained from different researchers which is summarized on table 5. It is a well-known fact for every crop and, of course, also for mangoes, that, besides plant material and pest and disease control, the interaction of climate and cultural practices is essential for optimizing yield and fruit quality. By looking table 5 it can be easily observed that **although high yields of the Floridian cultivars can be reached with different rootstocks all over the world, those obtained with rootstock '13/1' in Israel, 'Turpentine' in Florida, and to a lesser extend with 'Kensington Pride' in Australia are higher than with any other rootstock**, which may imply as a general recommendation the use of these rootstocks as ideal rootstocks for these cultivars. One must, however, not over emphasize this conclusion because the excellent crop management usually done by the farmers of these three countries may be responsible in great part of these increases in production. In fact, high yields are also reported for example for 'Keitt' in Costa Rica using 'Jamaica' (possibly identical to 'Turpentine') and for Floridian cultivars grafted on the Gomera types in Spain**.** To mention also that yield results for 'Ataulfo'only were given in Florida with worst production on 'Turpentine' than the Floridian cultivars grafted in the same rootstock or, also with poor production, in Mexico, although average yield for all cultivars in this country are on the low range, around 10t/ha.

Literature review.

Introduction

According to recent FAO statistics the average annual yield of the main mango producing countries, with the exception of Brazil (around 15 t/ha), is scarcely over 10 t/ha, although countries like Israel reaches average mango yield close to 30 t/ha (Galán Saúco, 2015b). The impact of rootstocks on quantitative and qualitative yield of mangoes has been already indicated in different mango books (Galán Saúco, 2008; Litz, 2009), but a fully in depth bibliographic literature review is so far missing. There is no doubt that an update of the information existing on mango rootstocks and cultivar/ rootstock interaction will contribute not only to improve yield and fruit quality, but also be of great benefit for mango cultivation all over the world. For a better understanding of this literature review, it will be grouped in different sections related with the desired characteristics that a good rootstock for the world mango industry must have obtained through the interviews realized for this project and described in the first part of this report.

Tolerance to salinity

Early works realized in Israel (Kadman *et al*., 1976) and in the Canary Islands (Galán Saúco *et al.*, 1988,) identify rootstocks tolerant to salinity. The studies in Israel were carried by exposing 3,200 seedlings of both poly and mono embryonic types from 80 cultivars to calcareous soils (pH of 7.8 and 12-15% of $CaCO_3$) irrigated with saline water (EC 3.2 mmhos). Results indicated that the polyembryonic progeny of '13/1', '8/16'. 'Sandersha', 'Warburgh' and 'Feizensou' as well as monoembryonic '1/7', '7/11' and 'Has- el.-Has' exhibited relatively strong tolerance to salinity and vigorous growth. Some of the cited monoembryonic seedlings were most outstanding that '13/1', but the problem of lacking uniformity on the offspring make them not appropriate for its use as rootstock unless a practical method of clonal propagation be obtained. It was also clear that 'Sabre' and 'Peach' considered before as good rootstocks for the coastal region of Israel (Oppenheimer 1958 and 1968) showed high sensitivity to saline conditions. From the leaf analysis conducted in the experiment it was clear that the tolerant plants had lower ash, lower potassium, lower calcium content, lower sodium but higher chlorine. This seems to indicate that the resistance to salinity in this case is due to a tolerance to chlorine of the leaf tissue rather than to a selective uptake of this element. This last may be a problem for the grafted cultivars under highly saline conditions, despite of which '13/1' was soon recommended (Gazit and Kadman, 1980) as preferably rootstock for calcareous soils and is used since then until nowadays as the standard rootstock, and with very high yields, for all mango cultivars in Israel, including the Floridian cultivars Kent, Keitt and others. '13/1' has been demonstrated to tolerate calcareous soil containing 20% calcium carbonate and saline irrigation containing <600ppm chlorine (Kadman, 1985). This rootstock may have, in addition, a certain dwarfing effect according to the results obtained regarding takes growth parameters in a nursery trial in Egypt with 3 cultivars ('Ewais', 'Zebda' and 'Keitt') grafted on 4 rootstocks ('Zebda', 'Sukkary', 'Sabre' and '13/1'), in which '13/1' had the lowest values of vegetative growth parameters both in roots and aerial parts (Shaban, 2010).

Trials in Canary Islands demonstrate that the polyembryonic rootstock 'Gomera 1' (G-1) was found to be more tolerant to salinity that the rest of the polyembryonic types tested ('Gomera 3', 'Gomera 4', 'Peach', 'Turpentine' and 'Kensington'). 'G-1' was able to behave well in water containing 560 ppm of chlorine and 560 ppm of sodium, similar to levels tolerated by '13/1' in

Israel. In addition, the lower concentration of Na and Cl on roots and leaves of ‘G-1’ compared with the other rootstocks may indicate that tolerance to salinity may be due to selective uptake of salts by this rootstock, which is of capital importance for any scion grafted on it. Although all Gomera types were locally selected from the traditional mangoes cultivated in the island of La Gomera (Galán Saúco and García Samarín, 1979), ‘Gomera 1’ was later found to be not different from what Popenoe (1920) named as ‘Manga blanca’ (Grajal-Martín, 2012), still used as rootstock in Cuba (see table 2a). Both the tolerance of ‘Gomera 1’ to salinity and the association of the tolerance with the capacity of this rootstock to restrict the uptake and transport of Cl- and Na+ ions from the root system to the aboveground parts was later confirmed by Durán Zuazo *et al*., (2003 and 2004) in a trial with plants of the cultivar Osteen grafted on ‘Gomera 1’ and ‘Gomera 3’ exposed to salinized irrigation waters measured by electrical conductivity (1.02, 1.50, 2.00 and 2.50 dS m^{-1}). It is of interest to note that ‘G-1’ as rootstock was also found to produce higher yield (on kg/tree) of ‘Osteen’ than ‘Gomera 3’, although the reverse occurred with ‘Keitt’ that yielded higher on ‘Gomera 3’ than on ‘G- 1’. ‘Gomera 1’ also produces smaller trees on both ‘Keitt’ and ‘Osteen’ (Durán Zuazo *et al*., 2005) which may be an advantage for high density plantings. Similar observations regarding smaller size of mango trees grafted on ‘Gomera1’has been observed by the author of this report for most cultivars in the Canary Islands where until recently only ‘Gomera 1’ was used commercially as rootstocks.

Rootstocks tolerant to salinity are also reported by Van Hau *et al*., (2001) who indicates that rootstock ‘Chau Hang Vo’ is only affected by salinity levels of 12 dS/m while ‘Buoi’, the main rootstock used in Vietnam (see table 2b), only tolerates 8 dS/m. Moderately tolerant to salt stress polyembryonic rootstocks (‘Bappakai’, ‘Olour ‘and ‘Kurukkan’) have also been found in India (Dubey *et al*., 2007). Two of these tolerant cultivars ‘Olour’ and ‘Kurakkan’, and one monoembryonic viz., non-descript seedling (common mango rootstock) grafted with the scion ‘Amrapali’ were also studied to better understanding the rootstock influence on ion exclusion and biochemical changes under irrigation with water containing 0.0 or 50 mM NaCl at four days’ interval for 90 days (Dayal *et al*., 2014). Results indicates that ‘Olour’ and non-descript seedling rootstocks exhibited more salt tolerance than ‘Kurakkan’ with ‘Olour’ more effective in exclusing Cl- a non-descript seedling in excluding Na+ from leaf tissues of scion cultivar, both exhibited lower growth inhibition in plant height, leaf numbers and shoot dry weight of ‘Amrapali’ plants tested in the present study. On the contrary, pronounced growth inhibition of scion and quick symptoms of leaf burning, relatively more defoliation and scorching was observed in grafts onto ‘Kurakkan’. Since ‘Amrapali’ onto ‘Kurakkan’ had more Cl- leaf content the increase in leaf burning and defoliation was probably associated with leaf Cl- build up rather than with Na+ accumulation. Lower inhibition of growth and defoliation on ‘Olour’ and/or non-descript seedling rootstock might be associated with lower leaf Cl- concentration, higher proline content, and more upregulated peroxidase (POX) activity under stress in leaves of ‘Amrapali’ grafted onto these rootstocks**.**

Salt resistant mango rootstocks have also been found recently in Sudan and Bangladesh. Experiments at the nursery level in Sudan (Elgozouli, 2011) were realized applying three times a week during 12 weeks 500 ml of a saline solution with 4 concentrations of NaCl (0, 2 ,4 and 6 mmoh/cm) to seedlings of 7 polyembrionic rootstocks (‘Kitchener’, ‘Iwais’, ‘Sabre’, ‘Taimour’, ‘Gulbeter’, ‘Mistwak’ and ‘Zebda’). Results indicated that the only rootstock used commercially in Sudan, ‘Kitchener’, together with ‘Iwais’and ‘Sabre’ from which did not differed significatively, were the less affected with ‘Zebda’ showing the highest damage. Th experiment at Bangladeh indicated that ‘Rangpur line’ rootstock withstand salinity levels of 8dS/m with much less damage that other rootstocks, but no field experiment with grafted plants have been reported (Roy *et al*., 2013). Trials made in Egypt (Hafez *et al*., 2011) also found rootstock ‘Sukkary’ as appropriate rootstock for use in regions irrigated with saline water reaching 4,000 ppm salt content. In this experiment the rootstock system of ‘Sukkary’ uptake less Cl and Na from the soil solution than ‘Zebda’, the other rootstock tested. It is of interest to notice that the proline content in the leaves of ‘Sukkary’ (more resistant to salinity), was higher than in ‘Zebda’ (salt sensitive), similar not only to the results indicated above by Dayal *et al*., 2014 but also to those obtained by Hurkman *et al*., (1989) who indicated that proline concentration in many salt tolerant plants has been found to be higher than that in salt sensitive ones, and that accumulation of proline in plants grown under saline conditions may provide storage of nitrogen that is re-utilized when stress is over, and may play a role in osmotic adjustment. This opens the possibility to use proline content as a chemical marker to quickly evaluate resistant to salinity on seedlings.

Studies regarding tolerance to salts have also done in Australia where Hoult *et al*., (1997) studying the response in the nursery of potted plants of seedlings of 21 polyembryonic mango cultivars irrigated with water containing 480 mg/l of ClNa through drip irrigation found that the seedlings of 8 cultivars (‘Orange’, ‘Golden Tropic’, ‘Banana’, ‘Ti Tree 3’, ‘Red Harumanis’, ‘Pico’, ‘KRS’ and ‘Brodie’) were comparative to ‘13/1’ in excluding Na from leaf tissue and 5 of them (‘Orange’,’ Golden Tropic’, ‘Banana’, ‘Red Harumanis’ and ‘Pico’) as good or better than ‘13/1’ in excluding Cl as well. They did not however study the tolerance to higher salt concentrations or under field conditions.

In a trial to evaluate the influence of NaCl salinity in combination with different root zone temperatures on '13/1' and 'Turpentine' rootstocks Schmutz and Ludders (1998) found that NaCl salinity had the lowest effects on leaf growth and roots of the more tolerant rootstock '13/1', while roots and leaves of 'Turpentine' were more affected. '13/1' stored significantly more Na+ and Cl- in the roots than 'Turpentine'. In 'Turpentine' leaves a significantly higher Na+ content was found, while the Cl- content was slightly lower. It was concluded that the difference in saline tolerance is probably based on the ability of '13/1' to protect leaves from excessive Na+ and to accept higher Cl- contents in the leaves without severe growth damage. Significantly higher Ca++ and Mg++ contents were found in leaves and roots of '13/1' compared to 'Turpentine'. They might be responsible for tolerating higher Cl- contents in leaf tissues of '13-1' as well as for a higher Na+ retention potential in roots and stems of '13/1'. It is worth to mention here that the higher concentrations of calcium in the leaves of 13/1 may be of help to reduce the incidence of Internal Fruit Breakdown.

It is also important to know that Schmutz (2000) through studies of whole plant CO_2 exchange under controlled environment conditions found that promising higher tolerance than in 13/1 may exist in *Mangifera zeylanica*, but although this species has been successfully grafted on ‘Turpentine’ rootstock in Florida (Campbell and Ledesma, 2013) it has not been proven as rootstock for mango.

For future breeding work it is worth noticing that significant differences for sodicity tolerance were found among polyembroynic mangoes collected after the tsunami in the Andaman Islands (Damodarama *et al*., 2013) proving that natural selections in polyembryonic mangoes in hot spots of diversity subjected to natural disturbances can serve as a potential tool for selecting the most adaptable rootstock with salinity tolerance. Six of the accessions collected ‘GPL-1’, ‘GPl-3’, ‘ML3’, ‘ML-4’, ‘ML-2’ and ‘GPL-4’ exhibited tolerance to high sodium conditions under levels of pH 9.51 and sodium of 9.21 meq/L. The accessions ‘GPL-1’ and ‘ML-2’ collected from the sites affected by inundation of sea water during the tsunami were found to have the highest tolerance level to high pH and sodium content in sodic soils. The tolerant accessions accomplished lower Na+/K+ ratio which facilitated the higher shoot growth and reduced the toxic scorching symptoms of Na+.

Dwarfing effect

Besides any other characteristics the first thing that is required in a rootstock is to have vigour at the moment of grafting. This explains why, in the absence of constraints that limits growth, rootstock vigour is very important for the choosing of a rootstock. In any case as it was clear since early rootstocks investigations that higher vigour does not always implies higher yield Furthermore with the modern trend towards high density plantings, reducing mango tree vigour and diverting energy into production is critical for sustainable high yields, but as indicated by Bally *et al*., (2015), very few rootstocks are known to reduce tree vigour in mango and those that do only work on a few scion varieties.

From the beginning of modern mango cultivation some scientists cast doubts about the utility of using dwarfing rootstocks for this species. Oppenheimer (1960), for example, indicated that the effect of dwarfing rootstocks, when occurring, was only temporary, disappearing after several years. The economic rationale of the idea of getting dwarfing rootstocks was also put in doubt by Cull (1991) who indicates that as a terminal flowering plant, the external surface area of the canopy correlates directly with yield capacity.

These ideas were apparently corroborated by different trials done in Australia at the end of the last century. In a trial with 7 cultivars (‘Glenn’, ‘Haden’, ‘Irwin’, ‘Kensington Pride’, ‘Kent’, ‘Tommy Atkins’ and ‘Zill’) grafted on two rootstocks ‘Sabre’ and ‘Common’ (‘ARC’, a local common selected by its apparent low vigour) Smith *et al*., (1992) observed that all cultivars grown in ‘Sabre’ produced markedly smaller tree canopies (results not so obvious in ‘Kensington Pride’ and ‘Tommy Atkins’) and generally yield less with the exception of ‘Kent’, which produced almost twice, and ‘Haden’, an indication of the existence of interaction rootstocks/scion/environment. Later works by the same research group (Smith et al., 1997) indicated that the highest yield efficiency tended to occur on rootstocks that produce quite vigorous trees while low vigour rootstocks such as ‘Sabre’ have generally produce low yields and low yield efficiency which led them to the conclusion that we must not be obsessed by the idea of obtaining dwarfing rootstocks.

However, early works by Swamy *et al*., (1969) had demonstrated that these fears may not be true for all rootstocks or cultivar/rootstocks environments. These Indian researchers in a trial with ‘Neelum’ and ‘Baneshan’ grafted in 8 polyembryonic rootstocks (‘Pahutan’, ‘Goa’, ‘Olour’ ‘Salen’, ‘Kurkan’, ‘Mylepalium’ and ‘Nileswara Dwarf’) and monoembryonic seedlings observed that the least vigorous rootstock produced the maximum yield of ‘Neelum’ while in the case of ‘Banesham’ the most vigorous rootstock produced the higher yield. They also observed that trees grafted in polyembryonic rootstocks were more vigorous that those grown in monoembryonic seedlings. Although they concluded indicating that the polyembryonic rootstocks ‘Pahutan’ and ‘Goa’ were the best rootstocks for ‘Neelum’ and ‘Olour’ and ‘Pahutan’ the best for ‘Baneshan’, they also observed many interactions in many tree characteristics and concluded that the choice of a rootstock for a particular scion has to be made only after experimentation. Many other studies since then have allowed the discovery of rootstocks with high yield per unit area and dwarfing effect (Reddy *et al*., 2003) but all of them have indicated a great interaction rootstocks/scion/environment.

It is of interest to note that the dwarfing effect of a rootstock is not always translated to the grafted plants in the field. This was the case in the experiments done by Oppenheimer (1958) comparing three polyembryonic rootstocks in Israel, in which, despite its dwarfing nature, 'Sabre' was found superior in growth and production to 'Warburg' and '14.12', illustrating clearly that a dwarf tree must not necessarily be a dwarfing rootstock and also that cultivars producing vigorous seedlings may not translate this vigour to scions. These ideas have been confirmed by different experiments in India (Swamy *et al*.,1972) and also in a trial in Puerto Rico with 3 Floridian cultivars, ‘Edward’, ‘Palmer’ and ‘Irwin’ grafted on 4 rootstocks, ‘Julie’, ‘Malda’, ‘Manzano Tetenene’ and ‘Eldon’ (Cedeño- Maldonado *et al*. 1988). The results of this trial showed that despite of producing vigorous seedlings, ‘Eldon’ was the most effective in reducing scion diameter, tree height and canopy volume of ‘Irwin’ and ‘Palmer’, and ‘Julie’ in the case of ‘Edwards’. The dwarfing characteristic of ‘Eldon’ was later confirmed by Duvivier and Cedeño Maldonado (2000) in a study with two cultivars ('Parvin' and 'Tommy Atkins') grafted onto 5 rootstocks ('Eldon', 'Colombo Kidney', 'Cubano', 'Malda' and 'Julie'), where 'Eldon' was found to be dwarfing for both 'Parvin' and 'Tommy Atkins' while 'Malda' reduced the tree size only for 'Tommy Atkins'. Although dwarfing combinations gave lower yields compared to 'Cubano' 'Colombo Kidney' and 'Julie' rootstocks, all of the rootstocks had equal yield efficiency (yield tree size). The authors concluded that within the group, 'Eldon' is the best rootstock for 'Parvin' while 'Malda' and 'Eldon' are equally good for 'Tommy Atkins' compared to the control 'Colombo Kidney'.

Perhaps the most complete and interesting rootstock trial done so far is the one made in Australia where it was observed the performance of ´Kensington Pride’ during the first 4 years of production on 64 polyembryonic cultivars from different origins, (Smith *et al*., 2008). In this experiment clear differences in growth rate by more than 160% were detected in ‘Kensington Pride’ grown in 64 different rootstocks and, more interesting, the results of the trial regarding dwarfing make clear that no relation was established between tree size or rootstock vigour and yield efficiency which justify the possibility of selecting highly efficient yielding dwarfing rootstocks. In this experiment ‘Brodie’ and ‘MYP’ were clear examples of rootstocks which impart to ‘Kensington Pride’ high yield efficiency with smaller size) but also others than despite giving a large tree size can give high early yield allowing them to be used for high density plantings (Ex. ‘B’ and ‘Watertank’).

The results of this experiment were compared with those given in India (Reddy *et al*., 2003) for other cultivars, among them ‘Álphonso’, grafted on some of the 64 rootstocks considered in the Australian experiment. It is worth to mention that while in India the rootstock ‘Vellaikulamban’ imparted the major effect regarding dwarfing, giving also high yield efficiency, in the Australian experiment, this rootstock also reduced vigour and produce the smallest canopy size and the lowest growth rate of the 64 rootstocks but Kensington Pride yielded poorly on it., a consequence, no doubt, of the mentioned great interaction rootstocks/scion/environment which obliges to specific recommendations for location and cultivars. The Indian researchers indicated that ‘Vellaikulamban’ has a good potential for high density orchards but also recommend the use of Olour’ because of its high yield efficiency together with high initial vigour that subsequently decreases, allowing the cultivar Alphonso grafted on it to occupy quickly the allotted space in the orchard without causing over-crowding later on. The paper clearly establishes also that the biennial pattern of ‘Alphonso’ is governed more by exogenous than by endogenous factors and that is only very limited influenced by rootstocks

These two rootstocks, ‘Vellaikulamban’ and ‘Olour’ were also mentioned by their dwarfing effect, the first for ‘Dashehari’ and ‘Alphonso’ and the second for ‘Langra’ and ‘Himsagar’ (Kulkarni, 1991) and both also for ‘Dasheri’ (Jauhari *et al*., 1972). However, on the contrary that reported by Reddy *et al*., (2003) or Smith *et al*. (2008), in the Kulkarni trial the rootstock ‘Vellaikulamban’ did not had any dwarfing effect on ´Langra’, and even their values for tree and canopy height and spread were only exceeded by one of the 8 rootstocks considered in this experiment. In another trial, studying ‘Dasheri’, grafted on 25 rootstocks, 13 mono and 12 polyembryonics, Srivastava et al. (1988), did not find any influence of the rootstocks on plant height, rootstock and graft circunference and plant diameter, illustrating once more, the mentioned interaction rootstocks/scion/environment.

Other rootstocks with dwarfing effect mentioned in India included ‘Kalapady’, ‘Kerela Dwarf’,’Manjeera’, ‘Creeping’, ‘Amrapali’, ‘Mylepalium’ and ‘Ambalavi’ (Jauhari *et al*., 1972; Singh and Singh, 1976; Iyer and Subramanyan, 1986). The dwarfing effect of ‘ Amrapalli’ was also corroborated in Brazil by Vargas Ramos *et al*., (2001,2002 and 2004) who in trials with 8 rootstocks (‘Mallika’, ‘Amrapali’, ‘Santa Alexandrina’, ‘Extrema’, ‘Imperial’, ‘Maçã ‘Comum’ and ‘Rosinha) and 4 cultivars (‘Tommy Atkins’, ‘Haden’, ‘Winter’ and ‘Van Dyke’) found that although ‘Maçá and ‘Amrapali’ had been reported to show dwarf behavior (Pinto *et al*.,!993) only Amrapali produced a significant reduction in height of around 70 cm regardless the scion cultivar, except for cultivar ‘Haden’ that was considerably taller than any other, particularly than ‘Tommy Atkins’ and ‘Van Dyke’. The relatively uniformity of this dwarfing effect is certainly surprising because not only of the mentioned interaction between rootstocks, cultivars and locations but also by the monoembryonic nature of ‘Amrapali’ and the supposed heterogeneity of its progeny.

In a recent experiment done in India (Chandari *et al*., 2006) with eight rootstocks (‘Nakkare’, ‘Bappakai’, ‘Olour’, ‘Kitchner’, ‘Ec 95862’, ‘Muvandan’, ‘Starch’ and monoembryonic local seedlings) and ‘Dashehari’ as scion, the rootstock ‘Nakkare’ had, among the polyembryonic rootstocks the most dwarfing effect reducing considerably the height and canopy size of ‘Dashehari’. Differences in trunk diameter, height of trees, and canopy width had also been found in young non bearing trees of `Cat Hoa Loc’ scion grafted on different asian rootstocks in Vietnam where the most common rootstock ‘Buoi’, which grows smaller than other trees may have sone promise as dwarfing rootstock (Van Hau *et al*., 2001). Arauca’ has also been reported as dwarfing rootstock in Colombia (Anon. 2013, see also table 2b).

The discovery by Galán Saúco *et al*., (2000) of the occurrence of spontaneous tetraploids in mango opened the door for the use of them as dwarfing rootstock as done, for instance, in citrus (Lee *et al*., 1988). Trials made in Australia comparing diploid and tetraploid seedlings from an Australian rootstock, Reyner 2x and Reyner 4x. indicate a reduction in size without decreasing yield efficiency in the tetraploid, but this may not happen in all tetraploid seedlings **(**Smith *et al*., 2008). Reyner (2002) had also proven the dwarfing effect of spontaneous tetraploids on ‘Palmer’ and ‘Kensington’ scions grafted on them. Apparently the production of spontaneous tetraploids morphologically distinct from the normal diploid progeny is a common fact in many polyembryonic rootstocks (Grajal- Martín, 2012) and that is of great interest for searching superior dwarfing rootstocks in the future.

Rootstock work undertaken in the Northern Territory in Australia Hoult (2010) indicates, among other conclusions, that no relation seems to exist between the morphology of seedlings of the different genotypes and its subsequent performance as rootstocks. This is very relevant because previous work done by Mukherjee and Das (1976) had found morphological and physiological differences (i.e. number of secondary roots, bark percentage of roots and respiration rate) between seedlings of vigorous and dwarfing cultivars which might be thought that could be translated to the scion. The same authors (1980) also found that the seedlings of dwarfing rootstocks like 'VellaiKulamban', 'Ambelavi', 'Olour' and 'Mylepalium' had thicker bark both in stems and roots and small vessels that vigorous types like seedlings of 'Dashehari' which was similar to what was previously reported for apples by other authors cited by these researchers and that can be useful for further research.

The height of non-grafted mango rootstock seedlings in the nursery was also proposed as a measure of mango rootstock vigour (Abirami *et al*. 2011; Mukherjee and Das 1976; Srivastava *et al*. 2009) but there was poor support for relationships between nursery seedling height and subsequent orchard development. More interesting for future research are the studies done by Bithell *et al*., (2010) which demonstrate in a field trial of 13-year-old trees that the effects of mango rootstock cultivars on scion vigour may be predicted by scion growth rate being negatively related to fine root dry matter (DM)/scion trunk cross sectional area (TCSA). Across rootstock cultivars, tree vigour (TCSA growth rate) was negatively and significantly related to the ratio of fine roots DM/scion TCSA, with the smallest trees, on the rootstock 'Vellaikulamban' having the least of feeder roots and the intermediate size trees on rootstock 'MYP' having the most feeder roots suggesting this may be a useful indicator of the vigour that different rootstocks confer on the scion. Its usefulness has been corroborated in a trial with five rootstocks (Smith *et al*. 2008) in which they found that the DM mass of roots less than 7.5 mm in diameter differed among rootstock cultivars including DM differences relative to scion size. Further, the fine root DM relative to scion size was significantly related to orchard tree growth rates and may be a promising method for predicting the vigour of mango rootstock cultivars.

The role of the primaty roots and its importance for the selection of a good rootstock has been observed in other trials. In an experiment done at the nursery level in Kano, Nigeria four local morphotypes ('Binta Siga', 'Gwaiwar Rago', 'Dankamaru' and 'Fafaranda'), factorially combined with three scions ('Alphonso', 'Peach' and 'Taymour'), 'Binta Siga was identified as the best rootstock in terms of plant establishment, probably due to production of higher number of roots, stem diameter, number of leaves, percentage of taking and general crop vigor: Because of this good characteristics it was recommended for use as rootstock by nurserymen for higher profit margin in the Kano environment. However, as in many other trials an interaction between rootstock and the scion was observed to be significant, in this case related to the obsevations on number of primary roots per plant. Both 'Taymour' and 'Peach' grafted on 'Binta Siga' but also 'Alphonso' on 'Dankamaru' had the highest number of primary roots while the least was obtained with 'Alphonso' on 'Fafaranda' (Baita *et al*., 2010).

Dwarfing can also be achieved through the use of interstocks. Several trials using this technique have been conducted in different countries. In a trial in Mexico with the cultivar Manila and several interstocks/rootstocks combinations, Ávila Reséndiz *et al*., (1993) found for 9 years old trees that the combinations 'Manila'/'Irwin'/'Irwin' and 'Manila'/'Thomas'/'Esmeralda' reduced both tree height and canopy diameter by 51% and 40% respectively with an increase in yield efficiency of 161% and 216% compared with 'Manila' seedling trees. They concluded indicating that these combinations may allow plalnting densities of up to 500 trees/ha. The dwarfing effect of ‘Irwin’ as interstock has been also observed in Australia for ‘Kensington Pride’ (Reyner, 2002).

Similar results were obtained by Vázquez-Valdivia *et al*. (2005) evaluating the effect of ‘Esmeralda’, a dwarf genotype, as interstock of ‘Ataulfo’ in a mango orchard established using ‘Criollo’ seedling rootstocks on top of which ‘Esmeralda’ was grafted in lengths of 0 to 20, 21 to 30, 31 to 40 and 41 to 50 cm and after ‘Ataulfo’ was grafted. ‘Esmeralda’ interstock affected the size of the trees when compared to control trees by reduccing height, canopy diameter and volume and trunk perimeter. No significant differences were detected in this case for the yield of four harvesting seasons (1996 to 1999); but significant differences were detected in the 2000 season. Trees with interstocks of 21 to 30 cm yielded 226 kg while the control trees yielded only 191 kg. Nutrimental content was not affected by the interstock. An inverse proportional relation was found between length of the interstock graft and vigour of the trees with a maximum canopy volume reduction of 35%.

The use of the rootstock ‘Piva’ as interstock has proven very efficient in different countries to reduce tree size (S. Oosthuye. 2016- Hort Reeaarch. South Africa Personal communication) and this has been also proven with several cultivars in Florida (N. Ledesma.2016 Fairchild Tropical Garden. Florida. Personal communication).

Ability to absorb nutrients

Very scarce information has been written about this important characteristic for a rootstock, besides of what was commented in the paragraph of tolerance to salinity about the capacity of ‘13/1’ to restrict absorption and translocation of Na and Cl and facilitate the absorption of other nutrients, particularly calcium, this last one of great importance to reduce the incidence of Internal Fruit Breakdown. Of interest is to note that although no information has been given about translocation of calcium to the leaves of the grafted plants, Internal Fruit Breakdown is not a great problem in Israel, where is only detected occasionally in ‘Kent’ (Y. Cohen. 2016. Volcani Center. Israel. Personal communication). One interesting study about differences in nutrient absorption was written by Tenhku Ab Malik (1996) indicating the higher capacity of the rootstock ‘Tangkai Panjang’ versus other Malysian rootstocks to absorb calcium. Unfortunately, not later reports of trials with this rootstock have been made and even attempts to take this rootstock out of Malysia and incorporate to the Australian experiments with rootstocks has failed (M. D. Hoult. 2016. Northern Territory Department of Primary Industry and Fisheries. Australia. Personal communication).

It is relevant to indicate here that Hoult (2010) suggests the possibility that good stocks forage for soil moisture via greater root density spatially and uniqueness of soil/root membrane interface which may also implicate better uptake of key cations. According to him, productive stocks may store and re-mobilise carbohydrates better at critical phenology stages. He recommends the study of the root system to quantify root system structure, spatially, and also studies of the anatomy of the graft union and vascular bundle connectivity between stock and scion which leads to uniqueness in assimilate/solute flow between stock and scion.

Adaptation to flooding, dry conditions or problematic soils

Despite the notorious interest of many countries (see table 3) very few rootstock trials done so far report about these items and those that discuss them indicate only not quantified information. This is, however, summarized below:

As early as in 1946, Gutnaratman, cited by Jauhari *et al*. (1972), recommended the variety ‘Pullima’ as rootstock for the dry zones of Ceylan (actual Sri Lanka). The rootstock ‘Than Ca’ is also believed to tolerate flooding in Vietnam (Van Hau *et al*., 2001). Mossler and Crane (2013) indicate that the rootstocks Turpentine' and 'Number 11,' used in Florida, 'are tolerant of high soil pH while ‘Hilacha’, the rootstock more used in Colombia (see table 2a), possesses well-developed root system which gives good tolerance to adverse drainage conditions (Anon., 2013).

With the exception of what has been commented for tolerance to salinity, nor has any written report about adaptation of rootstocks to problematic soils been found in the present literature review.

Tolerance to pests and diseases

The only disease in which the influence of a rootstock has been reported to influence in reduction of their incidence is called ‘Seca’, word which, in Spanish or Portuguese, makes allusion to the sudden death of the mango tree originated by this disease. This disease, caused by the fungi *Ceratocystis fimbriata* (in Brazil) or *Ceratocystis manginecans* (in Oman and Pakistan) and transmitted by its vector insect *Hypocryphalus mangiferae*, may enter the plant either through the aerial parts or through the roots and because of this the selection of a resistant or tolerant rootstock is important.

Several rootstocks, listed below, have been reported as resistant to ‘Seca’:

In Brazil:

‘IAC 101Coquinho’, ‘IAC 102 Touro’, ‘IAC 106 Jasmin’ and ‘IAC 104 Dura’ (Rosetto *et al*., 1997**),** ‘Manga de agua’, ‘Corazon de buey’ (Ribeiro, 1993) and ‘Espada’ (Netto *et al*., 2002).

In Oman:

Taimour’ and ‘Hindi Besennara’ (Al Adawi *et al*. (2013).

Elsewhere:

Carabao’ and ‘Pico’ (Galán Saúco, 2008).

An interesting trial has been recently established at the Mango Research Institute in Pakistan (Ullah, 2013-2014) to test the influence of three polyembryonic rootstocks (‘Carabao’, ‘Kensington Pride’ and ‘R2E2’) on performance of ‘Chaunsa Sammar Bahisht’ against mango sudden death disease (*Ceratocystis fimbriata*), but there are not yet clear results about it.

Although in principle all of the resistant rootstocks can be utilized as rootstock in places where this disease is prevalent, there are not much information available about their influence on yield or in any other of the important characteristics desired for a mango rootstock and cannot, in consequence be fully recommended for commercial mango plantings.

Rootstocks especially susceptible to ‘Seca’ also exist as it has been shown in a trial done in Brazil (Simao *et al*., 1994) with 6 scions (‘Extrema’, ‘Pahiri’, ‘Imperial’, ‘Oliveira Neto’, ‘Carlota’ and ‘Bourbon’) and 7 rootstocks (‘Extrema’, ‘Espada’, ‘Oliveira Neto’, ‘Carlota’, ‘Bourbon’, ‘Coco’ and ‘Pahiri’) all from local cultivars plus the Indian cultivar Pahiri, Results clearly indicate that the cultivar Bourbon when used as rootstock was more suceptible to *Ceratocystis* that any other rootstock.

It is also worth to mention that in a trial done by Vazquez-Luna *et al*., (2011) to test the effect of the rootstock ‘Criollo’ in the cultivar Manila comparing grafted and non-grafted ‘Manila’ trees observed that the fruits of the grafted plants had increased firmness and have higher 3-carene levels and main flavonoids content of the fruits, resulting in a greater resistance to infestation of the Manila cultivar by the fruit fly (*Anastrepha. obliqua*). However, since several local selections are grouped under the name 'Criollo' without specifying them individually (V.M. Medina Urrutia, 2016 CUCBA-Universidad de Guadalajara Personal communication), it will be difficult the practical use of this information which is, undoubtedly, of great value for future investigations about resistance to fruit flies.

Improve of fruit quality

The influence of rootstocks in fruit quality was reported in a trial done in India (Gowder and Irulappan, 1971) where the cultivar Neelum was found to get higher total soluble solids, and also better yield, when grafted on the polyembyonic rootstock 'Bakkapai' than when grafted on grafted on 'Olour' or in several monoembryonic rootstocks. It was also reported by Jauhari *et al*. (1972) in a trial with the commercial cultivar Dashehari, grafted in four polyembryonic rootstocks ('Ambalavi', 'Mylepalium', 'Olour' and 'Vellai Kelambam' plus seedlings of 'Dashehari'), observing that the fruits of this cultivar, grafted on 'Mylepalium' and 'Vellai Kolumbam' exhibit higher values on total soluble solids and sugars than the others, although no statistical analysis was conducted.

The effect of rootstocks on fruit weight, fruit size and shape of the scion has been also indicated by Avilán *et al*. (1997) in a trial done in Venezuela with 4 cultivars ('Haden', 'Edwards', 'Tommy Atkins' and 'Springfels' grafted on several rootstocks (5 polyembryonic,'Rosa', 'Camphor' 'Ceniap', 'Perú' and 'Pico de Loro' and 3 monoembryonic, 'Divine', 'Tetenené Manzana' and 'Currucai'), selected by their medium to small growth habit. Results indicated a strong rootstock/scion interaction with the rootstocks modifying the fruit dimension, weight and shape, and these changes varying according to the scion/rootstock combination used. In general, the cultivars Edward and Springfels increased their fruit weight and size significantly. 'Haden' and 'Tommy Atkins' increased fruit weight and size also, but the fruit shape was modified, as compared to the fruits from the CENIAP old collection (> 35 years) that were considered as standard. The fruits of 'Haden' grafted on 'Ceniap', 'Perú' and 'Pico de Loro' where bigger than the others. In the case of 'Tommy Atkins'there were notorious differences on fruit shape from rounded fruits with a pronounced beak for those grafted on 'Tetenené Manzana' to oblong types on the other rootstocks.

A notorious influence of rootstocks on fruit quality as is summarized below has also been detected in several rootstock trials in Australia:

In the before mentioned trial realized with **7** cultivars ('Glenn', 'Haden', 'Irwin', 'Kensington Pride', 'Kent', 'Tommy Atkins' and 'Zill') grafted on two rootstocks 'Sabre' and 'Common' (Smith *et al*., 1992**)** differences on fruit size were detected for 'Kent' which produced considerably larger fruits on 'Common' but not in the case of 'Kensington'. But differences in fruit size may be taken with care because they are influenced by fruit load and it was clear that 'Kent' on 'Sabre' carried a large number of fruits which may contribute to reduce fruit size. While in this trial not differences on maturity times was observed, the same research group detected in another trial (Smith *et al*., 1996) a clear influence of rootstock on time of maturity of 'Kensington Pride' with rootstock 'Red Harumanis' giving the earlier maturing fruits and rootstock 'Batavi' delaying maturity. Furthemore, differences on fruit size, depending on the rootstocks were also detected by them (Smith *et al*., 1997) with the fruits of ´Kensington Pride' weighing 128 gr. more on the rootstock 'Strawberry' that when grafted on 'Teluk Anson'.

Trials in which the influence of the rootstock about fruit quality has been rather scarce also exist, ilustrating again, the referred rootstock/scion/environment interaction. On a trial in Colombia with 3 cultivars ('Irwin', 'Tommy Atkins' and 'Davis-Haden') and two rootstocks ('Arauca' and 'Hilacha') Casierra-Posada and Guzmán (2009) did not find differences depending on rootstocks regarding fruit quality parameters which were most different between cultivars, with the exception of the weight of the fruit for the cultivar Tommy Atkins that was significatively higher when Arauca was used either as rootstock or as interstock.

From an Australian project initiated in 2006 with 100 rootstocks in one location and 64 rootstocks on another site to identify the best rootstock for 'Kensington Pride' ('KP') (Wicks *et al*., 2006**)** a number of elite rootstocks have been observed to influence key commercial criteria for the main Australian commercial cultivar, 'KP', such as tree size (canopy area and trunk girth), fruit number, average fruit weight, fruit maturity (days to soft ripe from harvest) and quality (º brix) but no information exists on the influence of rootstock on new cultivars such as 'Calypso' and 'Honey Gold' nor on the main Floridian cultivars, Haden, Kent, Keitt or Tommy Atkins. It was observed considerable variation within rootstocks which may suggest either that seedlings are in some cases different of the mother tree (i.e. not 100% polyembryonics) and/or soil differences at the trial site. This clearly indicates that in any roostock trial with polyembryonic material morphological or molecular comparisons, if existing, should be always done to ensure that the seedlings were true to the mother plant. The production of morphologically offtypes plants, presumably zygotic in origin, is common in polyembryonic rootstocks and variable among cultivars. For example, in a trial in Florida using isozimes to identify offtypes (Schnell and Knight Jr., 1991), the rootstock '13/1' produced 0% offtypes, 'Sabre' only 4%,'Turpentine' 24%, 'Madoc' 36%, and 'Golek' 64%, while in the experiments made in Australia (Smith *et al*., 1992) 'Sabre' produced a higher number of true to type seedlings that 'Common', this illustratng clearly the superiority of '13/1', followed by 'Sabre' regarding progeny uniformity**.**

Increase of yield (see also dwarfing)

Besides the already commented influence of interstocks in yield, differences caused by rootstocks on the yield of the grafted cultivar has been found since early times as reported in the mentioned trials by Gowder and Irulappan, (1971) indicating that the cultivar Neelum was found to get higher yiel when grafted on the polyembyonic rootstock 'Bakkapai' than when grafted on 'Olour' or in several monoembryonic rootastocks and by Jauhari *et al*., (1972), in which experiment 'Dashehari' grafted on their seedlings gave the highest yield compared with the 'Dashehari' plants grafted in other polyembryonic, although, as indicated before no statistical analysis was made

More recntly, the influence of rootstooks in the yield of the grafted cultivar has been detected in the several Australian experiments already mentioned. Thus, in the trial with **7** cultivars ('Glenn', 'Haden', 'Irwin', 'KP', 'Kent','Tommy Atkins' and 'Zill') grafted on two rootstocks ('Sabre' and 'Common'), Smith *et al*., (1992) found significant differences, among other charcteristics, regarding yield, with clear influences of rootstocks for most cultivars. They observed that all cultivars grown in 'Sabre' yielded less with the exception of 'Kent' which produced almost twice when grown on 'Sabre', and 'Haden'. Smith *et al*., (1997) also reported that marketable yield of 'KP' was strongly influenced by rootstock with the highest yielding rootstock 'Sg. Siput' (a Malaysian MARDI cultivar, syn. 'Ma 159 Bahagia') outyielding the poorest ('Sabre') by around 90% and, similarly, 'Sg. Siput' giving better results than 'Sabre' regarding yield efficiency (fruitweigt per canopy area).

In a later trial with 9 rootstocks over a 10-year period the same group of researchers (Smith *et al*., 2003) found that, regarding cumulative yield, the best rootstock for ‘Kensington Pride’, ‘Sg. Siput’, exceeded the worst, ‘Sabre’, by a 141%, and by a 41% higher to the next highest yielding rootstock. They also found that the effects on yield and yield efficiency were generally consistent across seasons. As indicated before, the contrast between the poor results obtained for ‘Sabre’ in this and other experiments made in Australia with those from Oppenheimer (1960) who concluded that Sabre was the best rootstock regarding yield for non-problematic soils of Israel illustrates the need as in many other subjects dealing with rootstocks of conducting research having in account not only rootstocks/cultivar interactions but also the edapho-climatic characteristic of each particular location.

This interaction rootstock/cultivar regarding yield was also very clear in a Brasilian experiment with four scions (‘Tommy Atkins’, ‘Haden’,’Winter’ and ‘Van Dyke’) grafted on 8 rootstocks (‘Mallika’, ‘Amrapali’, ‘Santa Alexandrina’, ‘Extrema’, ‘Imperial’, ‘Maçá’, ‘Comum’ and ‘Rosinha’). (Vargas Ramos *et al*., 2002) in which the best results were obtained with ‘Tommy Atkins’ on ‘Rosinha’ (7.77 t/ha) but not differing significantly from ‘Tommy Atkins’ on ‘Comum’ (7.04 t/ha), while ‘Winter’ had the best yield on ‘Extrema’ (7.6 t/ha). However, since in this experiment the reported yields are much below average yields from Brazil of around 16t/ha (Galán Saúco, 2015c) other yield component, distinct from rootstocks, like cultural practices or edapho-climatic conditions, may be playing an important role. Other experiments done in Brazil also ilustrate the effect of rootstock on yield of the grafted cultivar. In a trial to evaluate ‘Tommy Atkins’ grafted on 'Coquinho'', 'IAC-LOI', 'IAC-L02', 'Carabao'', 'Pico' and 'Manga D'água' total yield of ‘Tommy Atkins’ was higher when grafted on ‘Carabao (Mourão Filho *et al*., 2000). ‘Coquinho’ has been very much used as rootstock in Sao Paulo and has been reported to confer high productivity to the cultivar grafted on it (IAC, 1994), but in general Espada is the most prefered by the nurseries since it is also resistant to ‘Seca’.

But perhaps the influence of rootstocks on yield of the grafted cultivar was more clearly demonstrated in the repeatidly mentioned trial done in Australia by Smith *et al*., (2008) where it was observed the performance of ´Kensington Pride’ during the first 4 years of production on 64 polyembryonic cultivars from different origins, which clearly indicated among other results that:

1) Cumulative yield ranged from 36 to 181 kg/tree.
2) Yield efficiency for the best rootstock was 35 times more than for the worst. The most promising rootstocks regarding yield efficincy for ‘KP’ on this experiment were. ‘MYP’, ‘B’, ‘Watertank’ ‘Manzano’ and ‘Pancho’.
3) On the contrary that in previous experiments there was an improved performance regarding yield and yield efficiency of ‘KP on ‘Sabre’ and ‘KP’ that on ‘Sg. Siput’, and even that ‘KP’ on ‘13/1’ performed better than on ‘Sg Siput’ but worse than on ‘KP’. The authors explained this results on the base of different soil types, the first trials done in sandy soil and this one on a clay loam. As with many other crops it is much unlikely that a single rootstock may perform well in all kind of soils.

It is important to take in account in any rootstock trial, as indicated by the authors, the need for caution in assuming that morphologically identical polyembryonic cultivars will behave similar when used as rootstock since some of the 64 cultivars with different names had been assumed before to be the same thing and performed quite different in this experiment.

As mentioned before for other rootstock characteristics, different edapho-climatic characteristics of different locations may quite change the results. Thus, when compairing the results given in India (Reddy *et al*., 2003) for other cultivars grafted on some of the 64 rootstocks considered in the Australian experiment the behavior of many rootstocks in terms of fruit production changes considerably, such as occurs, for example, with ‘Muvandan’ rootstock, which render the best yielding in India but in Australia was included into the lowest 15% in terms of cumulative yield.

It is also worth mentioning some of the conclussons extracted by Hoult (2010) from the several Australian trials realized in the last 20 years regarding the influence of the rootstocks on the yield of the cultivar grafted on them:

1) A two and half fold increase in cumulative yield has been found between the highest and lowest yielding stock for ‘Kensington Pride’ (KP) over nine seasons on 9 different polyembryonic stocks planted on a deep sandy loam (Smith *et al*., 2003).

2) A five-fold increase in cumulative marketable yield has been found between the highest and lowest yielding stock for ‘KP’ over the first 4 cropping seasons on 64 different stocks planted on a shallow clay loam overlaying fractured limestone and this translated to a five-and-a-half-fold increase in cumulative gross income for highest yielding stock compared with the worst rootstock (Smith *et al*, 2008).

3) Significant yield differences were detected between different stock scion combinations with ‘KP’, ‘Tommy Atkins’ and ‘Glenn’ scions grafted to ‘Common’ yielding better compared to the same scions grafted on ‘Sabre’, while ‘Haden’ and ‘Kent’ scions produced more on ‘Sabre’ than on ‘Common’, for a single harvest year only (Smith *et al*, 1996).

4) Up to three-fold increase in yield efficiency on a kg of fruit per square metre of canopy silhouette area or kg of fruit per square metre of trunk cross-sectional area for ‘KP’ scion (Smith *et al*. 2003, 2008).

Despite all the trials made in Australia (and also elsewhere) which proves the role of different rootstocks in improving yield and another desired characteristic for mango cultivation we may ask for the reason why, for instance, ‘Kensington Pride’ is still the main and almost exclusive (together with ‘Common’) rootstock used commercially in Australia (see table 2b). According to M. Hoult (2016. Northern Territory Department of Primary Industry and Fisheries, Plant Industry Division. Australia. Personal communication), this can be explained by different reasons:

A) Because of the relatively “immature” Australian mango industry there has not been a long tradition of known rootstock scion combination benefits as for other more mature industries.
B) There has been no serious soil born pathogen/pest afflicting the commercial success of the Australian mango industry like for example in the case of avocados and *Phytophthora* root rot.
C) There is plenty availability of seeds of ‘Kensington Pride’ and to a minor extend of ‘Common’.

D) The seed availability of potential new rootstocks is very restrictive.

E) Undoubtedly the high cost and the length of time needed for driving sound results are the most significant constraints to large scale field evaluation of rootstocks and**,** unfortunately, long term funding for rootstock development in Australia, as in any other places, has been very limited and reflects more pressing industry issues.

F) Lastly, with a number of new scion cultivars emerging in Australia there are signs of potential incompatibilities or delayed incompatibilities developing with some stock/scion combinations

Some of these reasons, together with the high yields obtained under cultivation of mango with appropriate cultural techniques (see table 5), but, especially, full availability of seeds of polyembryonic rootstocks longtime introduced in the country and theoretically well adapted to the local environment, as indicated by most of the persons interviewed for writing this report, explain the continuous use in many countries of the same rootstocks along many years.

Identifying future research needs and cooperative projects on mango rootstocks

Introduction

Rootstock breeding and selection offers a great potential for improvement in mango cultivation. However, the evaluation of rootstocks is not an easy subject due to the following considerations:

1) Even those of the desired characteristics for a mango rootstock appearing simple to evaluate like tolerance to salinity need not only be evaluated for the rootstock itself but also by their effect on the cultivar after grafting. In addition, the fact that inconsistent yield patterns and/or biennial bearing are the most frequent situations facing mango production all over the world implies that trials to adquire sound information about yield and yield efficiency must cover several seasons.
2) Although the effects on yield and yield efficiency are generally consistent across seasons, the observations about compatibility must last longer, may be at least 15 years, before recommending a new rootstock even for commercial use.
3) The great interaction rootstocks/scion/environment for most of the desired characteristics of a rootstock obliges to specific recommendations for location and cultivars.
4) The uncertainty about uniformity of the progeny of a polyembryonic tree which obliges that in any rootstock trial careful morphological or molecular observations, if existing, must be always done to ensure that the seedlings are true to the mother plant.

Future research lines to develop

The high cost and the length of time needed for driving sound results are, in consequence the most significant constraints to large scale field evaluation of rootstocks. Because of this, as this report clearly shows, there are not clear and sound indications for recommending the best rootstock even for the most commercial cultivars which imply the need to impulse several lines of research such as those indicated below:

1) **Developing standardized coordinated trials of rootstocks and cultivars** in different edapho-climatic locations in the main tropical and subtropical countries. The number of rootstocks and cultivars should be small due to the high cost involved, but should include at least the main Floridian cultivars and the important local cultivars. Ideally the most worldwide important rootstocks, either by theirgeneralized use or because of their special characteristics, like '13/1', 'Gomera1', 'Turpentine', 'Piva' and 'Kensington Pride' together with the local rootstock in each country, should be included, when available, in these trials. Due to the low productivity reported for 'Ataulfo' and its increasing presence on the USA market, it may be of great interest to concentrate efforts in the evaluation of different rootstocks for increasing yield of this cultivar.

2) **Clonal propagation studies.** Since seed availability is one of the main reasons for choosing a determined rootstock the developing of commercial clonal propagation systems will facilitate the use of new rootstocks. It also will allow the utilization of monoembryonic rootstocks or even of *Mangifera* species compatible with mango - already used in several countries-, some of which, as reported in the literature review, possesses some of the desired characteristics for a mango rootstock.

3) **Molecular and chemical markers studies.** The developing of valid molecular or chemical markers for identifying some of the desired characteristics of

a rootstock (i.e proline content and salinity tolerance) and, specially in order to assure the uniformity of the progeny of polyembryonic rootstocks is of great importance for rootstock evaluation trials.

4) **Ploidy studies.** The potential use of tetraploids as dwarfing rootstocks without losing other desired characteristics of a rootstock deserves a special line of research.

5) **Morphological, physiological and anatomical studies of different rootstocks.** Especially of the characteristics of the root system and bark thickness of the rootstocks in relation with the vigour of the grafted plant, but also for the facilities for absorption of water and nutrients.

6) **Interstocks studies**. Both for the dwarfing effect of the interstock as well as because of its possible influence on the flowering behavior and on yield. The potential of even monoembryonic rootstocks as 'Amrapali' is of interest in this type of studies because of the vegetative nature of the interstock piece not subjected to variability as in the case of monoembryonic seeds.

Possibilities for future cooperative projects

Many countries are interested in receiving information on mango rootstocks but only those in which mango is an important crop are actually doing research on this subject (see table 4). At the present moment, not any cooperative rootstock project between countries is being carried out, although many of the institutions and researchers interviewed had expressed their willingness for undertaking cooperative rootstocks projects in different subjects as it is exposed below, grouping them by different areas of the world:

American continent and the Caribbean

Although only in two countries it has been detected the existence of ongoing projects or research on mango rootstocks, Mexico, with phenological and physiological studies of cultivars Kent and Ataulfo on different rootstocks, and Florida with studies of compatibility of *Mangifera* species, the possibility to establish cooperative projects to study the potential of rootstocks is fully open. Practically all the interviews have shown the interest of most countries from this area of the world on the use of rootstocks for tolerance to salinity, dwarfism and increase yield and have expressed their willingness to cooperate in future research trials. Only countries where mango is not an important crop and have no potential for new plantings like Chile, France (Martinica and Guadalupe), or by specials situations, like Venezuela, because of its economic and political crisis, or Ecuador where new plantings are not being done, may not probably be involved in future cooperative trials. The fact that Floridian cultivars dominate the plantings of these countries and the relative low yields obtained in most of them opens the door for the implementation of standardized coordinated trials of rootstocks and cultivars in different edapho-climatic locations to evaluate not only yield but also other desired characteristics for a mango rootstock.

Asia and the Pacific

As can be seen both in the literature review and in the interviews (see table 4) India and Australia are by far the two countries which have devoted more effort to rootstock research and also the ones that are conducting much research in the subject. India, in particular, has even a hybridization program at the Central Institute for Subtropical Horticulture for developing new polyembryonic rootstocks tolerant of salinity and adapted to problematic soils and is specifically interested in cooperative rootstock trials to evaluate the potential of rootstocks for high density plantings. Australia is also very much interested in testing any potential rootstocks for altering the vigour and architecture of scion varieties on existing and new Australian cultivars and also for tolerance to salinity. Both countries are conducting field trials with different rootstock/cultivar combinations and are especially interested on compatibility studies. There are also some private individuals in Australia who are developing some rootstocks, especially tetraploid rootstocks. Only other two countries in the area, Pakistan and Bangladesh, have also active field projects for rootstocks evaluation but practically all of the countries, except Japan, where mango is produced at a very small scale under greenhouse, have indicated the interest in cooperative rootstock trials. As in America, the most important subject of research for most countries are salinity, dwarfism and increase yield, but subjects as tolerance to pests and diseases, resistance to drought and increase of fruit quality are also of interest.

Africa. Middle East and Europe

Only Israel, Egypt, Oman and Spain are conducting rootstock trials at present with especial emphasis in tolerance to salinity, but practically all of the countries, except Portugal, where mango is a very minor crop, have indicated the interest in cooperative rootstock trials in the same subjects than in other part of the world, that is especially the effect of rootstocks on tolerance to salinity, dwarfism and increase of yield. Of special interest is a trial initiated two years ago in Oman for comparing the behavior of several cultivars grafted in the two most well-known rootstocks tolerant to salinity, ‘Gomera 1’ and ‘13/1’. Although no cooperative projects are established, the presence in several countries of Africa of CIRAD, the French research institution dealing with tropical and subtropical fruits, may facilitate cooperation in many African countries.

Summary of findings and Conclusions

Worldwide commercial cultivars for the fresh market

1. **The Floridian cultivars** 'Tommy Atkins', 'Kent', 'Keitt' and, to a minor scale, 'Palmer', 'Haden', 'Edwards' or 'Irwin' **dominate the global fresh-fruit export market**, particularly when destined to the European Union (EU) and the United States (USA). In the USA market the offer is reduced almost exclusively to Floridian cultivars plus 'Ataulfo', from Mexico and 'Madame Francis' from Haiti, while in the EU the offer is much wider, including Israeli new selections, the Floridian 'Osteen' from Spain, some Indian and Pakistani cultivars, 'Nan Doc Mai' from Thailand, 'Amelie' and 'Valencia Pride', from African countries and 'Cavallini' from Costa Rica. Some Dominican Republic cultivars like 'Banilejo' and 'Mingolo' start to be commercialized successfully both in USA and the EU.
2. **The markets for fresh fruits in Middle East Countries, South East Asia and China prefer their own cultivars including green-ripe types**, particularly in Thailand. Japan and Taiwan are the only places where the Floridian cultivar 'Irwin' is preferred by its red colour, although recent commercial agreements of China with some Latin-American countries like Peru or Ecuador may lead to the presence of 'Kent' and 'Keitt' in this market. This last cultivar is also produced commercially in Australia together with 'Kensington Pride', 'Maha Chanuk' from Thailand and new Australian selections like 'Calypso', this last also recently exported to USA.
3. **The Floridian cultivars are also planted in South Africa, Hawaii and other islands of the Pacific and constitute the base of the mango industry of most Latin-American mango producing countries**. 'Keitt' and especially 'Kent' are being increasingly planted in several African countries for export to the EU. As a curiosity, the Floridian cultivar 'Cogshal' is the main commercial cultivar in Reunion Island.

Rootstocks for commercial cultivars. Influence of rootstocks in quantitative and qualitative aspects of mango production.

1) **In practically all the countries, rootstocks are chosen because of the facility of obtaining seeds. In the great majority of cases they are of polyembryonic nature coming from local and well adapted trees long introduced in the area,** except in a few countries in Asia, near or in the area of origin of the mango, and in Hawaii where monoembryonic types or even some close compatible *Mangifera* species are also used.
2) **The same rootstock is almost always used for all cultivars**. The Floridian cultivars, when commercially cultivated, are grafted on them without any problems of incompatibility or contraindications. Exceptions are only indicated in Brazil where 'Coquinho' is not recommended as rootstock for 'Tommy Atkins' and 'Van Dyke because of imparting excessive vigour, in the Dominican Republic where 'Mameyito' is not recommended as rootstock for 'Keitt' due to problems of iron chlorosis in alkaline soils and in Colombia where 'Arauca' is preferred to ´Hilacha' as rootstock for most Floridian cultivars in areas under dry conditions. Nor any recommendations have been found for ´Haden' or 'Ataulfo'**.**
3) Besides the obvious requirement of compatibility with the grafted cultivars, **tolerance to salinity and dwarfism are the two characteristics more desired for a rootstock**. Other important characteristics include improve of yield and yield efficiency, good ability to absorb nutrients, particularly iron and calcium, tolerance to flooding, tolerance to dry

conditions, tolerance to pests and diseases and improve of fruit quality, adaptation to problematic soils and deep-rooting condition, shortening of the juvenile phase and resistance to Internal Fruit Breakdown.

4) **Not any of the rootstocks used commercially or evaluated in any trial so far exhibit all the desired characteristics for a good mango rootstock** and, furthermore, there is not even a single rootstock which combines the two attributes more demanded for a rootstock by the mango industry: tolerance to salinity and dwarfing effect.

5) Although several rootstocks are mentioned as tolerant to salinity in the interviews or in the literature review there is **only** enough scientific evidence that '**13/1' from Israel, 'Gomera 1' ('G1') from the Canary Islands, 'Olour' from India and 'Sukkary' from Egypt are effectively polyembryonic salt tolerant rootstocks**. Only '13/1' and 'G1' have been successfully proven as rootstocks for the Floridian cultivars (Tommy Atkins', 'Haden', 'Kent' and 'Keitt' among others). There is not much information in the case of 'Ataulfo' grafted on these two rootstocks, except that from the germplasm collections in the Canary Islands where no any incompatibility problem has been detected for this cultivar grafted on 'G1', but no data from yield has been recorded so far.

6) A clear **effect of** several polyembryonic **rootstocks** (and even of some monoembryonic ones like 'Amrapali' from India) **in the reduction of tree size** of the grafted cultivar has been reported in many research trials and also in several interviews but all the experiments realized so far indicates the existence of a **great interaction rootstocks/scion/environment** which obliges to specific recommendations for location and cultivars regarding the dwarfing effect of a rootstock. Because of this **is not possible to make definitive recommendations for the Floridian cultivars and/or 'Ataulfo'**. However, recent information indicates that **'Piva'** from South Africa either as rootstock or interstock **may be dwarfing for the Floridian cultivars**, especially for high density plantings. Other **interstocks** like 'Irwin', 'Esmeralda' and 'Amrapali' are have also proven to be **dwarfing for different cultivars**, including not ony the Floridian types but also ''Ataulfo'.'

7) Despite the information given in the interviews about the good capacity of some local rootstocks to absorb nutrients, **only** in the case of **rootstocks 'Tangkai Panjang' from Malaysia and '13/1'** there is scientific evidence of their **ability to absorb nutrients,** especially calcium and iron, of great interest for the control of the Internal Fruit Breakdown, and only '13/1' has been regularly used as rootstocks for Floridian cultivars with scarce problems of IFB.

8) Although several rootstocks were indicated in the interviews and in the literature review as **resistant to dry conditions or flooding**, only, in the case of the Colombian **rootstock 'Hilacha',** among those used normally as rootstocks for Floridian cultivars, published reports support the affirmation of better adaptation to flooding and salty conditions. However, there are experimental evidence of a **better adaptation** of **'Turpentine' and '13/1' to adverse soil conditions**, particularly high pH and alkaline soils.

9) The effect of rootstocks on the **incidence of pests and diseases** have been reported and scientifically documented only for the case of ***Ceratocystis* spp** and the fruit fly ***Anastrepha obliqua***, but there are not reports involving the Floridian cultivars or 'Ataulfo', but for '**Manila'**. The fruits of this last cultivar, when **grafted on 'Criollo'**, one of the local polyembryonic rootstocks utilized in Mexico for most cultivars, increase their firmness and also the richness of some fruit chemical components which **enhance its resistance to fruit fly**.

10) Although **influence on fruit quality** of the grafted plants has not been indicated for any rootstock in any of the interviews, there are experimental trials which indicate the influence of rootstocks on fruit weight and size, fruit shape, total soluble solids content and even in the time from harvesting to the point of fruit ready for consumption. The information **for the Floridian cultivars only exists for local rootstocks in Venezuela, Brazil or Colombia** and not for the influence of '13/1', 'Turpentine', 'Piva' or 'Kensington Pride' on them with no information at all existing for 'Ataulfo'.

11) **The rootstock 13/1 exhibit more of the desired charracteristic for a rootstock** than any other one: tolerance to salinity, a certain, good adaptation to adverse soil conditions, good ability to absorb nutrients and a high degree of uniformity in its progeny and it has been claimed to have some dwarfing effect on reducing tree size, only detected at the nursery phase In addition, high yields for many cultivars including Floridian cultivars but not 'Ataulfo' have been obtained in Israel when grafted on it. However, because of the clear interaction rootstock/cultivar/environment detected in many trials and the excellent yield obtained with other rootstocks in different parts of the world**, no definitive conclussions can be given about the suitability of this rootstock for the Floridian cultivars and also not**, of course, **for Ataulfo.**

12) **Differences caused by rootstocks on the yield of the grafted cultivar has been demonstrated in many experiments** with important significant differences and a clear interaction with cultivars and locations being indicated also for the Floridian cultivars and especially for 'Kensington Pride'. However, the high yields reported in the interviews for Floridian cultivars grown in different parts of the world or for 'Kensington Pride' in Australia, when adequately cultivated, together with the availability of seeds, **explain why no especial recommendations has been made so far to change the traditional rootstocks used in each country**.

Identifying future research needs and cooperative projects

1) **The non-existence of clear indications for recommending the best rootstock** even **for the most commercial cultivars** implies **the need to implement standardized coordinated trials of rootstocks and cultivars in different edapho-climatic locations** in the main tropical and subtropical countries as well as impulse several lines of research such as: **Clonal propagation** studies, **molecular and chemical markers** studies, **ploidy** studies, **morphological, physiological and anatomical studies** of different rootstocks and **interstocks** studies.

2) Although only those countries in which mango is an important crop are actually doing research on mango rootstocks, the institutions and researchers of most important mango producing countries of the world had expressed their willingness for undertaking cooperative rootstocks projects. **The fact that the effect of rootstocks in three main aspects of mango behavior: tolerance to salinity, dwarfing and effect on increasing yield, are prevalent**, among other desired characteristics, **in the great majority of the countries** consulted for writing this report **is**, no doubt, **a driving force for implementing future research and developmental cooperative rootstock projects**, non-existing today, provided appropriate funding can be allocated for them.

Bibliography cited

Elgozouli, A. A. 2011. Characterization and evaluation of selected mango (*Mangifera indica* L.) cultivars using moephological descriptors and DNA molecular markers. Ph.D. Thesis. Department of Horticulture. University of Khartoum. Sudan.

Abirami, K., Singh, S. K., Singh, R., Mohapatra, T. and Kumar, A. R. 2008. Genetic diversity studies on polyembryonic and monoembryonic mango genotypes using molecular markers. Indian Journal of Horticulture: 258-262.

Al Adawi, A.O., Al Sadi, B.A., Al Jabri, M.H., Barnes, I., Wingfield, B.D., Deadman, M.L. and Wingfield, M.J. 2013. Evaluation of Mango Cultivars for Resistance to Infection by *Ceratocystis manginecans*. Acta Horticulturae 992: 393-402.

Anon. 2013. Modelo Tecnológico para el cultivo del mango en el Valle del alto Magdalena en el Departamento del Tolima. 2013 Corporación Colombiana de Investigaciones Agropecuarias (CORPOICA).

Ávila Resendiz, C., Mosqueda Vázquez, R., Pérez García, R. and Matheis Toledano, C: 1993. Production effects of compact 'Manila' mangoes grafted onto different interstock-rootstock combinations. Acta Horticulturae 341:281-283.

Avilán, I., Leal, F., Rodríguez, M., Ruiz, J. and Marín, C 1997. Mango rootstocks and their influence on fruit shape and size. Acta Horticulturae 455: 479-488.

Baita, H. U., Manga, A.A. and Mustapha, Y. 2010. Evaluation of different morphotypes of mango (*Mangifera indica* L.) for use as rootstock in seedlings production. Bayero Journal of Pure and Applied Sciences 3(1): 79 – 82.

Bally, I., Ibell, P. and Rigden, P. 2015 Project: The small tree high productivity initiative-researching the shape of future mango orchards http://www.industry.mangoes.net.au/resource-collection/2015/7/3/the-small-tree-high-productivity-initiative-researching-the-shape-of-future-mango-orchards.

Bithell, S. L., Tran-Nguyen, L. T. T., Hearnde, M. N., Hoult, M. D., Hartley, N. and Smith, M. W. 2016. Fine root dry matter relative to mango (*Mangifera indica*) tree scion size grafted on size-controlling rootstocks, is negatively related to scion growth rate. Online paper. Springer. Trees DOI 10.1007/s00468-016-1355-z

Casierra-Posada, F. and Guzmán, J. A. 2009. Efecto del portainjerto y del injerto intermedio sobre la calidad de fruta en mango (*Mangifera indica* L.) Agron. Colomb. 27 (3). Bogotá. Sep./Dec.2009. Print version 0120-995.

Cedeño – Maldonado, A.; Pérez, A. y Reyes – Soto, I. 1988. Effect of dwarfing rootstocks on tree size and yield of selected mango varieties. The Journal of Agriculture of the University of Puerto Rico 72(1): 1 – 8.

Cull, B. 1991 Mango crop management. Acta Horticulturae 291: 154-171.

Chandan, P. M., Kadam, J. H. and Ambad, S. N. 2006. Effect of different polyembryonic and monoembryonic rootstocks on performance of Dashehari mango. Ambad Internat. J. Agric. Sci. 2(2): (594-595).

Damodarana, T., Rajan, S., Kumar, R., Sharma, D.K., Misra, V.K, Jha, S.K. and Raic, R.B. 2013. Post-tsunami collection of polyembryonic mango diversity from Andaman Islands and their ex situ reaction to high sodium in sodic soil. Journal of Applied Horticulture 15(1): 21-25.

Dayal, V., Kumar Dubey, A., Prakash Awasthi, O., Pandey, R. and Dahuja, A. 2014. Growth, lipid peroxidation, antioxidant enzymes and nutrient accumulation in Amrapali mango (*Mangifera indica* L) grafted on different rootstocks under NaCl stress. Plant Knowledge Journal. Southern Cross Publishing Group ISSN: 2200-. Australia EISSN: 2200-5404 3(1): 15-225390.

de Castro Neto, de C: M. T., Fonseca, N., Santos Filho, H. P. S and Cavalcante Junior, A. T.2002. Chapter 6. Propagaçao e Padrao da Muda. In**:** Genú, P. J. C. and Pinto. A. C. Q: (Eds.). A Cultura da Mangueira. Embrapa Ram. Informaçao Tecnológica. Brasilia: 117-136.

Dubey, A.K. Singh A.K., and Srivastava, M. 2007. Salt stress studies in mango- a review Agric.Rev. 28(1): 75-78.

Durán-Zuazo, V.H., Aguilar-Ruiz, J. and Martínez-Raya, A. 2005. Fruit yield, plant growth and nutrient status in mango: effect of rootstocks. Int. J. Fruit Sci. 5(4): 3-22.

Durán Zuazo, V. H., Martínez-Raya, A. and Aguilar Ruiz, J. 2003. Salt tolerance of mango rootstocks (*Mangifera indica* L. cv. Osteen). Spanish Journal of Agricultural Research 1(1): 67-78.

Durán Zuazo, V. H., Martínez-Raya, A. Aguilar Ruiz, J. and Franco Tarifa, D. 2004. Impact of salinity on macro- and micronutrient uptake in mango (*Mangifera indica* L. cv. Osteen) with different rootstocks. Spanish Journal of Agricultural Research 2 (1), 121-133.

Duran Zuazo, V. H., Rodríguez Pleguezuelo, C. R., and Franco Tarifa, D. 2006. Fruit yield, growth and leaf-nutrient status of mango trees grafted on two rootstocks in a marginal growing area (South-East Spain). Fruits 61 (3): 163-170.

Duvivier, P. and Cedeño-Maldonado, A. 2000. Evaluation of mango rootstocks for yield efflclency of 'Parvin' and 'Tommy Atkins' varieties, Proceedings of the 35 Annual Meeting of the Caribbean Food Crops Society, Castries, St. Lucia, W.I..25-31 July 1999: 144-154.

Elgozouli, A. A. 2011. Characterization and evaluation of selected mango (*Mangifera indica* L.) cultivars using moephological descriptors and DNA molecular markers. Ph.D. Thesis. Department of Horticulture. University of Khartoum. Sudan.

Galán Saúco, V. 2008. El cultivo del mango. (2nd ed.). MundiPrensa.Madrid. 340 pp

Galán Saúco, V. 2009. Physiological Disorders. In Litz, R. (Ed.) The Mango, Botany, Production and Uses (2nd edition. CAB Internacional): 303-316.

Galán Saúco, 2015a. Situación actual, importancia y tendencia en la investigación agronómica de los frutales tropicales y subtropicales leñosos. Invited paper at the XVI Congreso Nacional and II Congreso Internacional de Ciencias Hortícolas. Boca del Río. Veracruz. 19-24/10/2015.

Galán Saúco, 2015b. Trends in mango world production and marketing. Invited paper at the XI International ISHS Mango Symposium. Darwin Australia 28/09/15- 02/10/15. Acta Horticulturae (in review).

Galán Saúco, V. 2015c. Ventajas y desventajas del cultivo del mango (*Mangifera indica* L.) en zonas subtropicales y potencial del cultivo bajo invernadero. Acta Horticulturae 1075: 167-178.

Galán Saúco, V. and García Samarín. J. 1979. Pasado, presente y futuro del mango en Canarias. Cuadernos INIA, 9. 39 pp.

Galán Saúco, V., Acuña Barreto, J.F., Fernández Galván, D., Socorro Monzón, A.R. and Herrera Rodríguez, L. 1988. Tolerancia de distintos patrones de mango (*Mangifera indica* L.) a la salinidad. Actas de Horticultura 1: 83-89.

Galán Saúco, V., Coello Torres, A., Grajal Martín, M.J., Juárez, J., Navarro, L. and Fernández Galván, D. 2000. Occurrence of Spontaneous Tetraploid Nucellar Mango Plants. HortScience 36 (4): 755-757.

Gazit, S. and Kadman, A. 1980. 13-1 Mango rootstock selection. Horstscience 57: 81-87.

Gerbaud, P. 2016. Close-up Mango. Fruitrop 239: 40-84.

Gowder, R.B. and Irulappan, I. 1971. Performance of Neelum variety of mango (*Mangifera indica* L.) on polyembrionic rootstocks as compared to that of mango monoembrionic rootstock. Madras Agric J. 58: 183-189.

Grajal-Martín. 2012. Selecciones de mango en Canarias. Actas de Horticultura 62: 235-236.

Hafez, O. M., Saleh, M. A., Ellil, A., and Kassab. O. M. 2011. Impact of Ascorbic Acid in Salt Tolerant of Some Mango Rootstock Seedlings. Journal of Applied Sciences Research, 7(11): 1492-1500, ISSN 1819-544X.

Hermoso, J. M., Guirado, E., González- Fernández, J. J. and Farré, J. M: 2015. Study on Performance of ‘Keitt’ Mango on Different Rootstocks in a Mediterranean Climate. Acta Horticulturae 1075: 115-119.

Hoult, M.D. 2010. Mango rootstocks. Moving beyond the fiction? Mango R and D presentation. May 2010**.**

Hurkman, W.J., Fornari, C.S. and Tanaka, C.K., 1989. A comparison of the effect of salt on polypeptide and translatable mRNA in roots of a salt tolerant and salt sensitive cultivar of barley. Plant Physiol. 131: 516-524.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. Volume 1: Global and Sectoral Aspects and Volume 2: Regional Aspects. IPCC/WGO/UNEP.

Jauhari, O. S., Teaotia, S. S. ad Upadhyay, S. K. 1972. Rootstocks studies in *Mangifera indica* L. Acta Horticulturae 24: 107-109.

Kadman, A.; Gazit, S. and Ziv, G. 1976. Selection of mango rootstock for adverse water and soil conditions in arid areas. Acta Horticulturae **57:** 81-88.

IAC. 1994. Cultivar de manga IAC 101 Couquinho. Porta enxerto Resistente a Seca-Da-Mangueira. Instituto Agronómico Campinas. Sao Paulo.

Iyer, C.P.A. and Subramanyan, M.D. 1986. Creeping, a promising genotype for introduction of dwarfness in mango. Indian Journal of Horticulture 43**:** 221-223.

Kulkarni, V.J. 1991. Tree vigor control in mango. Acta Horticulturae 291, 229-234.

Lee, M.S. 1988. Citrus polyploydy – origins and potential for cultivar improvement. Austral. J. Agr, Res.: 735-747.

Litz, R. (Ed.). 2009. The Mango, Botany, Production and Uses (2nd edition). CAB International. Wallingford. Oxfordshire. 680 pp.

Mossler, M.A. and Crane, J. 2013. Florida/Crop Pest Mangement Program. Profile: Mango. University of Florida. IFAS Extension. Publication #CIR 140. https://edis.ifas.ufl.edu/pi052.

Mourão Filho, F. A. A., Kluge, R. A., Bacic Olic, F. and Antunes Ribeiro, I.J. 2000. Desenvolvimento e produtividade iniciais de mangueira Tommy Atkins' sobre diferentes porta-enxertos. Rev. Bras. Frutic. 22 (2): 281 -285.

Mukherjee, S. K. and Das, D. 1976. Screening of mango seedlings for use as dwarfing rootstocks. Progressive Horticulturae 8 (1): 5-11.

Mukherjee, S. K. and Das, D. 1980. Anatomical screening of mango (*Mangifera indica.*L.) seedlings for use as dwarfing rootstocks. Science and Culture, 46 (1): 333-336.

Normand, F., Lauri, P-É and Legave, J.M. 2015. Climate Change and its Probable Effects on Mango Production and Cultivation. Acta Horticulturae 1075; 21-31.

Oppenheimer, Ch. 1958. A stock-scion trial with the mango in Israel. Hort. Adv. 2: 27-36.

Openheimer, Ch. 1960. The relationship between tree size and yield in mango. (*Mangifera indica* L.) and avocado (*Persea americana* Mill.). Hort. Advance 4:6-15.

Openheimer, Ch. 1968. A Second Stock-Scion Trial with Mango in Israel. Experimental Agriculture 4(03): 209 - 218.

Popenoe, W. 1920. Manual of tropical and subtropical. Hafner Press. Nueva York. (Facsímil de la edición de 1920): 474 p.

Pinto, A.C.O., Genú. P.J. Ramos, V. H. and Jumqueira, N.T.V. 1993. Programa de hibridaçao de mangueiras na regiao do Cerrados Brasileiros. Revista Brasileira de Fruticultura 15(1):141-146.

Reddy, Y.T.N., Kurian, R. M., Ramachandar, P. R: Singh, G. and Kohli, R. R. 2003. Long-term effects of rootstocks on growth and fruit patterns of 'Alphonso' Mango (*Mangifera indica* L). Scientia Horticulturae 97: 95-108.

Reyner, K. 2002. The effect of rootstocks on Kensington Pride mango. The University of Western Australia.

Ribeiro, I.J.A. 1993. Seleçao de porta-enxertos de mangueira (*Mangifera indica* L.) resistentes ao fungo *Ceratocystis fimbriata* Ell. and Halst. Jaboticabal, FCAV/UNESP. 98 p. (PH. D. Thesis).

Rossetto, C. J., Ribeiro, I.J.A, Gallo, P.B., Soares, N.B., Sabino, J.C., Martins, A.L.M., Bortoletto, N. and Paulo, E.M.1997. Mango breding for resistance to diseases and pests. Acta Horticulturae 455: 299-304.

Simão.S., Nylander, O. Otassi, B, and Barbin, D. 1994 Study of several varieties of tree crowns on different rootstocks of mango (*Mangifera indica* L.) Scientia Agricola Piracicaba 51(3): 509-512.

Singh, U.R. and Singh, A.P. 1976. Rootstock studies in mango (*Mangifera indica* L.). Prog. Hort. 8 (1): 13-19.

Smith, M. W., Bright, J.D., Hoult, M.D., Renfree, R. A. and Maddern, T. 2008. Field evaluation on 64 rootstocks for growth and yield of 'Kensington Pride'. Hortscience. 43: 1720-1725.

Smith, M. W., Hoult, M.D. and Bright, J. D. 2003. Rootstocks affect yield efficiency and harvest rate of 'Kensington Pride' mango. Hortscience 38(2): 273-276.

Smith M. W., Hoult, M.D., Bright, J. D., Foord, G., Mc Alister, S., Brown, C., Smith, G.S. and Landrigan, M. 1996. Rootstocks for Kensington Pride Mangoes. Northern Territory Department of Primary Industry and Fisheries-Horticulture Division Technical Annual Report 1996/97.*Technical Bulletin No. 268*, page 20.

Smith, M. W., Hoult, M.D., Bright, J. D., Mc Alister, S. and Foord, G. 1997. Rootstock Research: Opportunities for the Australian Mango Industry. Acta Horticulturae 455: 383 390.

Smith, Toohill, B: L., Thompson, R: P., Hoult, M.D. and Bright, J: D: 1992. Report on a mango variety experiment at Australian Mango grower's orchard. Katherine, Northern Territory. Results for the 1992 season. N.T. Department of Primary.

Schmutz. U. 2000. Effect of salt stress (NaCl) on whole plant $C0_2$ gas exchange in mango. Acta Horticulturae 509: 269-276.

Schmutz, U. and Ludders, P. 1998. Effect of NaCl salinity and different root zone temperatures on growth and mineral composition of two mango rootstock (*Mangifera indica* L.). J. Appl. Botany 12: 131-135.

Schnell, R. J. and Knight Jr., R.J. 1991. Are polyembryonic mango dependable sources of nucellar seedlings for rootstocks? Proc. Fla. Sta. Hort. Soc. 104: 44-47.

Srivastava, K.C., Rapput, M.S., Surgle, N.P and Leal, B. 1988. Rootstock Studies in mango cv. Dasheri. Acta Horticulturae 231:.216-219.

Swanmy, G.S.; Rao, E.V.R and Raju. D. S. 1972. Polyembrionic rootstocks for mango. Acta Horticulturae 24**:** 110-113.

Tenhku Ab Malik, T.M. 1996. Screening for mango rootstocks with high calcium uptake. Proceedings International Conference on Tropical Fruits. Kwala Lumpur. Malasia. 23-26 / 07/ 1996. Vol. III: 189-196.

Ullah, H. 2013-14. 1.Horticulture Section. 1.1. Performance of mango cultivar Sammar Bahisht Chaunsa on various polyembryonic mango rootstocks. Annual Abridged Report. Mango Research Institute, Old Shujabad Road, Multan.

Van Hau, T., Viet Khoi. N. and Ngoc Tran, V. 2001. Effect of rootstocks on the growth of 'Cat Hoa Loc' mango scion. Mini-symposium on the Activities of Subproject B2, CTU, 24-25 July 2001.

Vargas Ramos, V. H., Pinto, A. C. Q, y Gomes A. C. 2001. Avaliação de sete porta-enxertos mono e poliembriônicos sob quatro cultivares de mangueira no Cerrado Brasileiro. Rev. Bras. Frutic 23(3). Online versión. http://dx.doi.org/10.1590/S0100-29452001000300036.

Vargas Ramos, V.H. Pinto, A. C. Q., Junqueira, N. T. V., Gomes, A. C., Andrade S. M. R.and Cordeiro, M. C.R. 2004. Effect of Mono and Polyembrionic Rootstocks on Growth, Yield and Fruit Quality of Four Mango Cultivars in the Central Region of Brazil. Acta Horticulturae 645: 201-207.

Vargas Ramos, V. H., Pinto, A. C. O., Nilton, T. V., Junqueira, N. T. V., Gomes, A. C., de Andrade, S. M. R. and Cordeiro, M. C. R. 2002, Crescimento e Rendimento de Quatro Cultivares de Mangueira enxertados em Porta-Enxertos no Distrito Federal. Boletim de Pesquisa e desenvolvimemto 103. EMBRAPA.

Vázquez-Luna, A., Rivera-Cabrera, F., Perez-Flores, L. J. and Díaz Sobac, R. 2011. Effect of Rootstock on Mango Fruit Susceptibility to Infestation by *Anastrepha obliqua*. Journal of Economic Entomology, 104(6):1991-1998.

Vázquez-Valdivia, V., Pérez-Barraza, M. H., Salazar-García, S. and Becerra-Bernal, E. 2005. Crecimiento, nutrición y rendimiento del mango 'Ataulfo' con interinjerto de porte bajo 'Esmeralda'. Rev. Chapingo Ser. Hortic. 11(2); 209-213.

Wicks, C., Azam. G., Renfree, R., Kahl, M., McRae, M., Connelly, M., Traynor, M. and Hoult. M. 2006. Project: Elite Rootstocks and Scion Cultivars for Improved Productivity of NT Mangoes and Citrus.

World Bank 2012. Turndownthe heat: why a 4ºC warmer world must be avoided. Washington D. C., Woprld bank.http://documents.worldbank.org/curated/en/2012/11/1709815/tur-down-heat-4ªC2%B0c-warmer-world-must-avoided

Table 1a. Important Commercial World Cultivars for the fresh market (Latin America and the Caribbean).

Country	Cultivars	Markets
Mexico	Tommy Atkins, Ataulfo, Kent	USA and Canada
Brazil	Tommy Atkins, Palmer, Kent, Keitt	European Union (EU), USA, Japan, Middle East
Peru	Tommy Atkins, Kent, Keitt Haden, Edwards, Ataulfo	EU, USA, Canada, China, Japan, Korea and neighbor Latin American countries
Ecuador	Tommy Atkins, Ataulfo, Kent, Keitt, Edwards, Haden, Madame Francis, Nan Doc Mai	EU, USA, Mexico, Chile, New Zealand, Canada, China (**)
Costa Rica	Tommy Atkins, Palmer, Keitt, Irwin, Haden, Cavallini	Panama
Venezuela	Tommy Atkins, Haden, Palmer,	Arura, Bonaire, Curasao, EU (***)
Guatemala	Tommy Atkins, Ataulfo, Kent, Brea (*)	EU, USA, El Salvador, Honduras
Puerto Rico	Palmer, Keitt, Parvin, Nan Doc Mai	EU, USA, Canada, Japan
French West Indies	Julie, Moustache	Local market
Cuba	Super Haden, Tommy Atkins. La Paz	Canada. EU
Dominican Republic	Keitt, Tommy Atkins, Kent, Banilejo, Mingolo, Crema de Oro, Madame Francis, Puntica	EU, USA
Honduras	Tommy Atkins, Haden	El Salvador
Haiti	Madame Francisque (only exported) (1)), Baptiste, Corne, Blanc and other local types	USA., Local market
Chile	Piqueño, Tommy Atkins, Keitt, Kent, Sensation, VanDyke, Lippens	Malvinas
Colombia	Hilacha, Tommy Atkins, Yulima, Azúcar, Kent, Vallenato	Local market
Florida	Tommy Atkins, Keitt, Haden	Local market

(*) For processing; (**). From 2016; (***) Temporary suspended (1) Madame Francisque is the same that Madame Francis

Table 1b. Important Commercial World Cultivars for the fresh market (Asia and the Pacific).

Country	Cultivars	Markets
India	Alphonso, Kesar, Dashehari, Chausa Banganapally, Himayath,	USA, EU, Japan, Middle East
Pakistan	Sindhri, Chaunsa (*), Sammar Bahist, Sufaid Chausa	European Union (EU), USA, Japan, Middle East, Malaysia, Singapore, Japan
China	Keitt	Singapore, Russia
Thailand	Nan Doc Mai, Sri-Tong, N0.4, Maha Chanok	Japan, Korea, China, Taiwan, Switzerland, EU, United Arab Emirates, Russia
Indonesia	Gedong Gincu, Arumanis	United Arab Emirates
Malaysia	Choc Anan, Harumanis (**), Sala	Singapore, Brunei, Japan
Bangla Desh	Langra, Khirsapat, Amrapalli	India, Pakistan, Middle East, EU
Vietnam	Cat Hoa Loc, Cat Chu, Xoai Boui	China, Korea, Japan, New Zealand, Australia, USA, EU
Sri Lanka	Beti amba, Willard, TomEJC, Karutha Colomban	Middle East, EU, Maldives
Philippines	Carabao	Hong Kong, Japan, Singapore, USA. Australia, UE, Middle East
Taiwan	Irwin	China, Hong Kong, Japan, Singapore., South Korea
Australia	Kensington Pride, R2E2, Keitt, Calypso,	China, Hong Kong, Japan, New Zealand, Middle East, South East Asia, USA
New Caledonian	Kensington Pride, Irwin, Tommy Atkins, Haden	New Zealand
Hawaii	Keitt, Haden	Japan
Japan	Irwin	Local market

(*) Chausa and Chaunsa are, most likely, the same cultivar. (**) Arumanis and Harumanis are, most likely, the same cultivar.

Table 1c. Important Commercial World Cultivars for the fresh market (Africa, Middle East and Europe).

Country	Cultivars	Markets
Senegal	Kent, Keitt	European Union (EU)
Sudan	Kitchener, Abu Samaka, Alphonso, Mulgoba, other local cultivars from seeds	Jordan, Saudi Arabia, United Arab Emirates, Bahrain, Lebenon
Ivory Coast	Kent, Amelie	EU
Egypt	Zebda, Sukkari, Kobania, Hindi Be Sennara, Keitt	EU, Middle East
South Africa	Kent, Keitt, Tommy Atkins, Sensation	Middle East, Malaysia, Netherland, Ghana
Israel	Keitt, Kent, Maya, Shelly, Omer, Noa, Tali	EU, Russia
France (Reunion Island)	Cogshal	France
Spain	Osteen, Keitt, Kent	EU
Portugal	Irwin, Osteen, Tommy Atkins, Keitt, Kent, Sensation, Manzanillo, Glenn, Otts, Rosa	Local market
Oman	Several indian cultivars like Alphonso, Langra, Dasheri and Mulgoba	United Arab Emirates

Table 2a. Rootstocks used in Latin America, USA and the Caribbean

Country	Rootstocks (*)	Observations
Mexico	Several poliembryonic local types (They are named with a collective word ‘criollos’)	Good adaptation to calcareous soils and acceptable tolerance to soil diseases
Brazil	Espada (**) Bourbon, Comum Del Cerrado (Región Central), Coquinho (Sao Paulo), Imbu (Minas Gerais)	Coquinho is not a good rootstock for Tommy and Van Dyke because gives great vigour to the grafted plants. Imbu also gives great vigour to the grafted plants
Peru	Criollo de Cholucanas (**), Camboyano (***), Saigón (***)	Camboyano and Saigón are monoembryonic Criollo de Cholucanas tolerates salinity, drought, flooding and increase nutrient absorption
Ecuador	Mango de chupar, Mango blanco, Mango de canela, Mango manzana, Mango reina)	All local seedlings
Costa Rica	Mango Jamaica (syn. mecha) similar to Turpentine) (**); Criollo	Jamaica tolerant to dry soil conditions
Venezuela	Bocado	Very rustic, vigorous and tolerant of dry soil conditions
Guatemala	Mango criollo (mango de racimo)	Tolerant to dry soil conditions. Irwin or Brea is used as interstock for making dwarf Tommy Atkins plants
Puerto Rico	Mayaguezano and Pasote (local)	
French West Indies	Mango vert	
Cuba	Mangas blanca y Manga amarilla, Mango filipins	Probable manga blanca = Gomera 1 and Filipino= Gomera 4 8In Canary Islands
Dominican Republic	Banilejo (**), Largo, Mameyito, Sumozo, Yamaguí, Piñita	Plants on Banilejo and Piñita are more dwarf that on other rootstocks.
Honduras	Local criollo types (’Mechón’, ‘Confite’ and ‘Anís’)	
Haiti	Mango ron (**), Fil, Labich	
Chile	Piqueño (criollo type) (**); 13/1(***), Gomera 3 (***)	Piqueño reported to be as resistant to salt as 13/1
Colombia	Hilacha (95%), Arauca (local), Sabre and many others not characterized	Hilacha has good compatibility, enhanced vigor, good productivity growing well in flooded and salty conditions. Arauca is more resistant to dry conditions, especially for Van Dyke, but also for Irwin, Kent and Tommy
Florida	Turpentine (**), 13/1 and Piva on collections at Fairchild Botanical Garden	Plants grafted on Piva (2) are more dwarf that on other rootstocks. The bark of 13/1 cracks when some cultivars (1), are grafted on it. *Mangifera lalijiwa* is used as interstock for some other *Mangifera species*
California	Turpentine	

(*) All polyembryonic and used for all the cultivars unless specified the contrary; (**) Principal (***). Only occasionally used; (M) Monoembriónico;(1) They have not Ataulfo, Haden, Tommy, Kent or Keitt grafted on 13/1;(2) Southafrican rootstock

Table 2b. Rootstocks used in Asia and the Pacific

Country	Rootstocks (*)	Observations
India	Local available seedlings	Mostly poly but some monoembryonic also
Pakistan	Chaunsa Sammar Bahisht (**), Desi	Both local and monoembryonic. Desi vigorous and high yielding
China	Seeds from local courtyard mango trees or even from the processing factory	Both poly and monoembryonic
Thailand	Kaew (**), Ta-Lub-Nak, Sam-Ru-Due	Kaew and Ta-Lub-Nak are tolerant to dry conditions and increase nutrient root absortion
Indonesia	Madu (**), Saigon 119, Lalijiwo-91, Wajik, *Mangifera kasturi*	Saigon 119 has dwarfing effect. *Mangifera kasturi* resistant to salinity
Malaysia	Mangga Telor	More tolerant of pests and diseases
Bangladesh	Bau mango 6,7 and 8, plus other indigenous varieties both poly and monoembryonic	Bau 6, 7 and 8 are dry and saline tolerant
Vietnam	Buoi (**), Cat Hoa Loc	
Sri Lanka	Willard, Karutha Colomban, Vellai Colomban, Kohuamba	Kohuamba is drought tolerant
Philippines	Carabao (**), Pico	
Taiwan	Tsar-Swan, Char-Swam, Jin Hwung (M)	Tsar-Swan, deep rooted and tolerant to dry conditions and absorbs more nutrient than another rootstock
Australia	Kensington Pride (**), Common	Kensington Pride grown sometimes on its own roots
New Caledonian	Diverse polyembryonic types	
Hawaii	Seedlings from monoembryonics monoembriónicos common trees (**), *M. kasturi, Ml lalijiwa*	Seedlings of 'Kom' dwarfs cultivar Raposa (local cultivar)
Japan	Bushwood mango seeds	Imported from Taiwan. Tolerant to dry conditions

(*) All polyembryonic and used for all the cultivars unless specified the contrary; (**) Principal

Table 2c. Rootstocks used in Africa and Europe

Country	Rootstocks (*)	Observations
Senegal	Local polyembrionic mangoes	Same rootstocks for other west African countries
Sudan	Kitchener	(locally called Baladi)
Ivory Coast	Cat head (**), Long mouth, Adams	Cat head and Long Mouth very rustic, adapted to dry conditions and also used in subSahelian countries (Burkina Faso, Mali, Niger)
Egypt	Sukkari (White Sukkary) (**),"Zebda", 13-1, Peach.	Sukkary is toleran to salinity and there is a claim that is also dwarfing. The seeds of Sukkary and Zebda come generally from the pulp and juice processing factories.
South Africa	Sabre (**), Peach, Piva	Sabre is tolerant to flooding. Piva is dwarfing and used in high density planting also in India and Egypt and introduced also to Perú and Mexico
Israel	13/1	Tolerant to salinity and high soil pH, dry conditions and efficient in iron root absorption
France (Reunion Island)	Maison Rouge	Resistant to strong winds
Spain	Gomera 3, Gomera 1 (only in Canary Islands),	Gomera 1 is salt tolerant. Gomera 3 is more vigorous
Portugal	Gomera 3 (**), 13/1, Raposo	Gomera 3 in Algarve and Madeira. Raposo (1)) only in Azores and 13/1 only in Algarve
Oman	Sindheri (**), Unknown local monoembryonic seedlings	Amrapali, Gomera1 and 13/1 in trials since 2015.

(*) All polyembryonic and used for all the cultivars unless specified the contrary; (**) Principal

(1) A local type different from the hawaian cultivar ‘Rapoza’

Table 3. **Desired characteristics of a rootstock by countries**

Reasons	Countries
Tolerance to salinity	Australia (T), Vietnam, Spain, USA (Florida California, Hawaii) Chile, Colombia, Costa Rica, Egypt, Brazil, India, Indonesia, Israel, Pakistan, Oman, Peru, Dominican Republic, Vietnam, Mexico, Sudan
Tolerance to flooding	Vietnam, Colombia, Ecuador, Brazil, Honduras, India, French West Indies, Peru, South Africa, Vietnam, Sudan
Tolerance to dry conditions	Vietnam, Spain, Colombia, Ivory Coast, Costa Rica. Ecuador, Brazil, Guatemala, Honduras, India, Indonesia, Israel, Thailand, Taiwan, French West Indies, Peru, Sri Lanka, Vietnam, Spain. Oman, Sudan
Increase iron and other nutrients (+ON) absorption	Australia (T) (+ON), Ivory Coast (+ON), Honduras, India, Taiwan (+ON), Ecuador, Florida, India, New Caledonian (*), Thailand, Oman (+ON), Peru (+ON)
Dwarfing	Australia (T), Vietnam, Colombia, Ivory Coast, Egypt, Guatemala, India, New Caledonia, Pakistan, Hawaii, Oman, Panama, Philippines, Dominican Republic, South Africa, Sri Lanka, Taiwan, Reunion, Mexico, Ecuador, Puerto Rico
Good adaptation to problematic soils	Mexico, Spain. Israel (calcareous and high pH soils); Vietnam (acid sulphate soil)
Changes in fruit size and/or improve of fruit quality	Australia (T), Ivory Coast, India, Indonesia, Vietnam, Reunion Island, Puerto Rico
Tolerance to pests and diseases	Ivory Coast (1), (9), Ecuador (2); Brazil (3), India, Malaysia, New Caledonian (1)(4), Pakistan (5), Peru, Oman (2), (3), Philippines (1) (6), South Africa (7), Mexico (8)
Altering cultivar vigour and architecture	Australia (T), Colombia, Reunion
Improving flowering	Vietnam, India, Indonesia
Low incidence of Internal Fruit breakdown	Spain
Maintenance of characteristics of scion	Costa Rica
Resistance to strong winds, Increasing root depth	Reunion, Taiwan
Shortening juvenile phase	Panama, Sri Lanka
Adaptation to greenhouse cultivation and to subtropical climates (cold winter and hot summers	Spain

(T) Detected in trials; (*). To reduce physiological disorders

(1) Anthracnosis, *Phytophtora*; (2) Lasiodiplodia, (3) *Ceratocystis*; (4) Mildew, bacteriosis; (5) Sudden death, probably *Ceratocystis*; (6) Twig borer; (7) Root rot; (8) Soil diseases; (9) Bacterial blight

Table 4a. **Ongoing trials and interest on international cooperation in rootstocks work on America and the Caribbean**

Country	**Trials in course/possible future cooperation and potential for research trials**	**Institution** (*)
Mexico	YES/YES, tolerance to calcareous soils, dwarfing, resistance to soil diseases	CUCBA-Universidad de Guadalajara, INIFAP
Brazil	NON/YES (salinity)	EMBRAPA
Peru	NON/ YES (dwarfing, increase of yield, salinity)	Ministerio de Agricultura, INIA
Ecuador	NON/YES (dwarfing, flooding, resistant to dry conditions, increase nutrient absorption, toleranc to pests and diseases)	Plantaciones de Mango Grupo Durexporta
Costa Rica	NON/ YES (dwarfing, increase yield)	Instituto Nacional de Innovación y Transferencia de Tecnología Agropecuaria (INTA)
Venezuela	NON/NON	
Guatemala	NON/ YES (dwarfing, increase of yield, improve of fruit quality)	Instituto de Ciencia y Tecnología Agrícola (ICTA)
Puerto Rico	NON/YES (increase yield)	Martex Farms
Cuba	NON/YES (non specified)	Instituto de Investigaciones en Fruticultura
Dominican Republic	NON/YES (dwarfing, problematic soils)	Ministerio de Agricultura
Honduras	NON/YES (increase of yield)	Fundación Hondureña de Investigación Agraria (FHIA)
Chile	NON/NON	
Colombia	NON/ YES (salinity, hydric deficit, dwarfing, flooding)	Universidad Nacional
USA (Florida)	YES/YES (salinity, dwarfing, compatibility with *Mangifera* species)	Fairchild Botanical Garden; University of Florida. Homestead;
Panama	NON/ YES (dwarfing, increase of yield)	Instituto de Investigación Agropecuaria de Panamá
Haiti	NON/?	
France (Martinica and Guadalupe)	NON/NON	

(*) There may be other Institutions willing to cooperate but those mentioned may serve as agglutinative

Table 4b. Ongoing trials and interest on international cooperation in rootstocks work (Asia and the Pacific)

Country	Trials in course/ possible future cooperation and potential for cooperative trials	Institution (*)
India	YES/YES (salinity, uniform size fruits, dwarfing, problematic soils)	Central Institute for Subtropical Horticulture, Fruit Research Station, Sangareddy
Pakistan	YES/YES (dwarfing, tolerance to pests and diseases, salinity)	Mango Research Institute, Multan
China	NON/YES (tolerance to pests and diseases, compatibility)	Chinese Academy of Tropical Agricultural Science
Thailand	YES/YES (dwarfing)	Katsetsar University
Japan	NON/NON	
Indonesia	NON/NON	
Malaysia	NON/YES (tolerance to pests and diseases)	Malaysian Agricultural Research Development Institute (MARDI)
Bangla Desh	YES/YES (dwarfing, drought, increase yield, improve of fruit quality	Bangladesh Agricultural University
Vietnam	YES/YES (flooding, drought, salinity)	Can Tho University
Sri Lanka	NON/Yes (dwarfing, drought, increase yield),	
Philippines	NON/YES (dwarfing, tolerance to pests and diseases)	University of the Philippines Los Baños
Taiwan	NON/YES (dwarfing, increase yield, resistance to typhoons),	Meiho University
Australia	YES/YES (dwarfing, increase of yield, salinity, nutrient absorption, change of vigour and tree architecture, compatibility studies.	Queensland Department of Agriculture, Horticulture and Forestry Science, Queensland Department of Agriculture, Horticulture and Forestry Science
New Caledonian	NON/YES (dwarfing, increase of yield, nutrient absorption, tolerance to pests and diseases)	Institut Agronomique néo-Calédonien
USA (Hawaii)	NON/YES (salinity)	University of Hawaii

(*) There may be other Institutions willing to cooperate but those mentioned may serve as agglutinative

Table 4c. Ongoing trials and interest on international cooperation in rootstocks work (Africa. Middle East and Europe)

Country	Trials in course/ possible future cooperation and potential for cooperative trials	Institution (*)
Senegal	NON/YES	CIRAD
Sudan	NON/YES (salinity, flooding, drought)	Administration of Horticulture Production
Ivory Coast	YES/YES (dwarfing, tolerance to pests and diseases)	CNRA (National Agronomic Research Center)
Egypt	YES/YES (salinity, dwarfing, tolerant to calcareous soils, dwarfing)	Horticulture Research Institute, Agricultural Research Center
South Africa	NON/YES (dwarfing, increase yield)	South African Mango-Growers' Association (SAMGA)
Israel	YES/YES (salinity) dwarfing)	Volcani Research Center
France (Reunion Island)	NON/YES (low vigor, yield, better fruit sensorial quality and firmness, resistance to strong wind (i.e. strong rooting).	CIRAD
Spain	YES/ YES (adaptation to greenhouse cultivation and subtropical climatic conditions, salinity, high soil PH)	Estación Experimental de Cajamar "Las Palmerillas
Portugal	NON/NON	
Oman	YES/YES (dwarfing, salinity, resistance to *Ceratocystis manginecans*)	Ministry of Agriculture, Royal Court Farms

(*) There may be other Institutions willing to cooperate but those mentioned may serve as agglutinative

Table 5. Yield of Floridian and other selected cultivars on different rootstocks reported as estimated for different researchers

Rootstock	Yield (t/ha)
13/1 (1)	**Keitt** (50 average, 80 some seasons; 30 profitable); **Kent** (30-40 possible)
Mayaguezano or Pasote (2)	**Keitt** (30 aver.); **Tommy Atkins** (30 aver.); **Parvin** (20 aver.); **Palmer** (20 aver.)
Kensington Pride (KP) (3)	**Keitt** (16 aver.; 37 maximum); **R2E2** (13 aver., 60 max.); **KP** (10 aver., 32 max.)
Gomera 3 (4)	**Osteen** (28 aver.); **Keitt** (25 aver.); **Kent (**16 aver**.)**
Gomera 1 (5)	**Lippens** (30aver.); **Tommy Atkins** (30 aver.); **Osteen** (25 aver.); **Keitt** (25 aver.); **Kent (**15aver**.)**
Criollo de Cholucanas (6)	**Tommy Atkins** (16 aver., 30 max.); **Kent (**18 aver., 35 max.); Haden (16 aver., 30 max.); **Keitt** (25 aver., 60 max.)
Turpentine (7)	**Tommy Atkins** (40 aver.); **Keitt** (35 aver.); **Kent (**30 aver**.); Haden** (30 aver.) **Ataulfo** (12 aver.)
Jamaica (8)	**Keitt** (20 aver., 35 max.); **Irwin** (10 aver., 18 max.); **Tommy Atkins** (10 aver., 15max.); **Haden** (6 max) (*)
Sabre (9)	**Normal density:** **Keitt** (25 aver.); **Piva (**)** (30 aver.). **Kent (**23aver.); **Tommy Atkins** (18 aver.); **Irwin** (23aver.); **Heidi** (22); **Sensation** (25 on year); 12-15 considered profitable and 25 are generally obtained by good conventional growers under irrigation **High density plantings:** **Keitt** (42); **Sensation** (40 on year); **Heidi** (38); **Kent** (38); **Tommy Atkins** (35-38)
Mexican Criollos (10)	**Tommy Atkins** (9.9 aver.); **Keitt** (7.3 aver.); **Kent (**9.2 aver**.); Haden** (8.2 aver.) **Ataulfo** (8.2 aver.); >20 for high density plantings of **Tommy Atkins, Kent y Keitt**

Source:

(1). Yuval Cohen. Israel; (2) Yair Aron Puerto Rico; (3) Mark Hoult. Australia; (4); Emilio Guirado. Spain; (5); V. Galán Saúco. Canary Islands. Spain; A. Gamarra. Peru; (7) Noris Ledesma. Florida; (8) Juan Mora. Costa Rica; (9) S. Oosthuyse. South Africa; (10) V. M. Medina Urrutia. Mexico.

(*) This cultivar is considerd not well adapted to climatic conditions at low elevations of Costa Rica. (**) There are not yield records of any cultivar under this dwarfing rootstock.

ANNEX 1. MANGO ROOTSTOCK SURVEY

Name:
Institution:
Email:
Air mail address:
Telephones (office and mobile):

1) Indicate the cultivars most planted in your country (region)

2) Indicate which cultivars are exported to other countries

3) Indicate countries to which you export mangos

4) Which are the rootstocks used in your country? Indicate if they are poly or monoembrionic.

5) Did you use the same rootstocks for all cultivars or do you have specific recommendations for any cultivar/rootstock combination?

6) What are the reasons for choosing rootstocks in your country (you can select more than one option)?
   A) Salinity tolerance
   B) Tolerance to flooding
   C) Tolerance to dry conditions
   D) Increase iron root absortion.
   E) Increase other nutrient root absortion
   F) Dwarfing
   G) Interstock (Please specify combination)
   H) Increasing yield.
   I) Increase or reduction in fruit size
   J) Tolerance to pests or diseases (Please specify)
   K) Improve of fruit quality (please specify the pursued improvement)

7) Please indicate if you have any publication (scientific, extension or other) and/or lecture or powerpoint specific for rootstocks in your country and, if available, please, email it to me or give the reference.

8) If you are working for a Research Center (private or public) or University, please answer the next questions:
   A) Are you (or anybody at your institution) conducting any research on rootstocks? If so, please indicate which one
   B) Are you (or somebody at your institution) interested in any line of research on rootstocks? If so, please indicate the subject and reasons (i.e. salinity problems, increasing yield, dwarfing, etc.) for it.
   C) If you have any rootstocks in collection or trials, please indicate it
   D) Are you interested in increasing your rootstocks collection?
   E) Are you interested in future cooperative trials in mango rootstocks?

9) Add any comments you wish

ANNEX 2. LIST OF INTERVIEWED PEOPLE

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