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Avocado rootstocks: What do we know; are we doing enough research?

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ABSTRACT

The rootstock is the hidden (and often forgotten) half of the tree. It supplies water and minerals, and through hormonal interactions participates in overall root : shoot : fruit controlling mechanisms. Tree vigour is strongly influenced by the rootstock, with increasing evidence for effects on fruit quality and even anthracnose tolerance. Selected clonal rootstocks in particular adapt the tree to soil stresses, the most important of which are Phytophthora root rot, poor soil aeration and high acidity in the humid subtropics, and salinity and calcareous soils in drier environments. The over-reliance of the South African industry on the Mexican germplasm clonal rootstock 'Duke 7' is a cause for concern, so that the commercial release of 'Merensky 2/ Dusa' (also Mexican) by MTS is to be welcomed. Breeding and selection programmes in California, Israel and South Africa are briefly reviewed, and Whiley's newly started Australian programme outlined. A case is also made for selected Guatemalan germplasm (e.g. 'Velvick') in the humid subtropics. A range of 4 to 5 elite rootstocks, with potential for ameliorating more than one soil stress, while having commercial resistance to root rot and enhancing horticultural attributes of scion cultivars, should be our target over the next 10 to 15 years. This should ideally involve more than one partner (currently only the important MTS breeding, importation, selection and evaluation programme). Realistically however, rootstock research is longterm, expensive, not always popular with growers and funding agencies, and reliant on commitment and assured funding.

INTRODUCTION

The rootstock (portion of the composite tree below the graft union), being largely underground is often the forgotten or neglected component of the tree. Yet it is equally important in the overall functioning of the tree, and it is true to say that the scion (portion of the tree above the graft union) and the rootstock mirror each other's health and vigour. If the scion is in trouble and unhealthy, then so is the root system, and *vice versa* – they are mirror images and inter-dependent. The rootstock's main functions are anchorage, water and mineral uptake, hormone interactions, and to varying extents storage of metabolites. Horticulturally, the most important rootstock function is to adapt the tree to soil stresses.

Each rootstock has genetically determined characteristics – and every seedling rootstock differs somewhat from others grown from seed. Hence variability is passed to the scion cultivar grafted onto it, in so far as non-genetic features of the scion are concerned. These are most commonly observed, in an orchard with seedling rootstocks, in indi-

vidual tree vigour and size, and therefore lack of orchard uniformity. However, different rootstocks will differ in ability to explore the soil for water and nutrients, in ability to take up specific mineral nutrients, and in tolerance to soil diseases, aeration, and acidity and salinity etc. It is therefore not surprising that evidence is accumulating for rootstock effects on fruit mineral content, fruit susceptibility to physiological disorders; and even fruit diseases such as anthracnose (Willingham *et al.*, 2001; Marques *et al.*, 2002).

The avocado is genetically very diverse (Lahav & Lavi, 2002; Scora *et al.*, 2002) and on a world scale rootstocks come mainly from the three botanical "races" (botanical varieties or subspecies) and their hybrids, viz. Mexican, Guatemalan and West Indian ecotypes. In the past rootstocks were selected based on availability, trial and error, and ease of propagation for nurserymen. Climate and soil considerations were also involved. California's cold winters, for example, resulted in the choice of Mexican types such as 'Topa Topa', soon found to be highly sensitive to root rot. In South Africa in the 1960's and 1970's, seedling 'Edranol' (Guatemalan type) was used, also an unfortunate choice from a Phytophthora viewpoint. The Israeli industry placed emphasis on salinity tolerance and tolerance to high lime soils, and settled on West Indian types. When selection for Phytophthora tolerance started in California, the emphasis on Mexican germplasm for rootstocks was maintained, and clonally propagated 'Duke 7', 'Thomas', 'Spencer', 'Toro Canyon' and recently 'Zentmyer' are overwhelmingly Mexican in origin. On the other hand, Australia's 'Velvick', an outstanding seedling rootstock, is predominantly Guatemalan with some West Indian genes.

Although rootstocks are the foundation of the orchard, rootstock research is longterm and expensive, and not popular with grower-based funding agencies. In fact, it is even less popular than breeding and selection of new scion cultivars. Yet evidence from the deciduous fruit and citrus industries proves the huge advances that are possible from dedicated rootstock programmes (Wutscher, 1979; Rom & Carlson, 1987). This mini-review will briefly outline avocado rootstock research worldwide, and then, in view of the comparatively large recent investment in an Australian rootstock programme (Whiley, 2002), attempt to answer the question: are we doing enough research in South Africa? The only comprehensive recent review on avocado rootstocks is that of Ben-Ya'acov & Michelson (1995), while currently used rootstocks are described by Newett *et al.* (2002).

ROOTSTOCK EFFECTS OF THE THREE RACES

Although there are differences within each race ecotype, in broad terms the following effects have been noted (Ben-Ya'acov & Michelson, 1995):

- Salinity: West Indian most tolerant; Mexican least tolerant (reduced productivity).
- Calcareous and alkaline soils: Guatemalan most sensitive to time-induced chlorosis; West Indian most tolerant.
- Poorly aerated soil: Variable responses, but Mexican more tolerant than West Indian.
- *Dorthiorella* and *Verticillium* wilts: Guatemalan more sensitive than Mexican.
- Cold: Mexican most tolerant; West Indian least.
- Heat: West Indian most tolerant; Guatemalan least.

On a worldwide basis, Mexican rootstocks appear to dominate, including the clonal 'Duke 7'. This is mainly because California set the pace, and being concerned with cold winters, selected Mexican germplasm. Later, when Phytophthora root rot tolerance was sought, Mexican types were again the most selected. This is in spite of sometimes serious soil salinity problems, which led to selection mainly from West Indian germplasm in Israel. Nowhere was Guatemalan germplasm widely used, although South Africa used 'Edranol' seedlings before 'Duke 7' became

prominent. In Australia however, the predominantly Guatemalan (but with some West Indian genes) 'Velvick' has proven to be an excellent rootstock in the humid subtropics. It imparts vigour, productivity and good fruit quality to the scion (including improved boron uptake), and is tolerant of Phytopthora root rot (Whiley, 2002).

THE MOST IMPORTANT ROOTSTOCK BREEDING / SELECTION PROGRAMMES

Due to the difficulties already mentioned, very few countries have initiated, and more importantly persisted, with large-scale and well-funded rootstock improvement programmes.

California

California has led the world in breeding for rootstock tolerance to *Phytophthora cinnamomi* root rot, especially since the 1950's. The main researcher until the 1990's was Zentmyer, along with Bergh and for a time Coffey. Mexican seedlings were screened for P.c. tolerance, and cloning of the selected rootstock types by the Frolich (Brokaw) technique (Frolich & Platt, 1972) was commercialized in 1977. The most successful clonal rootstock has been 'Duke 7', also widely used in South Africa. The 'Martin Grande' ('G755') series of clonal stocks has some genuine Phytophthora root rot resistance, but imparts high vigour to the scion cultivar thus delaying onset on heavy bearing (Kremer-Köhne & Köhne, 1992). It may have a place on poor, shallow or sandy soils, but would be disastrous for heavy clay, high organic matter, old banana land soils such as occur on diabase (as opposed to granite derived) plateaus in the Kiepersol / Burgershall area (Wolstenholme *et al.*, 2002). Other promising clonal rootstocks from this programme are 'Thomas', 'Barr Duke' and 'D9' (Ben-Ya'acov & Michelson, 1995; Whiley, 2002).

Since 1993, the California programme has been continued by Menge and co-workers (Menge,1998). It has continued with the evaluation of past selections, as well as new hybrids, concentrating on Mexican germplasm. The aim has been for improved root rot tolerance. New hybrids of 'Spencer', 'Thomas', 'Toro Canyon' and other breeding lines are being evaluated, with 'Zentmyer' the best to date.

Israel

A very comprehensive field rootstock programme was run by Ben-Ya'acov and co-workers from 1968 to 2001, with the close co-operation of many growers. The programme emphasized seedling selections until 1988, based on tolerance to soil stress factors, and on tree productivity determined from tree yield records. Soil stress factors are salinity, calcareous (high Ca) soils, poor soil aeration on heavy clay soils (grumusols), and, since the early 1980's, Phytophthora root rot. Notable differences in the effects of various seedling (and later clonal) rootstocks were found, and inferior rootstocks were gradually eliminated. Clonal propagation advances made possible the "copy-tree" programme, in which the rootstocks of outstanding trees were recovered and tested. The Israeli programme's main achievement has been the tailoring of rootstocks to specific soil stress factors and environmental conditions. By 1995, 20 clonal rootstocks (the VC series) had been released, and been proven superior for three cultivars (Ben-Ya'acov & Michelson, 1995). However, Homsky (2002) notes that Israeli demand for clonal rootstocks is still limited, due to high cost and lack of experience. Recent demand is mainly for seedling selections such as 'Deganya 117', 'Ashdot 17' and 'Tsrifin 99', all West Indian types, and seedlings of 'Waldin' and 'Fairchild' cultivars.

South Africa

The ITSC rootstock programme ran from 1992 to 2000, with Bijzet and co-workers giving regular reports in SAAGA Yearbooks until funding was withdrawn. The major objective was root rot tolerance, and over 40 000 open-

pollinated seedlings were screened. The developmental stage was completed in 1999 (Bijzet, 1999). With funding difficulties faced by ARC Institutes, it is a great pity that this programme is now in limbo.

Fortunately however, Merensky Technological Services (MTS) started a rootstock programme in 1993, with experimental orchard blocks planted in 1996 and 1998. The programme is similar to that of Menge in California, in that mainly Mexican germplasm is used, and greater root rot tolerance is a priority. However, importations from overseas are also being tested, and yield of 'Hass' as a grafted scion is being evaluated. Regular reports have been made (Roe *et al.*, 1995; 1996; 1997; 1998; Roe & Morudu, 1999; Kremer-Köhne & Duvenage, 2000; Kremer-Köhne *et al.*, 2001; 2002). The programme was crowned with success with the 2001 commercial release of 'Merensky 2'/ 'Dusa', which has also given promising results in California. This clonal rootstock outperformed the industry standard 'Duke 7' in root rot tolerance, tree vigour and 'Hass' yield, and also performs well under saline conditions and in heavy soil.

WHAT HAS BEEN ACHIEVED WORLD-WIDE?

The desired attributes of avocado rootstocks are:

- Commercial root rot resistance.
- Adaptability to the major soil stresses.
- Good, sustainable yield of scion cultivars grafted onto them.
- Good scion fruit quality.
- Smaller, semi-dwarfed trees (manageable tree vigour).

No one rootstock can meet all requirements, so that a range of 3 – 5 elite rootstocks is needed. In relation to the above requirements, world-wide we can only claim slight to moderate root rot tolerance, although a range of experimental rootstocks are under test. Salinity tolerant West Indian based rootstocks are available for Israel. Improved productivity, at least in young trees, has been claimed for the Israeli VC series, and for 'Merensky 2'/ 'Dusa' and 'Velvick'. We have very little evidence of improvement of scion fruit quality by rootstocks, although some claims have been made for 'Velvick' in Australia. Whiley (2002) concluded that based on the investment / outcomes ratio, after 40 years of research the search for root rot resistance has only been partly successful. There is still no rootstock resistant to Phytophthora root rot, eliminating the need for fungicides. Resistence has been found in other *Persea* species, but unfortunately in the graft incompatible *Eriodaphne* sub-genus.

THE WHILEY / AAGF ROOTSTOCK *EVALUATION* PROGRAMME

It is noteworthy that the Australian Avocado Growers' Federation is supporting a comprehensive rootstock evaluation programme by Dr. Tony Whiley, starting in 2003. The objective is to provide research data over a 10 year period for improved rootstocks for all Australian production areas, with a total cost of ca R8 mill. Currently only the initial 3-year programme (R1.5 mill.) has been approved. This for an industry only about one-third the size of South Africa's industry! The research will include recovery of "escape" rootstocks in heavily infected orchards and from documented high performing trees, as well as importation and testing of rootstock material from other countries. Selection criteria will emphasize sustainable high productivity of scion cultivars, Phytophthora root rot and trunk canker resistance, optimal fruit quality, and manageable tree vigour. Hopefully, economic benefits can be demonstrated for clonal as opposed to seedling rootstocks under Australian conditions, as clonal rootstocks are currently regarded as too expensive (Whiley, 2002; Whiley & Anderson, 2002).

THE SOUTH AFRICAN SITUATION

South African growers were amongst the first to use clonal rootstocks, and have overwhelmingly chosen 'Duke 7'. 'Duke 6' was

discarded early after a presumed virus scare; 'G6' offered no special advantages, while the 'Martin Grande' series gave excessive tree vigour on good, fertile soils. Several other Californian and Israeli clonal stocks are being tested in the MTS programme, which has also just released the very promising 'Merensky 2'/'Dusa' (Anon., 2003).

There are several problems with our over-reliance on 'Duke 7'. It was developed for Californian conditions and there have been some instances of mediocre performance. The Mexican germplasm results in relatively poor boron uptake (Whiley *et al.*, 1996), while there is evidence from Australia of higher incidences of anthracnose and some physiological fruit disorders as compared to 'Velvick' stocks (Willingham *et al.*, 2001; Marques *et al.*, 2002). 'Duke 7' is susceptible to trunk canker, is not good for replanting, and is intolerant of waterlogging (Whiley, 2002). It has served us well in a "caretaker capacity", while we search for improved rootstocks.

Evaluation of rootstocks for South Africa should also keep in mind our soil stress factors in addition to Phytophthora root rot. These are firstly poor soil aeration in high clay (more than ca 35%) soils, which aggravates root rot, limits rooting depth, and is associated with soil compaction. Secondly, our high rainfall granite and dolerite/diabase soils have high soil acidity (low pH value), low fertility (granites) unless high in organic matter, and often aluminium toxicity. Some soils with a wetness problem also have manganese toxicity. It is encouraging that 'Merensky 2' / 'Dusa' has been tested in such soils – this is the value of a home-grown evaluation programme.

MINIMUM TARGETS FOR SOUTH AFRICAN ROOTSTOCKS

In the light of the above discussion, it is suggested that our industry commit itself to a long-term programme of rootstock evaluation. Currently SAAGA has a 7 year, partial financial support commitment to the MTS programme, with several years yet to run. There are reasons to wonder if this is sufficient, including the apparent cessation or at least suspension of the Israeli programme with the retirement of Ben-Ya'acov; and possible uncertainties about California as Menge approaches retirement. A local ITSC programme may be too much to hope for under current financial constraints, although willing researchers are still available.

I suggest the following minimum targets for South African rootstocks, taking a 10 to 15 year timespan:

- Four to five proven, elite clonal rootstocks. They should be genetically diverse (both Mexican and Guatemalan ecotypes should be represented, alone or as hybrids, as well as West Indian types from Israel tested). Commercial resistance to Phytophthora root rot is a priority, eliminating the need for fungicides. Rootstocks should be available for different climates and soils and should promote high yield, good fruit quality, and more manageable tree size in the scion cultivar.
- There should be a continual evaluation programme of both local selections and imported material. Biotechnology advances should be monitored, allowing interspecific hybrids particularly with existing, presently inaccessible, resistant *Persea* subgenus *Eriodaphne* species.
- There should be a commitment to long-term funding (at least 15 years) for our own rootstocks breeding / selection / evaluation programme. At present we are fortunate to have the co-operation and leadership of MTS, which is achieving international success. Whether it is wise to have "all our eggs in one basket" is a moot point.
- Develop and maintain strong links with other countries, on a mutually beneficial basis. This is already happening to some extent and must not falter – we are too small and vulnerable to "go it alone". We cannot rely wholly on imported technol-

ogy and expect to remain competitive, but globalization is with us whether we like it or not.

CONCLUDING REMARKS

Rootstock research – specifically lack of it except for root rot tolerance, is a characteristic of the relatively young avocado industry in most growing regions. The avocado has however benefited from a comprehensive research base on other aspects, such that it is now one of the better understood crops in subtropical growing areas. The relatively neglected rootstock field represents an opportunity for spectacular advances – we have barely scratched the surface. Because of its long-term nature, this is not a popular research field, demanding as it does commitment, patience and not least assured funding. In answer to the question "are we doing enough", my reply would be that one can never do enough! At present we have only a short-term commitment, albeit in capable hands. I strongly believe that our Technical Committee should take steps to secure our position in the medium to long term.

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