

Reasons for the use of clonal avocado rootstocks around the world.

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In the past, some of the most limiting factors relating to successful avocado production worldwide were undeniably water quality, edaphic and climatic conditions, and the presence of *Phytophthora cinnamomi* root rot in the soil. However, some of these factors can now be managed through the use of a suitable clonal rootstock (*i.e.* vegetatively propagated). In California and South Africa the use of clonal rootstocks quickly became the norm after it was shown that selected clonal rootstocks reduced the detrimental effects of root rot, improved general tree uniformity and improved overall yield thereby increasing the profitability of the operation. Later, avocado growers in New Zealand, Australia, Spain, Kenya and Tanzania also started to adopt the use of clonal rootstocks to increase yields under specific conditions. More recently, countries which traditionally favoured seedling rootstocks such as Chile, Argentina, Brazil, Israel, Morocco and Peru have also started to investigate the potential advantages of using clonal rootstocks. In this paper the performance of clonal avocado rootstocks in several countries will be discussed. It is understood that the future development of clonal rootstocks will largely depend on the production of consistent high quality trees which fulfil the unique needs of each avocado growing region such as tolerance to *Phytophthora cinnamomi* root rot, salinity, hypoxia, high carbonates and good performance when replanting orchards. However, while conditions may differ between countries the common goal with clonal rootstock use remains increased productivity.

Key words: *Phytophthora cinnamomi*, seedling rootstocks, clonal rootstocks, hypoxia.

Razones para el uso de portainjertos clonales de paltos alrededor del mundo

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En el pasado los factores más limitante en lo que se refiere a una exitosa producción de aguacates a alrededor del mundo fueron, sin duda, la calidad de agua, condiciones edáficas y climáticas, y la presencia de *Phytophthora cinnamomi* en los suelos. Sin embargo, muchos de estos factores se pueden manejar mediante el uso adecuado de portainjertos clonales (propagados vegetativamente). En California y Sudáfrica el uso de portainjertos clonales rápidamente se transformó en la norma después que se demostró que determinadas selecciones reducían el efecto detrimental de la pudrición de raíces, mejoraban la uniformidad del huerto y mejoraban la productividad y por ende la rentabilidad general del cultivo. Más tarde, agricultores de Nueva Zelanda, Australia, España, Kenya y Tanzania también partieron adoptando los portainjertos clonales para incrementar rendimientos bajo condiciones específicas. Recientemente países con portainjertos de semillas favorables, tales como Chile, Argentina, Brasil, Israel, Marruecos y Perú también han empezando a investigar las ventajas potenciales del uso de portainjertos clonales. En este artículo se va a discutir el comportamiento de portainjertos clonales de aguacates en distintos países. Se entiende que el desarrollo futuro de portainjertos clonales va a depender en gran parte de la producción consistente de plantas de alta calidad que satisfagan las necesidades únicas de cada región productora de aguacates y su buen desempeño bajo condiciones de replante. Sin embargo, mientras que las condiciones pueden diferir entre los distintos países, el objetivo común con el uso de portainjertos clonales sigue siendo el aumento de productividad.

Palabras clave: *Phytophthora cinnamomi*, portainjerto de semilla, portainjerto clonal, hypoxia.

Introduction

The main problem in using sexually propagated seedling avocado rootstocks is the high genetic variability between avocado seeds. "A batch of seedlings grown from seeds taken from one tree may be quite variable from another but, if batches of seeds are taken from widely different trees the resulting seedlings are certain to vary much more widely" (Webber, 1926). It is because of this that the different selections made in the past showed variable behaviours under similar conditions. Since the cloning technique was developed by Frolich and Platt and subsequently modified and improved for commercial production by Brokaw Nursery in 1977 and other nurseries later (Newett, Crane and Balerdi, 2007) avocado rootstock breeding has become more important because it allows the transfer of beneficial characteristics from one plant to another. "According to evidence available relating to some other tree crops, uniform tree size and production are obtained only when the scion variety is grown upon rootstocks that are within themselves genetically identical. Also included in these data is evidence of a wide range in susceptibility to disease, tolerance of soil conditions, resistance to insects, quality of fruit, length of productive life, and other factors. It is a matter of record that the avocado industry is not the first to have suffered "economic pain" as a result of the character variance of seedling rootstocks" (Gillespie, 1954).

Today exciting clonal rootstocks are being planted both under commercial and trial conditions in different countries around the world. Because each growing region has its own characteristics and limiting factors there is the necessity to continue testing the already commercial rootstocks and new selections in different areas and under different conditions, as well as continuing to breed new rootstocks that help us overcome limiting situations. "Frequently, soil stress factors act together, sometimes synergistically, such as root rot and poor aeration or root rot and salinity, or sometimes antagonistically, such as root rot and lime. The breeder should take into account actual combinations of factors and select rootstocks for them, and not for one individual factor. The most frequent combinations are root rot and salinity, salinity and lime-induced chlorosis, salinity and poor aeration, root rot and poor aeration, and root rot and acidity" (Ben-Ya'acov and Michelson, 1995).

Successful Experiences

In United States the first avocado breeding program was started in the 1940s and it was based on productivity, but when *Phytophthora cinnamomi* root rot (PRR) was discovered to be a death threat to the industry in California, George A Zentmyer started to focus his interest on the selection of rootstocks resistant to this disease, interest that has continued until present times (Whiley et al., 2007). Some trees with some resistance to PRR were found, and this aroused interest in developing a technique that allowed the cloning of avocado rootstocks (Brokaw, 1987). The moderately resistant Duke 7 cultivar was selected from this program. "Duke 7 became the first *Phytophthora* resistant rootstock to be commercially accepted" (Smith, Dann, Pegg, Whiley, Giblin, Doogan and Kopittke, 2011). An example of another interesting selection found in California is 'Borchard', a rootstock selected from an escape tree, that has been found to have no resistance to PRR, but it has good performance when planted in alkaline soils (Brokaw, 1987).

PRR is also a major avocado disease in the main growing areas of South Africa, where the planting of avocados is limited mainly to frost-free areas with well drained deep soils. High rainfall is usually experienced in these areas, and it is concentrated during the warm summer months, conditions that are favourable for the fungus to develop. It is because of these climatic and edaphic factors that some PRR-resistant rootstocks (including 'Duke 7') were imported from the breeding program in California in 1962; it was found that it gave major advantages in its moderate tolerance to PRR and its growth uniformity (Roe, Kremer-Köhne and Köhne, 1995). This aroused interest in the use of clonal rootstocks in South Africa, and Westfalia Technological Services began testing avocado rootstocks as one of its main research activities. By tabulating yield records per tree, in a few years they were able to select their own rootstock candidates, propagated from outstanding trees under local conditions (Smith and Köhne, 1992, Smith, 1993, Ben-Ya'acov and Michelson, 1995). Some selections were found to be successful at various test sites, in particular the rootstock selection Merensky 2, also known as Dusa[®], which originated as a so-called escape tree (Kremer-Köhne and Köhne, 2007). The popularity of Dusa[®] has increased in recent years and is commercially available in many avocado-producing countries; it has become a standard against which other PRR-resistant rootstocks should be compared (Smith et al., 2011).

Avocado growers, both in the United States and South Africa have adopted clonal rootstocks as a norm, because, besides the benefits of being PRR-resistant, they have also given uniformity to the orchards and greater yields (Köhne, Kremer-Köhne and Mukhomo, 2004, Kremer-Köhne and Mukhomo, 2003, Menge, 2002, Roe, Kremer-Köhne and Köhne, 1997, Roe, Morudu and Köhne,

1999, Rose, 2003). In South Africa, 88% of the avocado trees sold during 2009-2010 were grafted to clonal rootstocks (Retief, 2011) and in California 90% of avocado trees sold for commercial fruit production are on clonal rootstocks (personal communication, Brokaw¹, 2011).

Based on the international experience of both WTS and Brokaw Nursery and conversations with role-players in the avocado industries of different countries, two groups can be made to describe the situation of clonal rootstocks in the remaining avocado producing countries: 1) those that have also started using clonal rootstocks in commercial plantings, but where their use is still not generalised, such is the case of New Zealand, Spain, Australia, Kenya, Zimbabwe and Tanzania, where they are seen as an opportunity to increase yields under specific limiting conditions; and 2) the countries where the commercialization of clonal rootstocks is very limited or nonexistent, but where some trials have been established, such as Chile, Argentina, Brazil, Israel, Morocco and Peru.

Countries with commercial planting experience but not yet the rule

In New Zealand, the main limiting conditions are the presence of *P. cinnamomi* and low temperatures. Therefore, the interest in clonal rootstocks is focused on resistance to PRR and cold temperatures. There are at least two nurseries selling clonal rootstocks in New Zealand and we have found that interest in the use of clonal rootstocks from growers is increasing (personal communication, Dixon², 2009.) Since June 2009 until June 2010 about 47.000 avocado trees were sold, and 20% of these were on clonal rootstocks, mainly on Duke 7 and Dusa (Personal communication, NZANA³, 2011)

In Spain, the limiting factors are mainly the presence of *P. cinnamomi* and *Rosellinia necatrix*, a disease that attacks avocado roots and is a serious problem. Rootstocks with resistance to *R. necatrix* have not been found, but efforts are being made to select survivor trees from infected orchards. Clonal rootstocks in this country have been commercially available since 1999. More than a 30% of the avocado trees sold in Spain every year are on clonal rootstocks (personal communication, Rob Brokaw⁴, 2011).

In Australia, "the main soil problem is the presence of PRR. Most of the soils in southern Queensland and northern New South Wales are acidic (pH 4.5 to 5.8) and infertile (Young, 1992). Drainage is good, but sometimes the soils are heavily saturated for extended periods during the wet season" (Ben-Ya'acov and Michelson, 1995). There is one commercial avocado nursery currently propagating the majority of clonal avocado rootstocks sold in Australia. Of the 50.000 to 60.000 trees sold by them per year 6.000 to 10.000 of these are clonally propagated avocado rootstocks of various varieties. These figures have remained relatively static throughout the past 10 years. The remainder of the rootstocks are all seedlings (personal communication, Australian Nurserymen's Fruit Improvement Company⁵, 2011.)

Kenya, Zimbabwe and Tanzania have similar conditions to South Africa, where PRR is a big problem, and larger growers routinely order commercial batches of avocado trees on clonal rootstocks from nurseries in South Africa. During the 2009-2010 season, 14% of the avocado trees produced in South Africa were exported, mainly to other African countries (Retief, 2011).

Limited or nonexistent experience

In Chile the limiting factors are soil quality (presence of salts and carbonates), root asphyxia and replant conditions. A major investigation into the use of clonal rootstocks in Chile was started in 2002 by researchers from the Plant Propagation Laboratory at the Agronomy Faculty of the Pontificia Universidad Católica de Valparaíso, Chile under the project name of "Horticultural Evaluation and Propagation of New Avocado Rootstocks and Cultivars in Different Agro Climatic Areas of Chile", with results such as the better performance (more Kg/m³ of canopy and a smaller alternate bearing index) of clonal avocado rootstocks compared to seedlings, and the better behaviour of clonal rootstock Dusa[®] under asphyxia conditions have been obtained (personal communication, Castro⁶, 2011). A few nurseries are making clonal trees in small amounts. About 15,000 trees are expected to be sold during

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the 2011-2012 season, but growers are starting to see the difference in uniformity when compared to seedling rootstocks. It is believed that in the future, the need to replant avocado orchards will bring about a higher demand for clonal rootstocks which can better handle the tree health challenges of replanting of old avocado orchards with new avocado trees.

The main limiting factor in Brazil is PRR and there is a trial with clonal avocados in Sao Paulo region, the main growing area. It has been suggested that there are very aggressive races of PRR in Brazil, because in commercial orchards trees with a rating of 10 on the Ciba-Geigy scale have been found. Additionally, most of the avocado orchards were previously planted with citrus or are close to citrus orchards, so *Phytophthora citricola* is also present, causing damage on the trunk and on the collar area (personal communication, Cantuarias⁷, 2011). The main interest in Brazil is to find a rootstock that can be a solution for both of these pathogens.

In Israel extensive rootstock breeding programs have been conducted because “the need for a highly salt tolerant rootstock is great since the water used in most avocado groves will range from 150 to 350 ppm of chlorides” (Gustafson, 1969). Some selections, mainly of the West Indian race, have been found which have shown to be more salt tolerant, but the use of clonal rootstocks on a commercial scale is still very limited. It is estimated that 5% of the total avocado trees planted in Israel are on clonal rootstocks (personal communication, Volcani Center Extension Officers⁸, 2011).

Argentina, Morocco and Peru are still very new in the use of clonal rootstocks. In Argentina only 300 trees on clonal rootstock are planted at Guayal’s farm, which is the only company producing clonal trees in the country. Their observations are a higher uniformity when compared to seedlings and they are considering using clonal rootstocks for all their new plantings (personal communication, Orell⁹, 2011). In Peru and Morocco some small trials have been recently established but no results are presently available.

Conclusions

Different reasons have been considered for the use of clonal rootstocks around the world, such as resistance to PRR, alkalinity and salinity. However, once growers have adopted this technology, they have discovered that the benefits of uniformity of trees and greater productivity pose significant additional incentives for the adoption of clonal rootstocks.

Given the increasing number of rootstocks available today and expected in the future from ongoing breeding efforts, it is expected that growers will be presented with ever increasing options not just for enhanced tree survival, but also for improved productivity in the presence or absence of problematic soil conditions. However, while conditions may differ between countries the common goal with clonal rootstock use remains increased productivity.

The main obstacle for the establishment of clonal avocado rootstocks worldwide is the difficulty of making a good quality tree. The cloning method differs in many senses from the traditional one used for growing seedlings, as well as the establishment stages. It is mandatory to get the best tree quality so they can show their best potential and not be misjudged.

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⁹ Enrique Orell, Guayal S.A., PO Box 5, Provincia de Tucumán, Argentina.

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