

Avocado rootstock evaluation techniques over the last 30 years

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Abstract

The South African avocado industry was originally based on seedling rootstocks. However, by the early 1970's the industry was crippled by the presence of *Phytophthora cinnamomi* root rot (PRR) in the soils of most of the main production areas. This led Westfalia Estates to import the first clonal rootstocks from California (e.g. 'Duke 7'), and based on the success of 'Duke 7' the advantage of a superior rootstock was soon realised. In fact by the early 1980's Westfalia Estates had started their own screening and selection process to identify more PRR tolerant rootstocks. Westfalia Technological Services (WTS) is today one of the few organisations worldwide involved in long term rootstock breeding, screening and evaluation. While their Merensky 2 (Dusa®) clonal rootstock is now sold internationally, the technique used to identify and verify its potential was the culmination of many years spent perfecting the technique. This paper will highlight a few of the techniques used over the years beginning with "spoke trials" in the field, where new selections were planted around PRR infected trees, to a more sophisticated screening method under controlled conditions in a mistbed inoculated with *P. cinnamomi*. The paper will outline the lessons learnt and will explain the importance of rigorous field testing. The paper will finally describe the WTS method used to screen thousands of seedlings annually and will shed some light onto why it takes at least 25 years to develop a commercially successful new rootstock.

La industria aguacatera sudafricana originalmente se basó en portainjertos de semilla. Sin embargo, a principio de 1970's la industria se vio amenazada por la presencia de *Phytophthora cinnamomi* (Pc) en suelos de las zonas productoras. Esto llevó a Westfalia Estates a importar los primeros portainjertos clonales desde California (Ej. Duke 7), y basándose en el éxito de Duke 7, la ventaja de un buen portainjerto fue evidente en poco tiempo. De hecho, a principios de 1980's Westfalia Estates comenzó su propio proceso de evaluación y selección para identificar portainjertos tolerantes a Pc. Westfalia Technological Services (WTS) es hoy una de las pocas "instituciones" alrededor del mundo involucradas en mejoramiento, investigación y evaluación de portainjertos a largo plazo. Mientras su mayor éxito, Merensky 2 (Dusa®), es vendido internacionalmente la técnica utilizada para identificar (y verificar) su potencial fue el resultado de muchos años de perfeccionamiento. Este artículo destacará algunas de las técnicas usadas a lo largo de los años comenzando con "ensayos hablados" en terreno, donde nuevas selecciones se plantaron alrededor de árboles infectados con Pc, a evaluaciones más sofisticadas en camas de ensayos. El artículo va a hacer énfasis en las lecciones aprendidas y explicará la importancia de un riguroso ensayo en terreno. Por último, se va a describir el método que WTS utiliza para evaluar miles de selecciones anualmente y dará alguna idea de porqué puede demorar hasta 25 años comercializar una nueva selección.

Key words Avocado, rootstock, *Phytophthora cinnamomi*, root rot, tolerance, Hass, production, Dusa® (Merensky 2), evaluation, screening

Introduction

In the 1970s, avocado root rot caused by *Phytophthora cinnamomi* severely impaired the South African avocado industry which was then based on seedling rootstocks of varied origin. The propagation and use of clonal avocado rootstocks started in the late 1970s when first vegetatively propagated rootstocks were produced at Westfalia Estate (W.E. Maddison¹, personal communication, 2005). Field evaluation of imported and locally selected root rot tolerant rootstocks was undertaken under South

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African growing conditions to establish genetically uniform and productive avocado orchards. This paper highlights a few of the techniques used over the years and outlines lessons learnt in the expensive, long-term rootstock development process prior to releasing a rootstock selection commercially.

Field evaluation of rootstocks of different origins

In South Africa, new rootstocks were often evaluated in replanted avocado orchards infected with *Phytophthora cinnamomi* (Kremer-Köhne & Duvenhage, 2000). For field tests conducted by Westfalia (previously Merensky) Technological Services (WTS), a minimum of 24 replicate trees per rootstock selection were grafted with 'Hass' and planted in a randomized block design. While Edranol seedling rootstocks were used as susceptible controls, the then current commercial clonal rootstock was also included in the rootstock evaluation orchard; this was previously 'Duke 7' (1996-2002) and is currently 'Dusa[®]'. Harsh conditions were created by not applying any root rot control treatments in the evaluation orchard from 1996 to 2010. This concept, however, needed to be revised. New trees are now to be protected from *Phytophthora* during the establishment period so that they can begin to grow vigorously and have the opportunity to express PRR tolerance once control measures are discontinued (Smith, Dann, Pegg, Whaley, Giblin, Doogan & Kopitke, 2011). All factors aiding young tree growth should be combined when establishing an experimental orchard: planting on mounds, post-plant fungicide applications and precise management, especially careful irrigation.

In early trials individual tree yields were recorded, and data on cumulative yields collected. Tree condition was rated at the end of winter (July), according to a disease index of zero (healthy) to 10 (dead) as described by Darvas, Toerien & Milne (1984). For tree size determination, trunk circumference was measured 20 cm above the ground level annually. Further observations on new rootstock selections included their susceptibility to diseases such as stem canker caused by *Phytophthora* species, their compatibility with the 'Hass' scion and their ease of propagation. This initial field evaluation took four to six years before rootstock selections with potential moved on to a larger scale pre-commercial evaluation.

Imported clonal rootstocks. The devastation caused by *Phytophthora cinnamomi* root rot (PRR) necessitated the importation of root rot tolerant rootstocks ('Duke 6', 'Duke 7', 'G6', 'G755', 'Thomas', 'D9' and 'Barr Duke') from California for vegetative propagation and evaluation under South African growing conditions in the 1970s. The Duke 7 rootstock generally out-performed the other imported avocado rootstocks evaluated in South Africa and therefore became the industry standard rootstock in South Africa for many years. Setbacks were experienced with the inferior performance of the Duke 6 and G755 rootstocks planted on commercial scale along side with 'Duke 7' at Westfalia Estate. After a few years the trees on 'Duke 6' started dying due to an unidentified disease associated with stem pitting, while 'G755' imparted excessive vigour to the scion, particularly when grafted with 'Hass' (Kremer-Köhne & Köhne, 2007). These experiences emphasized the need for thorough evaluation of rootstocks prior to planting them on a commercial scale. New rootstocks are imported continuously from various countries and evaluated under South African growing conditions. However, so far none of them has outperformed the commercial standard 'Dusa[®]'.

Westfalia survivor trees. In the 1980s, several survivor trees on seedling rootstock were identified in diseased South African avocado orchards. The seedlings were of West Indian, Mexican and Guatemalan origin, thus providing a comprehensive genepool for selection. Rootstock shoots were induced on these trees, the material propagated and then evaluated in field trials. Initially, spoke trials were conducted where new selections were planted around PRR infected trees and evaluated (W.E. Maddison¹, personal communication, 2005). Later on, field trials were laid out as described above, and the Westfalia rootstock selection Dusa[®] (Merensky 2) out-performed 'Duke 7' with regard to tree health and yield at various test sites. Data collected in South Africa, California, Australia and Chile over many years show that the rootstock Dusa[®] is significantly more PRR tolerant and more productive than 'Duke 7' (Roe, Kremer-Köhne & Köhne, 1997; Roe, Morudu & Köhne, 1999; Menge, 2002; Kremer-Köhne & Mukhumo, 2003; Rose, 2003; Smith et al, 2011; M. Castro², personal communication, 2011). 'Dusa[®]' is of Guatemalan x Mexican origin (T. Chao³, personal communication, 2002), and shows a good measure of

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tolerance to cold winters (D. Smith⁴, personal communication, 2005) as well as high salinity conditions (Menge, 2002; Crowley, 2004). In recent years, the situation in terms of the preferred clonal rootstock has changed considerably in South Africa and some other countries such as California. There has been a rapid increase in the popularity of the Westfalia rootstock selection Dusa[®], and a strong decline in the popularity of 'Duke 7'. Since 2002, the newly released rootstock Dusa[®] has been made available to avocado growers in several countries.

Westfalia super trees. These were obtained from specific 'Fuerte' trees on seedling rootstock identified at Westfalia Estate in the early 1990's, which consistently produced very high yields (Smith & Köhne, 1992; Smith, Köhne & Schutte, 1993). As a high production potential may be due to the rootstock, the scion or the rootstock/scion combination, rootstock shoots were induced on twelve high yielding trees by exposing roots to sunlight and girdling. Subsequently the super tree rootstocks were vegetatively propagated using standard avocado nursery procedures and screened in the mistbed for their tolerance to PRR as described below. The three best selections were then grafted with 'Hass', planted in a field trial and evaluated from 2003 to 2007. All three selections were in poorer condition and had a smaller trunk circumference than 'Dusa[®]'. As these promising selections were evaluated under very harsh conditions and many trees died within the first year after planting, they are now evaluated at other sites where they are being protected from *Phytophthora* during the establishment period. Their performance in terms of PRR tolerance and yield is to be monitored once PRR control measures are discontinued.

Avocado rootstock breeding

The requirements for superior new rootstocks can be defined clearly as tolerance to PRR and potential to produce high yields. Concurrently with the large scale selection program focusing on avocado productivity, the avocado rootstock breeding program at WTS was initiated in the early 1990's (Kremer-Köhne *et al.*, 2001). The only other breeding program exists at the University of California Riverside. The avocado rootstock breeding block contained 20 different rootstocks which have shown superior performance under PRR pressure (e.g. 'Duke 7', 'Merensky 1' and 'Dusa[®]', 'G755'). These trees were used as parent trees for breeding, and underwent open pollination. In 2010, the rootstock breeding block was re-established with a new range of PRR tolerant, genetically diverse rootstocks to increase the success of the breeding program (Douhan, Fuller, McKee & Pond, 2011). Pollen from commercial avocado cultivars was excluded from the breeding block by the remoteness of the breeding block from commercial orchards.

Seedlings from the breeding block were screened for their tolerance to PRR by exposure to a virulent strain of *P. cinnamomi* in a mistbed under controlled conditions. The cotyledons of the seedlings were removed three weeks before planting the seedlings in the mistbed to exclude their influence on the screening results. The seedlings were then planted in vermiculite inoculated with *P. cinnamomi*. It should be noted that the mistbed should have a roof to protect the plants from rain as careful irrigation of the mistbed is required to avoid waterlogging conditions. After six weeks, a visual evaluation of the root system of each seedling for PRR symptoms took place, and all seedlings with less than 60% healthy roots were discarded thereby culling over 99% of the initial plant material within the first year in this screening system. Selected seedlings with healthy roots were then vegetatively propagated using standard avocado nursery procedures and re-tested (10 of each) in the mistbed in comparison to 'Duke 7' (2000-2002) and 'Dusa[®]' (from 2003 onwards) clonal commercial rootstocks. Rootstocks with better root health than 'Duke 7' and 'Dusa[®]' respectively were selected in the second mistbed screening, vegetatively propagated using standard avocado nursery procedures and grafted with 'Hass' for field trials to confirm their PRR tolerance and evaluate their yield potential. The timescale for developing a superior rootstock in the WTS rootstock breeding and selection program is shown in Table 1. First promising rootstock selections are presently being evaluated in larger scale field trials in which high potential selections are heralding a new level of rootstock performance in terms of yield and tree health not achieved previously.

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Table 1. Timescale of the WTS rootstock breeding and selection program

Procedure	Year
Breeding block: pick fruit	1
Mistbed: screen seedlings for P.c. tolerance	2
Nursery: propagate selected seedlings	3
Mistbed: retest 10 copies per selection	4
Field trial: establish best selections grafted with 'Hass'	10
Pre-commercial plantings of best selections with good production potential	17
First commercial plantings in production	25

Conclusions

In many avocado-growing countries virgin soil for planting avocado orchards is limited, and production can only be increased by replanting old avocado orchards which are often infested with *P. cinnamomi*. This requires rootstock selections tolerant to PRR. The Westfalia rootstock breeding program continues to generate and evaluate new selections of rootstocks with the ultimate aim of increasing the profitability of avocado farming. Promising new Westfalia rootstock selections with the potential to outperform the PRR tolerant 'Dusa[®]' are presently undergoing stringent field tests. Further, these new Westfalia rootstock selections are also sent to various international research collaborators (e.g. University of California Riverside, The Catholic University of Valparaiso, Chile) during the early stage of their development to test their productivity/suitability for a wider range of conditions than found in South Africa (e.g. salinity, *Rosellinia* root rot, and calcareous soils). It is Westfalia's aim to select and produce other high potential rootstocks, such as 'Dusa[®]', which can adapt to a wide range of needs, beyond those found in South Africa.

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