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25 YEARS OF AVOCADO ROOTSTOCK DEVELOPMENT AT WESTFALIA, SOUTH AFRICA

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SOCIEDAD GARDIAZABAL Y MAGDAHL LTDA.

Introduction



- Merensky Technological Services is the research & development department of Hans Merensky Holdings (HMH) which also own Westfalia
- The farm Westfalia is situated in the subtropical areas in the Limpopo Province of South Africa, where most of the country's avocados are grown
- Hans Merensky Holdings currently has \pm 1100 ha of avocado under production



Westfalia

1. Westfalia rootstocks: from seedling to super clonal



- West Indian & Mexican race seeds introduced \pm 100 years ago
- By the late 1920's mainly Mexican seedlings were used as rootstocks
- These were more hardy and slightly less vigorous than the West Indian seedling trees

In the 1930's, Dr Hans Merensky planted first avocado orchards at Westfalia. Many years later, the Hans Merensky Foundation was established with the aim ...

*"... to promote and assist in the **development** of the resources of South Africa and neighbouring territories - particularly such **natural resources as soil, water, minerals, flora and fauna and welfare of the inhabitants**; more specifically by **research and demonstration** and through the correlation and **application of scientific knowledge.**"*



1950's

- Guatemalan seedling rootstocks used (Edranol & Nabal)
- High susceptibility to *Phytophthora cinnamomi* resulted in poor yields
- Orchard life \pm 12 years

1960's

- Duke seedlings used as rootstocks



- Plantings at \pm 100 trees/ha
- Thinned to \pm 50 trees/ ha to accommodate very large trees
- Very low yields / ha due to wide open spaces between & inside trees

The devastation caused by Pc in avocado orchards in many countries was the turning point & research focused on finding resistant or tolerant rootstocks



California

- The predictability of genetically uniform, root rot tolerant, productive trees was a distinct advantage over the variability of the seedling rootstocks
- California looked to clonal rootstocks for the solution... and we looked to California
- Hence clonal rootstocks were introduced into SA from California in the late 1970's, along with some costly lessons to be learnt...



Westfalia had land to develop & these Pc tolerant clonals seemed just the answer



- In the early 1980's Hass orchards with alternate rows of Duke 6 & Duke 7 rootstocks were planted on a large commercial scale
- Both rootstocks were said to be tolerant to Pc & non-vigorous
- After 2-3 years trees on Duke 6 started dying showing symptoms of stem pitting
- The disease was never identified but thought to have been caused by infected Duke 6 budwood
- About 100 ha of orchards were destroyed along with the mother trees & Duke 6 no longer exists in South Africa
- Duke 7 turned out to be a successful rootstock for the time being, providing uniform, productive & reasonably healthy orchards

Survivor Trees

- In the late 1970's, several extraordinarily healthy & productive survivor trees were identified in diseased seedling orchards on Westfalia Farms
- To induce the rootstock the Fuerte scion was cut off from the best performing of these trees
- The rootstock shoots were then used to produce clonal trees that were introduced into the rootstock evaluation program



- The 1980's saw Westfalia's revolutionary phosphorous acid injections bringing great relief as a means to control root rot
- This led to a planting boom & further rootstocks could be introduced for evaluation in the search for a superior rootstock
- G6, G755, Thomas, D9 & Barr Duke were brought in from California

Super Trees

Individual Tree Yield Records : kg/tree
 Record Individual de Producción par abo! : kg/aboi

| | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|-----|----|----|----|----|
| 4 | 6 | 2 | 35 | 43 | 12 | 1 | 18 | 17 | 70 | 9 | 11 | 0 | 0 | 0 |
| 8 | 9 | 4 | 16 | 11 | 5 | 10 | 5 | 16 | 15 | 7 | 33 | 24 | 17 | 0 |
| 0 | 0 | 21 | 6 | 1 | 2 | 3 | 21 | 3 | 3 | 15 | 0 | 2 | 40 | 0 |
| 20 | 5 | 2 | 4 | 24 | 0 | 2 | 0 | 1 | 47 | 55 | 39 | 1 | 8 | 0 |
| 25 | 10 | 11 | 1 | 31 | 22 | 6 | 3 | 37 | 36 | 48 | 18 | 6 | 8 | 46 |
| 4 | 7 | 21 | 3 | 2 | 37 | 39 | 17 | 15 | 48 | 39 | 31 | 41 | | |
| 12 | 0 | 2 | 8 | 4 | 1 | 10 | 25 | 24 | 45 | 30 | 57 | | | |
| 44 | 32 | 5 | 16 | 31 | 9 | 3 | 31 | 0 | 55 | 100 | 38 | 34 | 69 | 16 |
| 26 | 35 | 42 | 49 | 35 | 50 | 13 | 0 | | | | | | | |
| 24 | 8 | 26 | 21 | 0 | 10 | 16 | 37 | 72 | 35 | 58 | 23 | 47 | | |
| 0 | 0 | 4 | 2 | 5 | 5 | 2 | | | | | | | | |
| 3 | 11 | 5 | 3 | 35 | 24 | 14 | 6 | 7 | 38 | 0 | 0 | 0 | 0 | 0 |
| 4 | 10 | 9 | 2 | 34 | 29 | 46 | 32 | 31 | 15 | 41 | 61 | | | |
| 11 | 57 | 33 | 35 | 0 | 16 | 53 | 0 | 1 | 10 | | | | | |
| 1 | 0 | 26 | 11 | 25 | 34 | 12 | | | | | | | | |
| 10 | 0 | 0 | 0 | 25 | 31 | | | | | | | | | |

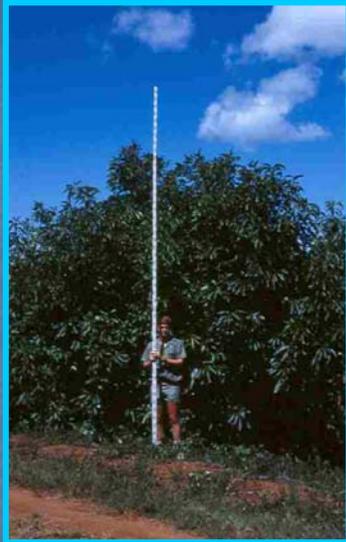
While evaluating these imported rootstocks, Westfalia also identified super trees with continually high yields in seedling orchards



- Some of these super trees could be manipulated to produce suckers from the rootstock
- The suckers were used to make clonal copies of these trees
- These copies were then introduced into the rootstock evaluation program alongside the imported rootstocks



Subsequently various rootstock test sites were established at Westfalia



Hass / Duke 7



Hass / G755 (Martín Grande)

CUMULATIVE PRODUCTION (YEAR 1 - 4)

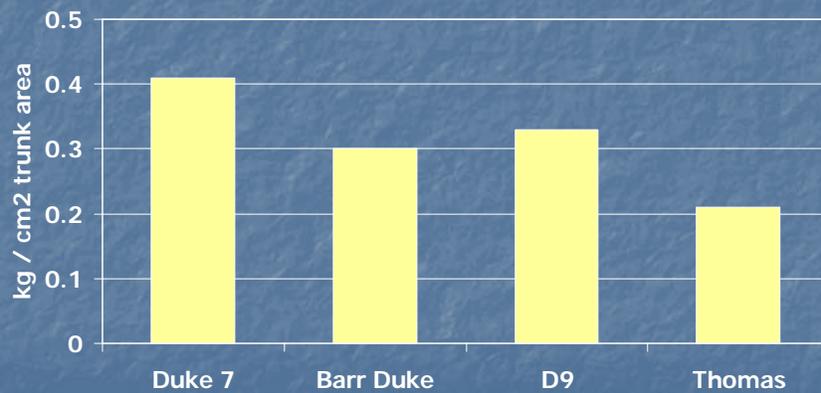
| CULTIVAR | ROOTSTOCK | YIELD (t / ha) | INCOME * (R) |
|----------|-----------|-------------------|-----------------|
| FUERTE | DUKE 7 | 3.4 | 5100 |
| | G6 | 2.2 | 3300 |
| HASS | DUKE 7 | 18.4 | 27600 |
| | G6 | 7.2 | 10800 |
| | G755 | 4.4 | 6600 |

* R 1500 / t

| | |
|--------|----------------|
| FUERTE | 200 TREES / HA |
| HASS | 400 TREES / HA |

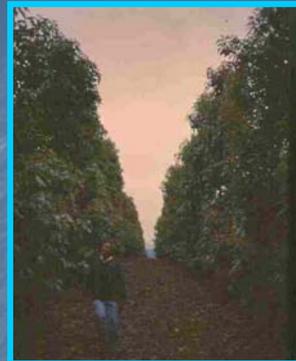
Kremer-Köhne & Köhne, 1992

Yield efficiency of Hass on different Californian clonal rootstocks in years 6-8, averaged over three sites at Westfalia Estate (Roe, Morudu & Köhne, 1999)



First Generation Clonal Rootstocks

| Rootstock | Results in South Africa |
|-----------|--|
| Duke 6 | Stem pitting and die back |
| G6 | Tolerance to Pc similar to Duke 7 but less productive |
| G755 | Moderate resistance with very poor production & excessive vigor |
| Thomas | Good tolerance to Pc but disappointing yields |
| D9 | Very slow growth rate resulting in small trees, yields satisfactory but not superior to Duke 7 |
| Barr Duke | Lower vigor than Duke 7 with production only slightly higher than Thomas |
| Duke 7 | Best clonal rootstock in the 1980's and 1990's |



The trend was shifting away from low density low yielding Fuerte to high density high yielding Hass. Vigor was no longer a concern as pruning & growth retardants were being introduced. These factors had to be considered when evaluating new rootstocks.



So what was required from this superior rootstock we were looking out for?

- High yields of Hass scion
- High tolerance / resistance to Pc, excellent tree health
- Good initial vigor to establish quickly & easily
- Uniformity in the orchards
- Easy rootability in the nursery & good graft take

Effect of grafting on susceptibility of rootstocks to *Phytophthora cinnamomi*

| Rootstock | Grafted to Hass | Ungrafted |
|-----------|---|-----------|
| | Length of lesion (mm) caused by <i>P. cinnamomi</i> | |
| Duke 7 | 15.7 a ¹ | 8.5 de |
| G6 | 12.5 abc | 7.1 ef |
| G755 | 11.6 bcd | 4.1 f |

¹ Mean values in each column followed by identical letters are not significantly different at P=0.05 according to Duncan's Multiple Range Test.
Data taken from Botha & Kotze (1989)

MTS Rootstock Breeding & Selection Program to generate new rootstocks

- Breeding Block : 20 rootstocks Year 1
- Seedlings screened in Pc mistbed Year 2
- 10 copies / selection re-tested Year 4
- Best selections (with Hass) planted in field trial Year 10
- Commercial recommendation Year 20
- First commercial plantings producing Year 25



Promising Selections Cloned

Rootstock Field Evaluation

- To date >30 rootstocks evaluated from many countries
- Origin of rootstocks:
 - selections from MTS Breeding & Selection Program
 - imported plant material
 - SA rootstocks of survivor & super trees

Rootstock Field Evaluation

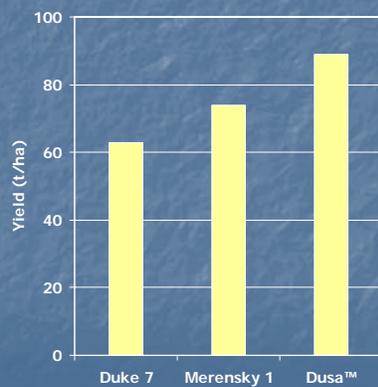


Groenkloof

- 24 to 30 trees / rootstock planted in randomised block design
- All trees grafted to Hass
- Initially Duke 7 used as control, now Dusa™ (Merensky 2) used
- Evaluated for minimum of 6 years
- Orchards established in 1996, 1998, 2000, 2003

25 Years of Rootstock Development

Cumulative yields of Hass trees on Westfalia rootstocks (1996-2004)



- ±US \$2 million invested in the program to date
- Dusa™ (Merensky 2) released to several countries recently
- More than 200,000 Dusa™ (Merensky 2) planted in South Africa & USA in the past 2 years

2. Commercial Hass plantings on Dusa™ (Merensky 2) rootstock in South Africa



Alternate rows of Hass / Dusa™ & Hass / Duke 7
at Westfalia, two years after planting



Hass / Dusa™ two years from planting



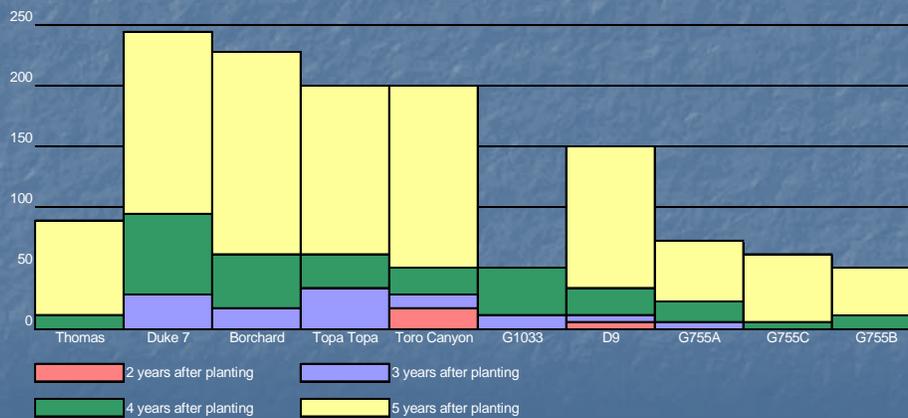
| Rootstock selection | Scion | No of trees | Planting date | Tree Health* | Total Yield | Harvest Date | Observations |
|------------------------|--------|-------------|---------------|--------------|-------------|--------------|---------------------------------------|
| MERENSKY II CONTROL | HASS | 354 | OCT'99 | 0 | 15,065 | AUG'02 | 20% INCREASE IN YIELD VS DUKE 7 |
| DUKE 7 | HASS | 1,188 | OCT'99 | 0 | 10,166 | AUG'02 | |
| MERENSKY II | FUERTE | 140 | SEPT'99 | 0 | 2211 | MAY'02 | 47% INCREASE IN YIELD VS DUKE 7 |
| DUKE 7 | FUERTE | 226 | SEPT'99 | 0 | 1,902 | MAY'02 | |

Feedback from Kakuzi

3. Rootstock field plots in California (Menge *et al.** 2004)

*J.A. Menge, G.A. Zentmyer, B. McKee, E. Pond, M. Crowley, M. Clegg,
B. Faber, G. Bender, P. Mauk, M.L. Arpaia, T. Chao, V. Ashworth

"First Generation" Rootstocks



“Second Generation” Rootstocks in California

- 30 field plots, about 6000 trees in total
- Dusa™ (Merensky 2) was introduced into California as part of a 20 year study on Pc resistant, high yielding, saline tolerant rootstocks
- Year 9 of 20 / 2001 : “It appears we have several rootstocks performing better than our standard resistant variety, Thomas. These are Merensky 2 (SA), Merensky 1 (SA), Uzi ... We have obtained first yield results and Merensky 2 appears to provide excellent yields & has been released to growers.” (Menge *et al.*, 2001)



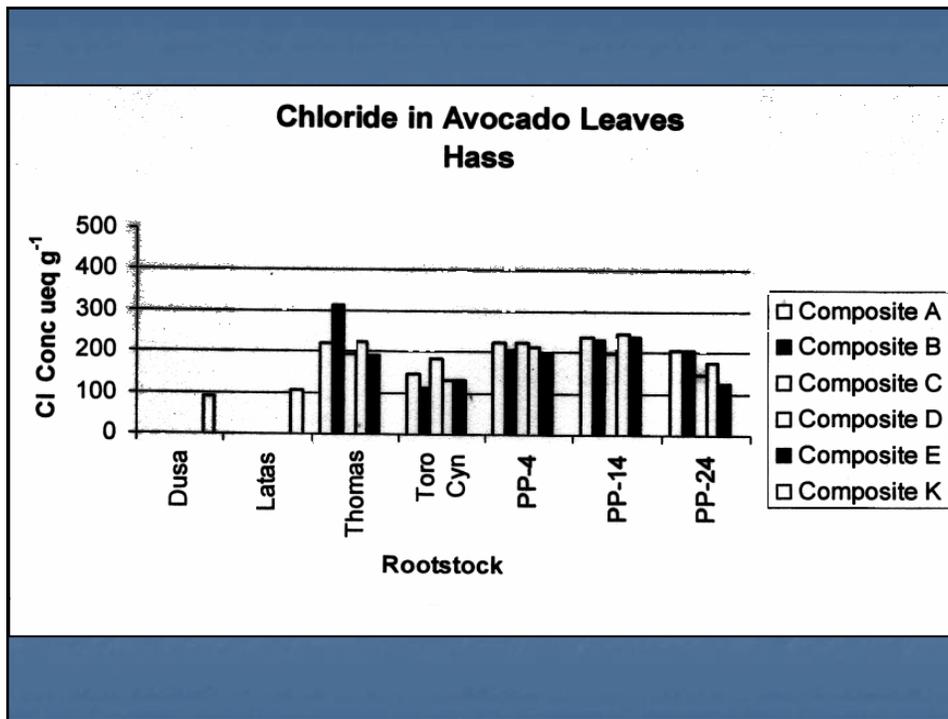
Dusa™ (Merensky 2) planted in
Phytophthora-infested soil,
California 2002 (3 years old)

Fruit yield of Hass avocados growing on various rootstocks in Escondido, CA, 2002

| Rootstock | Yield/tree (kg) | Individual fruit weight (kg) |
|---------------------|-----------------|------------------------------|
| Rio Frio | 24.7a | 0.19abc |
| Zentmyer | 21.0ab | 0.23a |
| Merensky II (Dusa™) | 18.6ab | 0.21ab |
| Uzi | 18.3ab | 0.18abc |
| Merensky I | 18.0ab | 0.16abc |
| Spencer seedling | 17.0ab | 0.17abc |
| Steddom | 16.6abc | 0.17abc |
| Thomas | 15.0abc | 0.17abc |
| VC241 | 12.2abcd | 0.20abc |
| Leo | 11.3bcd | 0.15abc |
| Spencer clonal | 11.3bcd | 0.14bcd |
| G755A | 9.6bcd | 0.12cd |
| Guillemet | 8.4bcd | 0.20abc |
| Duke 7 | 3.9cd | 0.13bcd |

Rating of Hass avocado on various rootstocks in Escondido, CA, 2003.

| Rootstock | Tree rating (0-5; 5=dead) | Canopy volume Cu ft | Trunk diameter cm |
|---------------------|------------------------------|------------------------|----------------------|
| Merensky I | 0.00d | 551ab | 10.7a |
| VC241 | 0.06d | 281efgh | 8.0abc |
| Rio Frio | 0.07d | 362efcd | 8.7abc |
| Zentmyer | 0.07d | 410bcde | 9.2ab |
| Merensky II (Dusa™) | 0.18d | 532abc | 9.4ab |
| Spencer seedling | 0.36d | 263efgh | 6.9bc |
| Uzi | 0.38d | 669a | 10.6a |
| Steddom | 0.39d | 478bcd | 8.6abc |
| Thomas | 0.47cd | 367cdef | 8.4abc |
| Leo | 0.77bcd | 274efgh | 7.3abc |
| Guillemet | 0.83bcd | 190ghi | 6.2bc |
| Duke 7 | 1.34bc | 127hi | 8.8abc |
| Spencer clonal | 1.44b | 211fghi | 5.3c |
| G755A | 1.69b | 322defg | 7.0bc |



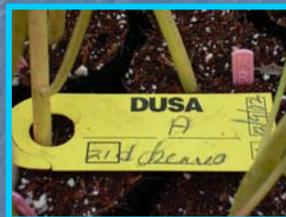
Leaf analysis of chlorine on Hass avocado growing on various rootstocks in Escondido, CA, 2002

| Rootstocks | Chlorine (ueq/g ¹²) | Rootstocks | Chlorine (ueq/g ¹²) |
|----------------|------------------------------------|---------------------|------------------------------------|
| Uzi | 16.79a | VC241 | 8.92de |
| G755A | 13.21b | Spencer seedling | 8.26e |
| Steddom | 12.96b | Duke 7 | 8.06e |
| Leo | 12.77b | Merensky I | 5.10f |
| Thomas | 11.83bc | Poly N | 4.51fg |
| Spencer clonal | 10.79bcd | Merensky II (Dusa™) | 4.35fg |
| Zentmyer | 10.78bcd | Rio Frio | 2.39g |
| Guillemet | 9.74cde | | |

Effect of various rootstocks on Hass avocado yield at South Coast Field Station, Orange Co., 2001 and 7-year-average.

| Rootstock | Yield/tree (kg) | |
|-----------|-----------------|----------------|
| | 2001 | 7-year-average |
| Dusa™ | 85.03 a | 27.05 a |
| Duke 7 | 68.92 b | 22.88 b |
| Thomas | 66.84 bc | 18.20 cde |
| UCR 2003 | 66.55 bc | 21.50 bc |
| Borchard | 59.65 bc | 19.40 bcd |
| Duke 9 | 58.34 bcd | 18.16 cde |
| Queretaro | 54.38 bcd | 16.78 de |
| Spencer | 52.54 cd | 12.82 f |
| UCR 2011 | 43.73 d | 15.54 ef |
| CRI-71 | 9.61 e | 3.04 g |

- Only release of UCR tested avocado rootstocks since 1994: Dusa™ (Merensky 2)
- Brokaw Nursery California: Master Licensee of Dusa™



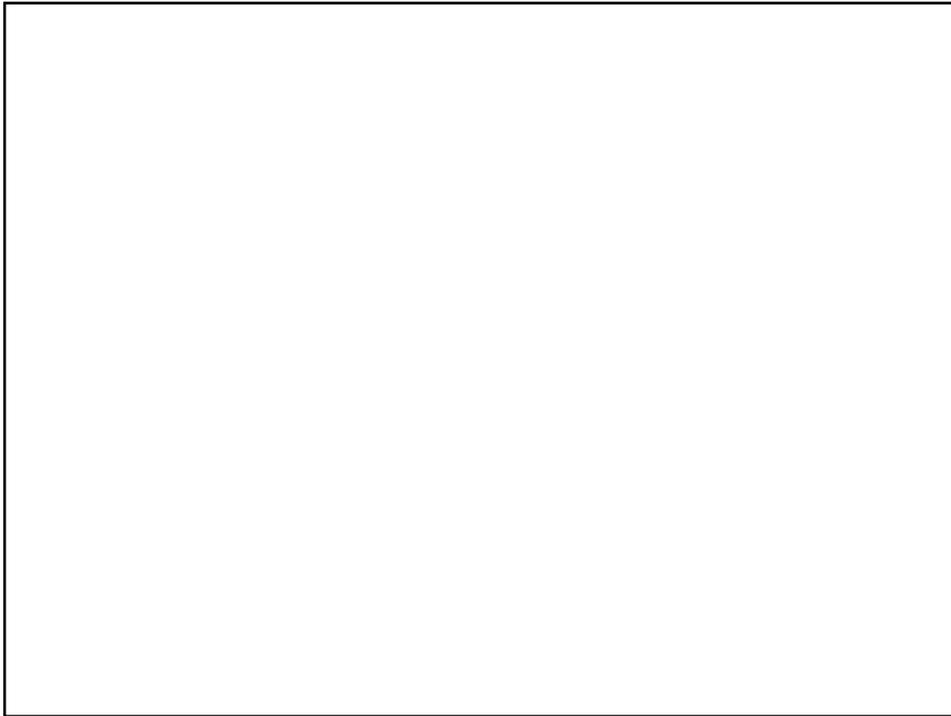
The Future

- The avocado rootstock Dusa™ has been imported into Chile and is presently propagated by licensed nurseries. The first plantings of the rootstock Dusa™ are imminent and we are hopeful that the superior results achieved in South Africa and California will be repeated in Chile.
- Not only have we through selection and thorough testing released a proven superior rootstock, Dusa™ (Merensky 2), but we are striving to assist the avocado industry with even better alternatives
- Presently Merensky Technological Services have 5 new promising clonal rootstocks under field evaluation at Westfalia.
- We look forward to sharing our exciting breakthroughs with you in the future

Merensky Technological Services:
Our Technology Bears Fruit!



THANK YOU

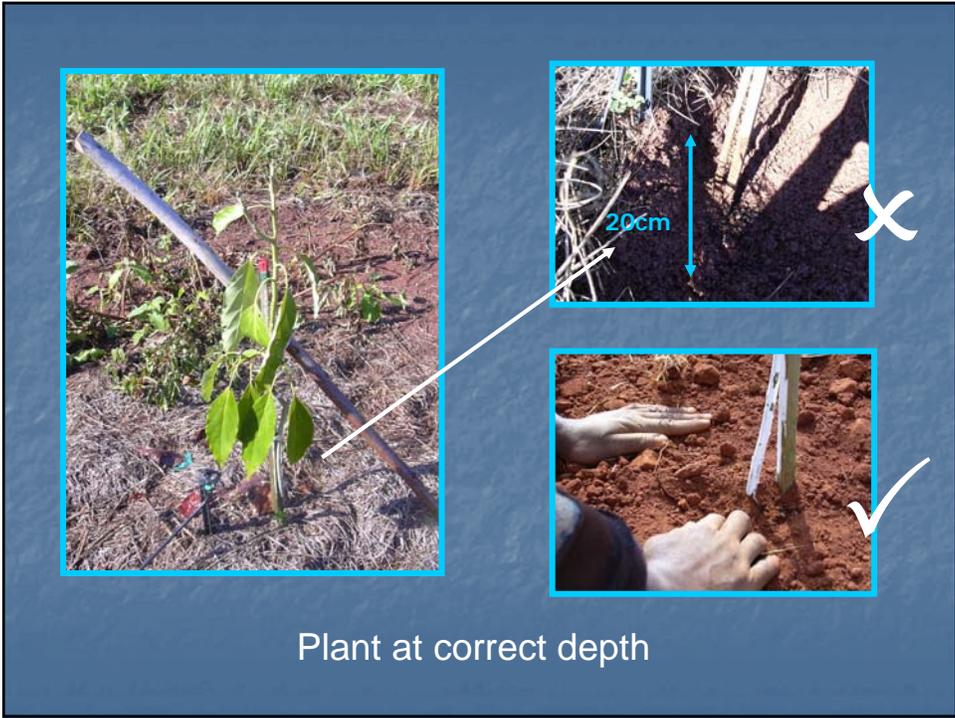


Growing with clonals : caution & care



Mpumalanga

Hass / Duke 7 both planted Dec 2002 – photo taken March 2003





Protection from buck & insects



Protection from sunburn



Apply mulch



Support tree



Chemical control in replant situations

| Rootstock | Origin | Results |
|-----------------------|-------------------------|---|
| G6 | Seedling selection | Tolerance to Pc similar to Duke 7 but less productive |
| G755 | Hybrid | Moderate resistance with very poor production & excessive vigor |
| Thomas | Survivor tree | Good tolerance to Pc but disappointing yields |
| D9 | Irradiated Duke budwood | Very slow growth rate resulting in small trees, yields satisfactory but not superior to Duke 7 |
| Barr Duke | Seedling of Duke 6 | Lower vigor than Duke 7 with production only slightly higher than Thomas |
| Colin V-33 | Dwarf scion cultivar | Used as interstock to impart lower vigor – no growth retardance noted in South African growing conditions |
| Dusa™ (Merensky 2) | Westfalia | Outperforms Duke 7 in terms of Pc tolerance & Hass production, tolerant to salt, released in 2001 |
| Merensky 1 | Westfalia | Better Pc tolerance than Duke 7, production promising, not released |