SEARCHING FOR "PARADISE" IN THE AVOCADO GERMPLASM

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SUMMARY

Genetic resource collections are important to the future security of fruit industries. Without research to locate, preserve, characterise and develop these resources they will be lost to future generations of avocado (*Persea americana* Mill.) growers and consumers. Dwarfing rootstock programmes rely on continued access to wild germplasm and to more formal collections in field gene banks. Such research provides an economic incentive to maintain and expand these collections. Strategies and progress on characterising traits potentially useful for identifying dwarfing genotypes in the avocado germplasm are discussed in this paper.

KEY WORDS: *Persea* Clus., dwarfing rootstocks, genetic resources, stem anatomy.

INTRODUCTION

The international avocado (*Persea americana* Mill.) industry is based upon relatively few cultivars when compared with other tree fruit industries. This suggests that only a small part of the *Persea* genetic resource has been developed and that it is even more important to protect and develop wild germplasm for this crop. Fruit and rootstock breeding programmes contribute to this process.

Initial selections in fruit breeding programmes are usually based on visual traits easily identified in the field. With rootstock breeding programmes, the process is more complex. Without reliable phenotypic or physiological markers, it is necessary to use propagated rootstocks (clonal or seedlings) to screen for dwarfing genotypes. This process requires an extended evaluation period and is reliant on a long-term commitment to the maintenance of the original genetic resource in both *in situ* and *ex situ* collections. This paper describes some of the strategies used in dwarfing rootstock programmes and the importance of the different types of genetic resource to this research.

WHAT IS A DWARFING ROOTSTOCK?

To ease propagation of fruiting cultivars, scions are often grafted onto seedling or clonal rootstocks. Some of these scion cultivars may be **dwarf** types, typically with small leaves and short internodes. Some of the rootstocks used can also affect tree size. These rootstocks are said to be **dwarfing**. While dwarf scion cultivars may be useful as dwarfing rootstocks, not all dwarfing rootstocks are dwarf scion cultivars (Tukey, 1964; Rom and Carlson, 1987).

Dwarfing rootstocks affect tree vigour, precocity and harvest index (Webster, 1995). They result in a mature tree that is smaller than when the scion is grown on its own roots or on a standard rootstock cultivar. In this context reduced vigour may be expressed as shortened internodes or average shoot length. More usually, however, it is a result of a shorter growing period or an absence of secondary growth flushes.

Dwarf scion cultivars are typically slow growing and slow to utilise their allocated orchard space. In contrast, scion cultivars growing on dwarfing rootstocks are relatively fast growing in their first years and then with the aid of early fruiting, exhibit slow growth and reduced vigour (Rom, 1994). Trees with this combination utilise their allocated orchard space more quickly and achieve maximum harvest index earlier than the same scion cultivar grafted onto a non-dwarfing rootstock.

ARE DWARFING ROOTSTOCKS NEEDED FOR AVOCADOS?

Large tree size and inconsistent fruit yields are major cost drivers for avocado growers in most countries. Today's avocado industries are "big tree" industries with relatively low harvest index. This is especially evident in New Zealand where our free draining soils and warm humid climate promote strong vegetative growth. At the previous World Avocado Congress in Israel, Dr Homsky commented that "we cannot control avocado tree growth because we do not produce 30 $t \cdot ha^{-1}$". Dwarfing rootstocks would be a major tool for avocado growers to achieve these increased yields and improved harvest index.

In the apple industry, maximum tree height for optimum fruit yields is 4m if a gap of 2m is left between the canopies (Rom, 1994). However, this depends on tree shape and row orientation (Palmer, 1989). Typically mature tree height for avocados in New Zealand is 8 to 10 m. A combination of dwarfing rootstocks and innovative pruning systems (e.g. Stassen *et al.*, 1998) would enable avocado trees to be grown to 4m in height or less. Trees of this stature, in high density planting systems have the potential to at least double fruit yields per hectare and cut harvesting costs by two thirds. One can see evidence of this in California with the high-density plantings of 'Reed' (R. Hofshi, pers. comm.), and in Chile with the cultivar 'Bacon' (Razeto *et al.*, 1998). These examples are with compact, upright growing cultivars with numerous non-dominant sylleptic shoots along their primary growth axis (Thorp and Sedgley, 1993). While fruit breeders can select for these tree forms, it is more efficient for these programmes to focus on fruit quality attributes with harvest index as a secondary criterion. Dwarfing rootstocks would provide an option to increase the harvest index of all cultivars, even the most vigorous types.

Genetic resources

Fruit tree breeding programmes depend upon access to wild germplasm. This germplasm may be held *in situ* in biological reserves and forests or *ex situ* in field genebanks, usually attached to research centres. Both types of conservation are valid and are generally treated as complementary strategies (Pistorius, 1997). Rootstock breeding programmes can help ensure greater genetic diversity and longevity for these collections.

Most of the avocado gene banks are maintained primarily as sources of fruiting cultivars and thus tend to be focused on relatively few genotypes with desirable fruit attributes. These collections often contain few "wild" accessions and collectively represent just a small part of the genetic diversity (Smith *et al.*, 1992). Rootstock breeding programmes, however, can expect to have wider interests and thus can perform an important role in expanding the genetic diversity of collections.

Smith *et al* (1992) have expertly summarised early efforts to identify and conserve *Persea* germplasm. More recently, the efforts of Dr. Barrientos-Priego and Luis López-López in Mexico, and Dr. Ben-Ya'acov in Israel, have been extremely important to increasing the genetic diversity in avocado field genebanks (Barrientos- Priego *et al.*, 1998; López-López *et al.*, 1998). The challenge now is to continue and expand their efforts.

Dwarfing rootstocks also provide an economic incentive to work with *Persea* genetic resources and help ensure the longevity of collections. Without an economic incentive, genetic resources tend to become neglected and material lost (Smith *et al.*, 1992).

STRATEGIES FOR SELECTING DWARFING ROOTSTOCKS

Despite the long history of rootstock development in a range of fruit industries (e.g. apples, pears, citrus), there is still little knowledge of how dwarfing rootstocks affect the growth of scion cultivars (Webster, 1995). Without reliable physiological explanations, there has also been little progress towards identifying markers for dwarfing. With avocados this means that every seedling and cultivar is a potential candidate until it has been screened either as a clonal rootstock or as an interstock. In practice not all plants can be screened and various methods can be used to make the process more efficient.

Ecogeographical surveys

With apples, it is likely that all of the major dwarfing rootstock cultivars can be traced back to a relatively narrow genetic base centred around the Caucasian Mountains (Tukey, 1964). Dwarfing apples from these regions came to be known as "Paradise" apples. When searching for the avocado equivalent of the "Paradise" apple, it may be worthwhile to focus on specific regions where wild populations are located rather than just on taxonomic surveys.

Ben-Ya'acov and Michelson (1995) have noted differences in dwarfing ability among the three races of avocado. Seedlings of West Indian types, in particular the Nachlat types identified in Israel, are more dwarfing than Mexican seedlings, which are more dwarfing than Guatemalan types. These authors mention that incompatibilty of graft and environmental response may have influenced their results and suggest the work be repeated on well-aerated soils. They conclude by saying that a search for dwarfing rootstocks in the Mexican highlands may have a better chance of success. This option should be considered in ecogeographical surveys.

Dwarfing species

Confining efforts to relatively few species can also be productive when screening for dwarfing genotypes. It is essential that this material is held *ex situ* in field genebanks to ensure the identity of candidate clones. Many of the dwarfing rootstocks for citrus belong to the species *Poncirus trifoliata* including the extremely dwarfing 'Flying Dragon' rootstock (McCarty and Cole, 1982). This rootstock with its ornate twisted growth habit is likely to have originated as a mutant of a non-dwarfing genotype (Cheng and Roose, 1995). Possibly the 'Wilg' clone in South Africa is an avocado equivalent of the 'Flying Dragon' (Roe *et al.*, 1998). However, it should be noted that trees on 'Flying Dragon' rootstock are said to be slow growing and that technically 'Flying Dragon' is not a dwarfing rootstock (Rom and Carlson, 1987).

Bergh (1975) has suggested the following clones and species as possible sources of dwarfing rootstocks: 'Mt4', 'Jalna', 'Wurtz', 'Nowels', *P. schiedeana, P. floccosa, P. americana* var. *nubigeana*. Systematic evaluation of these would be worthwhile.

Some preliminary screening work of *Persea* species has been completed using root and stem wood anatomy as possible markers for dwarfing genotypes (Tables 1 and 2). This complements previous work by López-Jiménez and Barrientos-Priego (1987). Beakbane (1952) referred to a relationship between the anatomical structure of dwarfing apple rootstocks and the recorded behaviour of scions grafted on them. If a similar and useful relationship can be demonstrated with avocado then we can use this to develop a rapid screening method for seedlings before field evaluation of promising types. In our work, plants from a range of *Persea* species were grouped according to density of xylem vessels in stem and root wood; and the ratio of bark transversal area and stem or root transversal area in roots and stems. While it remains to be tested if any of these characters are useful markers for dwarfing genotypes, if consistently applied the process does ensure that a range of phenotypes is included. For example, it would be our intention to include individuals representative of a wide range of vessel density including both extremes.

Many of the "Paradise" apple clones had a natural tendency to produce adventitious roots and so were easy to propagate from cuttings (Tukey, 1964). Often it was this character that first attracted plant selectors. Plants of *Persea steyermarkii* and *Persea americana* are also known to exhibit this character and thus could be included in a screening programme for dwarfing rootstocks (Barrientos Priego *et al*., 1998; Borys, 1991).

New Zealand as a site for *ex situ* collections

Although wild germplasm may be well adapted to its native environment, *in situ* genebanks can still be at risk. Native environments are not always conducive to healthy plant growth, especially if the soils are infertile and have poor drainage, and there are pressures from local pests and diseases (e.g. *Phytophthora cinnamomi* and sunblotch viroid). In these situations, it is useful to establish *ex situ* genebanks at sites with fertile soils and low pressure from pest and disease.

The free draining soils and low salinity conditions in New Zealand promote healthy tree growth and thus would be ideal for *ex situ* collections of *Persea* germplasm. New Zealand is also free of sun blotch viroid. Although limited to cold tolerant genotypes, avocado genebanks established in New Zealand would be a secure source of clean material for international breeding programmes.

Conditions in New Zealand that promote rapid plant growth are also ideal for the development of dwarfing rootstocks. Without the confounding effect of salinity or phytophthora on rootstock performance, dwarfing genotypes could be identified in New Zealand and then provided to overseas rootstock programmes selecting for tolerance to phytophthora or salt-laden soils. This type of collaboration would also reduce the chances of slow growing, potentially dwarfing genotypes being discarded from these programmes.

Once candidate clones have been identified for inclusion in a dwarfing rootstock programme efficient and effective screening techniques are needed. This can be achieved using seedling rootstocks, especially when evaluating populations based on geographical or taxonomic groupings. Greater consistency would be achieved if all candidate clones were screened as clonal rootstocks or alternatively as interstocks. Both methods have been useful with apples (Rom and Carlson, 1987).

An important consideration here is that the scion/rootstock combinations are graft compatible. Frolich *et al*. (1958) summarised their efforts to ascertain graft compatibility in the *Persea* genus. It would be useful to incorporate these data into an international register of graft compatibility within the avocado germplasm, which could then be updated when new information became available.

Frolich *et al*. (1958) suggested two distinct graft-compatible groups in the genus *Persea*, those compatible with *P. americana* and those compatible with *P. borbonia*. These two species are representative of the subgenera *Persea* and *Eriodaphne*, respectively (Kopp, 1966). While our immediate interest is with the subgenus *Persea* and to develop rootstocks, dwarfing or otherwise, for *P. americana* and in particular 'Hass', who is to say that future fruiting cultivars will not be selected from other species and avocado relatives. These new fruiting cultivars will also require dwarfing rootstocks.

Table 1. Vessel density and ratio of bark transversal area (BTA) and stem or root transversal area (TA) of stem and root wood samples of *Persea* species held at the University of California's South Coast Research and Extension Center. (Replicated data accompanied by ± 1 s.e.)

Sample	Species	Clone	Vessels[a] (per mm²)	± s.e.	BTA / TA (%)	± s.e.
Stem wood						
	P. americana					
		'Hass'	29	± 1.6	15.7	± 1.0
		'XX3'	28	± 2.1	17.6	
		'102'	16	± 0.7	24.6	
		'46-40-22'	34	± 1.8	16.7	
		'Colin V33'	-	-	17.3	± 0.7
	P. floccosa		18	± 0.8	12.5	± 1.0
	P. longipes		46	± 3.4	20.5	
	P. schiedeana		33	± 2.8	23.1	± 0.6
	P. steyermarkii		19	± 1.2	17.0	± 3.2
	P. tolimanensis		28	± 1.7	16.0	± 0.8
Root wood						
	P. americana					
		'46-40-22'	30	± 2.5	39.2	± 6.3
		'Toro Canyon'	38	± 2.6	40.3	± 3.1
		'Thomas'	46	± 4.8	45.1	± 2.5
	P. americana x P. schiedeana	'G755A'	46	± 4.7	43.5	± 2.4
	P. schiedeana		91	± 14.5	51.9	± 4.9
	P. steyermarkii		66	± 5.8	53.3	± 2.4
	P. tolimanensis		57	± 4.6	53.0	± 5.6

[a] Data taken from SEM micrographs of transverse faces of wood samples; Adobe Photoshop was used for image management, and vessel counts were made using Optimas 5.2 image analysis software.

Table 2. Ratio of bark transversal area (BTA) and trunk transversal area (TTA) of *Persea americana* cultivars at HortResearch's Te Puke Research Centre in New Zealand. (Replicated data is accompanied by ± 1 s.e.)

Clone	BTA / TTA (%)		Clone	BTA / TTA (%)	
102	22.2		Hayes	16.8	± 1.2
Arona	18.9	± 3.7	Hellen	13.6	± 0.8
Avila	13.4		HX48	16.6	± 1.7
Booth 80	19.8		HX73	17.4	± 1.1
Christina	26.6		Kent sdlg	11.0	
Colin V-33	24.9	± 3.2	Lula	15.8	± 1.1
DD 33	12.4		Malcom	12.8	
Duke 6	17.3	± 0.4	McDonald	15.0	± 0.1
Duke 7	11.9	± 0.6	Mexicola	7.0	
Esther	17.8	± 2.7	Nabal	24.2	± 0.8
Foxley	20.0	± 0.2	Nut Purple	14.9	± 3.5
Frazer	18.1	± 1.0	Quinonez	21.3	± 3.7
Front	25.6		Reed	16.2	± 0.4
Fuerte	13.6	± 1.5	Rincon	12.7	± 0.8
G6	19.4	± 3.5	Rodriguez	23.7	± 2.5
G755A	23.8		Russel	11.3	
G755C	22.6		Ryan	11.6	± 1.8
Garlick	16.4		Semill 44	18.3	± 1.0
Green Gold	25.5	± 1.0	Sharwill	14.5	
Gwen	13.8	± 1.7	Taylor	15.1	± 5.1
H.R. Kinge	10.0		Twentyman	12.1	
H287	19.1		TX531	11.1	± 0.2
H670	15.8	± 0.4	Vista	9.2	± 1.9
Hall	16.1		Whitsell	18.8	± 1.4
Hass	13.0	± 0.6	Yamagata	19.0	± 2.3
Hass/DD33	13.4	± 0.8	Zutano	12.1	± 1.4

Screening techniques

CONCLUSIONS

Dwarfing rootstock programmes provide a good incentive to maintain and develop genetic resources. Apart from the economic value of the new cultivars produced, it is this type of research that helps to promote an active and enduring interest in the preservation of genetic resources *in situ* and *ex situ* (Smith *et al.*, 1992). Ultimately, dwarfing rootstocks will provide a long-term solution to the implementation of small-tree orchard systems for avocados. Through international collaboration we aim to develop dwarfing rootstocks for avocado and at the same time help ensure *Persea* genetic resources are available for future generations of avocado growers and consumers.

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