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Breeding and evaluation strategy on avocado

C P du Plooy, Zelda Marais and A Sippel
Citrus and Subtropical Fruit Research Institute, Private Bag X11208, Nelspruit 1200, RSA

INTRODUCTION

Although the avocado has been known to westeners for nearly five centuries, and has experienced a great deal of selection pressure over the centuries, there is still considerable potential for the improvement of the current cultivar range (Bergh, 1987). One of the highest priorities, as far as worldwide avocado research is concerned, is the substantial upgrading of both scion and rootstock cultivars, combined with Plant Improvement Schemes (Wolstenholme, 1987). Cultivars such as Gwen and Whitsell, the first to arise from controlled crosses, are indicative of the potential to improve several important traits such as precocity, high yield potential and reduced tree size, by means of a directed conventional breeding programme.

At present the cultivars developed in California form the backbone of the avocado industries of Israel, Chile, Mexico, New Zealand, and several other countries, including South Africa (du Plooy, 1991). Due to the complexity of climatic and other factors, it is obvious that South Africa cannot continue to rely on California and Florida for improved germplasm. At the First World Avocado Congress, which was held in South Africa in 1987, it was pointed out that no country which hopes to remain competitive, can do without a local breeding programme. South Africa sadly lacked in this field of endeavor (Wolstenholme, 1987).

The CSFRI considerably expanded the local breeding and evaluation programme on avocados during the past year, to establish a competitive upgrading programme based on the available information and experience from the Californian programme.

GENETICS AND BREEDING LIMITATIONS

Two steps are usually involved in the improvement of the South African fruit tree crops, namely selection of improved genotypes and their fixation by asexual propagation. Since the avocado produces only sexual seeds, and flowering dichogamy largely ensures cross-pollination, the seedlings produced by a single tree are extremely variable. In Florida, as well as California, every major commercial cultivar (with the exception of Fuerte) is a local selection. On the other hand, the popularity of Fuerte and Hass, thousands of kilometers from their places of origin, is a reflection of the remarkably wide adaptability of these two cultivars.

The pollen of the avocado is sticky and tends to clump in a mass at the opened valve until it is removed by insects, or drops with the flower. Despite the fact that some

cultivars bear flowers estimated at close to a million per tree, the number of fruit that persist to maturity is in the order of several hundreds or perhaps a thousand (Bergh, 1991).

Although hand pollination can be used to control pollination, avocado hybrids from such controlled pollinations are extremely difficult to obtain. The pollen is sparse, sticky, and difficult to collect in any quantity. Several methods of pollen collection, which are successful with other fruit, give poor results with the avocado and the use of large insects, like bees, is the most practical procedure to achieve controlled pollination (Vithanage, 1990). Since self-pollination normally occurs to a rather great extent, isozyme analysis or RFLP's must be implemented to distinguish between self and cross-pollination in the progeny of caged trees (Degani & Gazit, 1984).

Similar to most fruit tree crops, the avocado has a relative long juvenile phase, which makes the evaluation of seedlings expensive and time consuming.

Girdling may considerably increase flowering intensity of seedlings (Lahav *et al,* 1986) and positive results in this regard were also obtained locally. As would be expected from crosses of highly heterozygous parents, characteristics of the progeny vary widely, with no definite lines of demarcation. However, in contrast to most citrus progeny, several traits in the progeny of certain avocado cultivars can be related to the parents (Lavi *et al*,1990).

Growth habit has a relative high heritability and if very upright trees are used as parents, a large percentage of the progeny would be likely to have the same growth habit. Other traits that seem to be inherited in the same manner, include fruit shape, skin texture, skin thickness and seed size. However, there is still a great variability and the progeny from selfing differ markedly from their parents.

Excessive vigour and fruitfulness are not fully compatible, and excessively robust seedlings usually have little or no fruit. Tree vigour declines with inbreeding, and is restored when inbred lines are crossed. Although outstanding cold hardiness is limited to the Mexican race, there are differences in hardiness within, as well as between the races. Heat tolerance varies even more erratically than cold tolerance, and there appears to be less genetic variability.

BREEDING OBJECTIVES

Breeding objectives change as consumer preferences in fruit-size and other qualities change, and as disease and other problems increase or decrease. However, there are several general objectives which will always form part of any avocado breeding strategy (Table 1).

TABLE 1 The most important advantageous characteristics which should be part of the evaluation criteria

Fruit
★ medium size (about 250–300 g)
★ matures over a relatively short period
★ long storage life on tree
★ spherical or ovate shape (Hass-like)
★ *uniformity in shape and size*
★ medium thick skin, easy to peel, attractive
★ small seed, tight in cavity
★ favourable pulp appearance, palatability, keeping quality
★ acceptable flavour and quality
★ russeting is undesirable
★ dark skin colour
Tree
★ vigorous, with semi-dwarf characteristics
★ horizontally spreading
★ tolerant of adverse conditions
★ consistent high yield
Rootstock
★ root rot resistance
★ dwarfing characteristics
★ salt resistance
★ drought and freeze resistance
★ consistent yield

As far as scion cultivars are concerned, the tree should have a spreading, rather than an upright growth habit to reduce wind injury, facilitate spraying and reduce picking costs. The tree should be vigorous, but not to a degree where fruitfulness is impaired.

Most of the major world avocado regions are subjected to occasional freeze damage, and cold tolerance is highly advantageous. However, fruit-set that is precocious, consistent and heavy, is the most important characteristic. Consistency of production is as important as heavy overall bearing. The fruit should mature over a relatively short period, to make selective picking unnecessary. Even more desirable is a long storage life on the tree, which gives the advantage of optimum harvest timing, as well as fewer different cultivars to supply the entire marketing season.

The skin should be thick enough to protect the flesh in transit, and should peel easily. A dark skin colour (purple to nearly black) is now preferred in most markets, and fruit should be glossy, attractive and unblemished. The seed should be small and tight in the cavity with the seed coat not adhering to the flesh. After ripening, the fruit should remain in good edible condition for a reasonable length of time (14 days under 5°C refrigeration and at least three days at room temperature).

The predominant desired trait for rootstocks, is adequate resistance to *Phytophthora* root rot. Limited resistance to the fungus is known in certain lines of the avocado and the closely related *Persea shiedeana.* Since the West Indian race may have the highest proportion of trees resistant to root rot, these cultivars would be preferred breeding

parents where they will flower and fruit.

Although there is much variability within each of the three races, in general, the greatest resistance to salinity is in the West Indian race and the least resistance in the Mexican race. Pure West Indian rootstocks have not proven satisfactory in California (low winter soils), but hybrids (especially with Mexican) seem well adapted. The Borchard rootstock from Brokaw Nursery has shown high resistance to salinity.

A dwarfing rootstock, as well as some drought and freeze tolerance, could be a major benefit to the avocado industry. Although the Colin V33 selection was reported to have a significant dwarfing effect, whether used as a rootstock or as an interstock, preliminary results at South Coast Field station is not very encouraging (du Plooy, 1991). However, there are several selections (including Colin V33) available which can be used as breeding parents, to obtain more acceptable dwarfing rootstocks.

Above all, the rootstock should be conducive to consistent heavy bearing of the scion top. Dwarfing or semi-dwarfing rootstocks would definitely be desirable, since a major weakness of many avocado cultivars is excessive vigour at the expense of fruit-set. The stock should be easy to propagate, sexually or asexually, should grow vigorously and be easy to graft or bud.

A stock that enhances scion cold hardiness, as with citrus, would be highly desirable. The most important rootstock objective is resistance to *Phytophthora cinnamomi,* which is decimating the avocado industry in most countries. Resistance to salt injury and other soil deficiencies is a major trait in Israel, and may be advantageous for certain production areas in South Africa.

STRATEGY

Following a study tour to California (du Plooy, 1991), a breeding strategy for avocados in South Africa was compiled (Figure 1).

Although not explored at this stage, South Africa has a relatively large gene source from diverse origin. The recent import of several promising selections will expand the gene source to a comprehensive source of genetic variability for breeding purposes. The development of an avocado computer database on all the important traits should receive high priority. The present database is designed to direct the choice of breeding parents to specific goals. It will expand at a later stage to determine genetic heritability of specific traits.

The initial programme will emphasize inbreeding. A limited number of seedlings from controlled cross breeding, as well as open-pollination, will also be established for Phase I evaluation.

The primary evaluations are done at the Nelspruit and Burgershall research stations, mainly because these plots are within a convenient distance from the laboratory for biotechnological analysis.

The evaluation of scion cultivars is based on horticultural traits, while rapid screening of potential rootstocks for *Phytophthora,* as well as indexing for sunblotch, are done with the assistance of a pathologist. The development of molecular markers to assess

important traits at the plantlet stage (isozymes and RFLP's) would be an important advantage for the conventional breeder. Such markers would shorten the time expended on Phase 1 evaluations with considerable saving on expenditure as far as field plots and labour are concerned.

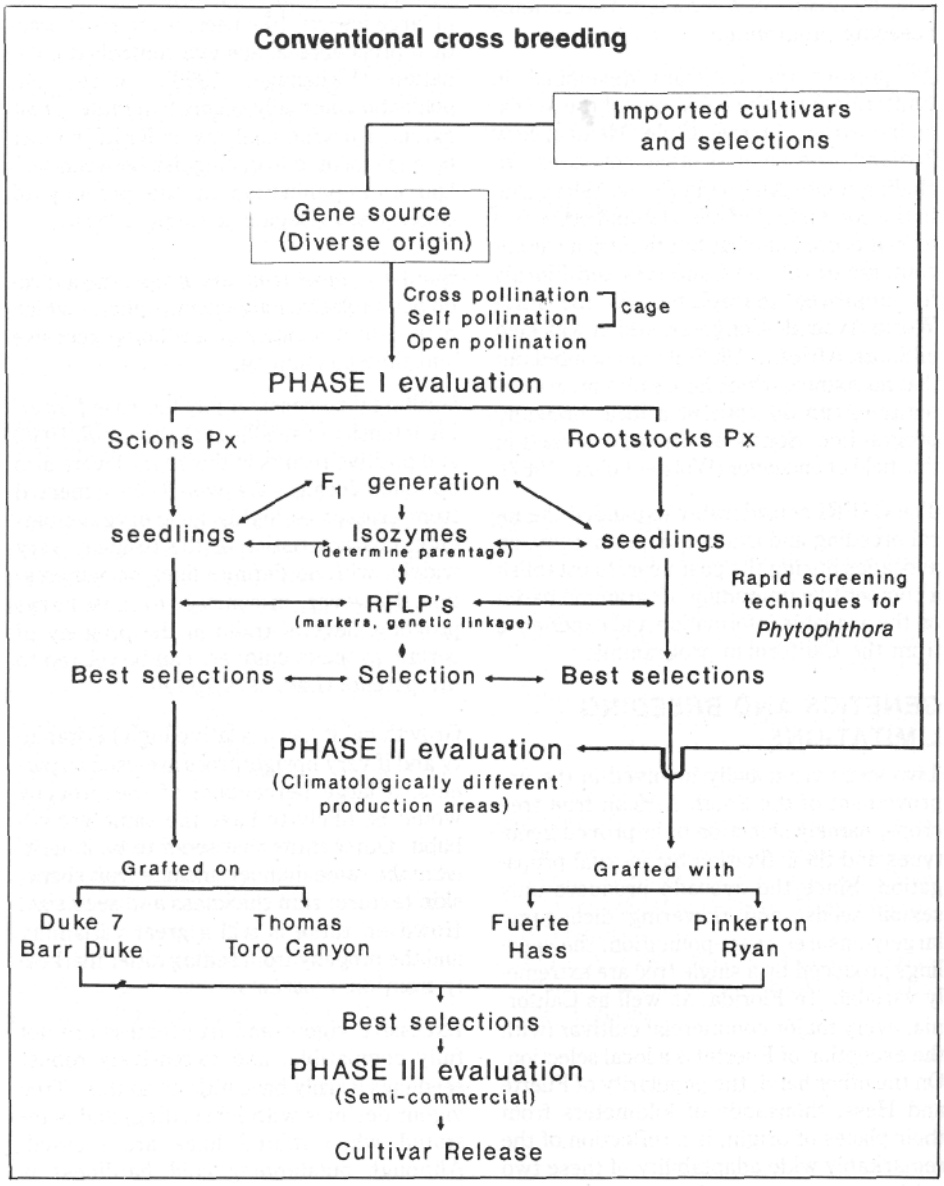

Fig 1 Avocado breeding strategy.

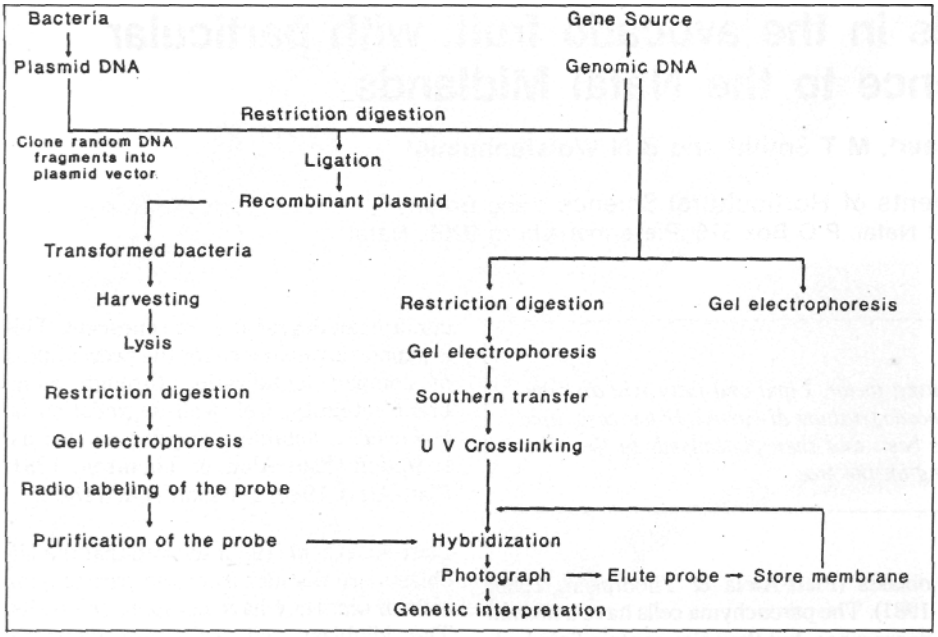

Fig 2 Restriction fragment length polymorphisms (RFLP's).

The elimination of inferior breeding parents would make the future programme far more efficient and directed, to obtain the best results within the shortest possible time. The best selections from Phase 1, as well as imported cultivare and selections, will be indexed for sunblotch and multiplied for Phase II evaluation.

Phase II evaluation is a more advanced evaluation to determine the performance of the best selections with regard to different scion/rootstock interactions and climatological adaptability. The evaluation trials will be established at the Nelspruit, Burgershall, Levubu and Letsitele research stations. The best scion selections from Phase I will be multiplied and grafted onto three rootstocks (Duke 7, Barr Duke and Thomas). Concerning the rootstock evaluation, the best selections from Phase I will be grafted with four scion cultivars (Fuerte, Hass, Pinkerton and Ryan). Descriptions of promising selections, to obtain protection of plant breeders rights, will also be accomplished during the Phase II evaluation.

Phase III is a semi-commercial evaluation of promising selections from Phase II. This part of the programme will be in close cooperation with the South African Avocado Growers' Association (SAAGA). Semi commercial evaluations of the most promising rootstocks/scion combinations will be established in different production areas (CSFRI research stations as well as private growers).

The practical implementation of modern molecular genetics and biotechnological procedures will be an integral part of the programme. This will become increasingly important as new information and methodology become available. At this stage, isozyme analysis will be implemented to determine the parentage of the F1 generation. This information will be implemented mainly in the determination of the heritability of important traits, as well as the identification of future breeding parents and the most suitable combinations for specific traits.

Restriction fragment length polymorphisms (RFLP's) will also be an important part of the Phase I evaluation. Since RFLP's are far more sophisticated, expensive and labour intensive than isozyme analysis, the primary goal will be to obtain a large number of clones (probes) that can be used as genetic markers (Figures 2). However, in cases where isozyme analysis is insufficient to determine parentage, RFLP's will also be implemented. A further advantage of RFLP's is the possibility to map the avocado genome, a prerequisite for the next step, which is the transformation of cell cultures (Figure 2).

CONCLUSION

The future of the avocado industry in South Africa is affected by some serious limitations, such as high production costs, low and alternative yield, small fruit size of certain cultivars, poor quality and transportability, as well as root rot susceptibility.

Since most of these factors are of genetic origin, the final solution will be in the development of improved cultivars. The recently implemented breeding strategy on avocados is based on the experience of a world authority in this regard, and in the near future it will be comparable to the best in the world. The expanded evaluation programme will supply information on the adaptability of local and imported selections, as well as rootstock/scion interactions in the different production areas, to ensure a competitive South African avocado industry for the future.

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