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Breeding Strategy and the Selection of Seed Parents in the ITSC Avocado Breeding Programme

Z. Bijzet & B. Cilliers
Institute for Tropical and Subtropical Crops, Private Bag X11208, Nelspruit, 1200, RSA

Abstract

The breeder can supply specific strategies to achieve the aims of a breeding programme. Some of these, such as, general combining ability, specific combining ability, cumulative effect of favourable genes, corrective mating, and repeated back crossing are briefly described. The phenomena of the interaction of genotype and environment and its implication are also discussed.

INTRODUCTION

Although the avocado has been known to the Westerners for nearly five centuries, and has been subjected to a great deal of selection pressure over centuries, there is still considerable potential for the genetic improvement of the current cultivar range (Berg, 1987).

A five-fold need for improvement of the current cultivar range is identified by Knight & Winters (1971), Slor & Spodheim (1972) and Terblanche (1988):

- low production efficiency of the available scion/rootstock combinations (this includes adverse vigour and growth habit that lowers the efficiency per unit area)
- alternate bearing
- extension of the harvest season by producing earlier and later cultivars
- the lack of resistance to devastating diseases of the scion, but more importantly, of the rootstock cultivars
- fruit quality, including low keeping quality due to physiological post-harvest disorders

The ITSC avocado breeding programme is attending to all of the above matters. Characteristics such as fruit size, yield, taste, disease resistance can all be addressed in a single cultivar. A variety of cultivars are, however, required to extend the harvest season and to maximise returns in different localities with different soils, climate regimes, etc.

Goals the avocado breeder may aspire to achieve may include:

- A Ryan with improved fruit quality and a more spreading growth habit;
- a Pinkerton with a more favourable flowering and fruitset period;

- a Fuerte with a regular, high yield and better shipping qualities; or, the most sought after scenario,
- a Hass with bigger fruit and better adapted to the South African climate.

Cultivars developed in California currently form the backbone of the avocado industries of Israel, Chile, Mexico, New Zealand and several other countries including South Africa (Du Plooy, 1991). At the first World Avocado Congress, held in South Africa in 1987, it was emphasised that no country can hope to remain competitive without a local breeding programme (Wolstenholme, 1987). This is a result of the significant effect of genotype-environment interaction on almost all quantitative characteristics. The significance of such interactions has been overwhelmingly demonstrated in all major crops of the world. It must also be pointed out that most of the production characteristics show a quantitative distribution (demonstrated in Figure 1), as opposed to a discrete distribution, for characteristics such as leaf shape, disease resistance, etc.

Inheritance and expression of quantitative characters are determined by a large number of genes. Different genotypes excel under different conditions of oil fertility, soil moisture, temperature, day length, light intensity, humidity, disease, cultural practices, or other environmental factors. These factors result in the expression of genotype-environment interaction for characteristics such as yield, fruit size, fruit quality, etc.

Because the Californian and other foreign breeding programmes can not supply in the specific needs of the South African producer, the ITSC launched a local breeding programme in 1991 under guidance of Dr. Du Plooy. Dr. Du Plooy visited California in order to draw on their experience prior to the initiation of the South African programme.

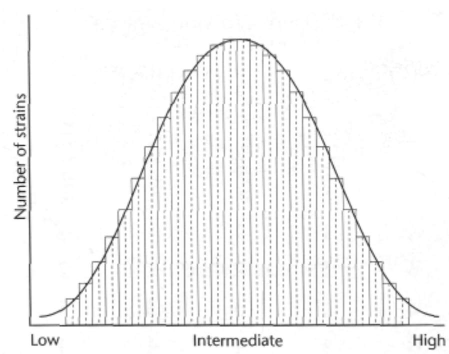

Figure 1
A normal distribution, illustrating the quantitative nature of a characteristic such as height

BREEDING STRATEGIES

Because the avocado:

- has abundant genetic variation at the disposal of the breeder,
- is a strong cross-pollinating crop,

- and can be vegetatively reproduced,

specific strategies can be applied by the breeder to achieve the aims of a breeding programme. Some of these will be briefly described.

GENERAL COMBINING ABILITY

A cultivar is said to have a good general combining ability when its progeny are generally of a good quality irrespective of its mating partner. The general combining ability of a parent genotype is determined by additive genetic effects of its genotype and determines whether a given strain should repeatedly be used in a breeding programme. A breeding parent with a good general combining ability is commonly being used in an open pollination programme. To illustrate, Berg (1987) stated that Fuerte has a low general combining ability and he decided not to use Fuerte in the open pollinated part of his programme.

Currently the gene source of the ITSC consists of 40 cultivars, 17 selections and 15 rootstocks. Little is known about their general combining abilities. Twenty-seven of these genotypes have already been used as open pollinated seed parents resulting in 5 240 seedlings of which most were planted at Burgershall. The rest were planted at Westfalia in the Tzaneen area. The breeding value of each parent will be determined as soon as these seedlings come into production. Thereafter the necessary adjustments in the pollination programme will be made.

SPECIFIC COMBINING ABILITY

Specific combining ability is shown by a particularly favourable cross between two parents that otherwise display low general combining abilities. Favourable offspring are often registered as new cultivars but usually fail as breeding parents.

CUMULATIVE EFFECT OF FAVOURABLE GENES

Exploitation of this property of quantitative genes is based on the use of two cultivars that are both outstanding with regard to the same quantitative characteristic. It is desirable to use two cultivars that are not too closely related to each other in order to minimize the number of common favourable genes in their genotypes. The progeny (F1) are planted and screened. It is often wise to intercross the F1 progeny followed by selection in the F2 generation. The above strategy is being followed when two early cultivars are being hybridised in order to select even earlier genotypes. For instance, cultivars such as Fuerte, Bacon, Ettinger and Collinson can be used in crosses to obtain cultivars earlier than themselves, or Hass, Ryan, and Reed can be used in crosses to develop later cultivars.

CORRECTIVE MATING

Corrective mating is a breeding strategy which is commonly used in animal breeding.

This is used when each of two cultivars, both exceptionally good, displays different weaknesses. The aim is to eliminate both weaknesses in the progeny while retaining other favourable characteristics. The strategy functions best when expression of the two weaknesses is controlled by a limited number of genes.

The F1 progeny is screened to uncover genotypes with all the desirable characteristics, particularly when dominant genes or genes with cumulative effects are involved. If recessive genes are responsible for favourable features, the F2 generation may have to be grown. An example of the application of this strategy in the avocado breeding programme is found in the cases of Reed and Pinkerton with a spreading growth habit (desirable) but green, whereas Hx48 and Stewart both produce black fruit, but with an upright growth habit.

REPEATED BACK CROSSING

This strategy is applied when an exceptionally good cultivar is lacking in one specific single gene. The favourable gene is often found in another, often undesirable cultivar. The aim therefore is to incorporate only the favourable gene from the unfavourable cultivar into the otherwise excellent cultivar. This process is extremely time-consuming, it extends over at least six generations and it is therefore unlikely to be used in an avocado breeding programme. However, a hypothetical example is given in Table 1 in order to explain the technique.

Table 1
Repeated back crossing

Female		*Male*
Hass	×	*Persea schiedeana*
F1	=	50% Hass + resistance
Hass	×	Hass (50%) + resistance
F2	=	75 % Hass + resistance
Hass	×	Hass (75%) + resistance
F3	=	87,5 % Hass + resistance
Hass	×	Hass (87,5%) + resistance
F4	=	99.156 % Hass + resistance
Hass	×	Hass (99,156%) + resistance
F5	=	99.578 % Hass + resistance
Hass	×	Hass (99,578%) + resistance
F6	=	99.789 % Hass + resistance

The introduction of disease resistance into the cultivar Hass (as an example) can be accomplished by repeated back crossing.

THE INTERACTION OF GENOTYPE AND ENVIRONMENT

This is not a breeding strategy but must be regarded as one of the most important phenomena to be considered in the execution of a breeding programme as it has a great influence on the structure and cost of the breeding programme. The phenomenon is explained in Tables 2 and 3.

Table 2
No interaction of genotype and environment: all the cultivars exhibit the same order for a certain characteristic in all the different growing regions

Cultivar	*Yield per cultivar*			
	Levubu	*Tzaneen*	*Kiepersol*	*Nelspruit*
A	1	1	1	1
B	2	2	2	2
C	3	3	3	3
D	4	4	4	4
E	5	5	5	5
F	6	6	6	6
G	7	7	7	7

Table 3
The interaction of genotype and environment: all the cultivars do not exhibit the same order for a certain characteristic in all the different growing regions

Cultivar	*Yield per cultivar*			
	Levubu	*Tzaneen*	*Kiepersol*	*Nelspruit*
A	1	1	3	7
B	2	3	2	5
C	3	2	1	3
D	4	5	5	4
E	5	4	7	1
F	6	6	4	2
G	7	7	6	6

In the absence of such interactions the best producing cultivar from one environment will be the best performer in all environments. Thus cultivar A will be the highest yielder in all areas followed by B, C etc. However if it is found that cultivar A performs the best in two areas, is the third best in the third area and totally drops out in the other, there is a definite genotype-environment interaction regarding the specific characteristic.

The practical implication is that newly bred material should be tested in a phase II programme in different areas in order to make accurate recommendations of cultivars suited for a given area. It might even be wise to select phase I seedlings in different areas where certain traits are sought after.

MALE PARENT CONTROL

In most of these breeding strategies (such as specific combining ability, cumulative effect of favourable genes, corrective mating and repeated back crossing) control over the male parent is desirable. The best way to ensure the identity of the male parent is by means of hand pollination. In the avocado hand pollination has proved to be impractical. Not only is the pollen sparse, sticky and difficult to collect in any significant quantity, but only several hundred of the approximately one million flowers that are borne on a single tree persisting to maturity.

A certain degree of male parent control can, however, be obtained by encaging trees. Encaged trees can consist of the two cultivars to be crossed, top worked onto one single tree or by the use of trees in pots (gigolo trees).

CONCLUSION

A variety of breeding strategies are available to the plant breeder for the improvement of his crop. With all the physical constraints experienced with regard to controlled pollination, juvenile phase, space and time, it is even more pressing to use scientific breeding methods to plan and execute a soundly structured meaningful breeding programme. Avocado breeding programmes worldwide are still very young. Little is therefore known of the breeding values of cultivars and selections. It is also important to investigate and compile a database of the properties of potential breeding parents in a breeding programme. Such information will reduce the hit-and-run component found in many programmes.

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