THE AVOCADO BREEDING AND SELECTION PROGRAM AT WESTFALIA TECHNOLOGICAL SERVICES

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SUMMARY
Avocado breeding programs are increasingly under threat and this has led to the realisation that WTS should extend their avocado evaluation program to also include an active cultivar breeding section. The WTS breeding program aims to select new avocado cultivars that are highly productive, tolerant to pests and diseases, and low storage temperatures, and have other characteristics such as improved fruit size, colour of flesh and texture upon ripening and shelf life. Specific breeding emphasis will be placed on selecting cultivars that have an early and late season of maturity. The breeding program was been divided into five phases, Phase 0 (Pre-breeding) to Phase 4 (Commercialisation). Mass selection was identified as a long-term breeding strategy to maximize long-term gains. To date efforts were focused on determining heritability, juvenility periods and precocity of various family lines. Controlled crosses of selected varieties were performed, however due to the low success rate this was identified as a minor strategy. As land availability was a challenge, seedlings were first established in 25L bags and were kept for 3-4 years. By year 3, most of the seedling trees showed stress of being pot bound. Seven hectares of land was thus reserved for the breeding program, and about 2ha was established from 2016-2018 with families from various lines. This paper summarises the journey of the WTS breeding program and outlines the challenges that remain in breeding avocados. Avocado mass selection is a long-term project with many challenges.

Keywords Avocado, heterozygosity, juvenility, pests and diseases, seasonality, nutrition

LA ESTRATEGIA DE MEJORAMIENTO GENETICO Y SELECCION DE PLANTAS OBTENIDAS POR POLINIZACIÓN ABIERTA EN EL PROGRAMA DE MEJORAMIENTO GENETICO DE WTS

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RESUMEN

Los programas de mejoramiento genético de aguacate están viéndose progresivamente amenazados, lo que ha llevado a la conclusión de que WTS debe extender su programa de evaluación de aguacate para incluir una activa sección de mejoramiento genético de cultivares. El programa de mejoramiento genético de WTS tiene como objetivo seleccionar nuevos cultivares de aguacate que sean altamente productivos, tolerantes a plagas y enfermedades, y a bajas temperaturas de almacenaje y que tengan otras características como un mejor calibre, color de la pulpa y textura al momento de la maduración y a lo largo de su vida útil. Especial énfasis se pondrá en la selección específica de cultivares de madurez temprana y tardía. El programa de mejoramiento genético ha sido dividido en cinco etapas, Etapa 0 (Pre-mejoramiento genético) a Etapa 4 (Comercialización). La selección masal fue identificada como una estrategia de mejoramiento genético de largo plazo para maximizar las ganancias a largo plazo. Hasta la fecha, los esfuerzos se han centrado en determinar la heredabilidad, los períodos de juvenilidad y la precocidad de varias líneas familiares. Se han

realizado cruzamientos controlados de variedades seleccionadas, sin embargo, debido a la baja tasa de éxito, se ha considerado como una estrategia menos relevante. Como la disponibilidad de la tierra era escasa, las plantas se establecieron en bolsas de 25 litros y se mantuvieron durante 3-4 años. Al año 3, la mayoría de las plantas mostraron estrés por haber colonizado completamente la bolsa. De esta manera, se reservaron siete hectáreas de terreno para el programa de mejoramiento genético, y desde 2016-2018 se establecieron aproximadamente 2 hectáreas con familias de distintas líneas. Este documento resume el recorrido que ha tenido el programa de mejoramiento genético de WTS y describe los desafíos que persisten en el mejoramiento genético de aguacates. La selección masal de aguacate es un proyecto a largo plazo con muchos desafíos.

Palabras clave Aguacate, heterocigosidad, juvenilidad, plagas y enfermedades, estacionalidad, nutrición

INTRODUCTION

WTS has been involved in cultivar research for many years in search of a superior cultivar to complement the traditional cultivar spread, both on a local and a global level. With avocado breeding programs increasingly under threat, this has led to the realization that WTS should extend their avocado evaluation program to also include a cultivar breeding section. Breeding a cultivar takes a long time and involves many steps.

During breeding, there are many different traits or attributes that breeders test at various stages of developing a new cultivar. Some attributes relate to the tree and how it grows, and some to physical and sensory attributes of the avocado. A new avocado cultivar would have to meet quality standards for all these attributes before it would be considered for possible commercialisation. According to Bergh (1961), during a breeding and selection programme the most important tree characteristics are precocity and a high consistent yielding ability. Thus, the main objective of the WTS breeding program is to select new avocado cultivars superior to current commercial varieties in productivity, fruit size, performance and stress tolerance. WTS aims to address the latter through:

- Breeding for resistance/tolerance to biotic stresses
- Breeding for tree traits
- Breeding for fruit quality traits

Besides the major objectives outlined above, specific breeding emphasis would be placed on identifying material and developing cultivars that have: (1) an early and late season of maturity; (2) higher yields (3) postharvest performance, and other "consumer" characteristics such as taste, improved fruit size, colour of flesh and texture upon ripening and improved shelf life. As the main commercial markets (Europe and UK) prefer a fruit with primarily Mexican heritage, fruit with similar taste spectrums would be selected. Continued emphasis would further be placed on selecting for tree traits such as precocity, and growth habits in terms of tree size and shape, plus for improved postharvest and processing qualities such as cold tolerance and low browning potential. The process of plant breeding within WTS would consist of four of the six major activities of plant breeding, being 1) collection of variation within a population; 2) making relevant selections from this population, 3) evaluating all plants with potential, and 4) releasing those with economical value.

MATERIAL AND METHODS

The development of the WTS avocado breeding program has involved different research steps.

1. Breeding method

The choice of the breeding method depends mainly on the mode of pollination, mode of reproduction, gene action and breeding objective of the crop species. In cross-pollinated crops, mass selection has contributed substantially to their improvement, particularly for characters of high heritability such as disease resistance and date of maturity (Luckett and Halloran, 2019). The breeding program at WTS will thus follow a multiple strategy approach using Mass selection as a long-term breeding strategy, to maximize long-term gains in the breeding program. Additionally, controlled crosses of selected varieties will be performed. This is to build the breeding population and to improve the phenotypic performance of an intermating population. By so doing, the frequency of favourable genes controlling traits of interest will be increased. To exploit additive gene effects, recurrent selection for recombining ability would be done as side project. But much emphasis will be placed on Mass selection.

2. Defining the breeding objectives

A small survey to establish the breeding objectives and selection criteria for avocado was conducted amongst different Westfalia teams; which included marketing, research, production and processing divisions. The participants were asked for their opinion on what breeding programs should prioritize when breeding new cultivars. In the questionnaire they were given a list of objectives and asked to rank them in the order of importance.

3. Collection of variation within the avocado population;

This is done in 3 steps. These steps are the outcome of discussions with Dr Uri Lavi (Avocado breeder, Israel).

- Identification of commercial cultivars and selections (chance seedlings) with potential as maternal sources
- Evaluation of key traits in existing cultivars; flowering time and ripening time; fruit quality traits;
- Generation of new progenies by planting out a number of seedlings from interesting maternal sources. The breeding procedure will involve open pollinations, fruit collection and seed extraction; bags in the nursery and, finally, planting the progenies in field.

Each year since 2014 a total of 1000 open pollinated seedlings from interesting maternal sources had been planted. Due to lack of land in the beginning of the program in 2014, seedlings were planted in pots with the aim of destroying the trees if they did not come into flower by the end of year 3. Manipulations with PGR's were also done when the seedlings were 1-2 years of age. In 2016, another batch of seeds was planted in the field at a spacing density of 1m x2m.

4. Assessment of seedling performance

Their evaluation is performed according to a 4-stage-evaluation which will involve phenotypic evaluation of progenies (flowering age and time, time of maturity, level of production, fruit quality traits) and preselection of interesting genotypes. The selection criteria will include parameters described by Wolstenholme and Whiley (1991) for avocado breeding.

- ***Phase 0:*** observation of the hybrid on its own roots. each progeny is individually observed on its own roots for at least 2 consecutive fruiting periods and the best ones qualifying as

'pre-selections' are then grafted onto a commercial rootstock in the second evaluation phase. The things that will be concentrated on particularly at the first stage of cultivar breeding is precocity and fruit quality

- ***Phase 1:*** evaluation of the best selections following grafting in the block. During the evaluation phase a focus is done onto productivity, fruit quality and seasonality.
- ***Phase 2:*** the elite materials are grafted onto a larger number of replications between 20 to 50 trees to assess their horticultural and commercial interest.
- ***Phase 3:*** assessment of the horticultural and commercial interest of the 'elite' accessions in small orchards of 1 Ha in different geographical areas to determine the effect of genotype-environment interaction on quantitative characteristics.

Although some traits are evaluated quantitatively by measurements, most are visually estimated. Evaluations will be done for traits as characterized by the IPGRI (1995) also known as the Biodiversity International Organisation; for flower, fruit and seed.

RESULTS

1. Defining breeding objectives

Defined breeding objectives and selection criteria may never be practiced unless the consumer perceptions and ideals are accommodated. Finding a selection criterion that are widely accepted and implemented is an overwhelming task that requires considerable time and interaction between scientists and the consumers. Results are shown in Figure 1. Overall, results showed that most consumers are of the opinion that breeding for tree traits is very important, this was followed by breeding for time of maturity, resistance/tolerance to biotic and abiotic stresses (Pests, disease). Breeding for fruit traits was equally rated as important, particularly in the early stages of breeding. Different traits for selection were also reviewed to ensure that the selection criteria would meet the breeding objectives of the consumers. The survey also revealed that 'Hass' and other black skin varieties (especially Gem) were the most preferred (Figure 2).

2. Collection of variation within a population;

A number of maternal sources were identified, and seed collected from each mother tree. Seedlings were planted in pots and kept for a period of 3 years (2014- 2017) but management of containerized seedlings became very laborious, and by year 3 most of the containerized seedlings showed severe stress of being pot bound. These were ultimately transplanted in the field at the end of 2017 in accordance with the suggestions of Dr Uri Lavi. Going forth, a sizeable proportion of the work done had been carried out in the field. The batch of seedlings established in high density (1m x2m) during the 2015/2016 season are now encroaching on each other, and thinning is required to let the light in. Further, more land (7 ha) had been reserved for the breeding program and 2 ha have been planted with seedlings from more than 40 different families since the beginning of 2018. In accordance with Dr Uri's advice, the planting density of 2m x 4m will be used in future plantings. We will continue to collect open pollinated seeds for this current cycle which will be planted out later this year.

3. Assessment of seedling performance

The previously containerized seedlings recovered very well and flowered for the first time in 2018. Seedling established during 2016 in a 2m x 1m plot also flowered in 2018 (Table 1). Manipulation with PGR's to enhance flowering did not yield any reliable results. The first phenotyping has been carried out in 2019 seedlings were evaluated for key characters such as tree architecture, size, precocity, as well as fruit quality traits. Some promising genotypes

have been observed that combine a range of desirable characteristics. The most promising selections would be grafted onto a Phytophthora tolerant rootstock available (e.g. Dusa), for detailed evaluation in Phase 1.

CONCLUSION

General objectives are mostly implemented, as we are interested in cultivars that are better than the current ones, but there is no or limited restrictions regarding fruit characteristics of new cultivars. Thus, the long-term aim of the WTS breeding program is to release new cultivars characterized by early maturing date, high productivity, high fruit quality and resistance biotic stress.

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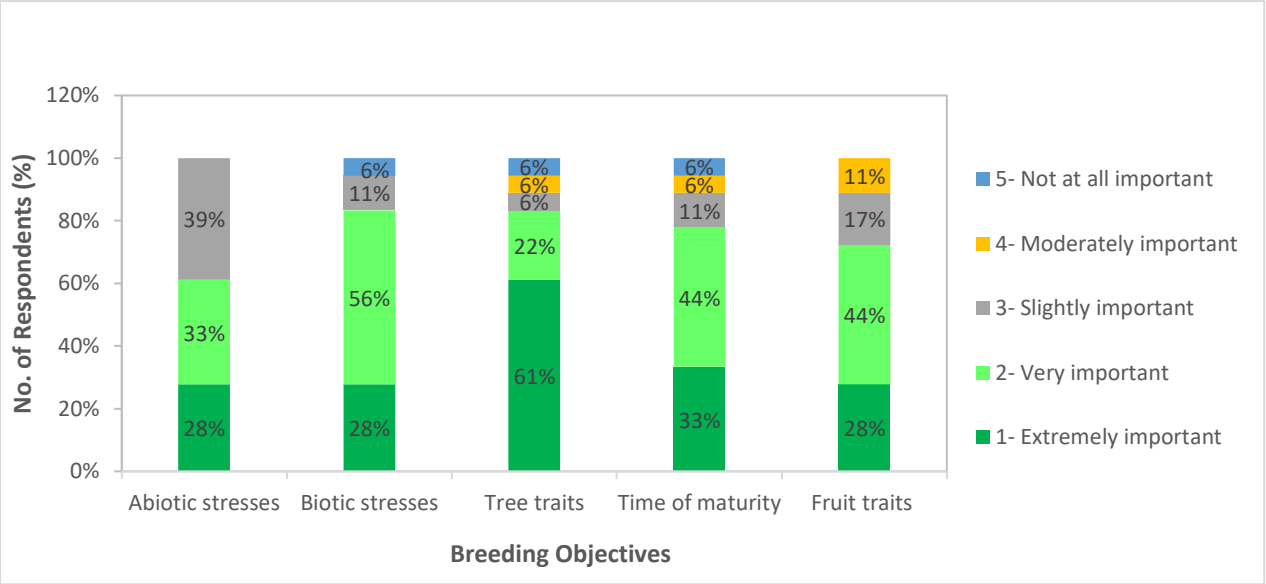

Figure 1: Survey results showing breeding objectives ranked as important for the WTS avocado breeding program.

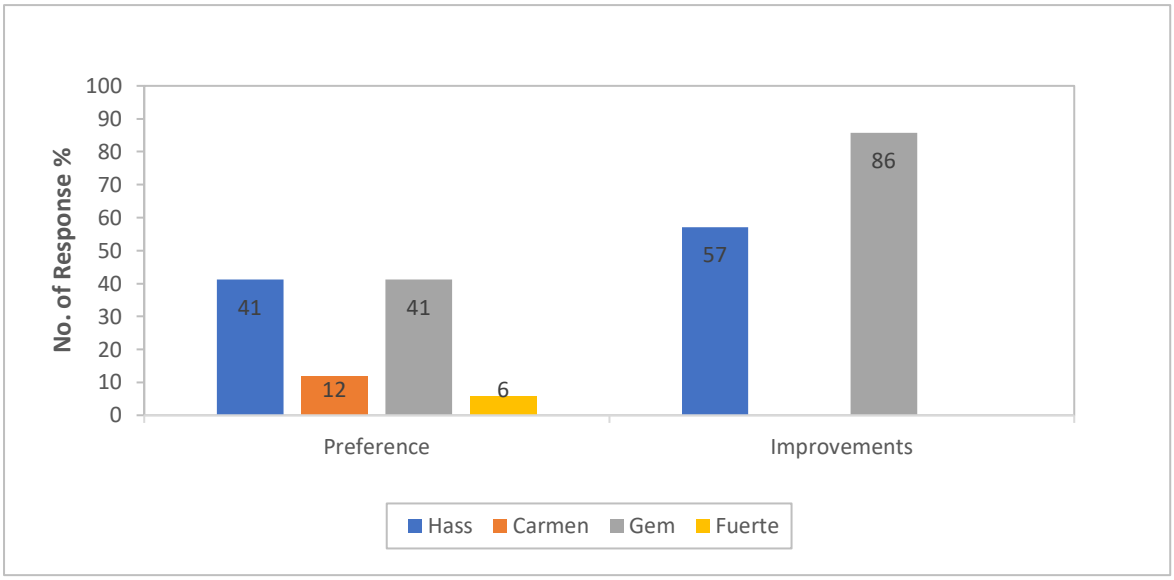

Figure 2: The most preferred cultivar as ranked by consumers in the breeding survey.

Table 1: Number of open pollinated seedlings from varying maternal sources planted at the WTS experimental farm from 2014 to 2018 as well as the percentage number of seedlings that flowered and set fruit.

No. Seedlings	**Season established****				
	2014-2015	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**
Planted*	2000	2200	1000	997	1004
Flowered	6%	9%	-	-	-
Set fruit	26%	40%	-	-	-
Evaluated	10%	26%	-	-	-

* Numbers of seedlings are based on the number of trees planted but the actual number of trees will be dependent on seedling survival in the field.

**The season planted is based on the year in which seeds were collected and planting is completed. Seeds collected are planted at the end of the year in Spring through to the beginning of the following year in summer.