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Some aspects of avocado research world-wide

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SYNOPSIS

World avocado production is expanding at nearly five per cent per annum. Research has made possible spectacular gains in productivity, especially in subtropical areas. Some research achievements from South Africa, the USA, Israel and Australia are discussed. The main research priorities are improved germplasm, manipulation of fruitfulness and vigour, intensive canopy management, and the maintenance of post-harvest fruit quality.

INTRODUCTION

Prominent avocado researchers and extension specialists met for the first time on an international basis in 1976 for the 'First International Tropical Fruit Short Course: The Avocado', at the University of Florida. A total of 24 review papers were presented, covering a wide range of topics (Sauls, Phillips & Jackson, 1977).

In the decade since then, the avocado has progressed steadily from infancy to early childhood as a world crop. The small core of largely subtropical countries with technologically advanced and commercially developed industries has increased. However, the world crop is still dominated largely by seedling production for home consumption in tropical countries, especially in the western hemisphere. Mexico, the world's leading producer, is a special case as it has both commercial vegetatively propagated orchards and a vast production from seedling trees.

The highly satisfactory development of the avocado as a significant world crop has in the final analysis been made possible by expanded knowledge from an increased research input. The objectives of this paper is to give a broad perspective of world production, the importance of research, examples of important research centres and achievements, and an indication of research priorities. The emphasis is on subtropical avocado production.

WORLD PRODUCTION TRENDS AND PROSPECTS

FAO production statistics (1984) give world avocado production as 1 586 million tonnes in 1983, compared with an average 1 183 million tonnes for the 1974-76 period. This represents an average growth rate of 4,9 per cent per annum.

Reflecting the central American origin of the avocado, it is significant that 83,2 per cent of world production was from North and South America. Also significant is that developing countries were responsible for 81,4 per cent of the world crop (Table 1).

The dominance of the western hemisphere is also evident from production statistics for the top 10 countries of the 39 listed as significant producers (FAO, 1984). Mexico is by far the largest producer with 28,8 per cent of the world crop, followed by the USA (13,8 per cent), Dominican Republic, Brazil, Peru, Indonesia, Haiti, Israel, Venezuela and El Salvador. Collectively, these countries accounted for nearly 80 per cent of world production.

Only small quantities of avocados enter world trade, these being produced mainly in the subtropics of Israel, South Africa, the USA, Spain and a number of smaller countries including Martinique, the Canary Islands, Kenya, etc. The EEC countries of France and the United Kingdom are the main importers, the former taking nearly 59 500 tonnes in 1985 (Naville, 1986). The exacting standards demanded by these markets have necessitated technologically advanced industries in the supplying countries. Prospects for further expansion of these and other sophisticated markets are favourable, but will be contingent on both increased research and promotional efforts.

TABLE 1 World avocado production by region. 1982 & 1983 average (FAO, 1984).

REGION	10^3 tonnes	%
N & C America	982,0	62,6
S America	323,0	20,6
Asia	140,5	9,0
Africa	116,5	7,4
Oceania	3,0	0,2
Europe	2,0	0,1
World	1 568,0	100,00
Developed countries	290,0	18,5
Developing countries	1 277,0	81,4

The role of seedling avocados in upgrading diets in developing tropical countries should not be under-estimated. In this regard, there is scope for considerable expansion in tropical Africa and Asia, with gradual upgrading of technology appropriate to these areas.

IMPORTANCE OF RESEARCH

Terblanche (1986) states "... there is no single example of a thriving agricultural industry in the world which is not strongly supported by research. No doubt, there is no better investment to be made for the betterment of agriculture than a well-organised and co-ordinated research effort. In fact, recent analyses have shown that return on investment in agricultural research far outweighed return on investments in any other sphere of business life. This fact, therefore, may clearly suggest that optimisation of avocado research is a pre-requisite for the optimisation of avocado production and quality". This message needs to be repeated ad *nauseum* to policy makers and those who control the

purse strings. Blumenfeld (1986) has pointed out that research becomes more complicated when supply exceeds demand, when quality becomes vital.

It is a fact that countries which have invested heavily in research now have the most successful and dynamic avocado industries. The author will briefly refer to some avocado research achievements in four subtropical countries, emphasising the South African experience. This in no way discounts the increasing volume of research emanating from Mexico, Spain, Cyprus and many other countries.

SOME IMPORTANT RESEARCH CENTRES AND ACHIEVEMENTS

South Africa

The quantity and quality of research which made it possible for South Africa to host this Congress, is the result of a successful partnership between the Citrus & Subtropical Fruit Research Institute (CSFRI), Nelspruit, and the South African Advocado Growers' Association (SAAGA). SAAGA's research effort has since 1976 been co-ordinated by Prof JM Kotzé of the University of Pretoria. With 80 current projects involving avocados, the CSFRI has excellent infrastructure and facilities. Its terms of reference, however, cover the full spectrum of evergreen fruits grown locally, and it is subject to changes in manpower and funding.

It was the perceived need by the industry for additional research, mainly directed at urgent short-term and *ad hoc* problems, which led to the formalisation of the voluntary, self-disciplined grower organisation. Research was funded initially by levies on exported fruit, and contracted out to universities, chemical companies, government and semi-government institutes, and larger companies, cooperatives and estates with SAAGA membership (Kotzé, 1986). The SAAGA Research Report, later the SAAGA Yearbook, has been published annually since 1977, and is testimony to national and international co-operation, and the benefits of applied and basic research.

Undoubtedly the main achievements of the co-operative, expanded research thrust have been in the spheres of disease control, and the problems of avocado export to markets 10 000 km distant. In the second half of the 1 970s, 80 per cent of avocado trees in South Africa were in various stages of decline due to *Phytophthora cinnamomi* root rot, and serious problems were being experienced with the marketing of exported fruit (Kotzé, 1986).

The first of many reports on the chemical control of *Phytophthora* (Darvas *et al,* 1978) revived a somewhat demoralised industry. The outstanding success of trunk injection of phosetylAl (Darvas *et al,* 1983) was quite literally the saviour of the industry, and the adaptation of this technique has led to further developments of great significance. For example, the results of injections of phosphorous acid were released in 1983 (Anon, 1983; Kotzé, 1983) but due to objection by the manufacturers of phosetyl-Al, based on patent regulations, the publication of the results was withdrawn. These exciting developments were spearheaded by a young pathologist working at Westfalia Estate, the largest and most scientifically-oriented avocado producer in South Africa, and are an outstanding success story in their own right.

Excellent progress has also been made on overcoming seemingly intractable pathological, physiological and marketing problems associated with export. International co-operation has led to the adoption of the dot-blot procedure for detecting avocado

sunblotch viroid (Bar-Joseph *et al,* 1986), facilitating progress on the Avocado Plant Improvement Scheme.

Identification of problems and priorities for research is catered for by the CSFRI's Avocado Advisory Committee, and SAAGA's Research Committee. Goodwill on both sides has, on balance, led to an effective co-ordination of actions. There is sufficient flexibility for changes of emphasis and direction in response to changing circumstances. The South African avocado grower has been the ultimate beneficiary.

United States of America

The modern world avocado industry has quite literally developed on the firm research foundations laid in the USA. Californian research on cultivars, management practices and marketing was adopted with modifications, by subtropical avocado industries based mainly on Guatemalan and Guatemalan-Mexican hybrid cultivars. The willing dissemination of accumulated knowledge and experience over several decades, partly through the prestigious California Avocado Society Yearbook, enabled other subtropical countries to short-circuit pitfalls and reduce the time spent on the 'learning curve'. This remarkable beneficence is, happily, no longer a one-way street.

Major changes have occurred in the structure of the University of California's horticulture, botany and plant sciences departments in the past 20 years. With accompanying changes in research financing, and retirement of most of the eminent 'old school' of researchers and extension specialists, some research impetus has been lost. Plant pathological and breeding research programmes however, continue to lead the world in many respects. Hopefully, the swing towards a more basic bio-technological research approach will in the long run, benefit the avocado industry.

In contrast, the University of Florida at Gainesville and Homestead has provided leadership for the much larger, but less glamorous and less publicised avocado industries of the semi-tropics and tropics, especially for central American countries. It must also be mentioned that much research of an *ad hoc* nature takes place in many unlikely physiology laboratories throughout the USA (and indeed elsewhere). The avocado tree or fruit is regarded as an interesting model for testing hypotheses and advancing basic knowledge.

Israel

The Israeli avocado industry, perhaps the most technologically efficient in the world, is still relatively young. It is without doubt an outstanding example of the continual application of research findings. This is aided by the small geographic spread of avocado growing; the unique kibbutz, moshav and other farming systems; the relatively small size but highly intensive care of orchards; and the continual interaction of well-educated and receptive growers with scientists.

Israeli research is conducted mainly at the Volcani Center and the Hebrew University at Rehovot. We owe much to both basic and applied programmes, which have a well-deserved international reputation. It is only fair to say, however, that much of this information is less readily and timeously accessible to outsiders than they would wish.

Australia

With a relatively new and small but expanding avocado industry, Australian research has come-of-age and has achieved a high degree of sophistication. A strong research programme has ensured the viability of the industry in a country with high costs and a small market. There are many examples of good basic horticultural and pathological research by CSIRO, University and Department of Primary Industry personnel in several states. The Maroochy Horticultural Research Station in Queensland is a leader in horticultural research, and has successfully developed and applied the concept of phenological modelling.

The most significant recent achievement has been the successful field testing and registration in Queensland of phosphorous acid trunk injections for *Phytophthora* control (Pegg et al, 1985; Whiley *et al,* 1987). The spectacularly successful results have extended earlier findings in California and South Africa.

AVOCADO RESEARCH PRIORITIES

It is a difficult task indeed to summarise world avocado research priorities, especially as the writer only has experience of subtropical avocado growing. The ideas set out below inevitably reflect the bias of a limited personal perspective.

Improved quality of germplasm

Although avocados have been known to westerners since 1519 (Gustafson, 1977), and have experienced selection pressure for centuries from primitive man, they are still in terms of modern horticultural requirements a relatively undomesticated crop. Grafting of selected cultivars is only about 100 years old. Perhaps the highest priority worldwide is a substantial upgrading of both scion and rootstock material, combined with Plant Improvement Schemes.

Scion cultivars

Fuerte, selected as a chance seedling from Mexico, and for several decades the corner-stone of the Californian and other subtropical avocado industries, was the best of many 'first generation' subtropical cultivars. It is still regionally important, although all but phased out of its adopted Californian landscape due to a poor yield history in that climate. In warmer climes, it is a better performer, but has been found deficient as an export cultivar when long-distance transport is needed.

A 'second generation' cultivar with an unlikely size and appearance, *viz* Hass, is the current standard of excellence,although not without problems. Today, we stand hesitantly on the brink of the first 'third generation' cultivars such as Gwen and Whitsell, the first cultivars to arise from controlled crosses (Bergh & Whitsell, 1982). With extreme precocity, very high yield potential and a semi-dwarfed growth habit, they are indicative of the future even if further testing unearths unexpected flaws.

California also has best artificial repository of avocado genetic diversity, thanks to the explorations and collections of Popenoe, Zentmyer, Schieber and others. An extensive collection of more tropical germplasm is in Florida. Further collections from the natural centres of diversity in central America are certainly justified, although the law of diminishing returns may apply.

Due to the complexity of climatic and edaphic factors in different areas, it should be obvious that we cannot continue to rely on California and Florida for improved germplasm. The logical first step remains a vigorous and sustained programme of germplasm exchange between avocado growing countries, backed by phytosanitary measures. Selection of chance seedlings, and of favourable mutations in existing cultivars, should be an on-going process. But in the final analysis, what country which hopes to remain competitive can do without a local breeding programme, however small? Israel and Australia are examples of what should be done. South Africa lags sadly in this field of endeavour. Breeding objectives have been summarised by Bergh (1977).

Rootstocks

Clonal rootstocks are the rootstocks of the future in avocado growing. There has been much progress in selecting clonals with *Phytophthora* tolerance, thanks to the work of Zentmyer (1984) and Coffey (1986) and co-workers. Similarly, we have clonal rootstocks with salinity and chlorosis tolerance for drier climates (Kadman, 1985). Ben-Ya'acov (1986) in Israel is testing over 100 clonal rootstocks. The dangers of excessive reliance on clonal uniformity have however been vividly illustrated by the Duke 6 lethal stem-pitting syndrome in South Africa (Moll, Grech & Van Vuuren, 1985). The greatest need in this field of endeavour is to spread the risk with a wider range of tested clonals, preferably locally selected, at least in part.

In the longer term, a genuine dwarfing or semi-dwarfing rootstock would be a great boon to avocado growers, facilitating the adoption of the highly intensive management practices that will ensure high yields.

Manipulation of fruitfulness and vigour

The ecophysiological and structural characteristics of evergreen fruit trees as discussed by Possingham (1986), Kriedemann (1986) and Verheij (1986) complicate avocado orchard management. A major problem is the effective manipulation of vegetative vigour at critical times to enhance fruitfulness and fruit quality. Research in three areas should receive priority.

Growth retardants are perhaps the most powerful manipulatory tool at our disposal in the short term. Paclobutrazol (Cultar®) can significantly dwarf avocado trees, and strategic timing of foliar sprays has given very promising reduction of vigour accompanied by substantially increased fruit set (Wolstenholme & Whiley, unpublished data). Extended research, including related chemicals, to 'fine tune' the early promise is an urgent priority.

Flowering and fruit-set have recently been reviewed by Davenport (1986) and will receive the attention of Sedgley and other speakers at this Congress. Evidence from the tremendous volume of floral research is that provision for cross-pollination is not always necessary, and that the avocado has evolved a fail-safe system of self-pollination.

Nevertheless, fruit-set and more so fruit drop remain pressing problems, at least in our current cultivars. Good chances for short-term gains in productivity may exist in a more detailed study of girdling, and of chemical growth regulator sprays other than paclobutrazol. Expansion of the basic research on plant growth substance changes in

developing fruits, supplementing the earlier work of Israeli scientists and of Cutting *et al* (1986) is indicated.

Physical tree manipulation on the basis of leads from the deciduous fruit industry (Chalmers, 1986) may lead to yield gains from altered assimilate partitioning. Preliminary trials have been started at Westfalia Estate, South Africa (Kohne, 1986) and will be followed with interest.

INTENSIVE CANOPY MANAGEMENT

Little is known about the light relationships of avocado trees in orchard situations, or on seasonal patterns of photosynthesis as affected by a range of management and stress factors. Similarly, the promise of carbohydrate management (Scholefield *et al,* 1985) must be followed up, particularly in view of the large energy demands of fruiting in this crop (Wolstenholme, 1986). A continued investigation of stress physiology is also needed in orchard situations, emphasising water relations.

Post-harvest fruit quality

Quantity of fruit is the primary concern of producers, but quality is what concerns the consumer. Quality is a complex amalgam of both pre-harvest and post-harvest factors, and becomes more critical the further the distance to the market. Our knowledge of the physiology of avocado post-harvest disorders is being reviewed (Bower, 1987, pers comm). Promising leads on the role of enzyme systems, calcium ions etc, must be pursued. Continued pathological inputs will also be vital.

Conventional refrigeration and storage technology is barely adequate for successful sea export of the problematical Fuerte from South Africa to Europe. The promise of controlled atmosphere storage has yet to be translated into the realms of practicality and economic viability. Continued research of this and related technology could ultimately be of great benefit to avocado trade world-wide.

REFERENCES

1 Anon, 1983. Resistance is the answer for avos. *Letaba Herald,* Nov 18, p7.

2 Bar-Jospeh, M, Yesodi, V, Franck, A, Rosner, A & Segev, D, 1986. Recent experience with the use of synthetic DNA probes for the detection of avocado sunblotch viroid. *S Afr Avocado Growers'* Assoc *Yrb, 9,* 75-77.

3 Bergh, BO, 1975. Avocados. In: *Advances in Fruit Breeding,* ed J Janick & JN Moore. West Lafayette: Purdue Univ Press.

4 Bergh, BO, 1977. Avocado breeding and selection. In: *Proceedings of the First International Tropical Fruit Short* Course: The *Avocado,* ed JW Sauls, RL Phillips & LK Jackson. Gainesville: Univ of Florida.

5 Bergh, BO & Whitsell, RH, 1982. Three new patented varieties.CalifA vocado *Soc Yrb,* 66, 51-56.

6 Blumenfeld, A, 1986. Symposium closing reviews. In: Acta *Horticulturae,* No 175, 373-374.

7 Chalmers, DJ, 1986. Research and progress in cultural systems and management in temperate fruit orchards. *Acta Horticulturae,* No 175, 215-225.

8 Coffey, MD, 1985. Progress in rootstock research in California. *S Afr Avocado* Growers' Assoc *Yrb,* 8, 15-16.

9 Cutting, JG, Lishman, AW, Hofman, PJ & Wolstenholme, BN, 1986. Plant growth substance trends in developing avocado fruit as determined by radioimmunoassay. Acta *Horticulturae,* No 175, 285-289.

10 Darvas, JM, Toerien, JC & Milne, DL, 1983. Injection of established avocado trees for the effective control of Phytophthora root rot. *Citrus and Subtropical Fruit Journal,* No 591, 7-10.

11 Davenport, TL, 1986. Avocado flowering. *Horticultural Reviews;* 8, 257-289.

12 Gustafson, D, 1977. World avocado production - 1976. In: *Proceedings of the First International Tropical Fruit Short Course The Avocado,* ed JW Sauls, RL Phillips & LK Jackson. Gainesville: Univ of Florida.

13 Kadman, A, 1985. Selection of avocado and mango rootstocks for calcareous soils. Acta *Horticulturae,* No 158, 63-67.

14 Kohne, S, 1986. Better yields from small trees. S Afr Avocado *Growers'Assoc Yrb, 9,* 61-62.

15 Kotzé, JM, 1983. Research column. *Avokad,* 3(5), 11. SAAGA, Tzaneen.

16 Kotzé, JM, 1986. Research in perspective. S *Afr Avocado Growers'* Assoc *Yrb,* 9, 5-6.

17 Kriedemann, PE, 1986. Tree water relations. *Acts Horticulturae,* No 175, 343-350.

18 Moll, JN, Grech, NM & Van Vuuren, SP, 1985. First report of lethal stem-pitting of Duke 6 avocado rootstock in South Africa. *Plant Disease,* 69, 727.

19 Naville, R, 1986. Les Importations francaises de fruits tropicaux et subtropicaux en 1985. *Fruits,* 41, 409-420.

20 Pegg, KG, Whiley, AW, Saranah, JB & Glass, RJ, 1985. Avocado root rot control with phosphorous acid. *Australasian Plant Pathology,* 14, 25-29.

21 Possingham, JV, 1986. Impact of physiological research on the productivity of tropical and subtropical fruit trees. *Acta Horticulturae,* No 175, 17-25.

22 Sauls, JW, Phillips, RL & Jackson, LK, 1977. *Proceedings* of the *First International Tropical Fruit Short* Course: *The Avocado.* Gainesville: Univ of Florida. 129 pp.

23 Scholefield, PB, Sedgley, M & Alexander, D McE, 1985. Carbohydrate cycling in relation to shoot growth, floral initiation and development and yield in the avocado. Scientia *Horticulturae,* 25, 99-110.

24 Terblanche, JH, 1986. Openingrede tydens SAAKV se negende simposium. *S Afr Avocado* Growers' Assoc *Yrb,* 9, 7-8.

25 Verheij, EWM, 1986. Towards a classification of tropical tree fruits. *Acta Horticulturae,* No 175, 137-150.

26 Whiley, AW, Pegg, KG, Wolstenholme, BN, Piccone, MF & Penny, SB, 1987. The phosphorous acid story. *Queensland Department of Primary Industries Bulletin,* RQN 87001.

27 Wolstenholme, BN, 1986. Energy costs of fruiting as a yield-limiting factor, with special reference to avocado. Acta *Horticulturae,* No 175, 121-126.

28 Zentmyer, GA, 1984. Avocado diseases. *Tropical Pest Management,* 30, 388-400