

MEETINGS

ABSTRACTS OF PRESENTATIONS ON PLANT PROTECTION ISSUES AT

THE THIRD WORLD AVOCADO CONGRESS

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A: AVOCADO PESTS AND THEIR CONTROL

Avocado Pest Management in New Zealand

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Avocados in New Zealand are damaged by six leafroller species (Lepidoptera: Tortricidae), all but one of which are native to New Zealand. The most important species are *Ctenopseustis obliquana* (Walker) and *Ctenopseustis herana* (Felder and Rogenhofer), which account for 90% of all caterpillars collected from fruit. The other species found occasionally are *Cnephasia jactatana* (Walker), *Planotortrix octo* (Dugdale), *Planotortrix excessana* (Walker) and the Australian *Epiphyas postvittana* (Walker). Caterpillars of *Stathmopoda* spp. are also sometimes observed damaging fruit. Other insects that can sometimes cause problems include the armoured scale species *Hemiberlesia lataniae* (Signoret) and *H. rapax* (Comstock), and the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché); further problems are due to mites.

Currently sprays are applied on a calendar basis, mostly for leafroller control, and growers use an average of six insecticides per year. However, research is underway to develop an Integrated Pest Management program.

The avocado plant referred to in these abstracts is *Persea americana* Mill. (= *Persea gratissima* Gaertn.), unless otherwise stated.

Current research on leafrollers has shown that most damage occurs between fruit set in December and June. In unsprayed orchards up to 20% of the fruit may be rejected for export because of caterpillar damage. Although pheromone traps are available for all the leafroller species, relatively low catches of the major pests *C. obliquana* and *C. herana* limit the potential for developing spray thresholds from trap data. A direct monitoring system, such as caterpillar counts on leaves or fruit, would be more feasible. (L)*

Avocado Pest Management in Australia

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Avocados grown in the tropical and subtropical areas of Australia (Queensland and northern New South Wales) are affected by four major groups of pests, namely, fruitspotting bugs (*Amblypelta* spp., Coreidae), leafrollers (Tortricidae), latania scale (*Hemiberlesia lataniae* [Signoret]) and tea red spider mite (*Oligonychus coffeae* [Nietner]).

The major pests are the fruitspotting bugs, which can cause more than 90% yield loss if they are not controlled. Prophylactic sprays with endosulfan are used to control them. However, endosulfan is under a cloud; while its use is preferred within the IPM system because of its minimal side effects on beneficial arthropods, several fish kills in local rivers and suspicions regarding its detrimental effect on lizards and frogs, suggest that its continued availability is threatened. Among alternative fruitspotting bug treatments, synthetic pyrethroids are particularly effective and also suppress leafrollers, but inevitably induce mite and scale outbreaks. Alternative fruitspotting bug management options are being investigated. (L)

Avocado Pests in Israel

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A survey of avocado groves throughout Israel was begun in 1969 and continued until 1995. During this period 94 species of pests belonging to 45 families of insects, mites, birds and mammals were recorded. The outbreaks of the long-tailed mealybug, *Pseudococcus longispinus* (Targioni-Tozzetti), which resulted from the drift of aerial sprays from adjacent cotton fields, were controlled by limiting sprays and by releases of the parasites *Arhopoideus peregrinus* (Compere) and *Anagyrus fusciventris* (Girault). The Japanese bayberry whitefly, *Parabemisia myricae* (Kuwana), introduced into Israel in the late 1970s, is successfully controlled by the imported Californian parasite *Eretmocerus debachi* (Rose & Rosen). Since 1980 the pyriform scale, *Protospulvinaria pyriformis* (Cockerell), has been an important pest of avocado. It is controlled by the exotic parasite *Metaphycus stanleyi* Compere and by the application of mineral oils. As only young caterpillars of the giant looper, *Boarmia selenaria* (Schiffmüller), are susceptible to *Bacillus thuringiensis* Berliner preparations, a monitoring system was developed using virgin female traps and scouting. *B. thuringiensis* is used as well against the honeydew moth, *Cryptoblabes gnidiella* (Millière), and the carnation leafroller, *Cacoecimorpha pronubana* (Hübner). The parasite *Thripobius semiluteus* Boucek, imported from California for the biocontrol of the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), has become established in numerous groves. Sabadilla was found to be effective against black vine thrips, *Retithrips syriacus* Mayet.

The appearance of sporadic, minor and potential pests was discussed. An Integrated Pest Management system has been developed in the avocado groves of Israel. (L)

*L = lecture sessions; P = poster (market place) sessions.

Monitoring and Control of the Giant Looper, *Boarmia selenaria*, in Avocado Orchards in Israel

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Boarmia selenaria (Schiffermüller) is the most important pest of avocado in Israel in the regions where cotton is planted. It is a polyphagous insect, damaging many agricultural crops throughout the world. In Israel, *B. selenaria* produces five generations per year, of which the most devastating ones are the first (spring) and the second (early summer).

Spiders are very common in avocado groves, and undoubtedly play an important role in the biocontrol of this pest. The thelytokous parasitoid *Apanteles cerialis* Nixon attacks young caterpillars of *B. selenaria*. In avocado groves *A. cerialis* appears in considerable numbers in October and November and parasitizes up to 70% of the caterpillars. The other important parasites of *B. selenaria* are tachinid flies, such as *Compsilura concinnata* Meigen and *Exorista* sp. The females attack developed stages of caterpillars and the population reaches its peak in late summer or in autumn.

In Israel local natural enemies curb the populations of *B. selenaria* effectively, but in regions where cotton is widely planted, the biological balance is upset by the drift of insecticides from aerially sprayed cotton fields. In those orchards commercial products containing the bacterium *Bacillus thuringiensis* var. *kurstaki* are used to control the pest. Since only young caterpillars (up to 1.5 cm in length) are sensitive to the bacterium, a monitoring system involving virgin-female-baited traps (attracting males) was developed. Two weeks after the peak of male trappings (preoviposition and incubation periods) and at the time of field sightings of the appearance of young caterpillars, the use of *B. thuringiensis* is recommended. This method has been used successfully in many avocado groves since 1977. (L)

Behavior of Introduced Parasitoids against the Pyriform Scale on Avocado

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Since 1980 the pyriform scale, *Protopulvinaria pyriformis* (Cockerell), has been an important pest of avocado in Israel. Parasitoids of the pyriform scale have been introduced into Israel from South Africa, Kenya, Florida, California and Spain. *Metaphycus swirskii* Anneck and Mynhardt, initially the most abundant parasitoid, was soon replaced by *Metaphycus stanleyi* (Compere), a later introduction which is now the most abundant natural enemy of the pyriform scale. *Metaphycus helvolus* (Compere) also became established on avocado, but to a lesser extent and is now quite rare. Two hyperparasites, *Pachyneuron concolor* (Förster) and *Marietta javensis* (Howard), have an adverse effect on the effectiveness of *Metaphycus* spp. In some groves 70% of the total parasite fauna consist of these two hyperparasite species. The percentage of active primary parasitization increases in September, is high during winter, and peaks in May; it then declines in summer, when the parasitoids are hard to find. This is due to both climatic factors and encapsulation.

Metaphycus spp. differ in the site, duration and rate of oviposition, in host marking, and in preference for host stages. *M. helvolus* oviposits in body margins of the pyriform scale, whereas *M. stanleyi* oviposits through the host's dorsum. The duration of oviposition is short (7 sec) in *M. stanleyi* and relatively long (68 sec) in *M. helvolus*; the former lays 13 eggs per hour, the latter only

3. *M. stanleyi* attacks mainly third-instar larvae and young females, whereas *M. helvolus* attacks also second instars, but may be repelled by the host's body movements. (L)

Parasitoid Encapsulation as an Obstacle for Successful Biological Control of the Pyriform Scale, *Protopulvinaria pyriformis*, in Avocado

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Encapsulation of eggs of *Metaphycus stanleyi* Compere by the pyriform scale, *Protopulvinaria pyriformis* (Cockerell), under both greenhouse and field conditions, was found to occur almost all year round. However, encapsulation rates varied considerably during the different seasons; they were correlated with the ambient temperatures and were affected by the host plant. Encapsulation rates (i) in scales infesting avocado in the Bet Dagan orchard, were lowest during October to May (0–11%) and highest during June to August (54–75%); (ii) in scales infesting *Hedera helix* and *Schefflera arboricola* under greenhouse conditions, were lowest during December to May (6–17%) and highest during July to September (78–100%). Under greenhouse conditions, encapsulation rates did not differ between scales grown on *H. helix* and on *S. arboricola*, but were significantly lower in scales grown on avocado.

Encapsulation rates of eggs of *M. stanleyi* and/or *Metaphycus swirskii* Annecke and Mynhardt in scales infesting avocado in the Miqwe Yisra'el orchard, were lowest during December to February (1–10%) and highest during July to August (49–75%). Encapsulation of eggs of *M. stanleyi* and/or *Metaphycus galbus* Annecke (42%) was also recorded in *P. pyriformis* on avocado from Spain.

The high rates of encapsulation of *Metaphycus* spp. eggs by *P. pyriformis* during the summer, may interfere with efficient biological control of the pest. (P)

Introduction and Establishment of the Parasitoid of the Greenhouse Thrips in Israel

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In Israel the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), develops heavy populations on some high-yielding varieties of avocado, e.g. 'Ardit'. After successful realization of the biological control program of the greenhouse thrips in California with a larval parasitoid, *Thripobius semiluteus* Boucek, it was decided to import this parasitoid into Israel. The first consignment was obtained from California at the beginning of 1991 and utilized for insectary propagation. Since May 1991 the parasitoids have been released on several ornamentals and in avocado orchards in many avocado-growing regions. Recoveries were made in 1992 and all subsequent years. Thus, *T. semiluteus* became established relatively quickly.

Detection of Avocado Sunblotch Viroid by Enzymatic cDNA Amplification

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We have developed a method for the detection of Avocado Sunblotch Viroid (ASBV) in nucleic acid extracts of infected avocado tissues by reverse transcription–polymerase chain reaction (RT-PCR) with ASBV cDNA-specific primers. Amplified cDNA products were analyzed by electrophoresis on non-denaturing 6% polyacrylamide slab gels and silver-stained. The size of the major RT-PCR product from ASBV-infected tissue was approximately 247 bp. This product was absent from amplified extracts of uninfected tissue. To confirm that the 247 bp amplification product was from ASBV, it was sequenced by the dideoxynucleotide chain termination method and compared with the published sequence J02020. Sequence homology was confirmed. The RT-PCR assay is sensitive and allows viroid detection without requiring large samples or molecular hybridization. (L)

Selection of Avocado Rootstocks Resistant to Root Rot in Israel: Update Report

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Root-rot disease, caused by *Phytophthora cinnamomi* Rands, is the main problem of the avocado industry around the world. In Israel it was first identified at the beginning of the 1980s. For the first decade it was distributed on a very limited scale, but during the last 3 years there have been actual outbreaks of the disease in the main avocado-growing regions.

Although chemical control is successful today in many avocado-growing areas, in others it is not effective. Moreover, chemical treatment causes environmental pollution and is contrary to the worldwide tendency of reducing the use of pesticides. The best long-term solution for controlling avocado root rot is to use *Phytophthora*-resistant rootstocks.

The aim of this research program is to select avocado rootstocks resistant to root rot and adapted to the local conditions such as salinity and lime; these rootstocks should be characterized by high productivity. The selection program is based on a long-term field test of grafted rootstocks from different genetic sources: (i) surviving trees of infected orchards, (ii) local commercial clonal rootstocks, and (iii) rooted trees from the avocado germplasm which was collected in the regions of the avocado's origin. The grafted plants are being tested in the same infected experimental plots. The outstanding selections of these three groups, approximately 15 rootstocks, were propagated clonally for commercial evaluation. After 10 years of selection, there are ten rootstocks showing a resistant reaction in field tests. (L)

Evaluation of West Indian Avocado Seedling's Tolerance-Resistance to *Phytophthora cinnamomi*, Compared with Clonal Resistant Rootstocks 'Duke 7', 'Thomas' and 'Toro Canyon', under Field Conditions

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The aim of this research was to find West Indian avocado germplasm resistant to *Phytophthora cinnamomi* Rands, as the West Indian race (WI) is well adapted to the Canary Islands conditions. The trial field selected was a long-established avocado plantation with a high degree of *P. cinnamomi* infection. After planting, symptoms expression of the clonal resistant rootstocks 'Thomas' (TH), 'Duke 7' (D7) and 'Toro Canyon' (TCY) was compared with that of WI seedlings and seedlings of *Persea indica* (L.) K. Spreng wild material (PI), the latter generally used as a susceptible test plant for *P. cinnamomi*. A randomized block design was used for all plantings and the trial was carried out during 3 years. The recorded data include: height, trunk diameter, disease severity, and surviving plants. The results indicate that D7 and TH are quite resistant to *P. cinnamomi*, under our conditions, but TCY is not. Most of the PI seedlings died, but the surviving plants exhibited a high degree of resistance. Unselected WI seedlings seem to have a considerable natural resistance to *P. cinnamomi* when compared with the clonal rootstocks. This could be of great interest for commercial avocado plantations in countries where the WI race is the preferred rootstock. (P)

Biocontrol of *Phytophthora cinnamomi* on Avocado: Identification and Field Testing of Local Natural Antagonists, and Evaluation of Rootstocks for Resistance

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Soils suppressive to root rot of avocado (caused by *Phytophthora cinnamomi* Rands) were first identified in South Africa in 1990. Microorganisms from these soils were tested for *in vitro* antagonism to *P. cinnamomi* and subsequently evaluated for suppression of root rot of avocado seedling plants in a mistbed. Three fungal antagonists, *Paecilomyces lilacinus* (Thom) Samson (PREM 50933), *Aspergillus candidus* Link ex Fries (PREM 50935) and *Trichoderma hamatum* (Bonorden) (PREM 50938), were effective in suppressing root rot. These antagonists have been evaluated since 1992 for control of root rot in avocado trees in the field. Populations of the antagonists have been found to increase in the root zone of newly planted trees following antagonist treatment in the nursery and in the orchard. To date, no increase has been observed in antagonist populations when the treatment was applied to established trees (planted in 1980).

In an isolated planting site consisting of various ungrafted avocado rootstocks (e.g. G1033, 'Dusa', 'Latas', D9, 'Duke 7', 'Barr Duke', 'Thomas', 'Velvic'), trees undergo open pollination. Seeds from this orchard, situated at Westfalia Estate, are germinated and the seedlings evaluated for resistance to root rot in a mistbed. A number of successful selections have been made and these are being clonally propagated and grafted with 'Hass'. These trees are to be planted in a root-rot-infected field site where they will be evaluated for yield and resistance to root rot. (L)

Chemical and Anatomical Events that Characterize the Resistant Response of Avocado Roots Inoculated with *Phytophthora cinnamomi*

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Inoculation of feeder-roots of susceptible avocado seedlings ('Topa Topa') with a virulent isolate of *Phytophthora cinnamomi* Rands (mating type A²) causes necrosis that covers the entire inoculated feeder-root (susceptible response). When similar seedlings are inoculated with a low-virulent isolate (A²) the necrosis is localized 1 or 2 cm from the root tip (resistant response). Similar responses are recorded when the small fruit *Persea* species – *P. borbonia* (resistant) and *P. indica* (susceptible) – are inoculated with a virulent isolate of *P. cinnamomi*. Upon microscopic examination of inoculated roots at the root tip area (up to 0.6 cm from the tip), the resistant and susceptible responses look identical. Tips are necrotic and profusely colonized with inter- and intracellular fungal mycelium. Clear differences between resistant and susceptible responses can be detected above the tip area. In the resistant response, necrotic cells in the cortex and the central cylinder are encircled by two rows of uniform cells that contain lignin- and suberin-like materials in their walls. Lignin-like material is also detected in the walls of the necrotic cells. The intercellular spaces inside the lesions are filled with a colored material which autofluoresces under UV. More distal to the root tip the lesions become smaller and eventually disappear, first in the cortex and later in the central cylinder. In the susceptible response the lesions are not localized and the encircling layer and the lignin- and suberin-like materials are absent. (L)

Mulch Effects on Avocado Root Rot

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In Ventura County, a coastal area near Los Angeles, an avocado orchard of approximately 2.5 ha which had succumbed to root rot was cleared and planted in spring 1994 to new 'Hass' on 'Toro Canyon', 'Duke 7' or 'Thomas' rootstock. Interplanted in the tree rows were 1-year-old 'Zutano' seedlings, as susceptible control rootstocks. A factorial, randomized, complete block design was used with factors of: (i) rootstock, (ii) gypsum (5 kg/tree), (iii) Aliette (fosetyl), and (iv) municipally-derived chipped eucalyptus tree prunings as a 10-cm mulch. Tree growth, root growth and tree survival records have been maintained and results were reported. (L)

Influence of Soil Solarization on *Phytophthora cinnamomi* in Avocado

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Two field trials were conducted to evaluate the effectiveness of soil solarization in controlling avocado root rot caused by *Phytophthora cinnamomi* Rands. The soils at the experimental site have exhibited a high degree of infection for the last 20 years.

In the first trial solarization was applied to 80 diseased adult trees and 60 control trees. Disease severity index (DSI) was measured visually on a scale of 0 (healthy plant) to 5 (dead plant). All trees were indexed as DSI 3-4 at the onset of the trial, improving to DSI 2-3 during the first year of solarization; a second treatment further improved trees to DSI 1-2. Maximum temperatures measured at the 5-cm depth were 40°C under the tree canopy and 45°C in the sun, higher than those described as effective for pathogen elimination.

In the second trial two plots were used to test 450 West Indian race avocados and 78 *Persea indica* (L.) K. Spreng, the latter as control due to its reputed susceptibility to *P. cinnamomi*. DSI was recorded over a 3-year period. Results showed that 88% of avocado and 92% of *P. indica* survived in the solarized plot; survival in the control was 21% for avocado and 8% for *P. indica*. The DSI for plants from the solarized plot was consistently better than that for the control. Both trials showed the high efficacy of this technique for control of *P. cinnamomi*. (P)

Control of *Dematophora necatrix* and *Phytophthora cinnamomi* in Established Avocado Orchards by Soil Solarization

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Experiments were carried out in the southern Mediterranean coastal plain of Spain to study the effectiveness of soil solarization in controlling the two most important soilborne pathogens of avocado crops in this area. Solarization was conducted during 5–8 weeks starting in mid-July in 1991–94, in four avocado orchards naturally infected by *Dematophora necatrix* Hartig, and in 1993–94 in two other orchards, naturally infected by *Phytophthora cinnamomi* Rands. Nylon bags containing root segments naturally infected by *D. necatrix* or *P. cinnamomi* and substrates infected by the latter were buried in the soil at several depths (from 15–60 cm) and locations (shaded and unshaded), both in solarized and untreated plots. Simultaneously, thermistors connected to a data-logger were introduced at the same depths and locations, to record hourly temperatures during the solarization period. Afterwards, transparent polyethylene films (75 µm thick) were laid on the wet soil, covering the whole surface between contiguous rows of trees.

During the solarization period, the daily maximum hourly temperatures in the solarized unshaded plots were increased over those of the untreated by 5–7°C depending on depth and experiment; for solarized shaded locations, the respective increments were 4–15°C. There were also large temperature differences between shaded and unshaded locations in untreated plots. Consequently, there was a drastic reduction in the viability of *D. necatrix* at all of the depths and locations of the solarized plots after 5–8 weeks of solarization. With regard to control of *P. cinnamomi*, the result of solarization was a complete loss of viability of the fungus in infected roots and a strong reduction of inoculum density in the soil. Furthermore, inoculum grown on substrate was nil after 6 weeks of solarization at all of the depths and locations tested. (P)

Effect of Different Fungicides and Methods of Fungicide Application to Control Avocado Root Rot in Southern Spain

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Preliminary results (3 years) of an experiment undertaken to evaluate the effect of fungicides and application methods on the control of *Phytophthora cinnamomi* Rands in commercial avocado orchards were presented. An orchard of 10-year-old 'Hass' avocado trees on 'Topa-Topa' rootstocks naturally infected by *P. cinnamomi*, located in Málaga (southern Spain), was used. The statistical design consisted of five treatments and a control replicated four times in randomized blocks. Each treatment included 20 trees with an average severity index of *ca* 7 on a disease scale of 0 to 10 (0=healthy, 10=dead). Phosphorous acid (PA) (20% phosphate solution adjusted to pH 5.8 with potassium hydroxide) and Aliette-Ca (AC) (fosetyl-Ca) (EF 2008-B) were injected into the trunk at a rate of 15 ml per meter of canopy area diameter (MAD). PA and fosetyl-Al (AA) (Aliette 80 WP) were used as foliar applications at a rate of 60 ml/MAD. Metalaxyl (R) (Ridomil 5G) was applied at a rate of 40 g/m² as soil drench. These fungicides were applied in July and November of 1992 and 1993. The assessment of results was based on: (i) rating trees according to the above disease scale in July 1992, December 1993 and November 1994; (ii) isolation frequency of *P. cinnamomi* from avocado feeder roots evaluated in March 1993 and 1994; and (iii) fruit yields (kg/tree) recorded at maturity in 1993 and 1994.

At 16 months, after three fungicide applications, the PA treatment, injected, was the most effective and decreased the average disease severity of trees by *ca* 17% (7 to 5.8). The beneficial effects of PA and AA as foliar applications and AC injected were similar and lower than of PA injected. R was not different from the control. At 28 months, with one more fungicide application, PA (foliar and injected) and AC both decreased the severity of disease, although the PA injected was 7% more effective. R continued to be no different from the control and in both treatments the severity of the disease increased. Between the two dates of isolation of pathogen its frequency decreased for all treatments except the control and was nil in the case of PA (foliar or injected). Yield increments were observed only for the fungicides injected (PA or AC), although PA increased the yield five times more than AC. In the rest of the treatments the yield decreased from 1993 to 1994. (P)

C: PRE- AND POSTHARVEST CONTROL OF AVOCADO FRUIT DISEASES

Biological Control of Avocado Leaf and Fruit Diseases in South Africa: An Overview

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Biological control has been evaluated as an alternative to chemical treatments for managing avocado leaf and fruit diseases. Results of the past 8 years showed that preharvest application of *Bacillus subtilis* on its own or integrated with copper oxychloride spray is more effective than copper oxychloride alone for controlling the postharvest diseases anthracnose, stem-end rot, and the *Dothiorella/Colletotrichum* fruit rot complex. *B. subtilis* furthermore reduced *Cercospora* spot and even sooty blotch when applied early in the season with or without supplementary copper

oxychloride sprays, especially when the antagonist was re-applied later in the season. Most effective disease control was nevertheless obtained with antagonists introduced to fruit as a postharvest dip, ultra-low-volume spray or incorporated into commercial wax. Product performance and consistency of biocontrol have been evaluated over the last few years both locally and in New Zealand and Australia. At present, emphasis is placed on antagonist attachment, survival and colonization and on developing monitoring systems for the antagonist. The mode of antagonistic action is being investigated with the purpose of identifying inhibitory substances. Preliminary registration of the biocontrol agent in South Africa is being pursued. (L)

Monitoring *Bacillus subtilis* Populations in Preharvest Biocontrol Programs on Avocado

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Pre- and postharvest biological control of avocado fruit diseases has been investigated at the University of Pretoria, South Africa, for the past 8 years. Postharvest application of antagonists provided more effective disease control than preharvest application, presumably due to impediment of antagonist survival and activity under field conditions. Poor antagonist survival under field conditions can thus affect the efficacy of the biocontrol program negatively. Therefore, monitoring antagonist survival is of prime importance in ensuring effective disease control. Various detection methods, *e.g.* electron microscopy (EM), leaf imprinting and dilution plating, were evaluated for determining the persistence of *Bacillus subtilis* biocontrol agents in field spray programs. EM studies showed an increase in bacteria on the leaves, in comparison with a decrease observed with the leaf imprint and dilution plate techniques. Since none of these techniques facilitated rapid and accurate screening of antagonists, monoclonal antibodies (MAB) were raised against the *B. subtilis* isolate used most commonly. The ELISA technique was optimized and utilized to monitor different antagonist concentrations under greenhouse conditions. MAB are at present being evaluated for field surveillance of antagonist survival as part of the preharvest biocontrol program on avocado. (L)

Effect of Biological and Physical Factors on the Modulation of Resistance of Avocado Fruit to *Colletotrichum gloeosporioides*

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The effect of wounding, challenge inoculation, ethylene treatments and exposure to a CO₂-enriched atmosphere on the enzymes involved in the biosynthetic pathway of epicatechin was studied. It was observed that wounding, challenge inoculation and ethylene enhanced epicatechin and an antifungal diene in a single transient increase occurring close to the application of the treatment, while treatments with 30% CO₂ increased the levels of epicatechin in a two-peak pattern, the second peak occurring 3–4 days after the fruits were transferred to normal atmospheric conditions. All the different treatments enhanced phenylalanine ammonia lyase and chalcone synthase; however, only CO₂ treatments that enhanced a second peak could bring about a significant increase in flavanone-3-hydroxylase (F-3-H). The results suggest that the activation of F-3-H is an important step in the induction of epicatechin levels and consequently in the levels of the antifungal diene and fruit resistance. (L)

Biological Control of Anthracnose in Avocado Fruits by Nonpathogenic Strains of *Colletotrichum magna*

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A nonpathogenic strain of *Colletotrichum magna* (path-1) did not cause any disease symptoms and protected fruits from inoculation with *Colletotrichum gloeosporioides* (Penz.) (isolate Cg-14). Inoculation of freshly harvested avocado fruit with path-1 inhibited subsequent decay development by the normal pathogen. *C. gloeosporioides* isolate Cg-14 and the mutant germinated on fruit peel, but Cg-14 formed more appressoria on avocado peel than did path-1. Path-1 and path-1 co-inoculated with Cg-14 also induced higher levels of phenylalanine ammonia lyase in freshly harvested fruits than in Cg-14-inoculated and untreated controls. The nonpathogenic mutant and the normal *C. gloeosporioides* differed, however, in the level and extent of induction of epicatechin and an antifungal diene in the peel of ripening fruits. Path-1 induced higher levels of epicatechin that lasted in ripening fruits, whereas Cg-14 induced epicatechin levels for 1 day only. It is therefore suggested that the enhanced resistance of avocado fruits to *C. gloeosporioides* by the nonpathogenic strain results from the induction of epicatechin, a phenol that inhibits oxidation of antifungal diene. The possible use of this new technique as a common means for the control of anthracnose in avocado fruits was discussed. (L)

Use of the Antioxidant Xedaphen-20 and the Fungicide Prochloraz for the Control of Postharvest Disease in Avocado Fruit during Storage

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Postharvest fruit rot diseases of avocado caused by *Colletotrichum gloeosporioides* and *Diplodia natalensis* were reduced significantly by treatment with an antioxidant, butylated hydroxy anisole (BHA) (commercial name, Xedaphen-20). Experiments were carried out in the USA on cv. 'Hass' and in Israel on cv. 'Fuerte'. There was a significant reduction of decay by a single treatment of Xedaphen-20 at 1200 µg a.i./ml; the mixture of the antioxidant with up to 250 µg a.i./ml prochloraz further reduced decay development. It is suggested that the antioxidant might reduce decay development in avocado by modulating the natural fruit resistance. The results obtained in semicommercial trials in the last three harvesting seasons were discussed. (L)

Yield Loss of 'Hass', 'Fuerte' and 'Ettinger' Trees Due to Salinity, and Its Reduction by Appropriate Rootstocks and Management

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Information on the response of avocado trees to salinity is needed to predict their yield loss due to an increase in the salinity of irrigation water. A survey in commercial orchards indicated that West Indian rootstocks (WIR) were not transferring salinity resistance (SR) as had been assumed. Eight combined irrigation water amount and salinity treatments, in the range of 80 to 400 ppm chloride (1 to 2 dS/m), and an enhanced nitrogen fertigation treatment (EN; from 30 to 70–100 ppm N) were imposed from planting to the age of 10 years, on three avocado cultivars. Each cultivar was grafted on three clonal WIR, assumed to transfer SR, and on one Mexican rootstock (MR). Chloride and sodium accumulated in the clay soil, but winter rains leached most of them out of the root zone, except for a minor increase in exchangeable sodium for high salinity. To estimate SR of trees, cumulative yield (CY; kg/tree) as a function of irrigation water chloride content (Cl; ppm) was analyzed by an exponential model $dCY/CY=B * dCl$. B values are reported in % per increase in Cl of 100 ppm. For trees on MR, B was –30, with additional damage due to a decline of some trees, which was equivalent to a B value of –10. Increasing water amount of each irrigation by 27% was not found to reduce soil salinity or its damage to trees. EN was not found to affect SR of trees, but on some WIR it affected CY negatively and in the extreme case it resulted in a 41% CY reduction. All three WIR transferred to 'Hass' trees a high SR, with an average B of –7. WIR transferred to 'Fuerte' trees an almost complete SR, with nonsignificant B values of: 1, 0 and –6. The first WIR, but not the second, also transferred a high fertility to the trees. SR of 'Ettinger' trees on WIR was found to be variable, with B values of: –20, –10 and –8. The SR and fertility observed with one of the 'Fuerte' trees on WIR encourage further search for rootstocks transferring SR and fertility to avocado trees. A short cut to this most time-consuming research may be found by analyzing mineral uptake. This was indicated by a correlation between SR and boron uptake found with the 'Hass' trees. (L)

Rootstock and Nitrate Involvement in Avocado Response to Salinity

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The damage caused by excess chloride in 'Ettinger' avocado plants grown on the Mexican rootstock 'Schmidt' appeared mainly in the leaves and shoots, whereas the main toxic influence of chloride on the West Indian rootstock 'Zrifin 99' appeared in the root system – which showed a strong peroxidative activity. The dry weight of the roots of 'Zrifin 99' was also reduced and shoot/root ratio was increased, whereas the roots of 'Schmidt' rootstock were much less affected. An increased level of chloride ion was detected in the leaves of 'Ettinger'/'Schmidt' compared with in plants on 'Zrifin 99'. The level of nitrate ion was higher in leaves of 'Ettinger'/'Zrifin 99' than in those of plants grown on 'Schmidt'. The activity of nitrate reductase was correlated with the damage caused by excess chloride to 'Ettinger' grown on either rootstock. The study evaluated and demonstrated the parts played by rootstock and nitrate in avocado response to chloride stress. (P)

Inhibition of Avocado Root Growth by NaCl Stress

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Avocado is very sensitive to NaCl in the root growth medium; even low levels of salt inhibit plant development and decrease productivity. Most reported studies concentrate on salinity effects on the shoot. Leaf burn induced mainly by Cl⁻ but also by Na⁺ was commonly described. Only few investigations have evaluated the responses of avocado roots to salt stress; the mechanisms of root sensitivity or tolerance are therefore not understood. In the present work we investigated the physiological mechanisms underlying growth responses of the root to salinity, to increase our understanding of the root's role in whole plant responses.

Non-grafted avocado plants cv. 'Degania 117' of the West Indian horticultural race, and cv. 'Schmidt' of the Mexican race, were grown in aerated nutrient solutions in a growth chamber. The plants were exposed to increasing concentrations of NaCl in the root growth solution (1 to 50 mM NaCl). Following salinization, both root and shoot elongation were inhibited. At 15 mM NaCl the 'Degania 117' root showed 50% inhibition and at 25 mM NaCl, 80% inhibition of elongation in comparison with the control. Root growth was found to be more sensitive to salt stress than leaf growth. The possible role of mineral ion accumulation, and tissue osmotic potential in the inhibition process were discussed. (*P*)

Postharvest Responses of Avocado to High Temperature Treatments

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High temperature treatment is a promising technology for postharvest disinfestation and storage of fruit. It has many potential benefits as it is a non-chemical disinfestation technique, and may also counteract quality problems during storage of many fruits. We have examined the response of 'Hass' avocados to both hot air and hot water treatments and found that "pretreatments" at 38°C confer tolerance to both low temperatures (chilling tolerance) and high temperatures (thermotolerance). This presentation concentrates on the chilling injury response.

Chilling injury to the skin of 'Hass' (0 to 4°C) is typically expressed as browning which progresses from the lower layers of the skin to the skin surface, particularly at the lenticels. This damage is evident in transverse skin sections even after 1 week at chilling temperatures, and becomes evident externally after about 2 weeks. Electrolyte leakage also increased during the development of chilling injury, and the role of enzymes such as polyphenoloxidase in this browning is under examination.

Specific temperatures and durations of hot air treatments can reduce external chilling injury induced by storage at 0 or 2°C. After 4.5 weeks, overall fruit quality can be maintained at levels superior to fruit stored at 6°C, the current industry standard. Hot water treatments also reduce chilling injury, and use of the fungicide prochloraz with, or immediately after the hot water treatment, may reduce disease incidence and maintain fruit quality.

The role of heat shock proteins (hsps) in the responses of avocado was examined by measuring expression of hsp genes and hsp synthesis. Both gene expression and protein synthesis were followed during heat treatments and subsequent low temperature storage, and we suggest that hsps may be involved in reducing the symptoms of chilling injury. (*L*)

A Preharvest Heat Treatment as a Means of Delaying Avocado Fruit Ripening and the Development of Low-Temperature Injury

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Holding 'Fuerte' avocados for various periods of time at temperatures between 37° and 46° C, slowed the rate of fruit softening and delayed the climacteric respiration and ethylene peak. Some of the time-temperature interactions also delayed the appearance of chilling injury and reduced its severity after regular air storage at 2° C for 6 or 9 weeks. The prestorage heat treatment led to the accumulation of heat shock proteins in the fruits. Activities of cellulase and polygalacturonase were lower in heat-treated fruit, in correlation with their slower rate of softening. In addition, when heated avocados were inoculated with *Colletotrichum gloeosporioides*, the infection developed more slowly than on unheated fruit. The treatments led in some cases to heat injury, and additional work is needed to be sure of achieving the benefit of the treatment without injury. (L)

Foliar Sprays for Frost Protection

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In the winters of 1993 and 1994, container-grown lemons (var. 'Eureka') and avocado (var. 'Hass') were treated with one of the foliar chemicals Kocide®, Anti-Stress 2000®, Frost Shield® and Frost Guard®, or water. Twenty trees of each species were sprayed with each of the materials. In 1993 the trees were placed in a refrigerated truck at -2.8° C and in 1994 they were placed in a processing plant cooler that varied between -2.8° and -3.9° C. Every 2 h, five trees of each treatment were removed from the cold, so that there were trees that had been in the cold for 2, 4, 6 and 8 h.

One week after cold exposure the trees were assessed for damage. In 1993, damage consisted of only burned young leaves, with the most severe effects from the 8-h treatments. Kocide on both crops and Frost Shield on avocado seemed to confer slightly ($P=0.01$) better protection than the other materials. Trees showed no effects of the cold 2 months after conclusion of the treatment.

In 1994, the tree leaves began dropping and changing color after 1 h of cold treatment. Trees were removed from the cold after 1, 2, 4 and 8 h exposure. In the 4- and 8-h treatments, the scion on all the trees was killed and in some cases the whole tree was killed. The 1- and 2-h treatments caused damage to the youngest leaves. The Frost Shield treatment showed somewhat better ($P=0.10$) protection than the other materials on avocado, but no material was better than the control on lemon. Six months after the cold treatment, there was no difference among the trees that had survived. (P)

Taking the California Avocado Breeding Program into the Next Century

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In recent years much attention has been directed toward propagating new avocado selections in a central test plot to compare their performance (as replicated trees) with standard varieties. Vital data such as precocity, production, fruit quality, maturity season, relative fruit size, flower type, and tree form are emerging. Early data from recent selections indicate some interesting prospects for commercialization. Among the selections showing valuable commercial traits are: BL122, Sirprize, BL 667, 3-29-5, Harvest (5N-5(-)4), OA 184, 5-552, BL 343 and Regal. These were described briefly in order of priority. Others, like RTS 176 and BL1058, are serious contenders as pollenizers. Isolated plots are currently being established to determine how effective these are in comparison with such standard pollenizers as 'Bacon', 'Fuerte' and 'Zutano'.

The priorities for the breeding program going into the next century were discussed, including: (i) The continued evaluation of scion material from crosses made in California and of any promising materials obtained from other international industries. (ii) Emphasis on 'B'-flower 'Hass'-like material that may extend the 'Hass' season and provide pollination benefit. Examination of outcrossing of 'Hass' and new 'B'-flower types, and the study of bee preferences, flower visitation, and the role of bees in outcrossing. (iii) Evaluation of salt tolerance of rootstock materials from both the rootstock breeding program and international sources. Examining the link between *Phytophthora* tolerance and salt tolerance. (iv) Examination of the potential of dwarfing rootstocks and interstocks on avocado phenology and production. (v) In the course of conducting routine field work in the breeding program, we will continue to provide innovative horticultural techniques to the industry in the areas of grafting, tree training and pruning. (L)

Avocado Breeding and Evaluation of Genotypes in the Republic of South Africa

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An avocado breeding program was initiated in 1991 by the ITSC in order to develop superior cultivars for southern Africa. The program consists of two main parts, namely, rootstock and scion breeding, followed by extensive Phase-II evaluation. The breeding programs were founded on the establishment of a gene source, continued introduction of improved overseas material, controlled self- and cross-pollinations, and evaluations in Phase-I orchards. Since the inception of the scion breeding program, 5,240 seedlings have been established; six of them were selected for Phase-II evaluation.

The rootstock breeding program is devoted exclusively to the selection of *Phytophthora*-tolerant types. Over the past three seasons 24,000 seedlings were grown under conditions of severe artificial infection by *Phytophthora*. Thirty-three seedlings were selected for further screening.

The breeding and selection programs are followed by Phase-II evaluations. Various rootstock/scion combinations in different production areas are evaluated for characteristics such as yield, fruit quality, shelf life, etc. To date, rootstocks 'Duke 7', 'Thomas' and 'Barr Duke' have been used in the trials. The rootstock selections are evaluated in combination with established scion cultivars: 'Fuerte', 'Hass', 'Pinkerton' and 'Ryan'. Ninety-two scion/rootstock combinations are currently being tested at two locations. (L)

Progress in the Study of Avocado Genetic Resources I. Central Part of Mexico

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The considerable diversity in ecological conditions found in Mexico has enabled great variability in genotypes of *Persea*. The first stage of this project involved the exploration and collection of interesting materials: the high variability found necessitated continued exploration work, in order to survey additional areas, including the states of Nayarit, Michoacan, Puebla and Mexico, in the search for individuals with outstanding characteristics.

At El Ruis, in Nayarit, at 180 meters above sea level (m asl), West Indian race avocados such as 'Venado 1' and 'Venado 2' were collected; they are outstanding in yield and fruit quality. In Amatlan de Canas (620 m asl), 'Avelar 3', which is tolerant to *Coptorus aguacatac*, and 'Avelar 4', with a thin, purple skin, were collected. In the villages of Carranza, Xalisco, El Ixote and El Aguacate (940 m asl), materials growing in soils with excessive calcium carbonate content were collected.

In Puebla, in the localities of Atlixco, Tochimilco and La Trinidad, very pronounced degrees of genetic erosion, caused by *Phytophthora cinnamomi* Rands, were found. Nevertheless, some indigenous materials were collected, such as 'Telez 1', which is a 400-year-old tree.

The regions of Tacambaro, Tingambato and Urupan were explored in Michoacan, where the 'Hass' variety flourishes and the number of native Mexican varieties has diminished. Outstanding materials such as 'Lonjas', 'Vargas', 'Zarcoli', 'Tucuata', 'Jimenez' and 'Aguacate Azul' were collected.

***In vitro* Shoot Proliferation in Avocado Induced by CPPU**

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Efficient methods of clonal propagation are required by the avocado industry, in order to increase the use of rootstocks with salinity and *Phytophthora* resistance. Tissue culture techniques in avocado are difficult to employ, because the tissues have the tendency to develop browning and later necrosis. This decreases the rooting potential *in vivo*, as well as *in vitro*.

Active growing shoots from summer, autumn and spring vegetative flushes, were excised and kept in a solution of 500 mg/l ascorbic and citric acids, plus 50% v/v of ice. Murashige and Skoog medium and WPM (McCown's woody plant medium) were used in assays for types of explants, season, surface sterilization, antioxidants and growth regulators. The improved protocol consists of using axillary buds, surface sterilized with 95% ethanol for 5 sec, followed by 0.5% sodium hypochlorite plus 0.1 ml/l Tween 20 and five rinses with antioxidant solution. Once inoculated, culture tubes were kept first in darkness and then under increasing light intensities (500, 1500 and 3500 lux), for periods of 7 days each. Phases I and II were carried out in the same medium (using 0.2% agar, 0.2% gelrite, 60 mg/l ascorbic acid). The optimal conditions for 'Lula' and 'Velvick' were 0.5 and 0.1 mg/l CPPU (forchlorfenuron), obtaining up to 92% establishment rate and 1.4 shoots per explant. Lower levels of browning were detected when using CPPU, in comparison with thidiazuron and benzyladenine. No seasonal effect was detected, as long as the mother plant exhibited vegetative growth.