THE ASIAN AND AFRICAN CITRUS PSYLLIDS DIAPHORINA CITRI KUWAYAMA, TRIOZA ERYTREAE (DEL GUERCIO), (HOMOPTERA PSYLLIDAE) IN THE SOUTH WEST OF SAUDI ARABIA.

PROPOSALS FOR AN INTEGRATED CONTROL PROGRAMME

REPORT TO THE FAO

B. AUBERT

IRFA-REUNION.

The terms of reference proposed by FAO for the consultancy were : *Biological control of the citrus psyllids in Saudi Arabia.*

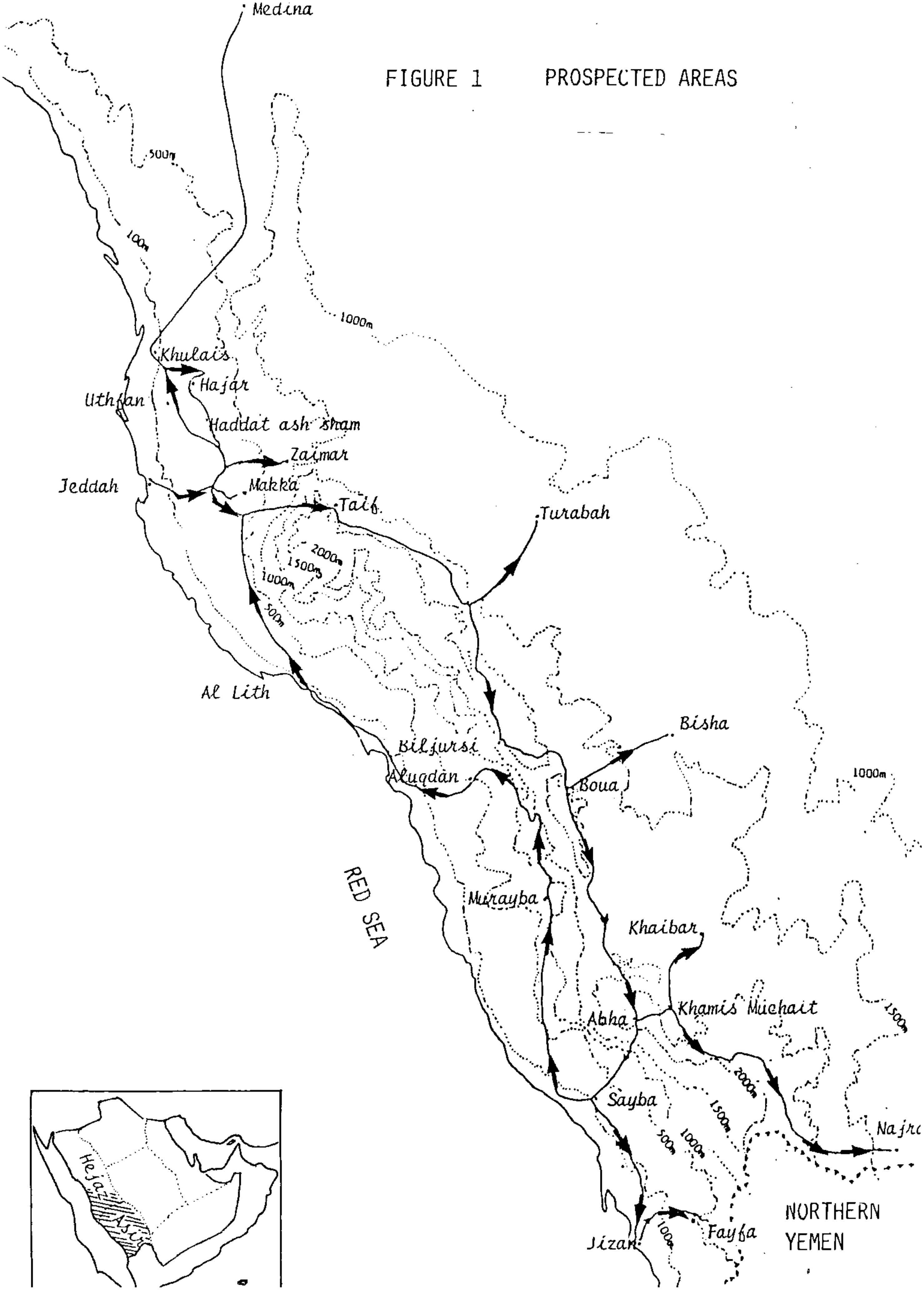
The visit started in Jeddah. Professor BOVE and Mr SARIEDINE had listed the orchards to be inspected after a discussion with the Director of the Agricultural Research Center Mr SALEM BA MUFLIH and the regional locust officer AHMED KHASAWNEH. The visits were carried out with Pr BOVE Dr SARIEDINE, Dr FUDL ALLAH and Mr ABDUL AZIZ ALIJAN entomologist at the Agricultural Research Centre of Jeddah.

The equipment used for collecting insects, included several mouth aspirators, gelatine capsules, glass vials, cottonwool, and 15 emergence boxes.

A total of 21 citrus orchards were seen in a situation ranging from sea level to 2.000 meters of elevation. In most of the orchards, homopterous insects, chiefly psyllidae scales or white flies, have been collected.

The taxonomy studies were made with the assistance of Dr BENASSY for scales Dr PANIS for parasitic waps. These two scientitists belong to the "Station de lutte biologique" INRA Antibes - Valbonne France. Dr HOLLIS from the British Museum of Natural History (BMNH) identified the nymph of *Acaudaleyrodes citri* and compared the saudian *Diaphorina citri* specimens with that of Brazil and Reunion Island. Cultures made on agar nutrient medium for isolating the bacterium causing the Citrus canker were dispatched to Dr CIVEROLLO USDA Beltsville USA and Mr LUISETTI INRA-Angers France.

FIGURE 1 PROSPECTED AREAS



PART ONE : DETAIL OF FIELD VISITS AND MATERIAL COLLECTED

The prospected areas are presented on the map of the Figure 1.

1. - <u>Uthfan</u> (Elev. 150 m)

   1.1. Orchard (on the roadside near the bridge) planted with mexican lime. Symptoms of motling on the leaves. Presence of *Diaphorina citri* Kuw adults and nymphs. *Tetrastichus radiatus* obtained from parasitized nymphs.

   1.2. Orchard planted with oranges, mandarines, grapefruits, mexican lime as well as table grape, figs, guavas and mangoes.
   The citrus are affected by greening, the mexican limes exhibit less yellowing than other citrus.
   Presence of heavy populations of *Diaphorina citri* Kuw. From parasitized nymphs of *D. citri*, 9 ♂ and 10 ♀ of *Tetrastichus radiatus* Waterston were caught in emergence boxes.
   Leaves attacked by *Pinnaspis strachani* COOLEY, and *Phyllocnistis citrella* the citrus leaf miner.

2. - <u>Khulais</u> (Elev. appr. 200 m) : Presence of *Diaphorina citri* Kuw. on mexican

lime's.The parasitized nymphs have given 10 ♂ and 14 ♂ of *Tetrastichus radiatus* WATERSTON and 1 ♂ of an hyperparasite : *Cheiloneurus cyanonotus* WATERSTON.

3. - Haddat ash Sham (elev. appr. 200 m)

Mexican limes trees planted under Date palm with papaws and bananas. Parasitized nymphs of *D. citri* observed on leaves of mexican lime.

4. - Zaymar (elev. appr. 500 m)

Three mexican lime trees heavely infested with *D. citri* adults and nymphs the latter being sometimes parasitized. No parasites adult caught.

5. - Wahdi Nahman (elev. appr. 500 m)

Visit of the orchard Al Saigh Farms (Oranges, grapefruits, lemons, limes and mandarines).
Parasitized nymphs of *D. citri* gave 5 ♂ and 1 ♀ of *Tetrastichus radiatus* collected + one unknown eulophideae
Visit of the orchard of the Mufti of Mekka : attacks of termites.

6. - Turabah Oasis (elev. appr. 1.000 m)

Visit of the orchards *Oda Gamdi* and *Moïd Ben Warm*. A few mandarines and oranges affected by greening show severe symptoms of dieback ; mexican lime trees exhibit leaf motling. All citrus harbour *D. citri* adults and nymphs. Some nymphs parasitized with *Tetrastichus radiatus ; 1 Cecidomyidae* obtained in the emergence box.
Release of 150 adults of *T. radiatus* imported from Reunion Island in the *Oda Gamdi* orchard. Some cases of *Phyllocnistis citrella* attacks seen.

7. - Boua (elev. appr. 1500 m)

Orchard near the road on the banks of the Wahdi Shugub River : Mexican limes in association with pomegranate ,guavas, date palm, table grapes, apricot. Not a single trace of *D. citri* nor galls of *T. erytreae* could be observed in this orchard.

8. - Bishah Oasis (elev. 1040 m)

Visit of the orchard *Abdelaziz Abdallah Saffar*, and of the orchard *Hassane M. Gharsane Bichitt*. According to these farmers the greening disease appeared in this oasis 10 years ago. Most of the mandarines and orange trees have been destroyed. The few specimens left are exhibiting a severe dieback. Presence of *Diaphorina citri* on mexican lime, and pamplemousse. No *Tetrastichus radiatus* could be collected. A sour orange not grafted was heavely infested with *Aonidiella aurantii* MASK. Galls of *T. erytreae* were absent.

The director of Agriculture for this area *Mohammed Ahmed AL. Nahary* mentionned that the date palms are occasionnally sprayed. Some attacks of *Oryctes* sp. or *Pseudophihes* sp. seen on the middrib of date palm leaves.

9. - Al Ullayah (elev. appr. 2.000 m)

Citrus orchard near the road when entering in this village : oranges estimated 7-10 years old, all without symptoms of greening. Gall of *T. erytreae* absent no trace of *D. citri*. Some *Coccus* sp. on leaves.

10. - Abha and Khamis Muchait (2.000 m)

No Citrus orchards observed.

11. - Brim Khaibar (estimated elevation 1.500 m)

Visit of the orchard *Said Hamood* : Mexican lime trees. This is the only orchard where leaf galls of *T. erytreae* were observed together with *D. citri* Galls of *T. erytreae* empty suggesting there is no parasitism on this african psyllid. From *D. citri* nymphs 2 ♁ and 1 ♂ of *Tetrastichus radiatus* obtained in emergence box. In this orchard, nymphs of *Acaudaleyrodes citri* (PRIESNER and HOSNY) have been observed on leaves of mexican lime, as well as a few specimens of *Icerya purchasi* MASK.

12. - NAJRAN

Visit of three private orchards, and visit of the FAO project with the director *Brim Nath* and the Co manager *Mohamed N. Boukhari*. Not a single trace of *D. citri* nor galls of *T. erytreae* could be observed in the Najran area. In some orchard *Aonidiella orientalis* NEWST have been seen on fruits or leaves of oranges trees. Some of these scales were parasitized but no hymenoptera could be obtained from the emergence box.

13. - Jizan

Visit of the FAO project with Dr *Augsburger* director, *Minas Papademetriou* horticulturist, *Mohamed Abo-Elfadel Morsy* Plant protection, *Ahmed Alsaffar* extension service, and *Yousif Abuzeid* Horticulturist former director of the Fayfa experiment station. Since the Jizan area is hot, grapefruits are of good

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quality, as well as Tahiti lime and Minneola Tangelo. The new Citrus collection is grafted on Rough Lemon. The plant have been introduced from Coral Reef Nursery (Florida) in 1981.
Not a single trace of *D. citri* nor galls of *T. erytreae* could be observed in this orchard.

14. - Fayfa

15. - Saybia

Visit of *Al Zabia* orchard : Mexican lime trees affected with leaf miner and citrus canker.

16. - Ad Darb

Visit of Sahad Mekhas : Attacks of leaf miner on mandarines and lemons but no citrus canker. Some trees are damaged by the local locust *Poecilocerus* sp. and by termites. Not a single trace of *D. citri* nor *T. erytreae* seen.

17. - Muraiba

A few isolated non grafted lime trees have been observed. No leaf miner, no citrus canker, and no trace of *D. citri* nor *T. erytreae*.

18. - Al Qunfidah

No citrus seen.

19. - Al Ugdan

One healthy mexican lime seen : no trace of *D. citri* nor *T. erytreae*.

20. - Al Lith

No citrus seen.

21. - Medina

PART TWO :INSECT PESTS OF THE SAUDIAN ORCHARDS,WITH PARTICULAR EMPHASIZE ON CITRUS PSYLLIDS.

1. INTRODUCTION

Citrus and other fruit trees are grown in most regions of South West of Saudi Arabia. Oranges and mandarines were traditionally cultivated near the date palm groves, before the appearance of the *greening disease*, together with other fruit trees like guavas, pomegranate, figs, and, in Taïf-Abha-Najran area, with deciduous and grapes.

Better communications inside and outside the Peninsula has promoted the transport of agricultural products and plant material, but also the introduction of new pests and diseases.

One of the most devastating insect pest mentionned for the first time in the Kingdom by WOOLER and al (1974), is the oriental psyllid *Diaphorina citri* Kuwayama, vectoring the asian strain of the *Citrus greening disease*.

The latter is associated with an endocellular bacteria of the phloem (GARNIER and BOVE 1977). Like any other homopterous insect, *D. citri* has a mouthpart adapted for piercing the plant tissue in order to suck the sap. When feeding on a contaminated citrus plant, the insect is able to acquire the *greening organism*, and transmit it subsequently to other plants. The disease has rapidly eliminated most of the mandarine and orange trees of the Jeddah-Mecca area and has invaded the oasis of Turabah and Bisha (BOVE and GARNIER 1983). The asian strain of *greening disease* affects all the citrus, irrespective of the species, varieties, scion-rootstock combination or ambiant condition of temperature. It is also transmissible by graft, but a classical disease free certification programme is not a sufficient prerequisite for controlling the maladie if viruliferous psyllid infestations are recurrent.

Moreover, during the present trip, we have observed leaf galls of *Trioza erytreae* (Del Guercio), the african psyllid, in the Abha area, and at Fayfa near Yemen border. In Africa this second psyllid transmits a heat sensitive, strain of greening (BOVE et al 1974).

It is now clear that *D. citri*, which arrived from the North (Jeddah-Mecca area), and *T. erytreae* from the South (Yemen border), have made a junction in the Asir. The two psyllids were observed by us in the same orchard at Brim Kaybar 50 km North East of Abha. This might change the situation prevailing so far in the areas harbouring only *T. erytreae*. In fact MASSONIE and al 1976 have demonstrated that the african citrus psyllid is able to transmit the asian heat tolerant strain of greening. The latter can now be spread in the high plateaux where *T. erytreae* breeds preferentially and thus beyond the hot and dry territory of *D. citri*. It is not even impossible that this asian strain might cross the Red Sea some day for invading the neighbouring african countries.

For these reasons, the greening disease is seriously threatening the citriculture of this part of the world.

Saudi Arabia is so far the only place, after the Mascareignes Islands (Reunion Mauritius and Rodrigues), to harbour both citrus psyllids.

In order to minimize the chances of greening infection spread by psyllids careful control measures should be adopted against the two vectors for maintaining the lowest level of pullulation. This goal might eventually be reached via an integrated pest managment.

2. IS THERE AN EFFECTIVE BIOLOGICAL CONTROL, POSSIBLE AGAINST THE CITRUS PSYLLIDS ?

Three main factors are influencing the abundance of citrus psyllids.

They are

i. prevailing climatic conditions
ii. shoot flushing rythm of the host plants
iii. parasitic activity of natural enemies

In some countries, parasitic activity brought about such a drastic reduction of citrus psyllids, that it proved to be economically satisfactory.

For instance in Reunion Island, excellent biological control of the two vectors of *greening* was achieved throughout the coastal plain (the main *D. citri* area) but also in the high plateaux above 600 m (where *T. erytreae* breeds preferentially). For this island of Indian Ocean, the project was not particularly sophisticated and relatively inexpensive. During the last decade, the citriculture of this Island could gradually recover its normal aspect.

The possibility of launching a similar biological control programme in Saudia Arabia against the african and the oriental psyllid will be dealt with in this report.

Several measures will be suggested, but it is extremely difficult to predict the success of introduced natural enemies until they are actually tested in the field.

Furthemore the situation prevailing presently in Saudi Arabia should be analysed and compared with similar conditions found in the Mascareignes Islands.

3. BRIEF DESCRIPTION OF THE RULES GOVERNING A PROGRAMME OF BIOLOGICAL CONTROL

Natural enemies are either predators (ladybird, beetles) or parasitoids (small minute wasps). Parasitoids reduce pest numbers more effectively than predators. Immature parasitoids usually feed internally and externally on a single host, and are of great value in limiting the increase of many pest species. Indiscriminate use of pesticides can have unexpected and sometimes disastrous consequences, since pesticides often kill the natural enemies of pests more effectively than they do the pests, allowing survivors to breed freely.

Such a free breeding alternative occurs equally when an insect pest of foreign origine becomes established in a new area and the natural enemies that attack it are left behind.

The aim of biological control is to rear, release and establish in a self renewing cycle natural enemies, to achieve a marked reduction in the average numbers of a pest population.

Pre-release studies should center on determining the suitability of the natural enemy for a given ecosystem where it will have to adapt.

There are several rules guiding a biological control programme against homopterous insects in general (DE BACH et al 1971) and citrus psyllid in particular (ETIENNE and AUBERT 1980) and (AUBERT and QUILICI 1983).

i. A fully effective parasite is always quickly and easely established, often through release of very small number

ii. No single parasite or predator is generally capable of controlling its host throughout a vast geographic zone since abiotic factors like temperature or relative humidity may interfer on the parasitism

iii. Addition of a second and even a third or fourth parasite can make the difference between partial and complete success in biological control

iv. In the case of citrus psyllids, alternate host plants, can maintain a better equilibrium of parasitoid complex at certain critical flushing periods.

v. The introduction of hyperparasites should be avoided.

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vi. The use of pesticides should be carefully restricted. If other insect pests like scales white flies, aphids... are originating economic losses, they must also be fought through a specific biological programme in order to establish an overall integrated pest managment.

Before concentrating on the two specific problems of *D. citri* *T. erytreae* in Saudi Arabia, a general description of the equilibrium regulating the population of insect pests in saudian orchards will be given.

4. - THE EXISTING BIOLOGICAL EQUILIBRIUM IN THE SAUDIAN ORCHARDS

The vast majority of the saudian orchards are typically established in the *oasis system* where the date palm occupies the top of the canopy, fruit trees and citrus the intermediate level, and vegetable or alfalfa the ground level (CF. Photo n°1).

A programme of biological control must, therefore, take into account all the insect pests affecting the production of the oasis. Any spraying programme should be restricted to localized situation, avoiding full cover sprays by air. At the same time, natural enemies should be husbanded for keeping low levels of pullulation.

According to MARTIN (1972), the majority of fruit tree pests known to exist presently in Saudi Arabia have been introduced from abroad. Many are of african origin : *Trioza erytreae, Papilio demodocus*, while others are from eastern regions : *Diaphorina citri, Papilio demoleus, Phyllocnistis citrella.*

A large number are typically mediterranean : the olive psylla *Euphyllura olivina*, or the bark beetle *Scolytus mediterraneus* and the mediterranean fruit fly *Ceratitis capitata.*

In an exhaustive survey of insect pests and diseases of Saudi Arabia, MARTIN (1972) emphazised the rich fauna of entomophagous insects and the fact that in the absence of chemichal treatments , this self renewing fauna would keep the populations of insect pests at a "*bearable level*".

A total of 28 mites and insect pests of Citrus were identified by MARTIN (1972) i.e. 7 mites, 1 Collembole, 1 Thrips, 1 Aleurode, 4 Aphids, 9 Scales and mealybugs, 1 Psylla, and 4 Lepidopteras. At the same time, 15 predators and parasitoids were discovered as regulating the outbreaks of the insect pests.

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~~Photo~~ 1 : A typical aspect of the BISHA oasis only three mexican limes are left from the former orange and mandarine orchard destroyed by the greening disease.

1. Alfalpa
2. Table grape

3.4.5. Mexican lime trees

6. Date Palm.

Table 1 : List of insect pests of Citrus and date palms with their predators.

After MARTIN

1.1 PREDATORS	HOST		CROP INFESTED
ACARINA - Eupalopselludae (det. C.I.E.)			
Saniosulus nudus Summers	Aonidiella orientalis	(Diaspididae)	Citrus spp. Psidium guajava
HETEROPTERA - Miridae (det. C.I.E.)			
Chellomenes vicina (Muls.)	Rhopalosiphum maidis	(Aphididae)	Setrria italica
Chilocorus bipustulatus (L.)	Aonidiella orientalis Parlatoria blanchardi	(Diaspididae) (Diaspididae)	Citrus spp. Phoenix dactylifera
Coccinella septempunctata L.	Aphis craccivora	(Aphididae)	Medicago sativa Citrus
	Therioaphis trifolii	(Aphididae)	Medicago sativa
Coccinella undecimpunctata spp.	Aphis craccivora	(Aphididae)	Medicago sativa Citrus
aegyptica Reiche	Therioaphis trifolii	(Aphididae)	Medicago sativa
Hyperaspis vinciguerrae Capra	Maconeilicoccus hirsutus	(Paeudococcidae)	Ficus carica Phoenix dactylifera Psidium guajava
Hyperaspis vinciguerrae Capra	Nipaecoccus vastator	(Paeudococcidae)	Citrus spp.
Hyperaspis vinciguerrae Capra	Planococcus sp.	(Pseudococcidae)	Ficus carica
Pharoscymnus ovoideus Sicard	Parlatoria blanchardii	(Diaspididae)	Phoenix dactylifera
Pharoscymnus setulosus (Chevr.) ssp. bardus (Muls.) (det. C.I.E.)	Aonidiella orientalis	(Diaspididae)	Citrus spp.
Rodolia argodi Sic.	Icerya purchasi	(Pseudococcidae)	Citrus spp. Casuarina sp.
Scymnus agrumi sp. novum Fursch	Nipaecoccus vastator	(Pseudococcidae)	Citrus spp.
Scymnus (Pullus) ebneri Wse. (det. R.D. Pope, C.I.E.)	Aphis craccivora Therioaphis trifolii	(Aphididae)	Medicago sativa Citrus
Scymnus levaillanti Mulsant	Aonidiella orientalis	(Diaspididae)	Citrus spp.
Scymnus syriacus Muls.	Aonidiella orientalis Aphis fabae	(Diaspididae) (Aphididae)	Citrus spp. Dolichos lablab Phaseolus vulgaris
Stethorus gilvifrons (Muls.)	Tetranychus cinnabarinus	(Acarina)	Solanum melongena escul.
COLEOPTERA - Cybocephalidae (det. dr. Endrody-Younga/O.I.L.B.)			
Cybocephalus nigriceps Sahlbg.	Parlatoria blanchardii	(Diaspididae)	Phoenix dactylifera
	Aonidiella orientalis	(Diaspididae)	Olea europea
Cybocephalus nigriceps spp. sinister E.-Y.	Parlatoria blanchardii	(Diaspididae)	Phoenix dactylifera
Cybocephalus rufifrons flaviceps	Aonidiella orientalis	(Diaspididae)	Citrus spp.
Reitter	Fiorinia phoenicis Parlatoria blanchardii	(Diaspididae) (Diaspididae)	Phoenix dactylifera Phoenix dactylifera
Cybocephalus spp.	Aonidiella orientalis Nipaecoccus vastator Parlatoria blanchardii	(Diaspididae) (Pseudococcidae) (Diaspidse)	Citrus spp. Nerium oleander Phoenix dactylifera
DIPTERA - Cecidomyiidae (det. Dr? Nijveldt/O.I.L.B.)			
Dicrodiplosis pseudococci (Felt.)	Nipaecoccus vastator	(Pseudococcidae)	Citrus spp.
DIPTERA - Syrphidae (det. P. Goeldlin/O.I.L.B.)			
Sphaerophoria turkmenica Bankowska	Aphis craccivora		
	Therioaphis trifolii	(Aphididae)	Pedicado sativa Citrus.

Table 2 : List of insect pests of Citrus and date palms with their parasites.

After MARTIN

1.2 PARASITES	HOST		CROP INFESTED
HYMENOPTERA - Aphelinidae (det. Dr. Ferrière/O.I.L.B.)			
Aphytis chrysomphali (Mercet)	Aonidiella orientalis Aspidiotus destructor Pinnaspis strachani	(Diaspididae) (Diaspididae) (Diaspididae)	Citrus spp. Musa sp. Citrus spp.
Aphytis mytilaspidis (Le Baron)	Parlatoria blanchardii Aonidiella orientalis	(Diaspididae) (Diaspididae)	Phoenix dactylifera Citrus spp.
Archenomus arabicus sp. novum Ferrière	Parlatoria blanchardii	(Diaspididae)	Phoenix dactylifera
Aspidiotiphagus citrinus (Craw)	Aonidiella orientalis	(Diaspididae)	Citrus spp. Ficus carica
Azotus sp. Marietta exitiosa Compere	Aonidiella orientalis Hyperparasite on Azotus	(Diaspididae)	Ficus carica
Prospaltella sp. (det. C.I.E.)	Aonidiella orientalis	(Diaspididae)	Citrus spp.
HYMENOPTERA - Aphidiidae (det. Dr. Mackauer/O.I.L.B.)			
Lysiphlebus?ambiguus (Hal.)	Aphis gossypii	(Aphididae)	Solanum melongena escul. Hibiscus esculentus Citrus
HYMENOPTERA - Encyrtidae (det. Dr. A. Hoffer/O.I.L.B.)			
Comperiella bifasciata Howard	Aonidiella orientalis	(Diaspididae)	Acacia cyanophila Citrus spp. Ficus carica Ficus nitida
HYMENOPTERA - Chalcididae.(det. C.I.E.)			
near Sympiesis sp. (det. O.I.L.B.)	Phyllocnistis citrella	(Gracillariidae)	Citrus spp.
Tetrastichus heeringi Del. (det. O.I.L.B.)	Aonidiella orientalis	(Diaspididae)	Acacia cyanophila Citrus
HYMENOPTERA - Pteromalidae (det. Dr. Boucek/O.I.L.B. & C.I.E. as indicated)			
Pteromalus puparum (L.)	Papilio demoleus	(Papilionidae)	Citrus spp.
Ocutellista sp. ?obscura (Forster)	Aonidiella orientalis Saissetia nigra	(Diaspididae) (Lecaniidae)	Citrus spp. Lawsonia inermis

As far as the date palm is concerned 15 insect pests were listed harbouring 10 predators or parasites. The list of insect pests of citrus and date palm is given on Table 1 with their respective predators and on Table 2 with their respective parasites.

MARTIN noted a fairly efficient biological control on citrus, but mentionned the problem of date-palm borers : *Oryctes* spp. and *Pseudophilus testaceus* in palm groves. It was thought that improved cultivation and better sanitation of the palm grove could reduce the threat of these borers : the wilting palm and dead trunks should be removed and burnt, and excessive humidity of the soil should be avoided by a proper managment of irrigation. Better ventilation by planting palms at a suitable distance would also decrease the infestations of these coleoptera. Neither citrus nor date palm were showing serious scale problems.

Were it not the new challenge of the spread of greening by *Diaphorina citri*, and *Trioza erytreae*, the situation of citrus insect pests we observed during our visit would be the same as described 10 years before by MARTIN.

To sum up, the natural equilibrium regulating the outbreaks of insect pests in the saudian orchards (including date palm groves) seems to allow the implementation of an integrated control programme against the two citrus psyllids.

4. - THE TERRITORY OF *T. ERYTREAE* AND *D. CITRI* IN THE ARABIAN PENINSULA

Climatic factors are influencing the survival of Citrus psyllids. In the case of *T. erytreae* high temperature and dry air induce a large percentage of mortality of eggs and first instar nymphs, while for *D. citri* low temperatures decrease seriously the possibilities of breeding. The result is the development of *T. erytreae* in highlying areas of the South West of Saudi Arabia, above 1000 m of elevation, while in the case of *D. citri* large pullulations are found in lowlying areas, generally below 1500m of elevation.

4.1. . *Trioza erytreae*

Like many other species of Psyllidae *Trioza erytreae* is known to be intolerant of high temperatures. Under controlled conditions in laboratory MORAN and BLOWERS (1967) found high mortality by dessication of eggs and young nymphal stages, when temperature was exceeding 32°C several hours daily.

In fact, upsurge of *T. erytreae* populations can be expected if climatic conditions do not result in excessive heat and drought .

This point will be analysed here.

By marking colonies in the field at the egg stage and following up with detailed counts at regular intervals until the emergence of adults, GREEN and CATLING (1971) showed the influence of prevailing weather. They demonstrated that the two most acceptable predictors of survival were : (i) mean daily maximum temperature, (ii) mean minimum vapor pressure. Combining these two meteorological parameters, one can obtain the air's evaporative power, or saturation deficit (SD). SD represents the quantity of vapour which would have to be added to the air, in order to obtain saturation vapour pressure at the temperature prevailing at the time. The maximum saturation deficit occurs at mid-day, and can be calculated from the maximum temperature (MT) and the minimum relative humidity (RH), by means of the following formula

$$SD = VPmt \times \frac{100 - RH}{100}$$

where SD = maximum saturation dericit

VPmt = saturation vapour pressure corresponding to the maximum temperature recorded during the day

RH = minimum of relative humidity

GREEN and CATLING found that on a *lethal day*, the saturation deficit exceeds 34,6 mbars, causing 70 percent mortality of eggs and first instar nymphs,and 100% mortality at 48 mmbars.

In the case of Reunion Island for instance the driest sites do not score a saturation deficit above 15 mmbars at midday.The cool and moist conditions of hyghlying areas of this island offers permanently ideal conditions for the development of *T.erytreae* (AUBERT et QUILICI 1983).

The situation is somewhat different for the highlying areas of Saudi Arabia.

Using the meteorological records of the year 1981, we calculated the maximum saturation deficit for 8 stations of South West Saudi Arabia (cf. table 3).

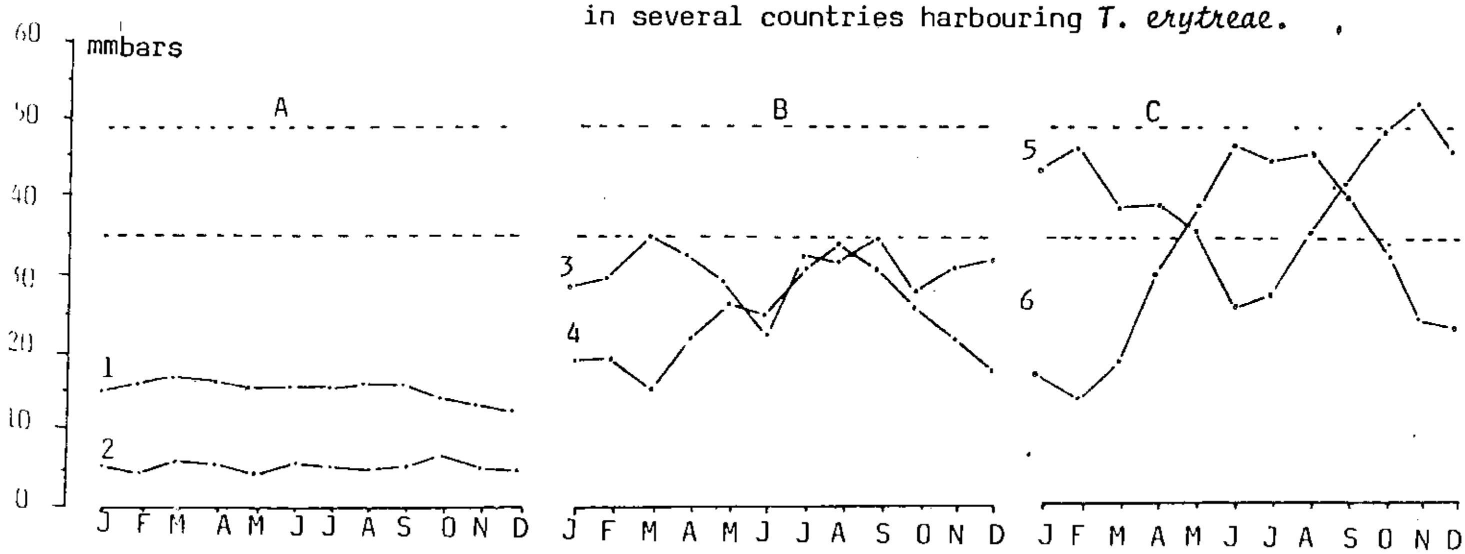
Since a saturation deficit of 35 mm bars leaves a low percentage of survival for *T. erytreae* one can see that the more suitable area for the development of *T. erytreae* is Jizan, where the highest monthly mean SD is 35,7mm bars. In fact the area of Fayfa situated in the mountain behind Jizan is still cooler and moister, thus offering more favorable conditions for the development of *T.erytreae*.Unfortunately we could not have access to meteorological data of this area.But we suspect that climatic conditions are extremely suitable for *T.erytreae*,in regard of the high percentage of curled leaves (with galls) seen by us in Fayfa.

By contrast ,the oasis of Bisha exhibits very low chances for *T.erytreae* development.while at Khamis Muchait,2000m of elevation,the maximum of

Table 3 :Monthly mean temperatures in °C,relative humidity(RH), and saturation deficit (SD) in millibars ,at midday for 6 stations of Saudi Arabia.

		J	F	M	A	M	J	J	A	S	O	N	D
Najran 1150 m.	T°C	26,3	26,7	28,1	34,0	36,0	38,5	38,8	38,2	33,3	30,2	21,2	26,2
	RH	32	27	41	18	17	10	11	13	17	19	30	24
	SD	22,9	25,2	22,0	43,1	48,8	60,6	60,8	57,3	41,9	34,3	17,4	25,5
Bisha 1040 m	T°C	28,4	26,4	29,4	34,0	35,6	38,7	38,7	39,1	35,8	31,8	29,5	26,2
	RH	18	17	23	13	13	4	7	6	7	9	15	15
	SD	31,7	28,2	31,1	45,7	50,0	65,3	63,3	64,9	54,0	41,9	34,6	30,1
Jizan	T°C	30,1	30,0	31,9	34,9	37,0	38,2	38,0	38,5	37,7	34,7	33,9	30,7
	RH	63	53	61	49	53	49	47	47	49	46	53	59
40 m	SD	15,6	19,7	18,2	28,2	29,1	34,7	34,5	35,7	32,9	29,5	24,5	17,8
Khamis Mucheit	T°C	22,4	22,6	22,4	26,1	28,3	31,6	30,4	30,9	29,1	26,3	24,7	22,9
	RH	29	36	47	30	26	49	25	25	21	24	29	29
2000 m	SD	18,9	17,3	14,1	23,3	28,1	23,4	32,1	33,0	31,2	25,6	21,7	19,5
Taif 1634 m	T°C	24,4	23,9	25,4	29,5	33,1	35,2	34,3	34,9	33,6	29,7	26,1	25,6
	RH	46	58	53	27	25	16	17	17	20	21	31	31
	SD	16,3	12,3	15,0	29,7	37,5	47,2	44,4	45,9	41,2	32,6	23,0	22,4
Medina 500 m	T°C	24,6	26,5	28,6	35,0	39,5	42,5	39,3	43,2	41,5	36,5	30,3	27,9
	RH	25	20	16	15	16	7	9	10	10	24	30	40
	SD	22,8	27,3	32,5	47,2	59,4	77,6	64,0	77,9	71,2	45,6	29,8	22,2

Figure 2 : Saturation deficit at midday (mean monthly maximum) in several countries harbouring *T. erytreae*.



1) St Pierre Réunion (100m) 3) Nelspruit South Africa 5) Rustenburg South Africa

saturation deficit never attains 35 mmbars, thus offering much higher chances of survival for eggs and first instar nymphs.

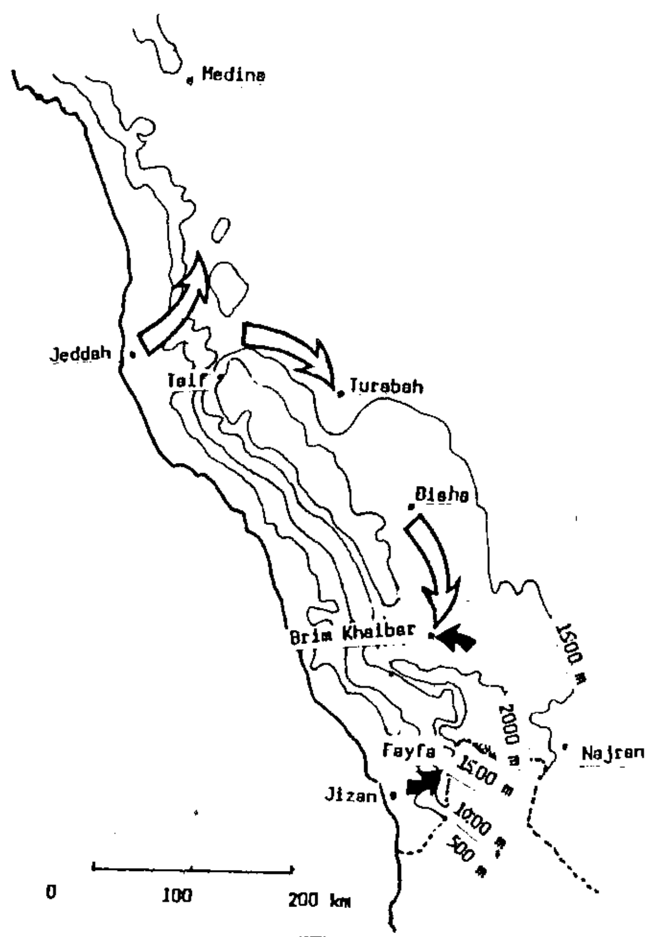
Other places like Najran Taif or Medina show only 4 to 5 months with an SD max. below 35,7 mmbars.

The monthly mean maximums saturation deficit for Reunion Island, Southern Africa and Saudi Arabia, has been plotted on Fig. 1A, 1B, and 1C. The *SD* of Fig. 1A goes with heavy attacks all throughout the year on limes or lemons which are more attractive for psyllids and exhibit more flushes than other citrus species. In the case of Fig. B, upsurges of the african citrus psyllid are concentrated during flushing periods at springtime. For both A and B cases, it is generally experienced efficient spread of the greening disease. But when saturation deficit is higher like on Fig. 1C, psyllid pullulations become very scarce and, at least in african conditions, the spread of greening is much slower. Finally there are two places where *T. erytreae* was reported during our survey namely Brim Kaibar and Fayfa (C.F. Figure 2). Najran was seen free of *T. erytreae*, in this place high saturation deficits are reached from april to september.

Fifure 2 :Map of citrus psyllids in Saudi Arabia

T.erytreae

D.citri



The possibility for *T. erytreae* to breed on wild Rutaceous endemic to Saudi Arabia is still ~~to be~~ unknown questionned. Unlike in Africa, the most active spread of this psyllid throughout the Peninsula seems to take place mainly by the transport of citrus plants.

4.2. - *Diaphorina citri*

The information collected so far in the kingdom of Saudi Arabia indicates that *D. citri* has appeared only recently in Jeddah area. This asian vector of greening was not listed in the 1972 survey of MARTIN, but mentionned for the first time by WHOOLER and al, two years later. This agrees with the opinion of the farmers indicating that oranges and mandarines began to decline 10 years ago.

The spread of this psyllid from one oasis to another has most probably occured by the transport of citrus plants. Contaminated nurseries are still operating nowadays. *D. citri* is not an active flying insect, and in most cases could not have covered the distances between two oasis by itself, except perharps through exceptional winds. The distribution of saudian agricultural land in *green patches* separated by desert region is a typical feature of the conditions prevailing in lowlying areas of the Peninsula (CF. Fig. 3). Therefore, from the point of view of insect spread, each oasis can be considered as an island.

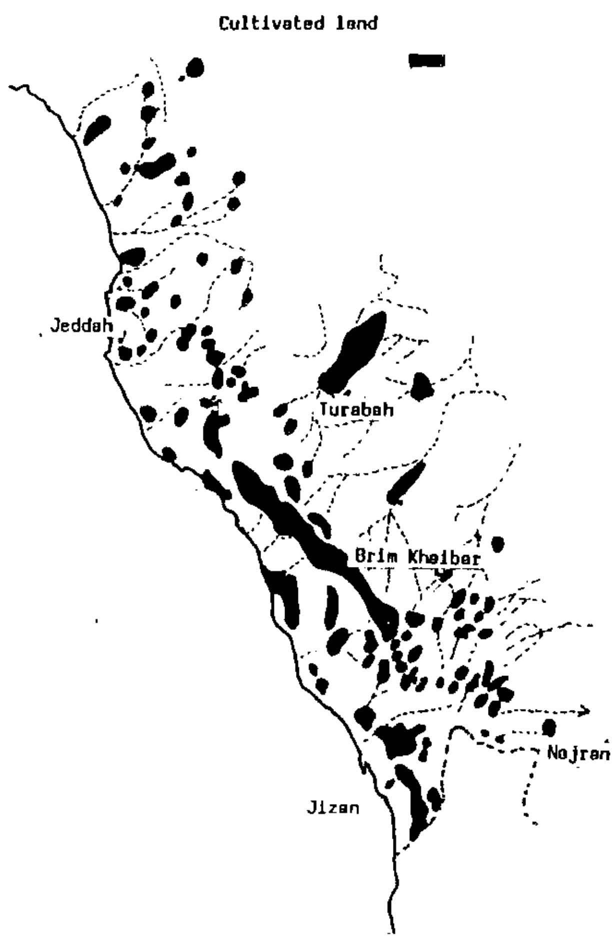


Fig. 3 : Cultivated land in the South West of Saudi Arabia.

During the present survey, *D. citri* was always found below 1500 m of elevation. But this psyllid was absent from the coastal Tihama plain extending South of Al Qunfidah down to the Yemen border. The oasis of Najran was equally discovered free.

In the Asir, the progression of *D. citri* has reached Brim Kaibar (CF. Fig. 2).

Several authors like CATLING (1968) in the Far East, and ETIENNE and AUBERT (1980) in the islands of Indian Ocean have clearly mentionned that *D. citri* breeds preferentially in hot and dry areas. For instance in Reunion Island (21° latitude South), *D. citri* does not move beyond 600 meters of elevation. In lowlying areas of this island the pullulations of this psyllid decrease with increasing rainfall and humidity, or when one moves from the leeward to the windward side.

Finally the prevailing weather regime suitable for high breeding of *D. citri* is exactly opposite of that mentionned earlier for *T. erytreae*.

5. PARASITES AND HYPERPARASITES OF CITRUS PSYLLIDS IN SAUDI ARABIA

5.1. - *Trioza erytreae*

During the present survey, no trace of parasitism could be detected on *T. erytreae*. Only empty galls were seen on curled leaves. This indicates a normal emergence of adults, followed quickly by the fall of the moults. When parasites are present, punctured mummies are left attached inside the galls for 10 months or more.

We insist on the fact that only empty galls were seen. Therefore a lack of parasitism is strongly suspected on *T. erytreae* at Brim Kaybar and Fayfa. It must also be emphasized that we made sure the galls observed were not mistaken with small convex distorsions of leaves induced by whiteflies.

Nevertheless at the time of our visit we could neither observed nymphs nor catch adults of *T. erytreae*.

5.2. - *Diaphorina citri*

As mentionned on pages 1 to 4, the primary eulophid parasite *Tetrastichus radiatus* WATERSTON was caught in many places i.e. Uthfan, Khulais, Wahdi Nahman, Turabah, Brim Kaibar. There is no doubt on the identification of this ectoparasite. We think that Haddat ash Sham, Zaymar and Bisha most probably

The emergence box corresponding to the sample of Khulais gave one hyperparasite : *Cheiloneurus cyanonotus* Waterston. This encyrtid is known to be hyperparasitic in Coccidae, coccinellidae, syrphidae and psyllidae. Mc. DANIEL and MORAN (1972) obtained *C. cyanonotus* from parasitized nymphs of *T. erytreae* in Zimbabwe. We are not absolutely sure that the adult caught in our emergence box has hatched from a *D. citri* nymphs, althought the probability is high.

Remark :

MARTIN (1972) obtained from *Aonidiella orientalis* two aphelinidae *Azotus* and *Marietta* sp. The latter is hyperparasitic of primary hosts like Coccophagus, Habrolepis, and Tetrastichus. We did not find *Marietta* sp. in the material collected during our survey.

TROISIEME PARTIE : DISCUSSION ET PROPOSITIONS.

1. REMARQUES GENERALES

1.1. - *D. citri*

Un pourcentage relativement important de parasitisme a été trouvé sur *D. citri*. Ceci était inattendu et le matériel de capture apporté lors de cette mission s'est avéré insuffisant. D'où les lacunes concernant certaines zones. Il conviendrait la prochaine fois de disposer d'une centaine de boites d'éclosion (au minimum trois par verger).

D'après les observations qui ont pu être faites, la présence de *T. radiatus* ne semble pas s'accompagner d'une réduction notable des pullulations de l'hôte, du moins actuellement. Ces dernières sont extrêmement importantes, allant jusqu'à provoquer de sévères distorsions des limbes. Plusieurs explications peuvent être avancées

- L'introduction de *T. radiatus* serait plus récente que celle de *D. citri*, et la phase d'équilibre des populations ne serait pas encore atteinte. Pour le savoir le seul moyen est d'étudier sur plusieurs années l'évolution de cet équilibre à l'aide de données chiffrées.
- Le taux d'hyperparasitisme pourrait être plus élevé qu'on ne le pense, selon les endroits et surtout selon les époques de l'année. Comme les hyperparasites signalés en 5.2. sont communs à d'autres espèces et notamment aux cochenilles, il importe de séparer soigneusement les larves de psylles de tout autre ravageur, lors du remplissage des boites d'éclosion. C'est à cette condition qu'il sera possible d'identifier avec certitude des hyperparasites de *D. citri*, ainsi que leur gamme d'hôtes.
- Le niveau d'équilibre observé actuellement à la Réunion sur les populations de *D. citri* résulte de l'action conjuguée de deux parasites : un eulophide ectoparasite *Tetrastichus radiatus* et un encyrtide endoparasite *Diaphorencyrtus aligarhensis*. La présence de ce dernier n'a pas été observée en Arabie Saoudite.

1.2. - *T. erytreae*

Les premiers indices dont nous disposons font penser à un défaut de parasitisme sur le psylle africain. Ce point mériterait d'être confirmé non seulement en Arabie mais également au Yémen.

2. PROPOSITIONS

La question du contrôle de la maladie du greening et des deux caractérise par

- un manque de suivi phytosanitaire au niveau des pépinières
- un commerce actif de plants d'agrumes douteux
- la répartition des vergers en îlots de verdure au sein d'une zone désertique
- l'absence apparente Rutacées sauvages ou ornementales plantes hôtes relais pour les psylles : (ce point mérite toutefois confirmation).

Les méthodes d'éradication ne réussiront que si elles sont totales. On peut à la rigueur les envisager pour de petites oasis où le greening a déjà entraîné la disparition de la majeure partie des agrumes. Toutefois elles ne dispensent nullement de la nécessité de poursuivre dans le même temps un programme de lutte biologique conduit à l'échelle de la Péninsule.

La construction de deux insectariums, l'un pour l'élevage des parasites de *D. citri* (*T. radiatus* et *D. aligarhensis*), l'autre pour l'élevage d'un parasite de *T. erytreae* : (*T. dryi*), s'avère indispensable. Des moyens financiers doivent être également prévus pour continuer l'inventaire des entomophages et suivre l'évolution des équilibres *in situ* sur des périodes de plusieurs années. Les investissements consentis pour la maîtrise des deux psylles vecteurs du greening auront à coup sûr des retombées bénéfiques pour la maîtrise des autres ravageurs des agrumes.

La production de plants dans les pépinières doit faire l'objet d'un contrôle efficace assurant une parfaite couverture chimique contre les psylles, et garantissant l'emploi de greffons sains.

L'expérience acquise à la Réunion en matière de greening montr que le renouvellement du verger peut se faire progressivement en quelques années si d'une part on engage un programme de lutte intégrée contre les psylles, et que parallèlement les agrumiculteurs ont la possibilité de replanter du matériel végétal sain.

A N N E X E

Au cours de la présente mission nous avons trouvé un foyer de chancre citrique à Sayba au Nord de Jizan. La photo 2 montre un aspect du premier verger trouvé atteint de chancre. Sur les deux feuilles de la photo 3 on peut voir des pustules chancreuses. La feuille de gauche montre des traces de chenilles mineuses d'un côté de la nervure et de l'autre un complexe chenilles mineuses plus chancre. Les blessures épidermiques occasionnées par l'insecte ont facilité la dissémination des germes. Sur la feuille de droite on a affaire à une inoculation par blessure d'épine.

La bactérie a été isolée et cultivée sur milieu YDC puis réinoculée expérimentalement sur feuilles de lime mexicaine en blessant celles-ci à l'aide d'une épingle infectée (Photo 4).

La souche saoudienne a été envoyée à la collection de référence de l'INRA d'Angers ainsi qu'à l'USDA de Beltsville.

D'après les informations recueillies il semblerait que ces plants d'agrumes infectés (et qui sont pour la plupart non greffés) auraient été achetés à des yéménites. Certains planteurs ont installé ces arbres sans protection brise-vent (Photo 5) ce qui favorise la dissémination de la bactérie. Il conviendrait d'éliminer sans tarder ce foyer de chancre

Photo 2

Photo 3

Photo 4

LITTERATURE CITED

AUBERT B. and QUILICI 1983 : Control of african and asian psyllids in Reunion. In Proc. 9th Conference Int. Org. Citrus virologists (in press)

BOVE J.M. et M. GARNIER 1983 : Citrus greening and psylla vectors of the disease in the Arabic Peninsula. In Proc. 9th Conf. Intern. Org. citrus virol. (in press)

BOVE J.M. CALAVAN E.C. CAPOOR S.P. CORTEZ R.E. SCHWARTZ R. 1974 : Influence of temperature on symptoms of California stubborn, South African Greening, India Citrus decline and Philippines Leaf Mottle. Proceedings of the 6th IOCV WEATHERS and COHEN ed. pp. 12-15

CATLING H.D. 1968 : Distribution and biology of Diaphorina citri the insect vector of "leaf mottling" disease of Citrus. FAO Report to the Government of the Philippines

DE BACH P. ROSEN D. et KENNETT C.E. 1971 : Biological control of coccids by introduced natural enemies. Biological control (Ed. C.B. HUFFAKER) Plenum Press New York pp. 165-194

ETIENNE J. and B. AUBERT 1980 : Biological control of psyllid vectors of greening disease in Reunion Island pp. 118-121 In Proc. 8th Conf. Int. Org. Citrus Virol. E.C. CALAVAN, S.M. GARNSEY et L.W. TIMMER (Edit.) Univ. California Riverside

GARNIER M. et J.M. BOVE 1977 : Structure trilamellaire des deux membranes qui entourent les organismes procaryotes associés à la maladie du greening des agrumes. FRUITS Vol. 32 pp. 749-752

GREEN G.C. and H.D. CATLING 1971 : Weather induced mortality of the citrus psylla *Trioza erytreae* (Del Guercio) a vector of greening virus in some citrus producing areas of Southern Africa. Agr. Meteorol. 8 305-307

HUSSEIN MAMZA BINDAGJI 1980 : Atlas of Saudi Arabia Oxford University press 50 p.

MARTIN H.E. 1972 : Report to the Government of Saudi Arabia on Research in Plant Protection. 38 p. 1 map. FAO Saudi Arabian Funds-in-Trust. Report Nº AGT:TA/207

MASSONIE G. M. GARNIER et J.M. BOVE 1976 : Transmission of India Citrus decline by *Trioza erytreae* (Del Guercio), the vector of South African greening p. 18-20 In Proc. 7th Conf. Intern. Organ. Citrus Virol. E.C. CALAVAN (edit.) University of California Riverside

MORAN V.C. and J.B. BLOWERS 1967 : On the biology of the South African Citrus psylla *Trioza erytreae* (Del Guercio) (Homoptera : Psyllidae) J. ent. Soc. Sth. Africa Vol. 30 Nº 1 pp. 96-95.

REPORT ON VIRUS AND VIRUS-LIKE DISEASES OF CITRUS IN SAUDI ARABIA WITH SPECIAL REFERENCE TO CITRUS GREENING

by

J.M. BOVÉ

with the contribution of B. AUBERT *for psylla parasites and hyperparasites.*

This report is based on three surveys that were carried out in 1981 (November 17 to 30), 1982 (April 20 to 27) and 1983 (December 10 to 21). It concerns essentially citrus greening since the discovery of this disease in the southwestern part of Saudi Arabia was the most important result of the surveys. Dr. S. SARRIEDINE (FAO, Ministry of Agriculture and Water, Riyadh) took part in all three surveys. Dr. B. AUBERT (FAO consultant, IRFA, Reunion island) participated in the December 1983 survey to gain information on the status of psylla vectors of greening and their parasites and hyperparasites.

In addition to Saudi Arabia, the 1982 survey also included the Yemen Arab Republic while the 1983 mission was extended to the Ras el Khaima - Masafi area in the United Arab Emirates, the People's Democratic Republic of Yemen and the Yemen Arab Republic.

I - INTRODUCTION : KNOWN FACTS ABOUT GREENING AND THE TWO PSYLLA VECTORS OF THE DISEASE

"Greening" is one of the most serious diseases of citrus in the world. The affection is known to exist on the African continent South of the Sahara in citrus growing countries including Ethiopia. The disease is not present in the Northern parts of Africa. The disease is transmitted in Africa by the "african" psylla *Trioza erytreae* (Del Guercio). This vector is intolerant to high temperatures and low humidity. Hence it is often confined to cool elevated areas, and so is the disease. For instance greening affects the "highveld" areas of Transvaal and Swaziland but not the "lowveld" regions of Swaziland. Similarly in the island of Madagascar, greening and *Trioza erytreae* are only present on the high plateaux, not on the coastal areas. The same is true in Kenya where greening is severe in the citrus areas above 700 m but absent from the coastal regions. A bacterium-like organism of the Gram negative type is present in the sieve tube elements of affected plants. This "greening organism" (GO) is thought to be the causal agent of the disease. The GO of african greening is intolerant, i.e. sensitive, to heat, so that no symptoms develop when plants grow at temperature above 32°C ; no GOs are found in such symptomless trees. The african strain of the GO is probably unable to multiply at the higher temperatures. The heat sensitivity of both the african GO and the african psylla vector, probably explains the geographical distribution of greening disease with altitude and latitude in Africa.

A second form of greening exists : the asian greening, a more severe and more widely distributed from of the disease. The affected citrus areas extend from China and South East Asia to Nepal, India and Pakistan. In Asia the GO is transmitted by the asian psylla *Diaphorina citri* (Kuwayama) but we have shown that the african psylla, *T. erytreae* can also transmit the asian strain of the GO (MASSONIE et al., 1976). Inversely, *D. citri*, the asian psylla, transmits the african strain of the GO (LALLEMAND, GARNIER & BOVE, unpublished). The asian psylla is a much studier insect than *T. erytreae*. It resists high temperatures and low himidities. Similarly, the asian strain of the GO is heat tolerant. Hence the geographical distribution of asian greening is very much less affected by climat and elevation. Asian greening occurs not only in cool, elevated areas, but also in hot coastal zones.

The two forms of greening as well as the two psylla species occur together in two islands : Reunion island and Mauritius island. In Reunion *Diaphorina citri* is present from sealevel up to an elevation of 600 m, and *Trioza erytreae* only above 600 m. Greening disease extends from sealevel up to 1000 m.

Greening is not present in the countries surrounding the Mediterranean sea, nor does it affect Jordan, Irak and Iran. However, as a result of the 1981 survey the disease was discovered in the Southwestern part of Saudi Arabia. The 1982 and 1983 surveys were intended to further study the distribution of the disease and its vectors in the Arabian Peninsula. African greening was then discovered in North Yemen.

II - MATERIALS AND METHODS

II-1) Diagnosis of greening

Diagnosis of greening was based on symptom expression and electron microscopical detection of the GOs in the sieve tubes of leaves and/or fruits.

Leaves and fruits were kept in plastic bags for a few hours until they could be further processed. The leaf midrib was cut out with a razor blade and chopped into 2 to 4 mm long pieces. About 5 such pieces were fixed by immersion into a 5 ml screwcap tube filled with 2 % glutaraldehyde in 0.1 M phosphate buffer pH 7.4. For a given tree, midrib pieces from about 5 to 10 leaves were used and placed in the same tube.

The pedoncular end of the fruit axis is rich in phloem tissue and represents a choice material for GO detection. The columella tissue was dissected from the fruit with a razor blade, chopped into 2 - 4 mm long fragments and fixed in the same way than the leaf pieces.

The samples remained in the 2 % glutaraldehyde solution for 2 to 4 weeks until they reached the Bordeaux laboratory where they were postfixed in 1 % osmium tetroxide in the above buffer. After dehydration in ethanol, specimens were embedded in Epon and thin sectioned. The ultrathin sections were examined in a Siemens Elmiscope 101 electron microscope.

SAUDI ARABIA

			[illegible]	[illegible]LLA (*Diaphorina citri*)	[illegible]ESENCE OF AFRICAN PSYLLA (*Trioza erytreae*)	PRESENCE OF *Tetrastichus* [illegible], PARASITE OF [illegible]	PRESENCE OF PSYLLA HYPERPARASITE	PRESENCE OF CITRUS CANKER
	[illegible]	not clear	NO	YES	NO	YES		NO
	[illegible]	not clear	NO	YES	NO	YES	*Chalcidoidea* [illegible]	NO
HADDAT ASH SHAM	200	not clear	ND(1)	YES	NO	*D. citri* nymphs parasitized		NO
ZAYMAH	500	YES	YES	YES	NO	*D. citri* nymphs parasitized		NO
WADI NAHMAN	500	YES	UI(2)	YES	NO	YES		NO
TAIF	[illegible]	YES	YES	YES	NO	N.S.(3)		NO
TURABAH	1400	YES	YES	YES	NO	YES		NO
KHURMAH	1400	YES	YES	YES	NO	N.S.(3)		NO
BOUA	1500	YES	YES	none seen	NO	none seen		NO
BISHA	1000	YES	YES	YES	NO	none seen		NO
AL ULLAYAH	2000	NO	ND(1)	NO	NO	NO		NO
BREHIM KHAIBAR	1500	YES	YES	YES	YES(4)	YES		NO
NAJRAN	900	NO	NO	NO	YES	NO		NO
JIZAN	20	NO	NO	NO	NO	NO		NO
SABIA	100	NO	NO	NO	NO	[illegible]		YES
FAYFA	1200-1800	not clear	UI(2)	NO	YES(4)	NO		NO
AD DARB		NO	ND(1)	NO	NO	NO		NO
MUPAYRA		NO	ND(1)	NO	NO	NO		NO
AL UGDAN		NO	ND(1)	NO	NO	NO		NO
MEDINA area		NO	ND(1)	NO	NO	NO		NO

(1) ND : not done (2) UI : under investigation (3) N.S. : not surveyed in December 1983

(4) based on the typical *T. erytreae* induced leaf galls

II-2) Detection of psylla parasites and hyperparasites

Dr. B. AUBERT (IRFA, Reunion island) took part in the December 1983 survey to get a first idea on the presence of psylla parasites and hyperparasites in Saudi Arabia.

A total of 21 citrus orchards were seen in a situation ranging from sea level to 2000 meters of elevation. In most of the orchards, homopterous insects, chiefly psyllidae scales or white flies have been collected.

The equipment used for collecting insects, included several mouth aspirators, gelatine capsules, glass vials, cottonwool, and 15 emergence boxes.

The taxonomic characterization of the parasitic wasps (*Tetrastichus* sp.) of *D. citri* were made with the assistance of Dr. PANIS (Station de Lutte Biologique, Valbonne, France) and Dr. G.L. PRINSLOO (Plant Protection Research Institute, Pretoria, South Africa).

II-3) Diagnosis of tristeza

Diagnosis of tristeza was based on symptom expression (vein clearing and stem pitting of mexican lime trees) and ELISA.

III - DISTRIBUTION OF GREENING DISEASE AND ITS PSYLLA VECTORS IN SAUDI ARABIA

III-1) Areas when greening and/or psylla vectors are present

III-1.1 : Areas where greening (asian form) and the asian psylla vector, *Diaphorina citri*, are present

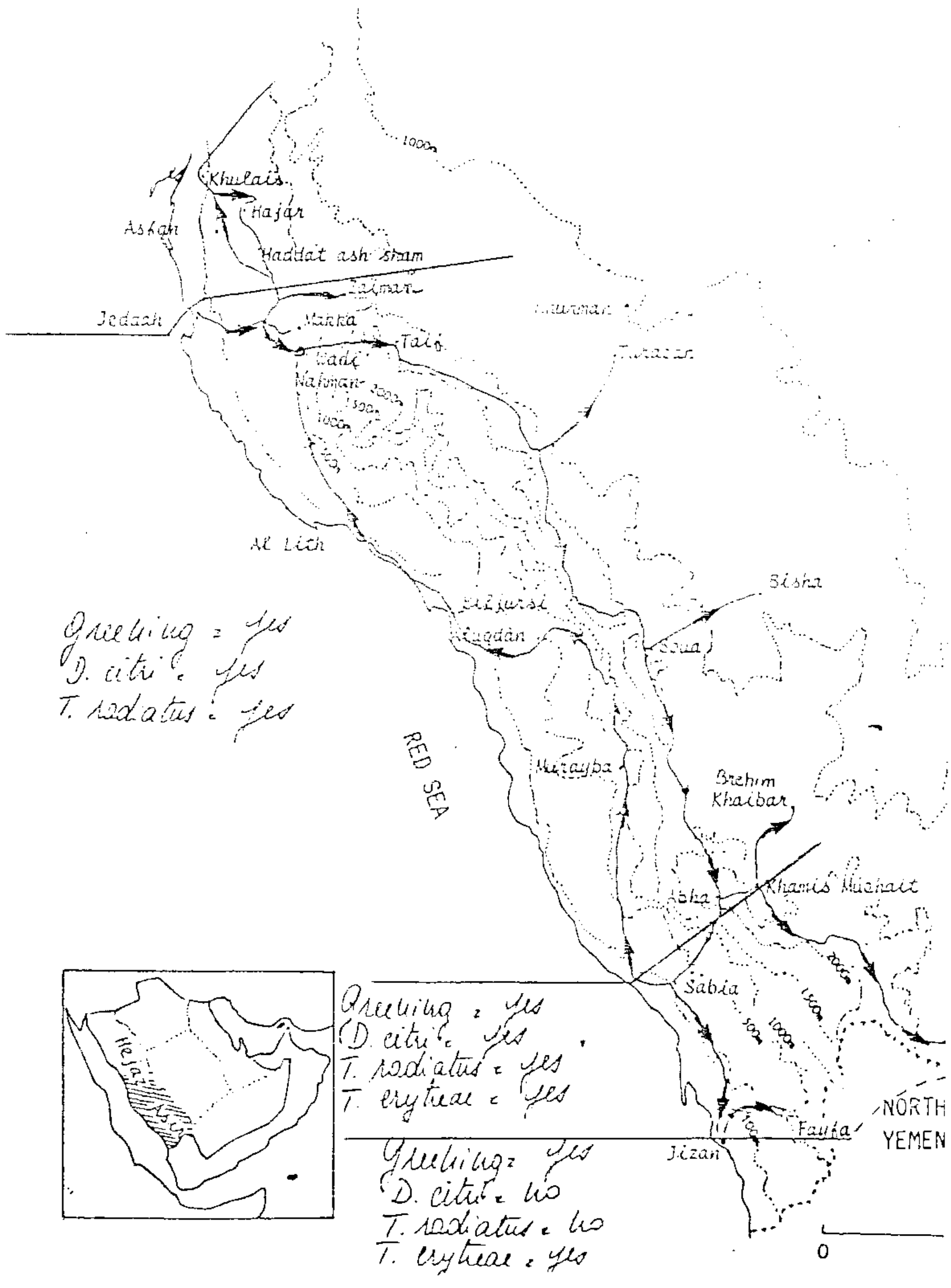
Clearcut symptoms of greening disease were observed in these areas and the asian vector of the disease, *D. citri* was present (see *Figure 1 and Table I*). The greening organism (GO) was detected by electron microscopy (EM) in affected citrus material from almost all of these areas and these studies proove that the symptoms observed are sites

e Decem-

parasi-

...uites = no

...RE 1 PROSPECTED AREAS



III-1.1.1 - Areas concerned

1) Jeddah - Mecca - Taïf area :
   - Zaymah
   - Wadi Nahman
   - Taïf
   - Taïf surroundings

2) Turabah oasis

3) Khurmah oasis

4) Bisha oasis

5) Boua : Mexican lime trees along the main road near Boua showed severe greening symptoms and were found positive by EM. Eventhough *D. citri* was not seen in this small orcnard (*Table I*), Boua is part of the region where *D. citri* is present.

III-1.1.2 - Citrus species affected

In the above areas, practically the only citrus species now grown is Mexican lime (*Citrus aurantifolia*). According to citrus growers, sweet orange and mandarin trees used to do well, but have been wiped out within the last ten years. Greening disease is very probably the cause of this destruction. Indeed, severe symptoms of greening were observed on moribond sweet orange and mandarin trees and electron micorscopy showed the GO to be present in these trees.

In the Taïf area, young sweet orange and mandarin orchards were seen. The 1 to 2 year-old trees did not yet show symptoms of greening, but since they grow next to old mexican lime trees badly affected by greening, they will undoubtedly be wiped out by the disease.

Mexican lime prooved to be less susceptible to greening than sweet orange and mandarin. In the affected areas, lime trees show greening symptoms (leaf mottle), and electron microscopy prooves then to be infected by the GO, yet they do achieve a decent size. An additional reason for relatively good growth is the fact that the virus disease named Tristeza is not present. This is a remarquable situation since in Africa and Asia, greening is always accompanied by tristeza. Mexican lime is highly susceptible to tristeza. Hence in areas where both tristeza and greening are present, the lime trees decline not so much because of greening, but because of tristeza.

While in some areas only a few small orchards exist, in others there are large Mexican lime orchards (Turabah, Khurmah, Bisha areas) covering many hectares and totaling thousands of relatively well developed trees. In fact the only adult, 10 to 15 year-old trees that can be seen in commercial orchards are those of mexican lime.

III-1.1.3 - *Diaphorina citri* : the psylla vector

In the above areas, high percentages of trees are affected. The reason for this high incidence of infection is the presence of the asian vector of greening : *Diaphorina citri*. The presence of this psylla was first observed in 1972 and reported in 1974 (WOLLER et al., 1974) on citrus in the Djeddah, Wadi Khulais, Mecca and Hadat Ash Sham areas. However eventhough it is known since 1966 that *D. citri* is a vector of greening (CAPOOR et al., 1967 ; CELINO et al., 1966) no thoughts were given until 1981 to the possibility that the disease might be present in the areas where the vector occurred in Saudi Arabia.

In November 1981, the author was stricken by the magnitude of *D. citri* populations. On Mexican lime trees the psyllas were so numerous in the visited areas (Taïf, Turabah) and the damage done so great, that it was hardly possible to recognize that one was looking at mexican limes. The agricultural services were aware of the problems since 1972 and have tried to control the psyllas with the use of various insecticides. From the situation as seen by the author in 1981, it seems as if these treatments were unable to achieve their purpose.

III-1.1.4 - Parasites of *D. citri* *(Table I)*

The primary eulophid hymenopterous parasite (ectoparasite) of *D. citri* is *Tetrastichus radiatus* (Waterston). An ectoparasite, identical to *T. radiatus* at first view bah. Parasitized nymphs of *D. citri* were seen at Zaymah but no *T. radiatus* individuals were obtained in the emergence boxes. It is however most probable that the ectoparasite is present. More sampling is needed. The Bisha area harbours *T. radiatus* probably also.

The strain of the Tetrastichus ectoparasite obtained from parasitized nymphs of *D. citri* in Saudi Arabia were found by Dr. PANIS (Valborne, France) to be morphologically indistinguishable from the species *T. radiatus*. However Dr. PRINSLOO (Pretoria, South Africa) found the Saudi Tetrastichus to be somewhat different from the strain of *T. radiatus* introduced from India (Bathinda area, Punjab) into Reunion island where it was used successfully to control *D. citri* biologically. Further work is required to fully characterize the Saudi *Tetrastichus radiatus* ectoparasite. It will be called in this report *T. radiatus* var. Saudi.

III-1.1.5 : Form of greening involved

For the following reasons the form of greening present is very probably the asian form :

- the vector is the asian psylla, *D. citri*. The disease has probably been introduced with *D. citri* from an asian country ; pilgrims might have played a role in this introduction.
- Even at the elevation of Taïf, the daily summer temperatures are well above 32°C. Only asian greening could resist this hot climat.
- From the destruction of sweet orange and mandarin trees, over the last years, the disease must have been of the more severe, asian form.

III-1.2 : Area where greening and the two psylla vectors, *D. citri* and *T. erytreae* are present : Brehim Khaibar *(Figure 1)*

One of the main results of the December 1983 survey was the discovery that in the oasis of Brehim Khaibar in the Abha area, the two psylla vectors of greening, *D. citri* and *T. erytreae* occur together in the same orchard. The detection of *T. erytreae* is based on the presence of the galls produced on the leaves by nesting nymphs.

emergence of adults, quickly followed by the drop of the moult. When psylla parasites are present punctured mummies remain attached inside the galls for 10 months or more. Hence, the absence of punctured mummies might indicate that in the affected area, *T. erytreae* is not parasitized, or at least not to a great extent. Obviously more observations must be made over a year-long period.

On the contrary, *D. citri* nymphs were parasitized and *T. radiatus* var. Saudi was obtained in the emergence box. Severe greening symptoms were observed on the only two moribond mandarin trees present and on the many mexican lime trees. The presence of the GO was confirmed by EM. The form of greening involved is probably the asian form eventhough the african form might also have been introduced with *T. erytreae*.

III-1.3 : Areas where greening (african form) and the african psylla vector, *T. erytreae*, are present : Fayfa

Many *T. erytreae* induced galls were seen on sweet orange leaves in the Fayfa mountainous area (1200 to 1800 m) near the boarder with North Yemen. The galls were practically all empty suggesting low level of parasitism. Only one punctured mummy was seen. *D. citri* was not observed.

Symptoms of zinc deficiency were severe on many trees, but the trees did not yet have the typical "greening" aspect. However electron microscopy was able to detect the GO in sweet orange tissues eventhough in very low numbers. In the absence of *D. citri* it is highly probably that the form of greening involved is the african one and that the disease is in it early stages.

III-1.4 : Area where the african psylla vector, *T. erytreae*, occurs apparently in the absence of greening : Najran

While no evidence for the presence of *T. erytreae* was found during the November 1981 and the December 1983 surveys in the Najran area, such evidence has been obtained in January 1984 by Dr. FUDL ALLAH who took also part in the December 1983 survey. Dr. FUDL ALLAH is at the National Center for Horticultural Research and Development in Najran

T. erytreae galls were observed in three different orchards on mexican lime, lemon and mandarin leaves. The galls contained punctured mummies indicating parasitism.

No symptoms of greening have so far been observed.

III.1.5 : Greening and *T. erytreae* in North Yemen

It must be mentionned here that citrus in North Yemen is also affected by greening and that the vector is the african psylla, *T. erytreae*. Advanced symptoms of greening disease were observed in April 1982 on many trees of the citrus collection at the Agricultural Research Station in Taïf (Aussfera farm). The trees of this collection were planted in 1974. Leaf and fruit samples taken on badly affected sweet orange trees were examined by electron microscopy at the Bordeaux laboratory. They were all found positive for the presence of the greening organisms (GO). These observations proove unambigously that the disease affecting these trees is greening. On the basis of the serological "ELISA" assay, the trees were negative for tristeza virus. Symptoms of greening (yellow branch) and *T. erytreae* were also observed in April 1982 at Hamman Ali in the Anis region.

A second survey carried out in December 1983 revealed that many young 3 year-old sweet orange trees at the Taïz Research Station are now also affected by greening as evidenced by severe symptoms and EM detection of the GO. The Barakani valley near Taïz is also fully infected. The Al Beida area, near the South Yemeni boarder, is contaminated too ; the disease and the vector were probably introduced with sweet orange trees from Taïz. Finally the disease and its vector were seen in Wadi Dahr near Sanaa, and EM detected the GO in the samples.

The areas where greening was seen, were all located at an elevation of 1000 m and more. No indication of the disease was found in the coastal Tihama areas (Garouba, Wadi Sardut, Jaraba). The Mareb and Hareb oases were also free of the disease and the vector. The geographical distribution of the disease reflects the distribution of the insect vector. In Saudi Arabia the vector is mainly the asian psylla, *D. citri*. In North Yemen the vector is the heat sensitive african psylla, *T. erytreae*. This psylla is known to exist in neighbouring Ethiopia from where it has

The form of greening present in North Yemen is very probably the heat sensitive african form for the following reasons :

1) the insect vector is the african psylla, *T. erytreae* ;
2) the disease as well as the psylla vector only occur on cool, elevated areas, not on the coastal plains or hot oases such as Mareb and Hareb.

T. erytreae being present all over North Yemen, it is not surprising that the insect has reached Saudi Arabia not only at the boarder areas with North Yemen (Fayfa, Najran) but also in areas further North such as the oasis of Brehim Khaybar near Abha. There *T. erytreae* moving up from South to North has met with *D. citri* moving down from North to South (see III-1.2).

III-1.6 : Additional areas where the asian psylla, *D. citri*, occurs in Saudi Arabia

Besides the areas mentionned in III-1.1 and III-1.2 *D. citri* is also present North of Jeddah at Asfan, Khulais and Haddat As Sham. The presence of the ectoparasite *T. radiatus* var. Saudi and parasitized *D. citri* nymphs was also established in these areas (*Table I*). Furthermore, the hyperparasite *Cheiloneurus cyanonotus* (Waterston) was obtained in the emergence box containing the mexican lime leaf samples from Khulais. This encyrtid is known to be hyperparasitic in Coccidae, coccinellidae, syrphidae and psyllidae ; *C. cyanonotus* was obtained from parasitized nymphs of *T. erytreae* in Zimbabwe. It is not absolutely sure that the adult *C. cyanonotus* obtained in the emergence box from Khulais has hatched from a *D. citri* nymph, but the probability is high.

The hyperparasite from Khulais was the only one that was obtained during the December 1983 survey. This does not mean that hyperparasites are absent from other areas. More observations over a year-long period must be made.

No clearcut symptoms of greening were seen in the area North of Jeddah. EM was unable to delect the GO in the samples studied. The areas concerned are at low altitudes (150 - 200 m). It is a possibility that the high temperatures prevailing in these areas in the summer are detrimental to the GO. Whether greening is really absent in these low lying areas must be further studied.

III-2) Areas free of greening and psylla vectors in Saudi Arabia

Citrus in the following areas was found free of greening and psylla vectors :

1) Areas along the coastal highway between Djeddah and Jizan (1983 survey) : - Jizan area including the FAO Wadi Jizan project
   - Sabia area
   - Ad Darb area
   - Murayba area
   - Al Ugdah area
   - Al Lith area

2) Medina regions (1983 survey) :
   - Abiar Al-Mashy area
   - Al Khelil area.

3) Kassim region (1981 survey) :
   - Unaysah area
   - Buraydah area

III-3) Other areas free of greening and psylla vectors in the Arabian Peninsula

1) The coastal Tihama area in North Yemen (remember however that greening and *T. erytreae* are present throughout North Yemen above 1000 m).

2) South Yemen : The surveyed areas (Lowdar, Wadi Hadramout) were free of greening and psylla vectors in December 1983. However the Wadi Beihan area near the North Yemeni boarder could not be surveyed. This area is close to the Al Beida region in North Yemen where greening and *T. erytreae* are present.

3) United Arab Emirates : In November 1983 there was no evidence for greening or psylla vectors in the Ras El Khaima (Hamraniya Research Station) and Masafi areas.

IV - DISTRIBUTION OF OTHER VIRUS AND VIRUS-LIKE DISEASES IN SAUDI ARABIA

IV-1) Insect vector transmitted diseases

Besides greening disease, two other important diseases are vector transmitted : Tristeza (virus disease) and stubborn (disease due to the mycoplasma *Spiroplasma citri*).

IV-1.1) Tristeza : no evidence for the disease in Saudi Arabia

No evidence for the presence of tristeza was seen in Saudi Arabia in 1981, 1982 and 1983. None of the many mexican lime trees observed showed leaf vein clearing or stem pitting, two symptoms specific of tristeza on lime trees. Furthermore budwood samples were taken on several suspicious trees, especially in the Najran area, and analyzed for tristeza in Bordeaux by the immunoenzymatic ELISA technique. They were all negative.

Tristeza virus is transmitted by various aphids. The very efficient tropical black aphid (*Toxoptera citricida*) vector is not present in the Arabian Peninsula, but other aphid vectors such as *Aphis gossypii* (cotton aphid) are present in Saudi Arabia and could transmit various strains of tristeza virus if introduced into the country.

IV-1.2) Stubborn disease is present in Saudi Arabia

Typical symptoms of Stubborn disease were seen in 1981 in the Kassim area in one orchard (Unaysah area, Saleh Abbad orchard). Fruit samples from the affected baladi sweet orange trees were taken to Bordeaux. *Spiroplasma citri*, the causal mycoplasmal agent of stubborn was cultured from the fruit samples. These studies confirm the presence of stubborn disease in Saudi Arabia.

In California, *S. citri* is transmitted by the sugar beet leafhopper *Neoaliturus* (ex. Circulifer) *tenellus*. The suspected vector in the Mediterranean area is *Neoaliturus haematoceps*, also a sugar beet leafhopper. These two leafhoppers are reported to be present in Saudi Arabia (Fauna of Saudi Arabia, WITTMER et al., eds, Ciba-Geigy).

IV-2) Diseases not transmitted by insect vectors

Many cases of the following diseases have been observed in Saudi Arabia : Scaly bark Psorosis, Concave gum, Blind pocket, Gummy bark, Impietratura, Cachexia. These diseases are not transmitted by insect vectors but they are spread by man when he takes budwood on the affected trees for propagation.

It can be assumed that practically all the grafted old line trees in Saudi Arabia are contaminated by one or several of these diseases.

In Saudi Arabia no records have been kept on the origin of the planted trees and the nature (species) of their rootstocks. This lack of information makes it often difficult to correlate observed symptoms such as stem pitting on the rootstock, with a given disease. Only guesses can be made. This situation is especially true in the Najran area.

Finally, certain commercial citrus species or varieties are known to be tolerant to certain virus and virus-like diseases : they show no symptoms of the disease eventhough the causal agent of the disease is present in the tree. For instance sweet orange or lemon trees can be fully infected by the viroïd of Exocortis without showing any symptoms. Only "indexing" on sensitive indicator plants or other techniques will detect the causal agents.

For all these reasons, in Saudi Arabia, one should not take budwood for citrus propagation on old line trees. Only budwood from well known and reliable sources and certified free of known diseases should be propagated.

V - PHYTOPHTHORA GUMMOSIS, A FUNGAL DISEASE

Many cases of Phytophthora gummosis have been observed all over Saudi Arabia. Most of these cases could be avoided by adequate horticultural practices. Only large enough rootstocks should be grafted so that the buds can be inserted on the rootstock seedlings at least 20 cm above soil level. Trees should not be planted too deep so that the budunion line is well above soil level. Trees should not be planted in a hole

VI - BACTERIAL DISEASE : CITRUS CANKER

Citrus canker, a very important disease due to the bacterium *Xauthomonas citri* has been detected by B. AUBERT near Sabia on mexican lime trees in the orchard of Mr Hasan Ali Ibrahim TALEBY (Al-Hagyriyh village) and that of Mr AL-MUTAREY (Damad road).

The author has submitted a note to Dr. S. SARRIEDINE on December 20th in Riyadh recommending immediate burning and destruction of the trees of the affected orchards.

The trees with canker symptoms might have been bought from Yemenis, as B. AUBERT and his party were told. This is very likely since anoutbreak of citrus canker has occurred in 1982 in the Tihama in North Yemen at the Al-Garaba station. The disease and the causal bacterium were very probably imported with citrus plants from India !

VII - SUMMARY OF RESULTS AND CONCLUSIONS

VII-1) Greening

1 - The most important disease problem on citrus in Saudi Arabia is greening.

2 - Over the last 10 to 12 years the farmers have witnessed the decline and disappearance of practically all sweet orange and mandarin trees in the Southwestern part of Saudi Arabia, from Djeddah to Abha. Greening disease transmitted by the asian psylla *Diaphorina citri* is very probably responsible for the destruction of these trees.

3 - The problem has started in the early 1970s with the spread of the vector *D. citri*.

4 - In the affected areas only mexican lime trees are left, sometimes as relatively large orchards. These lime trees are relatively tolerant to greening. This means that they are infected and show symptoms but that they do not suffer too much from the disease. Their relative tolerance to greening and the absence of tristeza virus explain why the lime trees have grown over the last 10-12 years into relatively well developed adult trees.

5 - The many infected lime trees are large sources of inoculum.

6 - Mexican lime is one of the favored hosts of the vector *D. citri*. This psylla has become a real pest on Mexican lime.

7 - All conditions for an efficient spread of greening disease are combined : a large population of spylla vectors feeding on an abundant host, the mexican lime trees, harbouring a vast amount of inoculum on which the psyllas will become infected for live.

8 - Saudi Arabia harbours the two vectors of citrus greening disease : *Diaphorina citri*, the asian psylla and *Trioza erytreae*, the african psylla.

9 - The two forms of greening disease : asian greening and african greening are both present in Saudi Arabia.

10 - *Diaphorina citri* and asian greening extend from Djeddah to Abha. This is the area where the disease has been most destructive.

11 - The spread of *D. citri* and asian greening in the affected areas has most probably occurred by the transportation of citrus plants from one oasis to another. Indeed most of the citrus trees grow in oases separated by desert regions. *D. citri* is not an active flying insect and in most cases could not have covered the distance between two oases by itself.

12 - The decline and disappearance of sweet orange and mandarine trees over the last 10 years was not a clearly perceived phenomenon and even if it had been,its cause was not realized. Hence nurseries continued to operate and distribute citrus plants and have probably been the main factor in the spread of the disease and its vector.

13 - *Trioza erytreae* has very probably entered Saudi Arabia from North Yemen. It is moving from South to North and has already reached the Abha area. It will probably continue to move further North if nothing is done to stop it.

14 - The Abha area harbours the two psyllid vectors in the same orchards. It is the zone where *D. citri*, moving South, has met with *T. erytreae*, moving North. After Reunion island and Mauritius island, Saudi Arabia is the third country where the two psyllid vectors occur concommitantly.

15 - If nothing is done to stop it, *D. citri* will very probably continue to move further South and might eventually reach Najran and North Yemen.

16 - So far, only *T. erytreae* has been found at Fayfa and Najran, South of Abha.

17 - At Fayfa, greening, very probably the african form, is in an early stage of development.

18 - The Najran area might still be free of greening.

19 - Eventhough *T. erytreae* has definitely been found in Wadi Najran, the psylla populations seemed to be low and in a state of decline, in January - March, 1983 at least (F.E. STRONG, F. A. O. - AGPP, personnel communication to the author). The climatic conditions might not be favorable enough for high populations of *T. erytreae* to become established. Eggs and young nymphs die when the temperature exceeds 32°C several hours a day, especially when the relative humidity is low. GREEN and CATLING (1971) have combined the mean daily maximum temperature and the mean minimum vapor pressure to characterize a "lethal day" for *T. erytreae* by the saturation deficit (SD) in mbars. SD is defined as follows :

$$SD = VPmt \times \frac{100 - RH}{100}$$

with VPmt = saturation vapor pressure corresponding to the maximum temperature recorded during the day,
and RH = minimum of relative humidity.

On a lethal day, the SD exceeds 35 mbar and causes 70 % mortality of eggs and first instar nymphs ; mortality is 100 % when the SD is higher than 48 mbar. Lethal day conditions occur in Najran from April to September as shown in *Table II*. The same is true for Bisha and Medina. However at Khamis Muehait, no lethal day conditions occur and this explains why nearby, at Brehim Khaibar, *T. erytreae* has been discovered. Even at Taïf, conditions might support the development of *T. erytreae*.

20 - Hence, in its North bound movement, beyond Abha, *T. erytreae* will find areas such as those between 1000 and 2000 m altitude where the weather conditions will be suitable for its development.

21 - While the Najran area is quite unfavorable for *T. erytreae*, it offers good conditions for the development of *D. citri* since the weather regime suitable for high breeding of the asian psylla is opposite to that for *T. erytreae*.

Table II : Monthly mean temperatures in °C, relative humidity (RH), and saturation deficit (SD) in millibars, at midday for 6 stations of Saudi Arabia.

		J	F	M	A	M	J	J	A	S	O	N	D
Najran 1150 m.	T°C	26,3	26,7	28,1	34,0	36,0	38,5	35,8	38,2	33,3	30,2	21,2	26,2
	RH	32	27	41	18	17	10	11	13	17	19	30	24
	SD	22,9	25,2	22,0	43,1	48,8	40,6	60,8	57,3	41,9	34,3	17,4	25,5
Bisha 1040 m.	T°C	28,4	26,4	29,4	34,0	35,6	38,7	38,7	39,1	35,8	31,8	29,5	26,2
	RH	18	17	23	13	13	4	7	6	7	9	15	15
	SD	31,7	36,2	31,1	45,7	50,0	65,3	63,3	64,9	54,0	41,9	34,6	30,1
Jizan 40 m	T°C	30,1	30,0	31,9	34,9	37,0	38,2	38,0	38,5	37,7	34,7	33,5	30,7
	RH	63	53	61	49	53	49	47	47	49	46	53	59
	SD	15,6	19,7	18,2	28,2	29,1	34,7	34,5	35,7	32,9	29,5	24,5	17,8
Khamis Mushait 2000 m	T°C	22,4	22,6	22,4	26,1	28,3	31,6	30,4	30,9	29,1	26,3	24,7	22,9
	RH	29	36	47	30	26	49	25	25	21	24	29	29
	SD	18,9	17,3	14,1	23,3	28,1	23,4	32,1	33,0	31,2	25,6	21,7	19,5
Taif 1634 m	T°C	24,4	23,9	25,4	29,5	33,1	35,2	34,3	34,9	33,6	29,7	26,1	25,6
	RH	46	58	53	27	25	16	17	17	20	21	31	31
	SD	16,3	12,3	15,0	29,7	37,5	47,2	44,4	45,9	41,2	32,6	23,0	22,4
Medina 500 m	T°C	24,6	26,5	28,6	35,0	39,5	42,5	39,3	43,2	41,5	36,5	30,3	27,9
	RH	25	20	16	15	16	7	9	10	10	24	30	40
	SD	22,8	27,3	32,5	47,2	59,4	77,6	64,0	77,9	71,2	45,6	29,8	22,2

22 - Parasites of *D. citri* nymphs are present in Saudi Arabia as witnessed by the many punctured mummies and the capture of the ectoparasite *Tetrastichus radiatus* var. Saudi. This natural parasitism is however unsufficient to keep the population of *D. citri* at a low level, probably because of hyperparasites.

23 - The psylla hyperparasite *Cheiloneurus cyanonotus* was captured in the Khulais area. Hyperparasites were not obtained in other areas probably because of unsufficient sampling or time of the year.

24 - Parasitism of *T. erytreae* (punctured mummies) was seen in Najran in March 1984 (F.E. STRONG, personnal communication) but was not observed at Brehim Khaybar. Only one punctured nursery was found at Fayhah.

25 - Greening is a high potential danger for citriculture in the Wadi Najran. This area is well suited for citrus and projects for citrus development are underway. Eventhough evidence for the presence of *T. erytreae* has been obtained, the psylla population was very low and greening is probably still absent. However *D. citri* and asian greening have come very close to Wadi Najran since they are in the Abha area. The arrival of *D. citri* and asian greening would ruin the citrus project in Wadi Najran.

26 - Greening is a high potential danger for citriculture in the Unayzah-Buraydah area. This area, also well suited for citrus, is still free of greening and psylla vectors. Introduction of the vector and the disease would be most detrimental to old and new citrus.

27 - Asian greening is a high potential danger for North Yemen. North Yemen harbours *T. erytreae* and african greening in areas above 1000 m but the disease and its vector are absent from the Tihama and the Mareb-Hareb regions, very probably because the weather conditions are unsuitable for *T. erytreae* (see above : point 19). *D. citri* and asian greening could however become established if introduced from Saudi Arabia. Their introduction would ruin several important citrus projects that are being developed in the Tihama at Jarouba, Wadi Sardut and Al-Garaba.

28 - The Mediterranean basin is free of greening and citrus psyllas. It is very probable that *T. erytreae* and especially *D. citri* would be able to multiply if introduced in the Mediterranean regions. It is highly likely that greening disease would be introduced with the vector.

VII-2) Tristeza and Stubborn, two vectors transmitted diseases

Tristeza virus does not seem to be present in Saudi Arabia.

Stubborn was found in the Unayzah area and *Spiroplasma citri* could be cultured from the affected trees. The disease did not seem to be of great importance at the time of the survey (November 1981). A few suspicious trees were seen in the Najran area.

VII-3) Virus and virus-like diseases that are not spread by insects

Many cases of the following diseases have been seen : Cachexia (Xyloporosis), Concave gum, Blind pocket, Gummy bark, Impietratura and Scaly bark psorosis. Exocortis disease is probably present also by analogy with other parts of the world but symptoms could not be detected in the absence of susceptible species or varieties. Indexing of several trees from Najran on Etrog citron is underway in Bordeaux.

Many trees showed psorosis young leaf symptoms (PYLS) without any other symptoms. PYLS is indicative of one or several of the following diseases : Concave gum, Blind pocket, Cristacortis, Scaly bark psorosis and Impietratura.

VII-4) Phythophtora gummosis

Most commercial citrus varieties are susceptible to phytophthora gummosis and must therefore be grafted on resistant rootstocks. But grafting will not solve the problem if the bud is grafted to low on the rootstock or if the grafted tree is planted too deep in the soil with the budunion lime to close to soil level. These wrong horticultural practices are the rule in Saudi Arabia and explain the numerous cases of Phytophthora gummosis.

VII-5) Citrus canker

Two cases of citrus canker have been detected in the Sabia area. The disease and its causal bacterium, *Xanthomonas citri* might have been introduced from North Yemen where a serious focus of the disease was discovered in the Tihama in 1982.

If no action is taken, citrus canker might become the second most important citrus problem, after greening.

VIII - RECOMMENDATIONS

VIII-1) Recommendations concerning greening

The type of recommendations that can be made depends on what level the problem is approached.

VIII-1.1) Should eradication of citrus be recommended ?

Greening is a very difficult problem. The most radical solution is eradication of all citrus in the affected areas. The purpose of total eradication of citrus would be to eliminate the source of inoculum (the GOs in the infected trees) and the host (the citrus plants) on which the psylla vectors feed. It is expected that in the absence of the citrus host the psyllas would disappear. Will eradication of citrus achieve these objectives ? It is the writer's opinion that it will be very difficult to achieve these objective (elimination of greening and of the psylla vectors) for the following reasons.

1) Even if a law is taken that makes it compulsory to up root all citrus trees, eradication will not be 100 %. There will always remain a small percentage of trees that will have escaped eradication. These will be enough to maintain a reservoir, however small, of greening inoculum and psylla vectors.

2) Even if eradication could be 100 %, two further facts must be considered :

a) Citrus has the property to produce shoots from roots. This means that when a citrus tree has been pulled out, some of the roots still remaining in the soil can produce shoots. These shoots are likely to be infected with greening since roots from greening infected trees contain GOs. It is probable that the shoots will be quickly colonized by psyllas, desperately in search for hosts to feed on.

b) There are wild rutaceous hosts on which psyllas can feed and reproduce. *T. erytreae* feeds on *Vepris lanceolata* (Lam), *Fagara capensis* (Thusb), *Calodendrum capense* (L.f.), *Clausena* sp. *V. lanceolata* is the preferred non citrus host for feeding and reproduction. *D. citri* feeds on *Murraya paniculata* (L) Jack, *Murraya koenigii* (L) Spreng, *Citropsis schweinfurthii* (Engl). *Murraya* sp. is at least as good a host as mexican lime.

It is not known whether some of these wild rutaceous plants are present in Saudi Arabia, but if they are, they would allow a psylla population to be maintained inspite of citrus eradication.

3) Eventhough citrus is mainly grown in oases separated by desert regions, there are scattered trees here and there, in backyards, inside towns. These trees might be difficult to localize.

4) The area involved extends from the North of Djeddah all the way to the North Yemen boarder : it is very large. The risk that some trees might be overlooked is so much the greater.

5) The total number of trees to be pulled out amounts to several thousands.

6) It is to be feared that the Saudi farmers are not psychologically ready for an eradication campaign.

7) If eradication is followed by replantation of young healthy citrus in the previously infected zones it is to be feared that the new trees might become infected again by the psyllas that might have survived on citrus that has escaped eradication or on wild rutaceous hosts.

8) Eradication of citrus in Saudi Arabia alone is not enough. Trees should also be uprooted in North Yemen, otherwise there will probably be a continous arrival of african psyllas from North Yemen into Saudi Arabia, especially if citrus replantation follows eradication.

For all these reasons, total eradication of citrus from the North of Djeddah all the way down to North Yemen does not seem feasable. However, since most of the cultivated land in this area is in the form of isolated oases or wadis, the feasability of eradication in individual oases could be studied provided that very strict control and restrictions be imposed on citrus movement (see below) and that a thorough search for wild or ornamental rutaceous hosts be made. The following recommendations can therefore be made.

VIII-1.2) Recommendations concerning the feasability of local eradication

- Choose an isolated oasis where citrus has greatly suffered from greening and where the number of mexican lime trees is low.

- Remove and burn all citrus trees, large or small; leave as little root material in the soil as possible.

- Remove all wild and ornamental rutaceous hosts of psyllas.

- Examine periodically the places where trees have been uprooted and remove eventual shoots developing from roots. Remove roots too !

- Introduce healthy citrus plants one or, better, two years after the eradication campaign.

- Be on the watch for psyllas and greening symptoms on the newly planted trees.

- Since this is a feasability study, all movement of citrus in or out the area should be prohibited. Only authorized officials should be allowed to take in new healthy citrus material when time has come.

VIII-1.3) Tetracyclin treatments of greening-affected mexican lime trees are not recommended

The antibiotic tetracyclin-HCl has been used in South Africa and various asian countries to get symptom remission of greening-affected trees. The antibiotic is injected into the trunc of large enough trees. The greening organism is affected by the compound but not killed and, hence, if the injection is not renewed every one or two years, the trees will relapse. With time the effect of the injections decreases probably because a tetracycline resistant mutant tkaes over.

The trees that are injected are essentially sweet orange, mandarin and grapefruit trees. These are very susceptible to greening and the antibiotic treatment produces some recovery. In the greening-affected part of Saudi Arabia, trees of these varieties have practically all died ; only adult mexican lime trees are left. These are relatively tolerant and not much would be gained by injecting them with the antibiotic. In addition, most mexican lime trees by lack of pruning have only divided truncs, requiring that each limb of the divided trunc be injected.

VIII-1.4) Feasability of biological control should be evaluated

VIII-1.4.1 : Biological control of citrus psyllas in Reunion

Biological control of the two psylla vectors of greening has been most successful in the island of Reunion (AUBERT et al., 1980 ; AUBERT, 1983). Two enlophid parasites (superfamily Chalcidoidae, Order Hymenoptera) : *Tetrastichus dryi* Waterston, a parasite of *T. erytreae* and *Tetrastichus radiatus* Waterston, a parasite of *D. citri* were introduced into Reunion from Southern Africa and India respectively. They were bred on their respective psyllas and released. They became established in a self renewing cycle with an original rate of release of 30 to 50 adults per square kilometer of citrus area. The two parasites have similar biologies. The female ley eggs on psylla nymphs of the 3rd, 4th and 5th instar. The larva is ectoparasitic and sucks out the body of the psyllid nymphs. Adults pupate in the mummy of the nymphs and emerge after 10 or 12 days by chewing a hole through the thorax of the psylla host.

A drastic reduction of *T. erytreae* infestation was noticed two years after the first release of *T. dryi*. In 1980, 1981 and 1982, only very rare and short appearances of the african psylla were noticed. During these three years the populations remained so low that *T. erytreae* could be considered as virtually eliminated.

T. radiatus, the parasite of the asian psylla, *D. citri*, was imported in 1978. The population of this psylla started to decrease significantly in 1980. However the presence of various citrus pests required sprayings and resulted in the development of integrated pest control. In 1981, *D. citri* could only be traced back in neglected orchards or background trees. By 1982 the psylla had even disappeared from these trees.

The success encountered with biological control of the greening psyllas in Reunion, is very probably due to the absence of psylla hyperparasites. The psyllas in Reunion, before the beginning of the biological control program, were not parasitized and having no parasites they had no hyperparasites either. When the parasites were introduced for biological control, great care was taken to avoid introduction of hyperparasites.

VIII-1.4.2 : Feasability of biological control of *D. citri* in Saudi Arabia

Unfortunately, *D. citri* is already parasitized in Saudi Arabia by *Tetrastichus radiatus* var. Saudi and therefore hyperparasites are to be expected too. Indeed one has been captured in Khulais : *Cheiloneurus cyanonotus*.

The parasite *T. radiatus* present in Saudi Arabia is morphologically somewhat different from the strain of *T. radiatus* that is present in Reunion and active in controling *D. citri*. The possibility that *T. radiatus* var. Reunion might be more effective than *T. radiatus* var. Saudi in controling *D. citri* in Saudi Arabia should be investigated. More generally speaking the feasability of biological control of the greening psyllas should be studied. To that purpose the following recommendations are made :

— Introduction from Reunion and release of *T. radiatus* var. Reunion —

In the first phase of the project and in order to gain time *T. radiatus* should be introduced from Reunion island where the facilities for its rearing do exist and where it is being reared presently by B. AUBERT. These facilities must be enlarged if they are to be used for Saudi Arabia.

The parasites should be released in well isolated oasis on Mexican lime trees where high populations of *D. citri* are prevalent, such as the Oda Gamdi orchard at Turabah. In Reunion the releases involved 50 *T. radiatus* adults per square kilometer of citrus area. The parasites can be released in oases other than Turabah if enough adults can be introduced from Reunion.

Following the releases, orchard inspections must be started. The degree of *D. citri* infestations can be checked by estimating the concentration of winged adults. The concentration is rated "heavy" when a 5 minute sucking-up with a mouth aspirator can collect 150 adults or more and "low" when less than 10 adults can be collected in the same period of time (AUBERT et al., 1983).

The intensity of parasitism can be obtained from the decrease of the *D. citri* populations and the number of punctured (parasitized) *D. citri* nymphs.

Similar observations should be carried out in comparable orchards where no parasite releases have been done.

— Prevent insecticide treatments. Use biological control also on crops other than citrus —

No insecticide treatments on citrus or any other plant should be carried out in or near the orchards where the parasite releases are made. The need to prevent insecticide treatments requires that biological control must take into account the major insect pests occuring on valuable crops within the oasis where the parasite releases are made. A major corp is date palm ; insecticide treatments against the scale *Parlatoria blanchardii* are carried out. Fortunately, biological control of this scale has been developed and works well, and should be included in the biological control program.

— Production of *T. radiatus* var. Reunion in Saudi Arabia —

While Reunion will be able to supply *T. radiatus* parasites for some time, these parasites must eventually be produced in Saudi Arabia. To that purpose an air-conditionned insectarium must be built. Djeddah would probably be the best place where to install these facilities. The insectarium should allow the asian psylla, *D. citri*, to be reared on mexican lime seedlings. These psyllas will then be used as host to rear the parasite *T. radiatus*. A continuous supply of *D. citri* nymphs on mexican lime seedlings should be available.

The insectarium should be equipped with the obvious instruments : binoculars, microscopes, etc. A small phytopathology laboratory should be attendant since the disease itself, greening, should not be overlooked and will require specimens to be analyzed, prepared for electron microscopy, etc. The laboratory should also be able to work on Tristeza and Stubborn detection.

— A pilot laboratory for biological control in Saudi Arabia —

The need to apply biological control to plants other than citrus, date palms for instance (see above) means that the insectarium should also be able to produce the parasites of insect pests such as the date palm scale, *Parlateria blanchardii*. In other words the insectarium should develop into a pilot laboratory for multipurpose biological control problems in Saudi Arabia.

VIII-1.4.3. : Feasability of biological control of *T. erytreae* in Saudi Arabia and North Yemen

The pilot laboratory must also produce *Tetrastichus dryi*, the parasite of *Trioza erytreae*, the african psylla, now present in Brehim Khaibar, Fayfa and Najran. The feasability of biological control of *T. erytreae* could thus be evaluated. While Reunion is able to supply *T. radiatus* it cannot do so for *T. dryi* since *T. erytreae*, the psylla host of this parasite, has completely disappeared from the island as a result of biological control.

Biological control of *T. erytreae* should also be evaluated in North Yemen since it would be useless to control the african psylla in Saudi Arabia if nothing was done in North Yemen where the main psylla problem is precisely *T. erytreae*.

VIII-1.4.4. : Behaviour and ecology of citrus psyllas. Identification of their parasites and hyperparasites

Biological control of the two citrus psyllas requires that their behaviour and ecology, the fluctuation of their populations be studied over at least a one-year period in relation with the climatic applied to the psylla parasites and hyperparasites. As a result of the December 1983 survey only *Tetrastichus radiatus* var. Saudi was found as a *D. citri* parasite. Its taxonomical characterization must be carried out. Are there other parasites ? In Reunion for instance not only the ectoparasite *T. radiatus* but also the encyrtid endoparasite *Diaphorencyrtus aligharensis* is operating.

If absent from Saudi Arabia, the use of this endoparasite (also to be reared in the insectarium) together with the ectoparasite *T. radiatus* var. Reunion might increase the effectiveness of the biological control approach.

Only the hyperparasite *Cheiloneurus cyanonotus* was captured in one location in Saudi Arabia (Khulais). Identification of hyperparasites in different locations must be pursued all year long. Of course, the study of the psyllas, their parasites and hyperparasites should be done also in places where *T. radiatus* var. Reunion will be released. The feasability of biological control will result from the comparison of psylla population between places with releases of parasites and those without.

VIII-1.4.5. : Search for alternate psylla parasites

If biological control with *T. radiatus* and *D. aligarenhsis* is ineffective, the possibility remains that other parasites not present in Saudi Arabia might be used. A prospection survey to India for new *D. citri* parasites should be envisaged. Similarly new parasites for *T. erytreae* can be looked for in Africa.

VIII-1.5. Discourage citrus production in the areas where greening and psyllas and present

This concerns mainly the areas between Djeddah and Abha. In these areas sweet orange and mandarin trees have disappeared. Farmers should be adviced not to plant trees of these susceptible species. More generally, these areas should be declared unsuitable for citrus production. They should not be part of a citrus development program in Saudi Arabia. Citriculture should concentrate on the regions where greening is not (yet) present : Unaysah and Buraydah. Najran and Fayfah were *T. ery-*

VIII-1.6. Measures to protect Najran from greening

Najran, where a major citrus project is underway has already had a small outbreak of *T. erytreae* but as indicated above, the climatic conditions are probably unfavorable for large populations of the african psylla to become established. Greening is probably not yet present. The following measures should be applied :

- Prohibit all introductions of citrus material into Wadi Najran. This prohibition should be very strongly enforced. To that purpose, establish controls and plant quarantine stations on the highway to Wadi Najran. Place large posters along the road indicating that is prohibited and illegal to move citrus material into Wadi Najran.

  Make arrangements with the Airlines that land at Najran ; make them announce before landing that introduction of citrus material is prohibited. Have a real plant quarantine station at the airport.

- Make frequent surveys of the citrus orchards in Wadi Najran for psylla (*T. erytreae*) outbreaks. Watch for *D. citri*, more difficult to spot than *T. erytreae*, since it does not reveal itself by leafgalls.

- Spray insecticides to kill eggs, nymphs and adults.

- Since the *T. erytreae* outbreaks are weak and affect only a small number of trees, eradication of the trees on which the psyllas have fed and reproduced should be seriously envisaged. Take no chance with greening !

- If trees suspicious for greening are encountered, leaf and/or fruit samples should be fixed in 2 % glutaraldehyde and used for electron microscopy (EM) detection of the GO. If EM is positive the tree(s) should be burned.

- Do not treat suspicious trees with tetracyclins. Suspicious trees should be examined and eventually pulled out. At this stage in Najran we do not want symptom remission, we want <u>no</u> greening.

VIII-1.7. The problem of Fayfa

In Fayfa, *T. erytreae* galls were numerous. They were seen on the sweet orange trees at the two locations (1200 and 1800 m) of the experiment station. Eventhough greening is probably in an early stage of development, it is to be feared that its intensity will increase and affect the sweet orange trees that are experimented as a replacement crop for cat. The climatic conditions at Fayfa seem to suit *T. erytreae* well. The area seems favorable for experimenting the feasability of biological control with *Tetrastichus dryi*. However since cat is a much more profitable crop than citrus, the question really is : how much do the farmers care for citrus ? Is it reasonable to push citrus in these terraced mountainous areas ?

VIII-1.8. Measures to prevent introduction of greening into regions still free of the disease

The Unaysah and Buraydah region (Kassim) have an appreciable amount of citrus. The conditions seem to be favorable for citrus production as judged by the performance of the trees growing there. The region must be kept free of greening and citrus psyllas.

VIII-1.8.1 : Prohibit introduction of citrus into the Kassim

While movement of citrus within the region can be tolerated, the introduction by farmers of citrus material from other parts of Saudi Arabia should be strictly prohibited. Efficient plant quarantine stations should be established on the major roads and in the airports (see recommendation for Najran : VIII-1.6).

VIII-1.8.2 : A citrus project for the Kassim

If Najran is remaining free of greening and if the Najran citrus project goes well, it is the understanding that citrus material from Najran will be used to develop citrus in the Kassim. Healthy certified citrus material from Najran will thus be allowed to enter the region. However in case greening does invade the Najran area it is highly recommendable that a citrus development project be immediately developed in the Kassim, perhaps as a side project of the one in Najran. The idea is also to prevent as much as possible movement of citrus from one citrus region to another.

VIII-1.8.3 : Need for continuous survey in the Kassim

Continuous surveys of citrus in the Kassim should be carried out to detect as quickly as possible any outbreaks of psyllas and/or greening.

VIII-1.8.4 : Need for continuous survey in other areas harbouring citrus

The Medina area has some citrus. Eventhough the climatic conditions seem to be unfavorable for *T. erytreae* as well as *D. citri*, inspections should be made regarding psyllas and greening. The same recommendations apply to all areas where citrus grows.

VIII-2) Recommendations concerning tristeza

No evidence for the presence of tristeza in Saudi Arabia was obtained. Suspicious trees should be immediately indexed by the enzyme-linked immunosorbent assay (ELISA). Kits to carry out these assays are available. Mexican lime trees when infected with most strains of the virus show symptoms of the disease. Some strains do not induce symptoms on mexican lime trees ; however they can be detected by ELISA.

VIII-3) Recommendations concerning stubborn

Stubborn disease and its causal agent, *Spiroplasma citri* were detected in the Unayzah area. A more extensive survey for the disease should be made in the Kassim and Najran regions. *S. citri* is transmitted by leafhopper vectors : *Neoaliturs* (ex-Circulifer) *tenellus* (Baker) and very probably *N. haematoceps* (Mulsant + Rey). These species have been reported to be present in Saudi Arabia. Their presence and importance in the Kassim region and in Najran should be studied. Two kits for the detection of *S. citri* in plants and insects are available. One is an ELISA kit, the other is based on the culture of the spiroplasma.

Transmission of *S. citri* in the field can be studied by exposing periwinkles to natural contamination in the field.

VIII-4) Recommendations concerning virus and virus-like diseases that are not spread by insects

Among these diseases those detected in Saudi Arabia are : cachexia, Concave gum, Blind pocket, Gummy bark, Impietratura and Scaly bark psorosis. Severe cases of these diseases are present in Saudi Arabia. They do not endanger new citrus development projects based on certified healthy plant material since they are not insect vector transmitted. They can however be transmitted by man when he takes buds for propagation on affected trees. It should be realized that infected trees do not show symptom necessarily. For instance, sweet orange on sour orange rootstock is tolerant on cachexia : infection of this combination by cachexia induces no symptoms. If however sweet orange buds from such a tree are budded on sweet lime symptoms will eventually appear on the susceptible sweet lime. Eventhough the symptoms will show up only on sweet lime, the whole tree including the sweet orange top is contaminated. Only "indexing" can reveal the presence or absence of a given pathogen in a tolerant combination.

For all these reasons, propagation in nurseries of citrus material taken on uncertified uncontrolled trees, often of unknown origin, should be stopped as soon as certified material becomes available.

VIII-5) Recommendations concerning phytophthora gummosis

The number of cases of phytophthora gummosis can be greatly reduced by appropriate horticultural practices : high enough budding, budunion line well above soil level, resistant rootstocks. Also, ethylphosphite of aluminium is very effective against phytophthora on affected trees.

VIII-6) Recommendations concerning citrus canker : eradication and quarantine

Citrus canker was seen in two orchards in the Sabia area. The first orchard (farm of Mr Hasan Ali Ibrahim TALEBY, Al-Hagyriak village) comprised 30 mexican lime trees. Two lime trees had canker. The second orchard (farm of Mr AL-MUTAREY, Damad road) had 20 mexican lime trees of which 8 had canker.

The 30 trees of the first orchard and the 20 trees of the second orchard must all be burned. Take no chance with canker !

In case canker is detected in large orchards the following action, experienced in Florida, should be taken :

1. Burn in place all infected trees immediately.
2. Defoliate the 8 trees immediately surrounding the infected trees with diquat.
3. Survey tree by tree for 300 ft in every direction. Then, if more infected trees are found, adjust accordingly.
4. The inspectors will use disposable shoe coverings and gloves while inspecting, and these will be changed after inspecting an infected tree or group of trees. Also, clothes will be changed and plastic gloves and shoes will be destroyed before going to next owner's grove.
5. The infested area will be mapped precisely, with location of all trees, whether they were infected, destroyed, defoliated, or healthy. Regulate one square mile or additional area if operation warrants. All equipment used in this operation will be desinfested.
6. The infested area shall be reinspected every month, or more frequently if possible for 1 year. For the next year, reinspect each major flush.
7. If a citrus nursery is found to have *Xanthomonas citri*, the whole nursery will be destroyed by burning and not be replanted for 2 years.
8. No citrus trees should be planted in eradicated area for a minimum of 2 years unless research shows justification for changing this time frame.

Remember that *Xanthomonas citri*, the causal bacterium of citrus canker can be easily transported on shoes and clothes. This is why the inspectors must be very careful (see point 4 !).

Instructions recommending destruction and burning of the canker affected trees were given in December 1983 only 48 hours after discovery of the disease.

No citrus material should be imported from North Yemen since citrus canker was detected in 1982 in the Tihama. In December 1983, eradication of these trees had not yet taken place.

A major disaster will occur if the eradication plans in Saudi Arabia and North Yemen will not succeed and they will not succeed if action is delayed.

VIII-7) General recommendations

- The importance of quarantine within Saudi Arabia (internal quarantine) and quarantine between Saudi Arabia and other countries (international quarantine) cannot be stressed enough. A training course on quarantine should be organized.

- The importance of the disease problems occuring on citrus can only be fully understood by well trained personnel. Therefor a training course on the major diseases of citrus and their impact on citrus production should be organized.

- The recommendations on biological control aimed towards the construction of a pilot biological control laboratory, require 2 entomologists, one rearing the parasites in the insectarium, the other studying the psyllas,their parasites and hyperparasites and in charge of the releasings of parasites. They should be assisted by three technicians.

- Continuous surveying for virus and virus-like diseases of citrus and their insect vectors requires a full time plant pathologist.

- Diagnosis of greening by symptoms alone is sometimes difficult and must be confirmed by other techniques. The greening organism can be detected by electron microscopy. An immunological techniques such as ELISA would be most wellcome. Work along these lines (preparation of monoclonal antibodies against the greening organism) is under way and should be supported.

REFERENCES

AUBERT B., J.M. BOVE & J. ETIENNE (1980) - La lutte contre la maladie du "greening" des agrumes à l'île de la Réunion. Résultats et perspectives.
Fruits, 35 (10), 605-624.

AUBERT B. et al. (1983) - Control of african and asian psyllids in Reunion.
in Proc. 9th Conf. Intern. Organization Citrus Virol., in press.

CAPOOR S.P., D.B. RAO & S.M. VISWANATH (1967) - *Diaphorina citri* Kuway, a vector of the greening disease of citrus in India.
India J. Agr. Sci., 37, 572-576.

CELINO C.S., A.A. SALIBE & R.E. CORTEZ (1966) - *Diaphorina citri* Kuway, the insect vector for the leaf mottle virus of citrus in the Philippines.
Bureau of Plant Industry, Manila, Philippines.

ETIENNE J. (1979) - Contrôle biologique à la Réunion de *Trioza erytreae* (Homopt. Psyllidae) au moyen de *Tetrastichus arui* (Hym. Eulophidae).
Fruist, 33 (12), 877-882.

ETIENNE J. & B. AUBERT (1980) - Biological control of psyllid vectors of greening disease in Reunion island.
p. 118-121. In Proc. 8th Conf. Intern. Organization Citrus Virol., E.C. CALAVAN, S.M. GARNSEY & L.W. TIMMER (eds), Univ. California, Riverside.

GREEN G.C. & H.D. CATLING (1971) - Weather induced mortality of the citrus psylla *Trioza erytreae* (Del Guercio) a vector of greening virus in some citrus producing areas of Southern Africa.
Agr. Meteorol., 8, 305-307.

MASSONIE G., M. GARNIER & J.M. BOVE (1976) - Transmission of India citrus decline by *Trioza erytreae* (Del Guercio), the vector of South Africa greening.
p. 18-20. In Proc. 7th Conf. Intern. Organization Citrus Virol., E.C. CALAVAN (ed), Univ. California, Riverside.

WOOLER A., D. PADGAM & A. ARAFAT (1974) - Outtreaks and new records Saudi Arabia *Diaphorina citri* on citrus.
FAO Plant Protection Bulletin, 22 (4), 93-94.