

Pest Survey of Citrus Crops in Lebanon (2011-2012)

Final specific crop pest survey report prepared for

The Ministry of Agriculture

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April 2013

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Contents

1. Acknowledgements	5
2. Executive Summary	8
3. Introduction.....	9
4. Methods.....	10
4.1. Crops Surveyed	10
4.2. Number and Distribution of Sites Sampled.....	10
4.3.1. Field Collection	11
4.3.2. Hygiene.....	14
4.4. Laboratory Determinations	14
4.4.1. Arthropods and Gastropods	14
4.4.2. Nematodes	14
4.4.3. Fungi.....	15
4.4.4. Bacteria.....	15
4.4.5. Viruses and Phytoplasmas	16
4.5. Definitions.....	16
4.5.1. Nature of Association	16
4.5.2. Status of the Record.....	17
4.5.3. Key to Results Tables	17
5. Results and Discussion: Arthropods and Gastropods	18
5.1 Lemon (<i>Citrus limon</i>).....	18
5.2 Mandarin (<i>Citrus reticulata</i>)	19
5.3 Orange (<i>Citrus sinensis</i>).....	20
5.4 Sour orange (<i>Citrus aurantium</i>)	22
5.5 Grapefruit (<i>Citrus paradisi</i>)	22
5.6. General Results and Discussion	23

6. Results and Discussion: Nematodes	53
6.1. Citrus nematode, <i>Tylenchulus semipenetrans</i>	53
6.2. Burrowing nematode, <i>Radopholus similis</i>	53
6.3. Root lesion nematodes, <i>Pratylenchus</i> species.....	54
6.4. Root-Knot nematode, <i>Meloidogyne javanica</i>	54
6.5. Dagger nematode, <i>Xiphinema</i> species.....	55
6.6. Other nematodes.....	55
6.7. Summary of new Records	55
6.8. General Results and Discussion	56
7. Results and Discussion: Fungi	62
7.1. Lemon (<i>Citrus limon</i>).....	62
7.2. Mandarin (<i>Citrus reticulata</i>)	64
7.3. Orange (<i>Citrus sinensis</i>).....	65
7.4. Sour orange (<i>Citrus aurantium</i>)	66
7.5. Grapefruit (<i>Citrus paradisi</i>)	66
7.6. General Results and Discussion	67
8. Results and Discussion: Bacteria	78
8.1. Lemon (<i>Citrus limon</i>).....	78
8.2. Mandarin (<i>Citrus reticulata</i>)	78
8.3. Orange (<i>Citrus sinensis</i>).....	78
8.4. Sour orange (<i>Citrus aurantium</i>)	78
8.5. Grapefruit (<i>Citrus paradisi</i>)	78
8.6. General Results and Discussion	78
9. Results and Discussion: Viruses and Viroids	84
9.1. Lemon (<i>Citrus limon</i>).....	84
9.2. Mandarin (<i>Citrus reticulata</i>)	85
9.3. Orange (<i>Citrus sinensis</i>).....	85

9.4. Sour orange (<i>Citrus aurantium</i>)	86
9.5. Grapefruit (<i>Citrus paradisi</i>)	86
9.6. General Results and Discussion	86
10. References.....	98

1. Acknowledgements

H.E. the Minister of Agriculture Dr. Hussein EL HAJJ HASSAN for his continuous and endless support to accomplish this work

The Italian Cooperation for the financial support to the project

FAO and FAO Representative in Lebanon, Dr. Ali MOUMEN

The Lebanese Agricultural Research Institute Director General, Dr. Michel AFRAM

The Director of Plant Resources in the Ministry of Agriculture, Eng. Mohammad ABOU ZEID

The Project Manager Eng. Dany LICHAA EL-KHOURY and the National Project Coordinator Eng. Hanadi JAAFAR

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Plant Protection Service, Ministry of Agriculture, Lebanon

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2. Executive Summary

- A national survey of pests of Citrus crops was carried out by the Plant Protection Service in The Ministry of Agriculture in Lebanon from October 2011 to December 2012.
- Five Citrus species spread over 166 sites in the growing areas of Lebanon were surveyed for pests.
- One thousand seven hundred and six (1706) arthropod and gastropod site-crop-organism records are reported from this survey; 69 of which (64 insects and 5 mites) were first records in Lebanon.
- One primary insect, the thrips *Pezothrips kellyanus* was recorded for the first time on lemon and orange.
- Six new species *Aleurolobus marlatii*, *Bemisia afer*, *Coccus capparidis*, *Eucalymnatus tessellatus*, *Icerya seychellarum* and *Urophorus humeralis* were recorded for the first time as potential primary pests.
- The predatory mite *Euseius stipulates* (Phytoseiidae) was a first record.
- One primary pest *Hemiberlesia latenia* was recorded as new host association on orange.
- Fourteen nematode species were reported to be pathogens to citrus, *Tylenchulus semipenetrans* was the only one that presented a problem in citrus orchards observed in Lebanon.
- Four nematode species (*Helicothylenchus multicinctus*, *Rotylenchulus reniformis*, *Xiphinema index* and *Meloidogyne javanica*) were recorded for the first time on citrus in Lebanon.
- Two hundred sixty (260) fungal specimens were identified. Eleven fungal species were reported for the first time in Lebanon, four of which are primary pathogens (*Botryosphaeria dothidea*, '*Botryosphaeria*' *lutea*, '*Botryosphaeria*' *stevensii* and *Glomerella acutata*) and one is potential primary pest (*Phoma glomerata*).
- Eight fungal species were reported as new host association in Lebanon, five of which are primary pathogens ('*Botryosphaeria*' *rhodina*, *Eutypa lata*, *Glomerella cingulata*, *Nectria haematococca* and *Phoma tracheiiphila*) and one is potential primary pathogen ('*Botryosphaeria*' *obtusa*).
- The Bacterium *Pseudomonas syringae* previously reported in Lebanon on lemon and sweet lime was detected only on grapefruit.
- *Xanthomonas citri* was not detected.
- The two viruses (CTV, CPsV) and five viroids (CEVd, CBLVd, HSVd, CVd-III, CVd-IV) were tested for 1660 samples of citrus. The most widespread were Citrus Psorosis virus (CPsV) and Citrus Tristeza Virus (CTV)
- Citrus exocortis viroid (CEVd) and Hop stunt viroid (HSVd) inducing exocortis and cachexia diseases, respectively, were also detected.
- Citrus bent leaf viroid (CBLVd) and Citrus viroid-III (CVd-III) were detected for the first time in Lebanon on orange, lemon and mandarin.

3. Introduction

From October 2011 to December 2012, the Plant Protection Service in the Ministry of Agriculture in collaboration and support of the Project GCP/LEB/021/ITA, carried out a national pest survey of five citrus fruit crops. This survey, along with the stone fruits pest survey, was the first comprehensive pest surveys within the plant protection service plan of surveillance of plant pests in Lebanon. The survey aims to detect the presence of any pest new to Lebanon as well as previously known pests with altered hosts or distributions, in addition to confirming or denying presence of pests historically reported in scientific articles. These data are fundamental to the preparation of pest lists that are used to set import requirements of agricultural commodities as well as providing reliable information to trading partners about crop/pests status in Lebanon.

The Ministry of Agriculture is reviewing import requirements of agricultural commodities. This will be based on pest risk analysis (PRA) which requires the NPPO of the potential supply country to provide appropriate crop/commodity pest list. To support the implementation of the PRA process of the pests listed and categorize them for Lebanon, a comprehensive, accurate, and up-to-date database of Lebanon agricultural pests is essential. Specific crop/pests surveys provide this information to the Plant Protection Service.

This report documents the findings of the national survey of Citrus pests, listing new findings, new hosts associations, update status of previously reported pests, and their base distribution. Significant findings are discussed.

Weeds are not crop specific therefore they were not included in this survey.

4. Methods

4.1. Crops Surveyed

Five citrus crops were included in this survey. These were Lemon (*Citrus limon*), Mandarin (*Citrus reticulata*) including tangerine, clementine and others, Orange (*Citrus sinensis*) including navel orange, sweet orange and others, Sour Orange (*Citrus aurantium*) and Grapefruit (*Citrus paradisi*).

4.2. Number and Distribution of Sites Sampled

The survey was designed to detect pests infesting $\geq 2\%$ of trees at $\geq 5\%$ of sites with 95% confidence, using the procedure of Dymock & Holder (1996). This means that all five citrus species were “treated” as a single crop for statistical purposes when calculating the total number of sites to be surveyed.

The Assumptions were:

- A particular pest is equally detectable on any crop it infests
- The proportion of infested sites follows a binomial distribution, and thus the number of sites to be surveyed can be calculated as

$$N = \log(1 - p_1) / \log(1 - p_2 p_3)$$

Where N is the number of sites, p_1 is the confidence in detecting a pest at one or more sites (95%), p_2 is the proportion of sites infested (2%), p_3 is the confidence in detecting a pest at a particular site (90%)

$$\begin{aligned} N &= \log 0.05 / \log(1 - 0.018) \\ &= -2.99573 / -0.01918 \\ &= 164.92 \end{aligned}$$

This gives a minimum of **165** sites to be surveyed nationally.

In this survey, a total of 166 sites were surveyed, 23 in Akkar, 17 in North-Lebanon, 9 in Mount-Lebanon, 14 in Nabatiyeh, and 103 in South-Lebanon. The distribution of sites was based mainly on the size of the areas. Table 4.1 lists site allocations for each crop by region. The GPS coordinates of the surveyed sites were plotted per species on a map using Geographic Information System (Figure 4.1)

In addition to commercial production sites (orchards), the survey included nurseries (5% of the total number of sites to be surveyed) and home gardens (5% of the total number of sites to be surveyed). Packing houses were not included in this survey.

Table 4.1 Region and Crop Site Allocations for Citrus Survey 2011/12

Crops¹	Regions²							Crop Totals
	AK	BE	BH	ML	NA	NL	SL	
Lemon	16	0	0	3	4	11	51	85
Mandarin	4	0	0	3	8	2	38	55
Orange	3	0	0	3	1	2	12	21
Sour Orange	0	0	0	0	0	2	1	3
Grapefruit	0	0	0	0	1	0	1	2
Total	23	0	0	9	14	17	103	166

¹: In this survey, commercial orchards (90%), nurseries (5%) and home gardens (5%) sites were examined. Where more than one host was examined at a property, these have been listed as separate sites

²: The region abbreviations from left to right: AK=Akkar; BE=Bekaa; BH=Baalbeck-Hermel; ML=Mount Lebanon; NA=Nabatiyeh; NL=North Lebanon; SL=South Lebanon

4.3. Sample Collection

4.3.1. Field Collection

The survey was designed to detect pests with 90% confidence at sites where the percentage of infested plants was at least 2%. The required number of plants for sampling per site was calculated as:

$$n = \log (1 - p_3) / \log (1 - p_4 p_5)$$

where: **n** is the number of plants to be sampled, **p₃** is the confidence in detecting a pest at a particular site (**90%**), **p₄** is the percentage of plants infested (**5%**), **p₅** is the efficacy of detecting an infested host (**90%**).

$$\begin{aligned}
 n &= \log 0.10 / \log (1 - 0.045) \\
 &= -2.302585 / -0.04604 \\
 &= 50.01
 \end{aligned}$$

This gives a minimum of **50** plants to be sampled per site.

Where there are only 50 plants or less, all plants (of the selected type of citrus) on the site are to be sampled. Note that for those plants requiring specialized sampling procedures (e.g., soil sampling for nematodes), fewer samples were taken per site. This means that the pests detected in such samples are likely to infest more than 2% of the plants in that site.

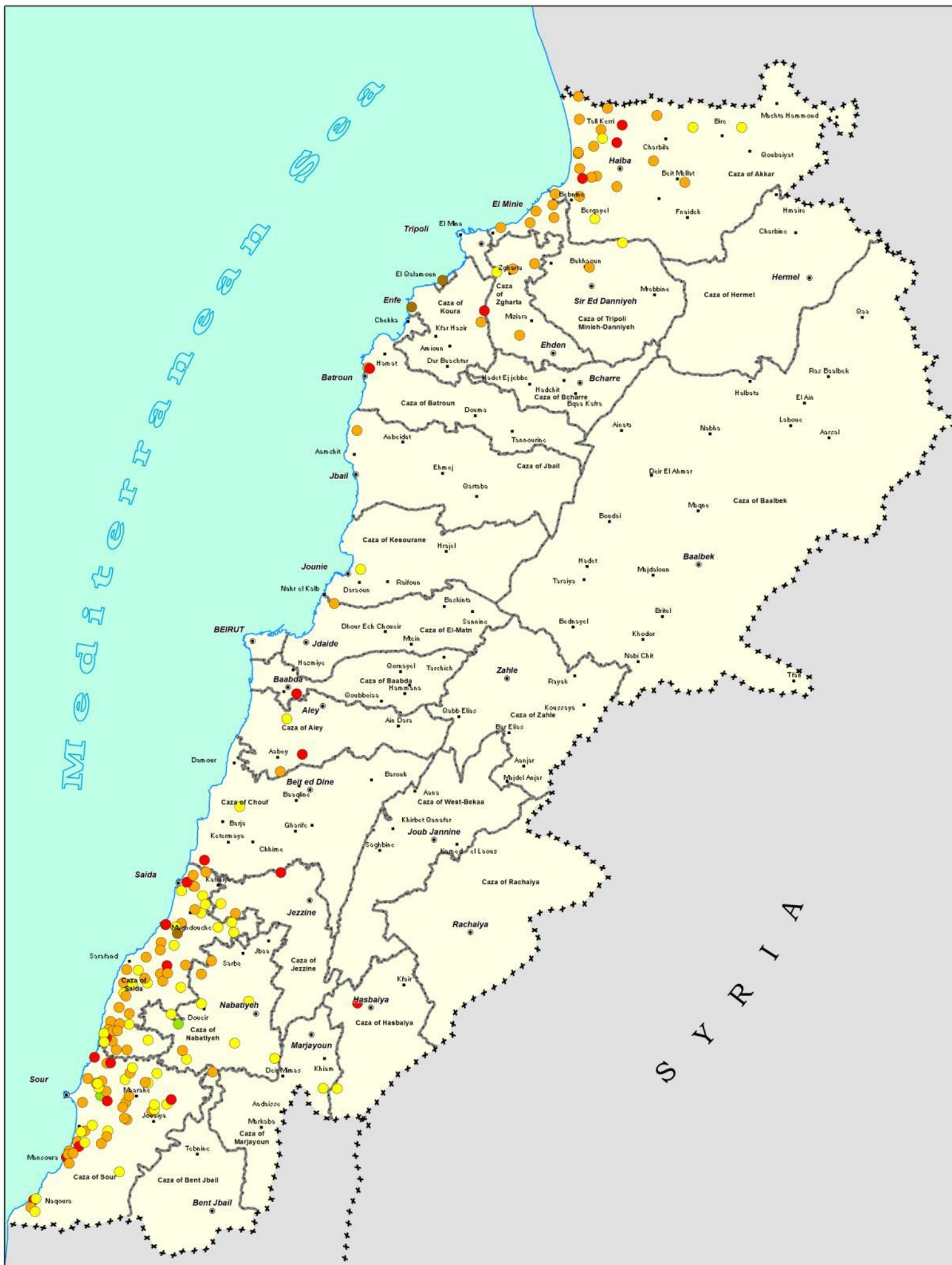
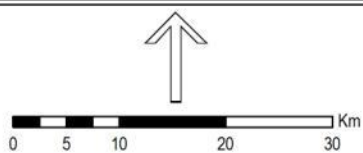


Figure 4.1

Distribution of sites
per citrus crop



The number of plants examined at each site was based on the following assumptions:

- Visible clumps of symptomatic plants will be sampled to help detect aggregated pests;
- All aerial parts of each plant are sampled;
- Infestation is randomly distributed at a site;
- At least 5% of the plants at a site are infested;
- There is 90% probability of correctly detecting an infested plant.

Wherever possible, at least 50 plants were sampled per site. However, where fewer than 50 plants were available, such as domestic properties, all plants were examined. Ill-thrift areas were also inspected. All parts of selected trees were examined, including buds, flowers, foliage, branches, and trunks. Plant material showing any signs and symptoms of pest or disease infection, as listed on a symptom booklet prepared by LARI team, were collected for laboratory analysis.

For virus and viroid sampling, a total of 10 randomly collected samples were gathered from each field, independently from the presence of viral symptoms. Each sample included 5 one-year-old shoot tips containing at least 3-4 pairs of leaves per shoot were collected from different sides of the tree canopy.

Trees with clear symptoms of virus infection were sampled and marked using spray paint. Marked trees numbers were also recorded in the remarks section of the sampling sheet.

The 10 samples were placed in one bag, labeled and placed into portable refrigerators (2-4 °C) as soon as possible after collection, prior to dispatch to the designated LARI laboratory.

For nematodes, 1 kg of soil was collected from each visited site. The sample consisted of at least 6 sub-samples collected randomly from the field under the trees canopy following a sampling scheme. Collected samples were subjected to subsequent nematode extraction in the laboratory. Particular emphasis was placed on sampling areas in the crop that showed poor vigour, reduced height or yield, stunted growth, wilting, chlorosis, or general ill-thrift.

While in sampling for fungi, bacteria, arthropods and gastropods samples were collected from trees showing symptoms of attacks of pests of these categories.

When symptomatic leaves were identified, the whole shoot bearing the infected leaves was sampled.

For arthropods and gastropods, the field borders were checked first before entering the field. Samples were then labeled in chronological order indicating the field code. The numbering pattern was independent from that of the samples for viruses.

Samples showing the same symptoms were placed together in the same bag and treated as one sample. In cases of uncertainty, a new code number was given to the sample (4-3-a; 4-3-b; 4-3-c, etc.; where 4: the field number, 3 is the sample code, a/b/c of samples showing variant symptoms).

Samples from each field were then gathered in a one big transparent plastic bag and tightly closed then transported in a cool box and delivered to the nearest LARI station where it was stored at 4 °C.

All samples of plant material, pests, and soil were labelled according to symptom, damage, or pest category and each was placed in a separate plastic bag or polycarbonate vial. Each bag/bottle constituted a sample and was given a separate number.

A sampling sheet designed for this survey and containing information about the site, crop, symptoms, and sample details was attached to each sample bag.

4.3.2. Hygiene

The survey teams were equipped with disposable gloves, and sampling equipment was cleaned after sampling each site by washing with water and sterilizing with 70% ethanol.

4.4. Laboratory Determinations

4.4.1. Arthropods and Gastropods

Pest identification was based on the morphological characteristics of the organism.

Plant samples were visually examined for the presence of arthropods, gastropods and related damages and/or symptoms using a stereoscope. When necessary, immature organisms were reared in the laboratory to reach the adult stage. Soft body insects and mites were mounted on slides after cleaning, clearing and maceration.

For specimens belonging to the orders of Coleoptera and Lepidoptera and to the Cicadellidae family, the insect's body was examined under the stereoscope then dissected. Legs, antennae and male genitalia (aedeagus) were then mounted for further detailed examination under microscope. Some specimens of the order Thysanoptera were sent to the Laboratory of Entomology at the National Museum of Natural History - Paris, France for identification.

4.4.2. Nematodes

Soil from collected samples was subjected to extraction using Bearmann funnel method (Nickel 1991; Shurtleff & Averre III 2005) where a bunch of 100-150 g crumbled soil was placed in the funnel and water was added slowly to moist the soil. After 24 hours, water was collected into a measuring beaker and the volume of water was recorded. Each sample was well mixed and 2 ml suspension was transferred into a counting chamber. Individual nematodes were picked up from soil temporarily mounted on a glass slide for diagnosis. Collected nematodes were afterwards preserved in 5% formaldehyde solution and permanent glycerine mounts of heat killed nematodes. Presence of nematodes in each sample was identified based on taxonomic characters and morphological measurements under light microscope (Southey 1986). The presence of stylet in plant parasitic nematodes allows the exclusion of saprophytic or free living nematodes from plant parasitic nematodes.

For the root knot nematodes identification, one two weeks old tomato seedling plant was planted in one collected soil sample and placed in 1 litre plastic pot. Pots were arranged on a bench in a randomised complete block design, and watered as needed. After 45 days of planting each tomato seedling was carefully removed from the soil and examined for root knot nematode infection. Galls of infected roots were collected

and stored at -20°C for biochemical analysis using isoenzyme present in native polyacrilamide gel electrophoresis and differences in esterase pattern (Ibrahim & Perry 1993). Tail characteristics, stylet length and morphology, perennial patterns and tail morphologies of J2 were important taxonomic characters used to identify *Meloidogyne* species (Perry et al. 2009; Nickle 1991)

4.4.3. Fungi

From each visited site, symptomatic samples from leaves, stems, fruits and/or branches were collected. Disease specimens showing fructifications of fungal species were mounted and examined by direct microscopy.

For samples of leaves and fruits, diseased portions were surface sterilized and placed in sterile humid chambers. Two to seven days later, fructifications were observed by direct microscopy. When needed, evident fructifications of the arising fungal species were transferred to culture media and cultures were stored at 4°C for later identification.

For samples collected from twigs, branches and roots, portions were surface sterilized and at least 10 wood chips were transferred to appropriate culture medium (Potato dextrose agar added with 0.5 g.l⁻¹ streptomycin). Pure cultures were then prepared for the fungal isolates that appeared in culture.

Identification of the isolates was done based on the morphological characteristics of the fungal species grown on water agar, malt extract agar and potato dextrose agar at 22±1°C.

4.4.4. Bacteria

The received citrus samples, suspected to be infected by bacterial diseases were isolated on semi-selective medium, King B medium for fluorescent pseudomonads bacteria and yeast extract dextrose carbonate agar (YDC) medium for *Xanthomonas* spp., and incubated for 48 hours at the appropriate temperature. Fluorescent colonies were visualized by observing plates under UV light (366 nm length) after two days of incubation.

After isolation, various physiological and biochemical tests were conducted to further identify the organisms to the species and pathovar level.

Identification was carried out using **LOPAT** tests including: **L**evan production on sucrose medium, **O**xidase reaction, **P**ectolytic activity on potato slices, **A**rginine dihydrolase production and **T**obacco hypersensitivity. Those tests lead to species level according to Schaad et al. (2001).

In addition, biochemical analyses based on **GAATTa** characters were done, including: **G**elatin liquefaction, **A**esculin/**A**rbutin hydrolysis, **T**yrosinase activity and **T**artrate utilization. Those tests guide to pathovars level according to Obradović et al. (2010).

Additional tests were carried out, based on the schemes presented in Bergey's manual of determinative bacteriology (Holt 2012) and Schaad et al. (2001), such as carbohydrates utilization, lecithinase and starch production, catalase and nitrate reductase reactions.

4.4.5. Viruses and Phytoplasmas

Two serological methods ELISA (Clark & Adamas 1977) and DTBIA (Garnsey et al. 1993) were used to screen the infection of 166 citrus sites by the following samples: Citrus Tristeza virus (CTV) and Citrus Psorosis virus (CPsV).

In addition, only 123 sites were tested only by RT-PCR for the presence of Citrus exocortis viroid (CEVd), Citrus bent leaf viroid (CBLVd), Citrus viroid-III (CVd-III), Citrus viroid-IV (CVd-IV) and Hop Stunt Viroid (HSVd). For RT-PCR assay, total nucleic acid (TNA) extraction and complete DNA synthesis were done as described by Foissac et al. (2001).

4.5. Definitions

4.5.1. Nature of Association

Primary: the organism is able to invade and gain sustenance (nutrition) from intact tissues of this plant (and may cause damage or disease to this host, possibly leading to economic loss).

Potential Primary: although the biology of this organism on this host is unknown, the part of the plant where this organism was found, and the biology of that family/genus on other hosts suggest a primary relationship.

Secondary: *plant Pathology:* the organism attacks and gains sustenance (nutrition) from already impaired tissues of this plant (and may then cause disease or damage to this host, possibly leading to economic loss).

Other than Plant Pathology: the organism infests and gains sustenance from already damaged/overripe tissues of this plant.

Saprophyte: *Plant Pathology:* the organism gains sustenance (nutrition) from decaying tissues of this plant.

Other than Plant Pathology: the organism gains sustenance (nutrition) from the rots/fungi that are growing on this host plant, or in decaying plant material. The organism could be associated with any host under similar conditions.

Unknown: there is no known information on the biology and hosts of this organism. Therefore, its significance on this crop is unknown.

In/On Soil: the organism has been found in/on the soil, not necessarily on the tissues of this host.

Casual: any organism that occurs accidentally or as a hitch-hiker, or passenger and is not known:

either: to gain sustenance (nutrition) from the tissues of this host plant;

or: to live off and gain sustenance from a pest organism that has a known primary, secondary, or saprophyte association with the host organism.

Predator/Parasitoid:

either: this life stage of this organism is found living off and gaining sustenance from another organism (e.g., another insect) to the detriment of that host organism.

or: life stage(s) of this organism are known to live off and gain sustenance from another organism associated with this host plant. This includes biological control agents and organisms that could be considered beneficial.

Symbiotic: organisms derive mutual benefit (e.g., protection, food etc.) by living together.

4.5.2. Status of the Record

New to Lebanon: the organism has not been recorded previously on any plant anywhere in the country and, therefore, is new to Lebanon.

New host: this is the first record with definite evidence that the organism was living on the plant tissues of this host.

New Distribution: this is the first time this pest has been found in this region in Lebanon, on any host.

New association: this is the first time this organism has been found in association with this crop. However, there is no evidence that the organism is gaining sustenance from the tissues of this plant.

Base Record: this record contributes to background and historical information gained prior to the commencement of this survey.

4.5.3. Key to Results Tables

●	Previously recorded on this host
n	Previously recorded on this host and in this survey
n	New to Lebanon
n	New host in Lebanon

Where *n* refers to the number of sites at which the organism was recorded

Lebanon Districts Abbreviations:

AK: Akkar, **BH:** Baalbeck–Hermel, **BE:** Bekaa, **ML:** Mount Lebanon,
NA: Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

5. Results and Discussion: Arthropods and Gastropods

Several organisms that are new to Lebanon were found during this survey. The most significant finding was the primary pest, *Icerya seychellarum*, Seychelles scales, found mainly on sour orange.

Probably, the capparid soft scale, *Coccus capparidis* was previously present in Lebanon, but due to the minor differences with the close species *C. hesperidum* (brown soft scale), misdiagnoses might have been done.

Other records apparently new to Lebanon may include previously unrecorded endemic species.

Some previously recorded species were not found in the survey.

A total of 451 samples were collected from 166 sites covering all Lebanon regions.

1706 site-crop-organism records were associated with citrus crops in Lebanon during the survey, where a particular species occurred in more than one sample from a particular site, it was recorded only once for that site-crop.

Following the text, tables list the presence of organisms found on each surveyed crop, and the number of sites per district where a particular organism occurred. The key to table shading is shown on the last page of each table.

5.1 Lemon (*Citrus limon*)

The following were found: 85 insects and 15 mites of which 26 were new records on lemon (24 insects and 2 mites). Prior to this survey, 2 insects have been recorded previously on lemon and listed in the tables followed by the sign (●) (Dosse & Musa 1967, Abdul Nour & Moussa 2006)

The new records on lemon were of the following types: 24 first records to Lebanon and 2 new hosts.

The nature of association for these new records was: 1 primary, 6 potential primary, 1 secondary, 8 saprophytes, 5 casual associates, 3 predators, 2 unknown.

Pest problems on lemon were mainly spread in South Lebanon district.

The most common arthropods on lemon were: *Phyllocnistis citrella*, citrus leaf miner (82% of sites), *Aleurothrixus floccosus*, woolly white fly (71% of sites), *Aonidiella aurantii*, California red scale (60% of sites), *Parlatoria pergandii*, shaff scale (51% of sites), *Lepidosaphes beckii*, citrus purple scale (49% of sites), *Paraleyrodes mineii*, nesting white fly (33% of sites), *Panonychus citri*, citrus red mite (22% of sites) and *Aceria sheldoni*, citrus bud mite (16% of sites).

Panonychus citri, citrus red mite and *Aceria sheldoni*, citrus bud mite were the most abundant mites on lemon in the survey.

During examination of samples, some scales were attacked by the parasitoid *Aphytis* sp. (Aphelinidae). Many species of *Aphytis* have been reported in Lebanon (Traboulsi 1969). Another important organism found in the survey was the predator of scales *Chilocorus bipustulatus* (Coccinellidae).

Aleurothrixus floccosus was attacked by the parasitoid *Cales noacki* (Aphelinidae) and by the predator *Clitosthetus arcuatus* (Coccinellidae).

Most predators of aphids on lemon belonged to the insect families, Coccinellidae and Chrysopidae.

▪ New to Lebanon on Lemon

Only one genus of saprophytic mite, *Novzelorriya* sp. (Tydeidae), is a new record to Lebanon.

Seven species of saprophytic insects were potentially new to Lebanon; most of them belonged to the order Psocoptera, which is probably endemic in the region. No studies have been done before in Lebanon. They are: *Ectopsocus* sp., *Graphopsocus cruciatus*, *Lachesiella* sp. and *Trichopsocus dalii*.

One new species of predatory mite, *Euseius stipulates* (phytoseiidae), was recorded in Lebanon. This species is closed to the phytoseiid *Euseius scutalis*, which was reported previously in Lebanon but not found in this survey.

▪ New Records of Primary and Potential Primary Pest Species on Lemon

Only one new species of insect, *Pezothrips kellyanus*, known as citrus thrips, was first recorded in this survey as primary pest on lemon.

Four new species of insect were recorded as potential primary pest for the first time on lemon. They are: *Coccus capparidis*, capparid soft scale, *Eucalymnatus tessellatus*, palm soft scale, *Icerya seychellarum*, Seychelles scale and *Uropholus humeralis*, pineapple beetle.

Among the new host records, two potential primary pests were recorded for the first time on lemon. They are: *Gynaikothrips ficorum*, Cuban laurel thrips and *Pterochloroides persicae*, clouded peach bark aphid.

Other newly recorded insect found occasionally on lemon are: *Haplothrips cerealis* (Phlaeothripidae), *Limothrips cerealium* (Thripidae), *Ripidothrips gratusus* (Aelothripidae) and *Protopion fulvipes* (Apionidae). All of them are grass feeding insects.

5.2. Mandarin (*Citrus reticulata*)

The following were found: 46 insects and 9 mites, of which 18 are new records on mandarin (17 insects and 1 mite).

The following types of new records were found in association with mandarin: 16 new to Lebanon, 2 new host records.

The nature of association for these new records was: 5 potential primary, 2 secondary, 6 saprophytes, 1 predator, and 4 casual associates.

The most common arthropods on mandarin were: *Phyllocnistis citrella*, citrus leaf miner (62% of sites), *Aonidiella aurantii*, California red scale (57% of sites), *Aleurothrixus floccosus*, woolly white fly (52 % of sites), *Parlatoria pergandii*, shaff scale (52% of sites), *Ceroplastes floridensis*, Florida wax scale (43% of site),

Dialeurodes citri, citrus whitefly (43%), *Aphis citricola*, green citrus aphid (38% of sites), *Lepidosaphes beckii*, citrus purple scale (38% of sites) and *Dialeurodes citrifolii*, cloudy winged whitefly (33% of sites).

Pests on mandarin were mainly distributed in Akkar and South Lebanon districts. Mite infestations were of less importance.

▪ New to Lebanon on Mandarin

One saprophytic mite belonging to the genus *Novzelorria* (Tydeidae) was recorded for the first time on mandarin in Lebanon.

Five saprophytic insects were potentially new to Lebanon; of which three belonged to the order of Psocoptera. They are: *Ectopsocus* sp. *Lachesiella* sp. and *Trichopsocus dalii*.

Two species of the genus *Carpophilus* (Nitidulidae) are considered secondary pest on mandarin.

Another organism recorded for the first time in Lebanon is the predator *Nephus* sp. (Coccinellidae).

▪ New Records of Primary and Potential Primary Pest Species on Mandarin

Three new species of insects were recorded in the survey as potential primary pest on mandarin. They are: *Bemisia afer*, sycamore whitefly, *Coccus capparidis*, capparid soft scale and *Eucalymnatus tessellatus*, palm soft scale.

Among the new host recordings, two potential primary pests were recorded for the first time on mandarin in Lebanon. They are: *Gynaikothrips ficorum*, Cuban laurel thrips and *Brachycaudus helishrysi*, peach leaf curl aphid.

5.3. Orange (*Citrus sinensis*)

The following were found: 97 insects, 17 mites and 2 gastropods, of which 31 are new records (28 insects, 2 gastropods and 1 mite).

The following types of new records were found in association with orange: 27 first records to Lebanon and 4 new host records.

The nature of association for these new records was: 9 potential primary, 2 secondary, 11 saprophytes, 6 casual associates and 2 predators.

Pest problems on orange were mainly detected in Akkar, North Lebanon and South Lebanon district where the production of citrus is concentrated.

The most common arthropods on orange were: *Aleurothrixus floccosus*, woolly white fly (75% of sites), *Phyllocnistis citrella*, citrus leaf miner (75% of sites), *Lepidosaphes beckii*, citrus purple scale (67% of sites), *Aonidiella aurantii*, California red scale (56% of sites), *Parlatoria pergandii*, shaff scale (54% of sites), *Dialeurodes citrifolii*, cloudy winged whitefly (45% of sites), *Paraleyrodes mineii*, nesting white fly (39% of sites), *Dialeurodes citri*, citrus whitefly (33%), *Aphis citricola*, green

citrus aphid (29% of sites), *Aphis gossypii*, melon aphid (21% of sites) and *Panonychus citri*, citrus red mite (21% of sites).

Ceratitis capitata, Mediterranean fruit fly, was the only fruit fly attacking orange fruits.

The aphid, *Toxoptera citricida*, which is the most important vector of citrus tristeza virus (CTV), has not been found during the survey or in any previous surveys.

Panonychus citri, citrus red mite, was the main mite affecting orange followed by *Phyllocaptrura oleivora*, citrus red mite and *Tetranychus urticae*, two spotted mite.

During examination of samples, some scales were attacked by the parasitoid *Aphytis* sp. (Aphelinidae). Many species of *Aphytis* were reported in Lebanon (Traboulsi 1969). Another important organism found in the survey was the predator of scales *Chilocorus bipustulatus* (Coccinellidae).

Aleurothrixus floccosus was attacked by the parasitoid *Cales noacki* (Aphelinidae) and by the predator *Clitosthetus arcuatus* (Coccinellidae).

Most predators of aphids on lemon belonged to the insect families, Coccinellidae and Chrysopidae.

▪ New to Lebanon on Orange

Eleven saprophytic insects were new records to Lebanon. Five of them belonged to the order Psocoptera (58 records) which are probably endemic in the region. They are: *Ectopsocus* sp., *Graphopsocus cruciatus*, *Lachesiella* sp., *Trichopsocus dalii* and *Valenzuela* sp..

Another saprophytic insect, *Hoplandrothrips bidens* (Phlaeothripidae), known as fungal feeder was also recorded in this survey.

One new species of predatory mite, *Euseius stipulates* (phytoseiidae), was recorded in Lebanon. This species is closed to the phytoseiid *Euseius scutalis*, which was reported previously in Lebanon but not found in this survey.

Another new species recorded in this survey is the predatory aphid, *Cheilomenes propinqua nilotica* (Coccinellidae).

▪ New Records of Primary and Potential Primary Pest Species on Orange

Five new species of insect were recorded as potential primary pest for the first time on orange. They are: *Aleurolobus marlatii* (Aleyrodidae), *Bemisia afer*, sycamore whitefly, *Coccus capparidis*, capparid soft scale and *Eucalymnatus tessellatus*, palm soft scale.

Three new species of secondary insects were recorded on fruit samples belonging to the genus *Carpophilus* (Nitidulidae).

New host associations reported for the first time on orange included 2 insects and 2 gastropods. They are: *Hypoborus ficus*, fig borer, *Palonema prasina* (Pentatomidae), *Xeropicta vestalis* (Hygromeiidae) and *Theba prinsona* (Helicidae).

5.4. Sour orange (*Citrus aurantium*)

The following were found: 21 insects and 3 mites, of which 2 new insects were recorded in Lebanon for the first time on sour orange. The nature of association for these new records was: 1 predatory and 1 saprophyte.

The most common arthropods on sour orange were: *Aleurothrixus floccosus*, woolly white fly, *Aonidiella aurantii*, California red scale and *Lepidosaphes beckii*, citrus purple scale which were found in all sites followed by *Dialeurodes citrifolii*, cloudy winged whitefly and *Phyllocnistis citrella*, citrus leaf miner (67% of sites each one).

Few pests were reported on sour orange in Lebanon. They were mainly distributed in North Lebanon district.

▪ New to Lebanon on Sour orange

One saprophytic insect of the genus *Ectopsocus* (Psocoptera) was recorded in this survey.

Another new species recorded in Lebanon is *Nephus includes* (Coccinellidae), known as predator of aphid.

▪ New Records of Primary and Potential Primary Pest Species on Sour orange

No primary or potential primary pests were recorded in this survey on sour orange.

Previously, unpublished report mentioned that *Icerya seychellarum*, Seychelles scale, heavily infested sour orange in the coastal area of Mount Lebanon (Moussa, Unpublished data).

5.5. Grapefruit (*Citrus paradisi*)

Few pests were reported on grapefruit in Lebanon, most of them were found in Nabatiyeh district.

The following were found: 9 insects and 1 mite, of which only two insects were new records to Lebanon in the survey, 1 saprophyte and 1 casual.

The most common arthropods on grapefruit were *Phyllocnistis citrella*, citrus leaf miner which was found in all sites (100% of sites), followed by *Aleurothrixus floccosus*, woolly white fly, *Aphis citricola*, green citrus aphid, *Bemisia tabaci*, sweet potato whitefly, *Ceroplastes floridensis*, Florida wax scale and *Myzus persicae*, green peach aphid (50% of sites each one).

The only mite pest found affecting grapefruit was *Panonychus citri*, citrus red mite.

▪ New to Lebanon on Grapefruit

One saprophytic insect of the genus *Ectopsocus* (Psocoptera) was recorded in this survey.

▪ New Records of Primary and Potential Primary Pest Species on Grapefruit

No primary or potential primary pest was recorded in this survey on grapefruit.

5.6. General Results and Discussion

During this survey, a total of 161 crop-organism associations were found on Citrus crops, throughout Lebanon, i.e., 138 insects, 21 mites, 2 gastropods. Including location information, 1706 site-crop organism records were found during this survey, i.e., 1524 insects, 179 mites and 3 gastropods.

Specimens were collected in the fields by using two methods. In the first, sample collection was based on visual inspection associated with/without damage symptoms, from twigs, stems, branches, leaves and fruits. In the second method, samples were taken by beating.

A comparison of the type of organism collected by these different methods is shown in the following table.

Summary of Collection Methods and Organisms collected

Nature	Visual and/or Symptom	Beating	Total
Primary	967	256	1223
Potential primary	37	23	60
Secondary	14	7	21
Saprophyte	64	76	140
Unknown	1	1	2
Casual	8	35	43
Predator	127	69	196
Parasitoid	11	10	21
Total	1229	477	1706

Primary pests were predominantly collected during visual inspection of plants. The large numbers noticed visually (967) implies that primary pest are readily detected on host plants and that the relationship pest-crop was very clear.

Potential primary pests were obtained by both methods of collection. 50% of new records on citrus that were collected by visual inspection were also found in beating tray sample.

A large number of casual organisms (35) was collected by beating which indicates the occasional association between organism and crops.

The majority of predator insects were collected by visual inspection of pest. The type of the predation was synchronized with the type of the primary pest on a specific crop, which indicates the relationship between predator-prey and pest-crop.

Immature parasitoids were collected by visual inspection of primary pests. Rearing of the parasitoids was necessary in the laboratory for the identification. Adults of parasitoids were only collected by beating. The type of the parasitism was synchronized with the type of the primary pest on a specific crop, which also indicates the relationship between pest-prey-crop.

The following primary organisms were regularly encountered during this survey:

Acari:

Panonychus citri (Citrus red mite): 34 records, mainly on lemon, orange and sour orange on the leaves.

Tetranychus urticae (Two spotted red mites): 15 records, on all crops except grapefruit.

Brevipalpus californicus (False spider mite): 10 records only on lemon and orange on fruits and twigs.

Brevipalpus phoenicis (False spider mite): 9 records on lemon, orange and mandarin on fruits and twigs.

Phyllocoptura oleivora (Citrus rust mite): 8 records on all crops.

Eutetranychus orientalis (Oriental red mite): 7 records on the stems and fruits of lemon and orange.

Aceria sheldoni (Citrus bud mite): 6 records on the fruits and stems of the lemon only.

Tetranychus cinnabarinus (Carmine spider mite): 4 records on orange, sour orange and lemon.

Insecta:

Aonidiella auranti (California red scale): 140 records on all citrus crops.

Lepidosaphes bekii (Citrus purple scale): 136 records on all citrus crops.

Phyllocnistis citrella (Citrus leaf miner): 126 records on all citrus crops.

Aleurothrixus floccosus (Woolly whitefly): 123 records on all citrus crops.

Paratoria pergandii (Chaff scale): 119 records on all citrus crops except for grapefruit.

Dialeurodes citrifoli (Cloudy winged whitefly): 79 records on all citrus crops except for grapefruit

Aphis citricola (Green citrus aphid): 65 records on orange, lemon and mandarin.

Dialeurodes citri (Citrus whitefly): 63 records on all citrus crops except grapefruit.

Parlatoria Mineii (Nesting whitefly): 61 records on all citrus crops except grapefruit.

Ceroplastes floridensis (Florida wax scale): 44 records on all citrus crops.

Aphis gossypii (Melon Aphid): 41 records on orange, lemon and mandarin.

Coccus hesperidum (Soft brown scale): 33 records on all citrus crops except for grapefruit.

Overall, *Phyllocnistis citrella*, *Aleurothrixus floccosus*, *Aonidiella aurantii*, and *Lepidosaphes beckii* have been encountered at the most sites and on all crops. Few pests were found on grapefruit and sour orange, which are little produced in Lebanon. *Aceria sheldoni* is limited only to lemon.

Pest problems on orange and mandarin were registered mainly in Akkar, North Lebanon and South Lebanon, while pest problems on lemon were mostly found in South Lebanon where the production of lemon is important.

A large number of predators have been found in this survey. Most of them belonged to the insect families, Chrysopidae and Coccinellidae.

There were 69 records that are new to Lebanon (64 insects and 5 mite), summarized in the following table.

Summary of New to Lebanon Records

Crop	Primary	Potential Primary	Secondary	Saprophyte	Casual	Predator	Parasitoid	Unknown
Lemon	1	4	1	7	5	3	23	2
Mandarin	-	3	2	5	4	1	15	-
Orange	1	6	4	8	7	3	29	-
Sour orange	-	-	-	-	-	1	1	-
Grapefruit	-	-	-	-	1	-	1	-
Total	2	13	7	20	17	8	69	2

Sixty nine organisms, mentioned in the table above, are newly recorded in Lebanon on citrus. They are divided into 64 insects and 5 mites.

Only one primary pest *Pezothrips kellyanus* was recorded for the first time on citrus. It was found on lemon and orange.

Six new species were recorded for the first time as potential primary pest on citrus. They are: *Aleurolobus marlatii* on orange, *Bemisia afer* on mandarin and orange, *Coccus capparidis* and *Eucalymnatus tessellatus* on mandarin, orange and lemon, *Icerya seychellarum* and *Urophorus humeralis* on lemon and orange

The most abundant saprophytic insects, which were encountered in all samples and on all crops, belonged to the order of Psocoptera (106 records). They are: *Ectopsocus* sp., *Graphopsocus cruciatus*, *Lachesilla* sp., *Trichopsocus dalii*, *Valenzuela* sp.. These species are probably endemic in the region. No study has been done before in Lebanon.

Another interesting finding included the first record of the predatory mite *Euseius stipulates* (Phytoseiidae): 8 records. This phytoseiid is very close to the other species of the same genus, *Euseius scutalis*, which was reported previously in Lebanon but not found in this survey.

Only one primary pest *Hemiberlesia latenia* was recorded as new host association on orange.

Six new species were records as new host association on citrus. They are: *Brachycaudus helishrysi* on mandarin, *Gynaikothrips ficorum* on mandarin and lemon, *Hypoborus ficus*, *Palonema prasina* and *Xeropicta vestalis* on orange and *Pterochloroides persicae* on lemon.

Table 5.1 Distribution of arthropods and gastropods on Lemon (*Citrus limon*)

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
Primary										
Acari										
<i>Aceria sheldoni</i>	Acariformes	Eriophyidae				1	1	1	4	8
<i>Brevipalpus californicus</i>	Acariformes	Tenuipalpidae							5	5
<i>Brevipalpus lewisi</i> ●	Acariformes	Tenuipalpidae				●				
<i>Brevipalpus phoenicis</i>	Acariformes	Tenuipalpidae					1		2	3
<i>Eutetranychus orientalis</i>	Acariformes	Tetranychidae							2	2
<i>Panonychus citri</i>	Acariformes	Tetranychidae	1			1			10	12
<i>Phyllocoptrura oleivora</i>	Acariformes	Eriophyidae					1		2	3
<i>Tetranychus cinnabarinus</i>	Acariformes	Tetranychidae						1	1	2
<i>Tetranychus urticae</i>	Acariformes	Tetranychidae	1			1			3	5
Insecta										
<i>Acaudaleyrodes rachipora</i>	Homoptera	Aleyrodidae					1		3	4
<i>Aleurothrixus floccosus</i>	Homoptera	Aleyrodidae				1	3	2	33	39
<i>Aonidiella aurantii</i>	Homoptera	Diaspididae	3			2	3	2	23	33
<i>Aphis citricola</i>	Homoptera	Aphididae	1			1	2		11	15

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
<i>Aphis gossypii</i>	Homoptera	Aphididae				1			9	10
<i>Aspidiotus nerii</i> ●	Homoptera	Diaspididae				●				
<i>Ceroplastes floridensis</i>	Homoptera	Coccidae					1		10	11
<i>Ceroplastes sinensis</i>	Homoptera	Coccidae					1		2	12
<i>Chrysomphalus aonidum</i>	Homoptera	Diaspididae							1	1
<i>Coccus hesperidum</i>	Homoptera	Coccidae				1	3		6	10
<i>Dialeurodes citri</i>	Homoptera	Aleyrodidae	2			1	1	1	13	18
<i>Dialeurodes citrifolii</i>	Homoptera	Aleyrodidae	3			2	2	1	16	24
<i>Frankliniella occidentalis</i>	Thysanoptera	Thripidae							5	5
<i>Hypothenemus aspericollis</i>	Coleoptera	Scolytidae							2	2
<i>Lepidosaphes beckii</i>	Homoptera	Diaspididae	1			2	2	1	21	27
<i>Parabemisia myricae</i>	Homoptera	Aleyrodidae							1	1
<i>Paraleyrodes minei</i>	Homoptera	Aleyrodidae				2	1		15	18
<i>Parlatoria pergandii</i>	Homoptera	Diaspididae	1			2		2	23	28
<i>Pezothrips kellyanus</i>	Thysanoptera	Thripidae							2	2
<i>Phyllocnistis citrella</i>	Lepidoptera	Gracillariidae	2			2	6	2	32	45
<i>Planococcus citri</i>	Homoptera	Pseudococcidae				1			4	5

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
<i>Pseudococcus longispinus</i>	Homoptera	Pseudococcidae				1	1		2	4
<i>Taeniothrips meridionalis</i>	Thysanoptera	Thripidae						1		1
<i>Thrips major</i>	Thysanoptera	Thripidae						1		1
<i>Thrips tabaci</i>	Thysanoptera	Thripidae					1		1	2
<i>Toxoptera aurantii</i>	Homoptera	Aphididae							4	4
Potential Primary										
Insecta										
<i>Agalmatium bilobum</i>	Homoptera	Fulgoroidae	1							1
<i>Assymetrasca decedens</i>	Homoptera	Cicadellidae					2			2
<i>Coccus capparidis</i>	Homoptera	Coccidae						1	5	6
<i>Eucalymnatus tessellatus</i>	Homoptera	Coccidae							1	1
<i>Gynaikothrips ficorum</i>	Thysanoptera	Phlaeothripidae							1	1
<i>Icerya purshasi</i>	Homoptera	Margarodidae	1						3	4
<i>Icerya seychellarum</i>	Homoptera	Margarodidae				1			3	4
<i>Lixus angustatus</i>	Coleoptera	Chrysomelidae					1			1
<i>Pterochloroides persicae</i>	Homoptera	Aphididae						1		1
<i>Stenozygum coloratum</i>	Heteroptera	Pentatomidae				1	1			2

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
<i>Thrips australis</i>	Thysanoptera	Thripidae	1							1
<i>Urophorus humeralis</i>	Homoptera	Nitidulidae					1			1
Secondary										
Insecta										
<i>Carpophilus hemipterus</i>	Coleoptera	Nitidulidae					1			1
Saprophyte										
Acari										
<i>Novzelorryia</i> sp.	Acariformes	Tydeidae					1			1
<i>Orthotydeus caudatus</i>	Acariformes	Tydeidae				1			2	3
<i>Tydeus</i> sp.	Acariformes	Tydeidae							1	1
Insecta										
<i>Aphthona Kuntzei</i>	Coleoptera		1				1			2
<i>Ectopsocus</i> sp.	Psocoptera	Ectopsocidae	1				1	1	11	14
<i>Graphopsocus cruciatus</i>	Psocoptera	Stenopsocidae							2	2
<i>Lachesilla</i> sp.	Psocoptera	Psocidae							3	3
<i>Melanophthalma rispini</i>	Coleoptera	Latridiidae							1	1
<i>Melanophthalma</i> sp.	Coleoptera	Coleoptera							1	1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
<i>Trichopsocus dalii</i>	Psocoptera	Trichopsocidae					1		4	5
<i>Valenzuela</i> sp.	Psocoptera	Caeciliusidae						1		1
Casual										
Insecta										
<i>Anthelephila pedestris</i>	Coleoptera	Anthicidae					1			1
<i>Bruchus</i> sp.	Coleoptera	Bruchidae							1	1
<i>Forficula auricularia</i>	Dermapterous	Forficulidae							1	1
<i>Guanchia brignolii</i>	Dermaptera	Forficulidae					1			1
<i>Haplothrips cerealis</i>	Thysanoptera	Phlaeothripidae						1		1
<i>Limothrips cerealium</i>	Thysanoptera	Thripidae						1		1
<i>Oxycarenus hyalinipennis</i>	Heteroptera	Lygaeidae							3	3
<i>Piezodorus lituratus</i>	Heteroptera	Pentatomidae					1			1
<i>Protapion fulvipes</i>	Coleoptera	Apionidae					1		1	2
<i>Rhipidothrips graciosus</i>	Thysanoptera	Aeolothripidae						1		1
Predator										
Acari										
<i>Agistemus</i> sp.	Aacriformes	Stigmaeidae				1				1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
<i>Euseius stipulatus</i>	Parasitiformes	Phytoseiidae	1			1			1	3
Phytoseiidae	Parasitiformes	Phytoseiidae						1	4	5
<i>Typhlodromus occidentalis</i>	Parasitiformes	Phytoseiidae							2	2
Insecta										
<i>Anthocoris</i> sp.	Heteroptera	Anthocoridae							1	1
<i>Aphidolette aphidimyza</i>	Diptera	Cecidomyiidae						1	5	6
<i>Chilocorus bipustulatus</i>	Coleoptera	Coccinellidae					1		1	2
<i>Chrysopa</i> sp.	Neuroptera	Chrysopidae	1			1	1		5	8
<i>Clitosthetus arcuatus</i>	Coleoptera	Coccinellidae				1	1	1		3
Coccinellidae	Coleoptera	Coccinellidae					1		2	3
<i>Conwentzia psociformis</i>	Neuroptera	Coniopterygidae				1			1	2
<i>Geocoris erythrocephalus</i>	Heteroptera	Lygaeidae							1	1
<i>Karnyothrips flavipes</i>	Thysanoptera	Phlaeothripidae							1	1
<i>Leucopsis</i> sp.	Diptera	Chamaemyiidae							1	1
<i>Lysiphlebus fabarum</i>	Hymenoptera	Braconidae					1			1
<i>Mantispa styriaca</i>	Neuroptera	Mantispidae							1	1
<i>Monalocoris</i> sp.	Homoptera	Miridae							1	1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
<i>Orius albidipennis</i>	Heteroptera	Anthocoridae							3	3
<i>Phytocoris</i> sp.	Heteroptera	Miridae							2	2
<i>Rhagonycha fluva</i>	Coleoptera	Cantharidae							1	1
<i>Scymnus apetezi</i>	Coleoptera	Coccinellidae					1			1
<i>Scymnus frontalis</i>	Coleoptera	Coccinellidae					2			2
<i>Scymnus</i> sp.	Coleoptera	Coccinellidae							1	1
<i>Stethorus gilvifrons</i>	Coleoptera	Coccinellidae					1		1	1
Parasitoid										
Insecta										
<i>Ablerus</i> sp.	Hymenoptera	Chalcidoidae							1	1
<i>Aphytis</i> sp.	Hymenoptera	Aphelinidae				1				1
<i>Cales noacki</i>	Hymenoptera	Aphelinidae							1	1
<i>Cirrospillus ingenuus</i>	Hymenoptera	Eulophidae							1	1
<i>Lysiphlebus fabarum</i>	Hymenoptera	Braconidae							1	1
<i>Quadrastichus</i> sp.	Hymenoptera	Eulophidae							1	1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			4	0	0	3	8	2	38	55
Unkown										
Insecta										
Cixius sp.	Homoptera	Cixidae							1	1
Hoplandrothrips ingennus	Thysanoptera	Phlaeothipidae							1	1
Tenothrips frici	Thysanoptera	Thripidae					1			1

●	Previously recorded on this host
n	Previously recorded on this host and in this survey

n	New to Lebanon	n:	No. of sites at which organism recorded
n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 5.2 Distribution of arthropods and gastropods on Mandarin (*Citrus reticulata*)

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			3	0	0	3	1	2	12	21
Primary										
Acari										
<i>Brevipalpus phoenicis</i>	Acariformes	Tenuipalpidae							1	1
<i>Panonychus citri</i>	Acariformes	Tetranychidae						1	1	2
<i>Tetranychus urticae</i>	Acariformes	Tetranychidae							2	2
Insecta										
<i>Aleurothrixus floccosus</i>	Homoptera	Aleyrodidae	2			1	1	2	5	11
<i>Aonidiella aurantii</i>	Homoptera	Diaspididae	3			3	1	1	4	12
<i>Aphis citricola</i>	Homoptera	Aphididae	1				1	1	5	8
<i>Aphis gossypii</i>	Homoptera	Aphididae					1		1	2
<i>Bemisia tabaci</i>	Homoptera	Aleyrodidae							1	1
<i>Ceratitis capitata</i>	Diptera	Tephrididae	1					•		1
<i>Ceroplastes floridensis</i>	Homoptera	Coccidae	2			2			5	9
<i>Ceroplastes sinensis</i>	Homoptera	Coccidae				1				1
<i>Coccus hesperidum</i>	Homoptera	Coccidae	2			1	1	1	2	7
<i>Dialeurodes citri</i>	Homoptera	Aleyrodidae	3			2			4	9

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			3	0	0	3	1	2	12	21
<i>Dialeurodes citrifolii</i>	Homoptera	Aleyrodidae	2			3			2	7
<i>Frankliniella occidentalis</i>	Thysanoptera	Thripidae				1				1
<i>Lepidosaphes beckii</i>	Homoptera	Diaspididae	2			1		1	4	8
<i>Myzus persicae</i>	Homoptera	Aphididae							1	1
<i>Paraleyrododes minei</i>	Homoptera	Aleyrodidae	1			2			3	6
<i>Parlatoria prergandii</i>	Homoptera	Diaspididae	3			3	1	1	3	11
<i>Phyllocnistis citrella</i>	Lepidoptera	Gracillariidae	3			3	1	1	5	13
<i>Planococcus citri</i>	Homoptera	Pseudococcidae	1						1	2
<i>Pseudococcus longispinus</i>	Homoptera	Pseudococcidae				1				1
<i>Toxoptera aurantii</i>	Homoptera	Aphelinidae							1	1
Potential Primary										
Insecta										
<i>Assymetrasca decedens</i>	Homoptera	Cicadellidae	1							1
<i>Bemisia afer</i>	Homoptera	Aleyrodidae					1			1
<i>Brachycaudus helishrysi</i>	Homoptera	Aphididae						1		1
<i>Coccus capparidis</i>	Homoptera	Coccidae	1			1				2
<i>Eucalymnatus tessellatus</i>	Homoptera	Coccidae				1				1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			3	0	0	3	1	2	12	21
<i>Gynaikothrips ficorum</i>	Thysanoptera	Phlaeothripidae				1				1
Secondary										
Insecta										
<i>Carpophilus obsoletus</i>	Coleoptera	Nitidulidae	1							1
<i>Carpophilus sp.</i>	Coleoptera	Nitidulidae	1							1
Saprophyte										
Acari										
<i>Tydeus sp.</i>	Acariformes	Tydeidae							1	1
<i>Novzellozoria sp.</i>	Acariformes	Tydeidae				1				1
<i>Orthotydeus caudatus</i>	Acariformes	Tydeidae				1				1
Insecta										
<i>Ectopsocus sp.</i>	Psocoptera	Ectopsocidae	2			2			4	8
<i>Epuraea sp.</i>	Coleoptera	Nitidulidae	1							1
<i>Lachesilla sp.</i>	Psocoptera	Psocidae							1	1
<i>Melanophthalma risipini</i>	Coleoptera	Latridiidae						1		1
<i>Trichopsocus dalii</i>	Psocoptera	Trichopsocidae	1			1			3	5

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			3	0	0	3	1	2	12	21
Casual										
Insecta										
Anthelephila ionica	Coleoptera	Anthicidae				1			1	2
Chironomidae	Diptera	Chironomidae					1			1
Neoheegeria gigantea	Thysanoptera	Phlaeothripidae					1			1
Protapion fulvipes	Coleoptera	Apionidae				1				1
Predator										
Acari										
Phytoseiidae	Parasitiformes	Phytoseiidae							3	3
Typhlodromus occidentalis	Parasitiformes	Phytoseiidae				1			1	2
Typhlodromus pyri	Parasitiformes	Phytoseiidae							1	1
Insecta										
Aphidolette aphidimyza	Diptera	Cecidomyiidae	1							1
Chrysopa sp.	Neuroptera	Chrysopidae	2			1			3	6
Chrysopa vulgaris	Neuroptera	Chrysopidae							1	1
Epysyrphus balteatus	Diptera	Syrphidae							1	1
Geocoris erythrocephalus	Heteroptera	Lygaeidae	1							1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			3	0	0	3	1	2	12	21
<i>Leucopsis</i> sp.	Diptera	Chamaemyiidae	1							1
<i>Nephus</i> sp.	Coleoptera	Coccinellidae							1	1
Parasitoid										
Insecta										
<i>Cirrospillus vittatus</i>	Hymenoptera	Braconidae	1							1
<i>Lysiphlebus fabarum</i>	Hymenoptera	Braconidae	1							1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 5.3 Distribution of arthropods and gastropods on Orange (*Citrus sinensis*)

Arthropod and gastropod species	Order	Family	Lebanon Districts							
			AK	BH	BE	ML	NA	NL	SL	Total
Total sites surveyed			16	0	0	3	4	11	51	85
Primary										
Acari										
<i>Brevipalpus californicus</i>	Acariformes	Tetranychidae	1					1	1	3
<i>Brevipalpus obovatus</i>	Acariformes	Tetranychidae							1	1
<i>Brevipalpus phoenicis</i>	Acariformes	Tetranychidae						2		2
<i>Eutetranychus orientalis</i>	Acariformes	Tetranychidae							4	4
<i>Panonychus citri</i>	Acariformes	Tetranychidae	3			2	1	2	10	18
<i>Phyllocoptrura oleivora</i>	Acariformes	Eriophyidae	1					1	3	5
<i>Tetranychus cinnabarinus</i>	Acariformes	Tetranychidae						1		1
<i>Tetranychus urticae</i>	Acariformes	Tetranychidae						1	4	5
Insecta										
<i>Acaudaleyrodes rachipora</i>	Homoptera	Aleyrodidae					1		1	2
<i>Aleurothrixus floccosus</i>	Homoptera	Aleyrodidae	13			2	2	6	41	64
<i>Aonidiella aurantii</i>	Homoptera	Diaspididae	13			3	3	7	22	48
<i>Aphis citricola</i>	Homoptera	Aphididae	6					3	16	25
<i>Aphis craccivora</i>	Homoptera	Aphididae	1							1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			16	0	0	3	4	11	51	85
<i>Aphis gossypii</i>	Homoptera	Aphididae	2			2		2	12	18
<i>Bemisia tabaci</i>	Homoptera	Aleyrodidae							3	3
<i>Ceratitis capitata</i>	Diptera	Tephrididae	●			●	●	●	6	6
<i>Ceroplastes floridensis</i>	Homoptera	Coccidae	6						6	12
<i>Ceroplastes rusci</i>	Homoptera	Coccidae						1		1
<i>Ceroplastes sinensis</i>	Homoptera	Coccidae							2	2
<i>Chrysomphalus aonidum</i>	Homoptera	Diaspididae	1			1		1		3
<i>Coccus hesperidum</i>	Homoptera	Coccidae	5					1	8	14
<i>Dialeurodes citri</i>	Homoptera	Aleyrodidae	9			1	2	3	13	28
<i>Dialeurodes citrifolii</i>	Homoptera	Aleyrodidae	11				1	6	21	39
<i>Drosophila melanogaster</i>	Diptera	Drosophilidae							1	1
<i>Frankliniella occidentalis</i>	Thysanoptera	Thripidae							2	2
<i>Hemiberlesia latenia</i>	Homoptera	Diaspididae	1							1
<i>Hypothenemus aspericollis</i>	Coleoptera	Scolytidae							2	2
<i>Icerya purchasi</i>	Homoptera	Margarodidae						1		1
<i>Lepidosaphes beckii</i>	Homoptera	Diaspididae	16			1	1	6	33	57
<i>Myzus persicae</i>	Homoptera	Aphididae					1	1		2

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			16	0	0	3	4	11	51	85
<i>Parabemisia myricae</i>	Homoptera	Aleyrodidae							4	4
<i>Paraleyrodes minei</i>	Homoptera	Aleyrodidae	10			1	1	5	16	33
<i>Parlatoria pergandii</i>	Homoptera	Aleyrodidae	8			2	1	7	28	46
<i>Pezothrips kellyanus</i>	Thysanoptera	Thripidae							1	1
<i>Phyllocnestis citrella</i>	Lepidoptera	Gracillariidae	14			3	3	7	37	64
<i>Planococcus citri</i>	Homoptera	Pseudococcidae	1						4	5
<i>Pseudococcus longispinus</i>	Homoptera	Pseudococcidae	1						1	2
<i>Retithrips syriacus</i>	Thysanoptera	Thripidae							1	1
<i>Thrips major</i>	Thysanoptera	Thripidae						1		1
<i>Thrips tabaci</i>	Homoptera	Thripidae	2					1	2	5
<i>Toxoptera aurantii</i>	Homoptera	Aphididae							3	3
Potential Primary										
Insecta										
<i>Aleurolobus marlatii</i>	Homoptera	Aleyrodidae							3	3
<i>Assymetrasca decedens</i>	Homoptera	Cicadellidae	1			1				2
<i>Bemisia afer</i>	Homoptera	Aleyrodidae							1	1
<i>Coccus capparidis</i>	Homoptera	Coccidae	1			1				1

Arthropod and gastropod species	Order	Family	Lebanon Districts						Total	
			AK	BH	BE	ML	NA	NL		SL
Total sites surveyed			16	0	0	3	4	11	51	85
<i>Eucalymnatus tessellatus</i>	Homoptera	Coccidae							1	1
<i>Hypoborus ficus</i>	Coleoptera	Scolytidae				1				1
<i>Icerya purchasi</i>	Homoptera	Coccidae	2						2	4
<i>Icerya seychellarum</i>	Homoptera	Margarodidae	3						1	4
<i>Palonema prasina</i>	Heteroptera	Pentatomidae						1		1
<i>Urophorus humeralis</i>	Coleoptera	Nitidulidae							1	1
Gastropoda										
<i>Theba pisana</i>	Stylommatophora	Helicidae	1							1
<i>Xeropicta vestalis</i>	Stylommatophora	Hygromeiidae							2	2
Secondary										
Insecta										
<i>Carpophillus</i> sp.	Coleoptera	Nitidulidae	1						2	3
<i>Carpophilus hemipterus</i>	Coleoptera	Nitidulidae							1	1
<i>Carpophilus multilatus</i>	Coleoptera	Nitidulidae	1						1	2
<i>Carpophilus obsoletus</i>	Coleoptera	Nitidulidae							1	1
<i>Drosophila melanogaster</i>	Diptera	Drosophilidae						1	2	3
<i>Drosophila simulans</i>	Diptera	Drosophilidae							1	1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			16	0	0	3	4	11	51	85
<i>Zaprianus indianus</i>	Diptera	Drosophilidae	1			1		2	2	6
Saprophyte										
Acari										
<i>Orthotydeus californicus</i>	Acariformes	Tydeidae					1		1	2
<i>Orthotydeus caudatus</i>	Acariformes	Tydeidae	2						3	5
Insecta										
<i>Aphthona Kuntzei</i>	Coleoptera	Curculionidae							1	1
<i>Colopterus sp.</i>	Coleoptera	Nitidulidae							1	1
<i>Ectopsocus sp.</i>	Psocoptera	Ectopsocidae	8			1			21	30
<i>Epuraea ocularis</i>	Coleoptera	Nitidulidae							1	1
<i>Epuraea sp.</i>	Coleoptera	Nitidulidae	1						2	3
<i>Graphopsocus cruciatus</i>	Psocoptera	Stenopsocidae							2	2
<i>Hoplandrothrips bidens</i>	Thysanoptera	Phlaeothripidae	1							1
<i>Lachesilla sp.</i>	Psocoptera	Psocidae	1			1			5	7
Staphylinidae	Coleoptera	Staphylinidae							2	2
<i>Trichopsocus dalii</i>	Psocoptera	Trichopsocidae	3					3	6	12
<i>Valenzuela sp.</i>	Psocoptera	Caeciliusidae	1							1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			16	0	0	3	4	11	51	85
Casual										
Insecta										
<i>Anthelephila ionica</i>	Coleoptera	Anthicidae	2						1	3
<i>Bruchidius bimaculatus</i>	Coleoptera	Bruchidae							1	1
<i>Bruchidius seminarius</i>	Coleoptera	Bruchidae					1			1
<i>Dendrothrips saltatrix</i>	Thysanoptera	Thripidae	1							1
<i>Hermeophaga ruficollis</i>	Coleoptera	Chrysomelidae					1			1
<i>Kalcapion semivittatum</i>	Coleoptera	Curculionidae	1							1
<i>Malvapion malvae</i>	Coleoptera	Apionidae	1							1
<i>Oxycarenus hyalinipensis</i>	Hymenoptera	lygaeidae	1						1	2
<i>Rhopalapion longirostre</i>	Coleoptera	Apionidae							1	1
Predator										
Acari										
<i>Euseius stipulatus</i>	Parasitiformes	Phytoseiidae	1			2	1	1		5
<i>Neoseiulus</i> sp.	Parasitiformes	Phytoseiidae						1	1	2
Phytoseiidae	Parasitiformes	Phytoseiidae	2				1		15	18
Stigmaeidae	Parasitiformes	Stigmaidae							1	1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			16	0	0	3	4	11	51	85
<i>Typhlodromus occidentalis</i>	Parasitiformes	Phytoseiidae						1	1	2
<i>Typhlodromus pyri</i>	Parasitiformes	Phytoseiidae							2	2
<i>Typhlodromus recki</i>	Parasitiformes	Phytoseiidae	1					1		2
Insecta										
<i>Adalia decempunctata</i>	Coleoptera	Coccinellidae	1							1
<i>Allothrombium</i> sp.	Acariformes	Trombiculidae	1					1		2
<i>Anthocoris</i> sp.	Heteroptera	Anthocoridae	1			1			1	3
<i>Aphidolette aphidimyza</i>	Diptera	Cecidomyiidae	3					2	3	8
<i>Cheilomenes propinqua nilotica</i>	Coleoptera	Coccinellidae						1		1
<i>Chilocorus bipustulatus</i>	Coleoptera	Coccinellidae						2	1	3
<i>Chrysopa</i> sp.	Neuroptera	Chrysopidae	6			3		3	17	29
<i>Chrysopa vulgaris</i>	Neuroptera	Chrysopidae	1							1
<i>Clitosthetus arcuatus</i>	Coleoptera	Coccinellidae	2					1		3
Coccinellidae	Coleoptera	Coccinellidae							2	2
<i>Conwentzia psociformis</i>	Neuroptera	Coniopterygidae	1						2	3
<i>Deraeocoris</i> sp.	Heteroptera	Miridae	1							1
<i>Geocoris erythrocephalus</i>	Heteroptera	Lygaeidae	1			1		1	2	5

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			16	0	0	3	4	11	51	85
<i>Hemerobius humulinus</i>	Neuroptera	Chrysopidae						1		1
<i>Hypodamia variegata</i>	Coleoptera	Coccnellidae	1							1
<i>Orius albidipennis</i>	Heteroptera	Anthocoridae	1							1
Phytoseiidae	Parasitiformes	Phytoseiidae	2							2
<i>Rhagozycha fluva</i>	Coleoptera	Cantharidae							1	1
<i>Scymnus apetizi</i>	Coleoptera	Coccinellidae						1		1
<i>Scymnus</i> sp.	Coleoptera	Coccinellidae	1					1	1	3
<i>Scymnus subvillosus</i>	Coleoptera	Coccinellidae	1					1		2
Parasitoid										
Insecta										
<i>Aphytis</i> sp.	Hymenoptera	Aphelinidae				1			1	2
<i>Cales noacki</i>	Hymenoptera	Aphelinidae						1	2	3
<i>Cirrospillus vittatus</i>	Hymenoptera	Braconidae	1							1
<i>Citrostichus phyllocnistoides</i>	Hymenoptera	Braconidae	1							1
<i>Lysiphlebus fabarum</i>	Hymenoptera	Braconidae				1			1	2

●	Previously recorded on this host	n	New to Lebanon	n	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 5.4 Distribution of arthropods and gastropods on Sour orange (*Citrus aurantium*)

Arthropod and gastropod species	Order	Family	Lebanon Districts							
			AK	BH	BE	ML	NA	NL	SL	Total
Total sites surveyed			0	0	0	0	0	2	1	3
Primary										
Acari										
<i>Tetranychus cinnabarinus</i>	Acariformes	Tetranychidae						1		1
<i>Planococcus citri</i>	Homoptera	Pseudococcidae						1		1
Insecta										
<i>Aleurothrixus floccosus</i>	Homoptera	Aleyrodidae						2	1	3
<i>Aonidiella aurantii</i>	Homoptera	Diaspididae						2	1	3
<i>Ceroplastes floridensis</i>	Homoptera	Coccidae						1		1
<i>Coccus hesperidum</i>	Homoptera	Coccidae						1		1
<i>Dialeurodes citri</i>	Homoptera	Aleyrodidae						1		1
<i>Dialeurodes citrifolii</i>	Homoptera	Aleyrodidae						2		2
<i>Icerya seychellarum</i>	Homoptera	Margarodidae				●				0
<i>Lepidosaphes beckii</i>	Homoptera	Diaspididae						2	1	3
<i>Paraleyrodides minei</i>	Homoptera	Aleyrodidae						1		1
<i>Parlatoria pergandii</i>	Homoptera	Diaspididae						1		1
<i>Phyllocnestis citrella</i>	Lepidoptera	Gracillariidae						2		2

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			0	0	0	0	0	2	1	3
<i>Pseudococcus longispinus</i>	Homoptera	Pseudococcidae						1		1
Potential Primary										
Insecta										
<i>Araecerus fasciculatus</i>	Coleoptera	Anthribidae						1		1
Saprophyte										
Insecta										
<i>Ectopsocus</i> sp.	Psocoptera	Ectopsocidae						1		1
Predator										
Acari										
<i>Typhlodromus occidentalis</i>	Parasitiformes	Phytoseiidae						1		1
Insecta										
<i>Chilocorus bipustulatus</i>	Coleoptera	Coccinellidae						1		1
<i>Chrysopa</i> sp.	Neuroptera	Chrysopidae						2		2
<i>Chrysopa vulgaris</i>	Neuroptera	Chrysopidae						1		1
<i>Clitosthetus arcuatus</i>	Coleoptera	Coccinellidae						2		2
<i>Cryptolaemus montrouizieri</i>	Coleoptera	Coccinellidae						1		1
<i>Nephus includense</i>	Coleoptera	Coccinellidae						1		1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			0	0	0	0	0	2	1	3
Parasitoid										
Insecta										
Aphytis sp.	Hymenoptera	Aphelinidae						1		1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 5.5 Distribution of arthropods and gastropods on Grapefruit (*Citrus paradisi*)

Arthropod and gastropod species	Order	Family	Lebanon Districts							
			AK	BH	BE	ML	NA	NL	SL	Total
Total sites surveyed			0	0	0	0	1	0	1	2
Primary										
Acari										
Panonychus citri	Acariformes	Tetranychidae							1	1
Insecta										
Aleurothrixus floccosus	Homoptera	Aleyrodidae					1			1
Aphis citricola	Homoptera	Aphididae					1			1
Bemisia tabaci	Homoptera	Aleyrodidae							1	1
Ceroplastes floridensis	Homoptera	Coccidae					1			1
Myzus persicae	Homoptera	Aphididae					1			1
Phyllocnistis citrella	Lepidoptera	Gracillariidae					1		1	2
Saprophyte										
Insecta										
Ectopsocus sp.	Psocoptera	Ectopsocidae							1	1
Casual										
Insecta										
Bruchus sp.	Coleoptera	Bruchidae					1			1

Arthropod and gastropod species	Order	Family	Lebanon Districts							Total
			AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed			0	0	0	0	1	0	1	2
Nysius sp.	Heteroptera	Lygaeidae					1			1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

6. Results and Discussion: Nematodes

Although more than 40 different species were found in association with the citrus rhizosphere worldwide (Cohn 1972, Duncan 1999), few have been documented to be economically important because they do not have any effect on tree productivity. The most widely devastating species is the citrus nematode *Tylenchulus semipenetrans*. With the exception of this pest, most nematodes currently known capable of damaging mature citrus tend to be regional and very limited. Among them, the migratory endoparasites have a more important role than other species. In addition, there are nematode species with unknown pathogenic potential commonly found in soil.

6.1. Citrus nematode, *Tylenchulus semipenetrans*

Refer to Tables 6.1- 6.5

Citrus nematode, an obligate parasite, occurs in all the citrus producing regions of the world (Duncan 2009).

Damage caused by citrus nematode infestation depends on the age and vigor of the tree where it can be excluded from new citrus plantings due to its narrow host range. (Van Gundy & Meagher 1977, Heald & O' Bannon 1987, Esser et al. 1993, Sorribas et al. 2000, de Campos et al. 2002, Iqbal et al. 2006, Maafi & Damadzadeh 2008, Sorribas et al. 2008).

This nematode is considered the causative agent of “slow decline” of citrus crops where growth of infested crops is retarded and leaves appear small and of yellow color.

Taylor et al. (1969) reported the occurrence of *Tylenchulus semipenetrans* in Lebanese citrus orchards.

Among 166 collected soil samples from all citrus producing orchards in the survey, 101 sites were infected with *Tylenchulus semipenetrans*.

Results have shown the presence of this pathogen in 53% (29) sites of lemon, 71% (15) sites of mandarin, 62% (53) sites of orange in addition to 1 grapefruit and 3 sour orange sites.

6.2. Burrowing nematode, *Radopholus similis*

Refer to Table 6.3

Radopholus similis has migratory endoparasitic habits, develops and reproduces inside host root tissues. Infected trees are characterized by a general decline with

fewer and smaller leaves. This severe disease, “Spreading decline” is caused by the citrus race of *Radopholus similis*.

The migrating nematode distribution in the soil is deep vertical where they survive no longer than 6 months in the absence of a host (Inserra & Vovlas 1977a). Thus, old trees with deep rooting system are highly affected by this pathogen while young trees having 50% of feeder roots in top soil are only moderately affected.

Although it was recorded in Lebanon previously on banana, this primary pest associated with citrus crops was reported only on orange crop for the first time in 2 sites of Akkar region.

6.3. Root lesion nematodes, *Pratylenchus* species

Refer to Tables 6.1 and 6.3

Nine species of lesion nematodes were found in association with citrus but only *Pratylenchus brachyurus*, *P. coffae* and *P. vulnus* were recognized as dangerous migratory endoparasites (Duncan 2005, Inserra & Vovlas 1977a, Inserra & Vovlas 1977b).

All active stages of *Pratylenchus vulnus* invade the cortical tissues of citrus rootlets, forming lesions and large cavities in feeder roots.

This parasite was observed in 7% (4) lemon sites and in a single orange site located in Mount Lebanon area. This new host to Lebanon with primary association, capable of causing severe damage to nursery seedlings, is not reported to damage mature trees (Inserra & Vovlas 1977a). It appears that *P. vulnus* has a very limited range within citrus species. Despite this pathogen known information that show sour orange as the only species heavily infected, the 3 sour orange visited sites were free of this infection.

Pratylenchus penetrans found in soil, was extracted from 13% (7) of lemon and 7% (6) of orange sites. It has no pathogenic effect discussed on citrus.

6.4. Root-Knot nematode, *Meloidogyne javanica*

Refer to Tables 6.1 – 6.4

Root Knot nematodes, *Meloidogyne* species, are occasionally found in citrus roots. The most common species (*M. incognita*, *M. javanica*, and *M. arenaria*) rarely mature, are not generally considered pathogenic to this crop. However, when good hosts are adjacent to citrus trees, these nematodes may cause problems. Also, they reproduced abundantly on weeds in the field.

Only *M. javanica* were extracted from soil samples from 13% (7) of lemon, 19% (4) of mandarin, 9% (8) of orange sites and at 1 sour orange orchard. This creates a new association of *M. javanica* with this host.

Inserra et al. (1978) reported extensive root damage due to invasion of citrus roots by *M. javanica* even without reproduction.

Besides, Orion & Cohn (1975) reported the infection of citrus by *M. javanica* resulting in a hypersensitive response and failure of giant cells formation.

6.5 Dagger nematode, *Xiphinema* species

Refer to Table 6.1

Numerous nematode species extracted from citrus rhizosphere belong to *Xiphinema* genera (Baines et al. 1978).

Little information showed the pathogenicity of dagger nematodes to citrus.

Cohn and Orion (1970) reported the association of *X. index* and *X. brevicollum* with unhealthy trees where they appear to be pathogenic to sour orange seedlings.

This survey showed the new association of *X. index* already reported on Lebanese vineyards with lemon in 2 different sites and the presence of *X. mediterraneum* in only 1 site of lemon located in South Lebanon.

6.6. Other nematodes

Refer to Tables 6.1 – 6.3

Many other species of nematodes such as *Tylenchus*, *Aphelenchoides*, *Rotylenchulus reniformis* (previously reported on banana in South Lebanon), *Tylenchorynchus*, *Paratylenchus*, *Aphelenchus* and *Gracilacus* were found in the soil samples and parasitized citrus roots; but their economic importance still uncertain due to their feeding effects less known.

All of these nematodes move freely in the soil searching for the host roots to feed. They usually feed on the selected site for a limited period of time moving to other new feeding points.

The spiral nematode, *Helicothylenchus multicinctus* common nematode on banana in Lebanon, feeds on citrus roots and produces lesions. It was found in 22% (12) of lemon, 9% (8) of orange soil samples and in only one site of mandarin at Nabatieh region.

6.7. Summary of new Records

New host records

This survey shows the following new host records:

Helicothylenchus multicinctus on lemon, mandarin and orange and *Rotylenchulus reniformis* on lemon and mandarin. Both were reported previously on banana.

Xiphinema index reported on 2 lemon sites at Akkar and South Lebanon sites.

Meloidogyne javanica extracted from lemon, mandarin, orange and a unique sour orange site at North Lebanon.

New to Lebanon

Five nematodes species with unknown pathogenic effect were reported in soil as new to Lebanon: *Tylenchus*, *Pratylenchus vulnus*, *Pratylenchus penetrans*, *Aphelenchoites* and *Aphelenchus*. Further investigation of these nematodes will confirm their nature of association.

6.8. General Results and Discussion

Among the 14 species reported to be pathogens to citrus, citrus nematode *Tylenchulus semipenetrans* is the only one that present a problem in citrus orchards observed in Lebanon. Results showed very high population of this nematode where its presence suppress, most of the time, the occurrence of other nematodes.

Young citrus trees are more affected than older ones in new plantings, where the damage usually decreases with plant growth (Inserra & Vovlas 1977a).

Extension of citrus plantings into old *Pratylenchus vulnus* infected olive growing areas may create a potential problem because this pest is common in olive groves but not in citrus orchards.

Under natural conditions, additional damage to plants occurs due to the invasion of roots by other microorganisms such as fungi, bacteria and viruses.

To make management decisions, it is essential to know the population estimation of the present species and to consider previous or neighbour crops that had problems caused by nematodes listed pathogenic on citrus. Also, care should be taken to use planting material free of citrus nematode when establishing new orchard.

Table 6.1 Distribution of nematodes on Limon (*Citrus limon*)

Nematode species	Nature of association	Lebanon Districts							
		AK	BH	BE	ML	NA	NL	SL	Total
Total sites surveyed		4	0	0	3	8	2	38	55
<i>Aphelenchoides</i> sp.	In Soil				1				1
<i>Aphelenchus</i> sp.	In Soil							1	1
<i>Gracilacus</i> sp.	In Soil						1		1
<i>Helicotylenchus multicinctus</i>	In Soil				2	1	1	8	12
<i>Melodoigyne javanica</i>	Secondary	1			2	2	1	1	7
<i>Paratylenchus</i> sp.	In Soil	1					1	1	3
<i>Pratylenchus penetrans</i>	In Soil	3			1	1	1	1	7
<i>Pratylenchus vulnus</i>	Primary	2					2		4
<i>Rotylenchulus reniformis</i>	Secondary	1			1	1		1	4
<i>Tylenchorenchus</i> sp.	In Soil					1		1	2
<i>Tylenchulus semipenetrans</i>	Primary	1			1	3		24	29
<i>Tylenchus</i> sp.	In Soil	1			1	1	1	2	6
<i>Xiphinema index</i>	Secondary	1						1	2
<i>Xiphinema mediterraneum</i>	In Soil							1	1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 6.2 Distribution of nematodes on Mandarin (*Citrus reticulata*)

Nematode species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		3	0	0	3	1	2	12	21
<i>Helicotylenchus multicinctus</i>	In Soil					1			1
<i>Meloidogyne javanica</i>	Secondary				2	1		1	4
<i>Rotylenchulus reniformis</i>	Secondary							1	1
<i>Tylenchulus semipenetrans</i>	Primary	2			3	1	2	7	15
<i>Tylenchus</i> sp	In Soil				1			1	2

●	Previously recorded on this host
n	Previously recorded on this host and in this survey

n	New to Lebanon
n	New host in Lebanon

n: No. of sites at which organism recorded

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 6.3 Distribution of nematodes on Orange (*Citrus sinensis*)

Nematode species	Nature of association	Lebanon Districts							
		AK	BH	BE	ML	NA	NL	SL	Total
Total sites surveyed		16	0	0	3	4	11	51	85
<i>Aphelenchoides</i> sp.	In Soil							1	1
<i>Aphelenchus</i> sp.	In Soil	1							1
<i>Gracilacus</i> sp.	In Soil	1					1	1	3
<i>Helicotylenchus multicinctus</i>	In Soil	3						5	8
<i>Longidorus</i> sp	Secondary						1		1
<i>Melodoigyne javanica</i>	Secondary	1			2		3	2	8
<i>Paratylenchus</i> sp.	In Soil	2						3	5
<i>Pratylenchus penetrans</i>	In Soil	2					1	3	6
<i>Pratylenchus vulnus</i>	Primary				1				1
<i>Radopholus similis</i>	Primary	2							2
<i>Tylenchorenchus</i> sp.	In Soil	1					1		2
<i>Tylenchulus semipenetrans</i>	Primary	8			1	3	3	38	53
<i>Tylenchus</i> sp.	In Soil	3			1			3	7

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 6.4 Distribution of nematodes on Sour orange (*Citrus aurantium*)

Nematode species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		0	0	0	0	0	2	1	3
<i>Meloidogyne javanica</i>	Secondary						1		1
<i>Tylenchulus semipenetrans</i>	Primary						2	1	3

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 5.5 Distribution of nematodes on Grapefruit (*Citrus paradisi*)

Nematode species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		0	0	0	0	1	0	1	2
<i>Tylenchulus semipenetrans</i>	Primary							1	1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

7. Results and Discussion: Fungi

A total of 257 samples of symptomatic branches, fruits, leaves and twigs were collected from the visited citrus sites. Details are shown in the table below. From the symptomatic organs, 260 fungal specimens were identified directly from the infected tissue or following isolation on appropriate culture medium.

Number of collected samples and fungal specimens from citrus crops

Host plant	Samples					Fungal specimens
	Branches	Fruits	Leaves	Stem/twigs	Total	
Lemon	8	30	16	43	97	116
Mandarin	3	5	7	18	33	28
Orange	8	25	24	57	114	109
Sour orange	0	0	1	3	4	3
Grapefruit	0	2	3	1	6	4
Total	19	62	51	122	254	260

Fungal specimens isolated from all citrus crops belonged to 19 species, five genera and one family. In order to assess the status of the record of each taxon, results were compared with previous reports and publications on phytopathogenic fungal species in Lebanon (Saad and Nienhaus, 1969; Khatib et al., 1970; Khouzami et al., 1996).

Incidence of the fungal species was calculated as follows:

$$\text{Incidence (\%)} = [\text{No. of infected sites} / \text{Total No. of sites}] \times 100$$

In general, the most widespread fungi in the visited citrus orchards were *Alternaria alternata* (19.9%), *Colletotrichum gloeosporioides* (19.9%), *Colletotrichum acutatum* (18.1%) and *Lasiodiplodia theobromae* (9.0%). Among these species, *C. acutatum* is a new species to Lebanon.

In addition, other primary pathogens were also common in Lebanese citrus orchards, such as *Eutypa lata* (6.6%), *Phoma tracheiiphila* (6.0%) and *Phomopsis citri* (6.0%).

Only one fungal species previously reported in Lebanese citrus orchards (Saad and Nienhaus, 1969) was not found in this survey: *Elsinoë fawcetti* (Syn. *Sphaceloma fawcetti*), causal agent of citrus scab.

In the Results Tables (Tables 7.1-7.5), all species are listed under their teleomorph names followed by their anamorph names (in brackets) where possible.

7.1. Lemon (*Citrus limon*)

A total of 55 sites were sampled from South Lebanon (predominately), Akkar, Mount Lebanon, Nabatiyeh and North Lebanon districts. From these sites, 27 fungal species

were detected (Table 7.1). Among these, eight were new to Lebanon (Table 7.1; bold text and red background); five were primary pathogens and three were saprophytes.

Five fungal species were new host records (Table 7.1; grey background); three were primary or potential primary, one was secondary and one was primary or saprophyte. Four taxa were classified as having unknown nature of association because the species level of identification was not possible.

Of the fungal species previously known to occur on lemon in Lebanon, nine were recovered in this survey and one species, *Elsinoë fawcetti*, was not noted. The most commonly detected base record species were *Phoma tracheiiphila* (16.4%), *Colletotrichum gloeosporioides* (14.5%), *Alternaria* sp. (10.9%), *Lasiodiplodia theobromae* (7.3%) and *Phomopsis citri* (7.3%). In addition, the primary base record pathogens *Phoma herbarum*, *Guignardia citricarpa* and *Phytophthora citrophthora* were detected in one, three and two sites, respectively.

▪ New to Lebanon on Lemon

Eight fungal species new to Lebanon were recorded on lemon in this survey.

Primary and Potential primary: *Botryosphaeria dothidea*, '*Botryosphaeria*' *lutea*, '*Botryosphaeria*' *stevensii*, *Glomerella acutata* and *Phoma glomerata*.

The importance of these species is their ability to cause dieback and cankers in affected twigs.

Glomerella acutata (*Colletotrichum acutatum*) was the second most widespread fungal species in all visited lemon orchards with an incidence of 20.0%. Isolates of *C. acutatum* were generally collected from twigs showing symptoms of dieback and rarely from fruit spots.

Secondary and saprophyte: *Acremonium* sp., *Cylindrocarpon lichenicola* and *Pleospora herbarum*.

▪ New Host Recordings for Lemon

Five fungal species were reported for the first time on lemon: *Alternaria alternata*, '*Botryosphaeria*' *obtusa* (*Diplodia seriata*), *Eutypa lata*, *Fusarium oxysporum* and *Nectria haematococca* (*F. solani*).

Alternaria alternata was the most widespread fungal species (29.1%) on lemon. This species can be either a primary pathogen on fruits, causing dark sports on the skin of fruits, or a saprophyte in the wood.

An important finding was the relatively high incidence of *Eutypa lata* (12.7%) on lemon, causing decline and internal wood discoloration associated or not with gummosis. This species is a primary pathogen on grapevine worldwide causing *Eutypa* dieback disease and was reported in Lebanon on wine grapes in Bekaa district (Choueiri et al., 2006).

In addition, '*B.*' *obtusa* and *Fusarium* species were previously reported in Lebanon on grapevine and vegetable crops, respectively (Khouzami et al., 1996; Choueiri et al., 2006). '*Botryosphaeria*' *obtusa* is a weak pathogen on woody hosts, whereas *F. solani* is a primary pathogen on a wide host range and on citrus, it causes dry root rot disease.

7.2. Mandarin (*Citrus reticulata*)

A total of 21 sites were sampled from South Lebanon (predominately), Akkar, Mount Lebanon, Nabatiyeh and North Lebanon districts. From these sites, 13 fungal species were detected (Table 7.2). Among these, three were new to Lebanon (Table 7.2; bold text and red background); one was a primary pathogen, one was saprophyte and one has an unknown nature of association because the species level of identification was not possible.

Six fungal species were new host records (Table 7.2; grey background); four were primary, one was secondary and one was primary or saprophyte.

Four fungal taxa previously known to occur on mandarin in Lebanon were recovered in this survey: Three genera (*Alternaria*, *Fusarium*, *Phoma*) and one species (*Guignardia citricarpa*). The first three had an unknown nature of association because the species level was not identified. On the other hand, *G. citricarpa*, the causal agent of black spot disease, was found in one site in South Lebanon.

The most commonly detected species on mandarin in this survey were *Glomerella acutata* (28.6%), *G. cingulata* (14.3%), *Alternaria* sp. (14.3%) and *A. alternata* (14.3%).

▪ New to Lebanon on Mandarin

Three fungal species new to Lebanon were recorded on mandarin during this survey.

Primary: *Glomerella acutata* (*Colletotrichum acutatum*).

The importance of this species is its ability to cause dieback in affected twigs. *Glomerella acutata* (*Colletotrichum acutatum*) was the most widespread fungal species in all visited mandarin orchards with an incidence of 28.6%. As in lemon, isolates of *C. acutatum* were generally collected from twigs showing symptoms of dieback and rarely from fruit and leaf spots.

One isolate of Botryosphaeriaceae, belonging to the genus *Neofusicoccum*, was recovered in one site of mandarin located in South Lebanon. The genus is new to Lebanon; the species identification was not possible due to the absence of characteristic fungal sporifications in culture.

Saprophyte: *Cladosporium cladosporioides*.

▪ New Host Recordings for Mandarin

Six fungal species were reported for the first time on mandarin: *Alternaria alternata*, '*Botryosphaeria*' *rhodina* (*Lasiodiplodia theobromae*), *Eutypa lata*, *Fusarium oxysporum*, *Glomerella cingulata* and *Nectria haematococca* (*F. solani*).

Alternaria alternata was recovered in 14.3% of mandarin sites. This species can be either a primary pathogen on fruits, causing dark spots on the skin of fruits, or a saprophyte in the wood. *Fusarium oxysporum* is a primary pathogen on vegetable crops in Lebanon (Khouzami et al., 1996) but is secondary on citrus crops.

An important finding was the recovery of four primary pathogens for the first time on mandarin. *Colletotrichum gloeosporioides* and *L. theobromae*, previously reported on lemon (Saad and Nienhaus, 1969), *Eutypa lata*, previously reported on grapevine

(Choueiri et al., 2006) and *F. solani*, a common pathogen on vegetable crops (Khouzami et al., 1996), were found in three, two, two and one mandarin sites, respectively. All four new host recording species can cause economically important diseases on mandarin and may significantly reduce the yield of the crop.

7.3. Orange (*Citrus sinensis*)

A total of 85 sites were sampled predominately from South Lebanon (60.0%), Akkar, Mount Lebanon, Nabatiyeh and North Lebanon districts. From these sites, 22 fungal species were detected (Table 7.3). Among these, seven were new to Lebanon (Table 7.3; bold text and red background); four were primary or potential primary pathogens, two were saprophytes and one has an unknown nature of association.

Five fungal species were new host records (Table 7.3; grey background); four were primary or potential primary and one was a primary/saprophyte. In general, five taxa were classified as having unknown nature of association because the species level of identification was not possible.

Of the fungal species previously known to occur on orange in Lebanon, 10 were recovered in this survey. The most commonly detected base record species were *Lasiodiplodia theobromae* (10.6%), *Penicillium digitatum* (9.4%), *Phomopsis citri* (7.1%) and *Alternaria* sp. (5.9%). In addition, the economically important primary base record pathogens *Phytophthora citrophthora* and *Guignardia citricarpa* were detected in one and three sites, respectively.

▪ New to Lebanon on Orange

Seven fungal species new to Lebanon were recorded on orange in this survey.

Primary and Potential primary: '*Botryosphaeria*' *lutea* (*Neofusicoccum luteum*), '*Botryosphaeria*' *stevensii* (*Diplodia mutila*), *Glomerella acutata* (*Colletotrichum acutatum*) and *Phoma glomerata*. The importance of these species is their ability to cause dieback and cankers in affected twigs.

Glomerella acutata (*Colletotrichum acutatum*) was the second most widespread fungal species in all visited orange orchards with an incidence of 16.5%. Isolates of *C. acutatum* were collected from twigs showing symptoms of dieback (52.9%), from fruit spots (29.4%) and rarely from leaf spots. Each of the remaining species was recovered in one orange site located in Akkar (*D. mutila*) or North Lebanon (*N. luteum* and *Phoma glomerata*).

One isolate of Botryosphaeriaceae, belonging to the genus *Neofusicoccum*, was recovered in one site of orange located in Akkar district. The genus is new to Lebanon; the species identification was not possible due to the absence of characteristic fungal sporifications in culture.

Saprophyte: *Acremonium* sp. and *Geotrichum candidum*.

▪ New Host Recordings for Orange

Five fungal species were reported for the first time on orange: *Alternaria alternata*, '*Botryosphaeria*' *obtusa* (*Diplodia seriata*), *Eutypa lata*, *Glomerella cingulata* (*Colletotrichum gloeosporioides*) and *Phoma tracheiiphila*.

Glomerella cingulata (*Colletotrichum gloeosporioides*) was the most widespread fungal species (21.2%) on orange. The species is a common dieback disease on lemon (Saad and Nienhaus, 1969). In addition, *A. alternata*, which is primary on fruits or saprophyte in wood, was recovered in 15.3% of orange sites.

As in lemon and mandarin, *Eutypa lata*, a primary pathogen on grapevine (Choueiri et al., 2006), was recovered also in orange orchards (2.4%). '*Botryosphaeria*' *obtusa*, a weak pathogen on woody hosts, reported on grapevine (Choueiri et al., 2006) was isolated from one orange site in South Lebanon.

An important finding was the recovery of *Phoma tracheiiphila* on orange in Lebanon. This pathogen is frequently associated with lemon production worldwide and rarely affects orange trees. In the present survey, *P. tracheiiphila* was isolated from one orange site located in Nabatiyeh district.

7.4. Sour orange (*Citrus aurantium*)

Three sites of sour orange were sampled from North and South Lebanon districts. From these sites, three fungal species were detected (Table 7.4). Among these, one primary pathogen was new to Lebanon (Table 7.4; bold text and red background) and two were new host records (Table 7.4; grey background).

▪ New to Lebanon on Sour Orange

One fungal species new to Lebanon was recorded on sour orange in this survey: *Glomerella acutata* (*Colletotrichum acutatum*). This species, as noted for the other citrus crops, can cause twig dieback symptoms in affected trees.

▪ New Host Recordings for Sour Orange

Two fungal species were reported for the first time on sour orange: '*Botryosphaeria*' *obtusa* (*Diplodia seriata*) and *Glomerella cingulata* (*Colletotrichum gloeosporioides*). The first is a weak pathogen reported on grapevine (Choueiri et al. 2006) and the second is a primary pathogen reported on lemon (Saad and Nienhaus, 1969).

7.5. Grapefruit (*Citrus paradisi*)

Two sites of grapefruit were sampled from Nabatiyeh and South Lebanon districts. From these sites, three fungal species were detected (Table 7.5). Among these, one primary pathogen was new to Lebanon (Table 7.5; bold text and red background), one was new host record (Table 7.5; grey background) and one is a base record genus having an unknown nature of association. The three recovered species originated from one site of South Lebanon.

▪ New to Lebanon on Grapefruit

One fungal species new to Lebanon was recorded on grapefruit in this survey: *Glomerella acutata* (*Colletotrichum acutatum*). This species, as noted for the other citrus crops, can cause twig dieback symptoms in affected trees.

▪ New Host Recording for Grapefruit

One fungal species was reported for the first time on grapefruit: *Alternaria alternata*. This species, previously reported on vegetable crops in Lebanon (Saad and Nienhaus, 1969), was isolated from grapefruit fruit spots during this survey.

7.6. General Results and Discussion

This report contains a comprehensive list of the fungal diseases affecting citrus crops in Lebanon. The newest publication concerning fungal diseases affecting these crops dates from 1969, when the authors identified the major diseases affecting all crops in Lebanon (Saad and Nienhaus, 1969). Later on, other reports had listed the diseases of citrus crops, however, in most cases, these reports were not based on scientific approach, and therefore the identification might have been erratic and unreliable.

From October 2011 till October 2012, a total of 254 samples of symptomatic organs were collected from 166 citrus sites. From these, 260 fungal specimens were identified directly from the infected tissue and/or following isolation on appropriate culture medium. Fungal specimens belonged to 19 different species, five genera and one family.

In general, 11 species were reported for the first time in Lebanon during this survey, five of which are primary pathogens. Also, eight fungal species were new host records on their respective host plant (refer to tables below).

Distribution of fungal species new to Lebanon on citrus sites

Fungal Species	Number of sites					Total
	Lemon	Mandarin	Orange	Sour orange	Grapefruit	
<i>Acremonium sp.</i>	1	-	2	-	-	3
<i>Botryosphaeria dothidea</i>	2	-	-	-	-	2
<i>B. lutea</i>	1	-	1	-	-	2
<i>B. stevensii</i>	1	-	1	-	-	2
<i>Botryosphaeriaceae</i>	-	1	1	-	-	2
<i>Cladosporium cladosporioides</i>	-	1	-	-	-	1
<i>Cylindrocarpon lichenicola</i>	1	-	-	-	-	1
<i>Geotrichum candidum</i>	-	-	1	-	-	1
<i>Glomerella acutata</i>	11	6	14	1	1	33
<i>Phoma glomerata</i>	2	-	1	-	-	3
<i>Pleospora herbarum</i>	2	-	-	-	-	2

Distribution of new host fungal species records on citrus sites

Fungal Species	Number of sites					Total
	Lemon	Mandarin	Orange	Sour orange	Grapefruit	
<i>Alternaria alternata</i>	16	3	13	-	1	33
<i>Botryosphaeria obtusa</i>	3	-	1	1	-	5
<i>Botryosphaeria rhodina</i>	-	2	-	-	-	2
<i>Eutypa lata</i>	7	2	2	-	-	11
<i>Fusarium oxysporum</i>	1	1	-	-	-	2
<i>Glomerella cingulata</i>	-	3	18	1	-	22
<i>Nectria haematococca</i>	1	1	-	-	-	2
<i>Phoma tracheiiphila</i>	-	-	1	-	-	1

The most widespread primary species on Citrus crops in Lebanon were *Glomerella cingulata* (*Colletotrichum gloeosporioides*) and *G. acutata* (*C. acutatum*), recovered respectively in 19.9% and 18.1% of visited sites. Both species were reported on lemon, mandarin, orange and sour orange, however, on grapefruit, only *C. acutatum* was recovered. In most cases, positive samples were infected with the two species at the same time.

Many species of *Colletotrichum* are plant pathogenic species, namely *C. acutata* and *C. gloeosporioides*. The fungi are cosmopolitan in their distribution and cause extensive crop losses every year. Both species cause diseases commonly known as anthracnose that can occur on leaves, stems, and fruits of host plant (Sutton, 1992). Economically important losses were reported on strawberry, apple, almond and citrus (Adaskaveg & Hartin, 1997; Smith, 1998; Gonzalez & Sutton, 2004).

On citrus, *C. gloeosporioides* may cause postharvest anthracnose from pre-harvest quiescent infections and is frequently associated with infections by *Phoma tracheiiphila*, the causal agent of mal secco disease (Anonymous, 2007). *Colletotrichum acutatum* does not produce postharvest anthracnose on citrus fruit, but causes distinct diseases on different species of citrus, such as post-bloom fruit drop and key lime anthracnose (Timmer et al. 1994).

In this survey, most of the isolates of these species were collected from twigs showing dieback symptoms, in which the pathogens can overwinter. Distinction between the two species was based on morphological characteristics in culture, mainly the size of conidia, the presence of setae and the production of the sexual state (Peres et al. 2005).

Furthermore, five fungal species and one unknown taxon belonging to the family Botryosphaeriaceae were found in this survey. These were: '*Botryosphaeria*' *rhodina* (*Lasiodiplodia theobromae*) (9.0% of visited sites), '*B.*' *obtusa* (*Diplodia seriata*) (3.0% of visited sites), '*B.*' *stevensii* (*D. mutila*) (1.2% of visited sites), *B. dothidea* (*Fusicoccum aesculi*) (1.2% of visited sites), '*B.*' *lutea* (*Neofusicoccum luteum*) (1.2% of visited sites) and three unidentified isolates belonging to Botryosphaeriaceae.

Species of Botryosphaeriaceae are important pathogens on many woody plants, causing fruit rots, frog-eye leaf spot, stem and branch cankers, gummosis, dieback and in some cases tree death (Slippers et al. 2007). Infection takes place either through wounds, or directly through the stomata and other openings (Kim et al. 2001). These fungi can then persist in healthy tissue. Successful infection and susceptibility of infected trees is closely linked to environmental conditions, where high temperatures, water logging and other forms of stress favour infection (Ahimera et al. 2003).

Effective management of diseases caused by species of Botryosphaeriaceae is achieved through integrated control strategies, which take into account cultivar susceptibility, environmental conditions, tree management and chemical (Beckman et al. 2003). This effective control requires knowledge regarding the taxonomy and epidemiology of the pathogen involved. Furthermore, due to enhanced quarantine requirements, correct identification of the fungal pathogens that affect citrus crops has become increasingly important in the export of fruit products.

Eutypa dieback, caused by the fungus *Eutypa lata*, is a major trunk disease of grapevines. In this survey, the pathogen was recovered on lemon, mandarin and orange with an incidence of 6.6%. *Eutypa lata* can infect 88 species of plants including stone fruit, pome fruit, citrus, fig, olive, pistachio, walnut, quince, poplar, and rose (Carter, 1991). The most commonly seen symptoms are stunted and deformed shoots, accompanied with cankers and internal brown, wedge-shaped necrotic area in the vascular symptom. The disease can be controlled by protecting wounds from infection by *E. lata* spores or by physically removing infected wood.

Diaporthe citri (*Phomopsis citri*), the causal agent of melanose, gummosis, phomopsis stem-end rot and other diseases on citrus, was recovered on lemon and orange with an incidence of 6.0%. The fungus attacks branches, stems, immature leaves, and fruits.

Under Mediterranean conditions, the dry climate prevailing during the fruit growth and maturation seasons makes fruit infection by this fungus rare (Tuset, 1988). In general, in the Mediterranean region, only citrus trees severely affected in the twigs and branches by *D. citri* lose their foliage, which becomes sparse, yellow and desiccated. Thus, in this region, *D. citri* behaves as a weak pathogen.

In the Mediterranean region, *Phoma tracheiphila*, the causal agent of mal secco, is the most destructive fungal disease of lemons. In this survey, the pathogen was detected mainly on lemon and occasionally on orange, with an incidence of 6.0%. Acervuli of the *Colletotrichum* state of *Glomerella cingulata*, a secondary invader of withered twigs, were often associated with the pycnidia of *P. tracheiphila*.

The first symptoms of mal secco appear in spring as leaf and shoot chlorosis followed by a dieback of twigs and branches. Gradually the pathogen affects the entire tree which eventually dies. On cutting into the infected twigs, a characteristic salmon-pink or orange-red discoloration of the wood can be seen; this internal symptom is associated with gum production within the xylem vessels (Ruggieri, 1953). The disease reduces the quantity and quality of lemon production in the areas where the pathogen is present, and limits the use of susceptible species and cultivars.

On the other hand, the most isolated fungal species during this survey was *Alternaria alternata*. This fungus is ubiquitous and has a wide host range. It may cause fruit rot disease of citrus or can be found as saprophyte in the wood. The fungus was recovered in 19.9% of visited on all citrus crops except sour orange.

Phytophthora citrophthora is one of the most economically important pathogen on citrus worldwide. It causes citrus brown fruit rot, trunk gummosis, collar and root rot, leaf and shoot blight. Root and trunk infections lead to poor growth and dieback of trees and severe losses of fruit to brown rot may occur both pre- and post-harvest.

The relatively low incidence of *P. citrophthora* (1.8%) in the visited orchards could be probably due to the fact that most citrus varieties in Lebanon are grafted on sour orange (*C. aurantium*), exhibiting a high level of resistance towards the pathogen.

Other fungal species having less economic importance on citrus were also reported in Lebanon, namely *Fusarium oxysporum*, *Nectria haematococca* (*Fusarium solani*) and *Pleospora herbarum* (*Stemphylium herbarum*). These are important primary pathogens on other host plants grown on large areas in Lebanon. *Fusarium* species are responsible for high economic damages on cucurbitaceae and solanaceae, causing Fusarium wilt disease in affected plants. *Pleospora herbarum*, however, is the causal agent of leaf blights on onion, radish, lettuce, etc.

Table 7.2 Distribution of fungi on Lemon (*Citrus limon*)

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		4	0	0	3	8	2	38	55
<i>Acremonium</i> sp.	Saprophyte							1	1
<i>Alternaria alternata</i>	Primary or saprophyte	1				4		11	16
<i>Alternaria</i> sp.	Unknown							6	6
<i>Botryosphaeria dothidea</i> (<i>Fusicoccum aesculi</i>)	Primary							2	2
<i>'Botryosphaeria' lutea</i> (<i>Neofusicoccum luteum</i>)	Primary				1				1
<i>'Botryosphaeria' obtusa</i> (<i>Diplodia seriata</i>)	Potential primary							3	3
<i>'Botryosphaeria' rhodina</i> (<i>Lasiodiplodia theobromae</i>)	Primary							4	4
<i>'Botryosphaeria' stevensii</i> (<i>Diplodia mutila</i>)	Primary	1							1
Botryosphaeriaceae	Unknown							2	2
<i>Cylindrocarpon lichenicola</i>	Saprophyte							1	1
<i>Diaporthe citri</i> (<i>Phomopsis citri</i>)	Primary				1			3	4
<i>Elsinoë fawcettii</i> ●	Primary								0
<i>Eutypa lata</i>	Primary	1						6	7
<i>Fusarium oxysporum</i>	Secondary	1							1
<i>Fusarium</i> sp.	Unknown							2	2

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		4	0	0	3	8	2	38	55
<i>Glomerella acutata</i> (<i>Colletotrichum acutatum</i>)	Primary	1				1		9	11
<i>Glomerella cingulata</i> (<i>Colletotrichum gloeosporioides</i>)	Primary	1			1	1		5	8
<i>Guignardia citricarpa</i> (<i>Phyllosticta citricarpa</i>)	Primary							3	3
<i>Nectria haematococca</i> (<i>Fusarium solani</i>)	Primary	1							1
<i>Penicillium digitatum</i>	Secondary							1	1
<i>Penicillium italicum</i>	Secondary				1			1	2
<i>Phoma glomerata</i>	Potential primary					1		1	2
<i>Phoma herbarum</i>	Primary					1			1
<i>Phoma</i> sp.	Unknown				1				1
<i>Phoma tracheiiphila</i>	Primary	2			1	1	1	4	9
<i>Phytophthora citrophthora</i>	Primary							2	2
<i>Pleospora herbarum</i> (<i>Stemphylium herbarum</i>)	Saprophyte							2	2

●	Previously recorded on this host
n	Previously recorded on this host and in this survey

n	New to Lebanon
n	New host in Lebanon

n: No. of sites at which organism recorded

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 7.3 Distribution of fungi on Mandarin (*Citrus reticulata*)

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		3	0	0	3	1	2	12	21
<i>Alternaria alternata</i>	Primary or saprophyte							3	3
<i>Alternaria</i> sp.	Unknown							3	3
' <i>Botryosphaeria</i> ' <i>rhodina</i> (<i>Lasiodiplodia theobromae</i>)	Primary						1	1	2
Botryosphaeriaceae (<i>Neofusicoccum</i> sp.)	Unknown							1	1
<i>Cladosporium cladosporioides</i>	Saprophyte							1	1
<i>Eutypa lata</i>	Primary							2	2
<i>Fusarium oxysporum</i>	Secondary							1	1
<i>Fusarium</i> sp.	Unknown							1	1
<i>Glomerella acutata</i> (<i>Colletotrichum acutatum</i>)	Primary	2			2			2	6
<i>Glomerella cingulata</i> (<i>Colletotrichum gloeosporioides</i>)	Primary	1					1	1	3
<i>Guignardia citricarpa</i> (<i>Phyllosticta citricarpa</i>)	Primary							1	1
<i>Nectria haematococca</i> (<i>Fusarium solani</i>)	Primary					1			1
<i>Phoma</i> sp.	Unknown						1		1

●	Previously recorded on this host
n	Previously recorded on this host and in this survey

n	New to Lebanon
n	New host in Lebanon

n: No. of sites at which organism recorded

Lebanon districts: **AK**: Akkar, **BH**: Baalbeck – Hermel, **BE**: Bekaa, **ML**: Mount Lebanon, **NA**: Nabatiyeh, **NL**: North Lebanon, **SL**: South Lebanon

Table 7.4 Distribution of fungi on Orange (*Citrus sinensis*)

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		16	0	0	3	4	11	51	85
<i>Acremonium</i> sp.	Saprophyte					1		1	2
<i>Alternaria alternata</i>	Primary or saprophyte	2			1		4	6	13
<i>Alternaria</i> sp.	Unknown							5	5
'<i>Botryosphaeria</i>' <i>lutea</i> (<i>Neofusicoccum luteum</i>)	Primary						1		1
' <i>Botryosphaeria</i> ' <i>obtus</i> (<i>Diplodia seriata</i>)	Potential primary						1		1
' <i>Botryosphaeria</i> ' <i>rhodina</i> (<i>Lasiodiplodia theobromae</i>)	Primary					1	2	6	9
'<i>Botryosphaeria</i>' <i>stevensii</i> (<i>Diplodia mutila</i>)	Primary	1							1
Botryosphaeriaceae (<i>Neofusicoccum</i> sp.)	Unknown	1							1
Botryosphaeriaceae	Unknown						1		1
<i>Diaporthe citri</i> (<i>Phomopsis citri</i>)	Primary	1					1	4	6
<i>Eutypa lata</i>	Primary						1	1	2
<i>Fusarium</i> sp.	Unknown	1							1
<i>Geotrichum candidum</i>	Saprophyte							1	1
<i>Glomerella acutata</i> (<i>Colletotrichum acutatum</i>)	Primary	3						11	14
<i>Glomerella cingulata</i> (<i>Colletotrichum gloeosporioides</i>)	Primary	5				1	4	8	18

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		16	0	0	3	4	11	51	85
<i>Guignardia citricarpa</i> (<i>Phyllosticta citricarpa</i>)	Primary	1				1		1	3
<i>Penicillium digitatum</i>	Secondary	2			1		1	4	8
<i>Penicillium italicum</i>	Secondary	1							1
<i>Phoma glomerata</i>	Potential primary						1		1
<i>Phoma</i> sp.	Unknown						1		1
<i>Phoma tracheiiphila</i>	Primary					1			1
<i>Phytophthora citrophthora</i>	Primary					1			1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 7.5 Distribution of fungi on Sour orange (*Citrus aurantium*)

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		0	0	0	0	0	2	1	3
<i>'Botryosphaeria' obtusa (Diplodia seriata)</i>	Potential primary						1		1
<i>Glomerella acutata (Colletotrichum acutatum)</i>	Primary							1	1
<i>Glomerella cingulata (Colletotrichum gloeosporioides)</i>	Primary						1		1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 7.6 Distribution of fungi on Grapefruit (*Citrus paradisi*)

Fungal species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		0	0	0	0	1	0	1	2
<i>Alternaria alternata</i>	Primary							1	1
<i>Glomerella acutata</i> (<i>Colletotrichum acutatum</i>)	Primary							1	1
<i>Fusarium</i> sp.	Unknown							1	1

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

8. Results and Discussion: Bacteria

The search for four types of pathogenic bacteria, *Pseudomonas syringae* pv. *syringae*, *Agrobacterium tumefaciens*, *Xanthomonas axonopodis* pv. *citri* and *Xylella fastidiosa* was conducted on all the citrus crops. Results found in this survey did not show the presence of *Agrobacterium*, *Xylella* or *Xanthomonas citri* but only *Pseudomonas syringae* on one crop, grapefruit from one district, Nabatiyeh. The climate conditions in all areas may not have been conducive for diseases development.

One pathogenic bacterial species, *Pseudomonas syringae*, previously reported in Lebanon on lemon and sweet lime (Saad & Nienhaus 1969) was not recovered during this survey on these crops (Saad & Nienhaus 1969).

8.1. Lemon (*Citrus limon*)

Among five samples of lemon received from SL and NL, none showed any bacterial growth.

8.2. Mandarin (*Citrus reticulata*)

Two saprophytic bacteria, *Xanthomonas campestris*, were detected in SL and NL districts.

8.3. Orange (*Citrus sinensis*)

From two samples, one saprophyte bacterium was found in SL.

8.4. Sour orange (*Citrus aurantium*)

The unique sample of sour orange, originally from Jezzine (SL), did not show any bacterial activity

8.5. Grapefruit (*Citrus paradisi*)

A grapefruit sample from Nabatiyeh region revealed the presence of *Pseudomonas syringae* pv. *syringae* previously recorded on citrus in Lebanon (Saad and Nienhaus 1969).

8.6. General Results and Discussion

From all samples received, only one significant *Pseudomonas* canker on grapefruit was recorded in Nabatiyeh, in an orchard containing old trees. This bacterium is a primary host on citrus group. Many other bacteria belonging to saprophyte group have been detected for the first time during laboratory testing but without any significant pathogenicity. We can conclude that most of farmers are using resistant cultivars; this might explain the low incidence of bacterial diseases on citrus crops.

Table 8.1 Distribution of bacteria on Lemon (*Citrus limon*)

Bacteria species	Nature of association	Lebanon Districts							
		AK	BH	BE	ML	NA	NL	SL	Total
Total sites surveyed		4	0	0	3	8	2	38	55
<i>Agrobacterium tumefaciens</i>	Primary								0
<i>Pseudomonas syringae</i> pv. <i>syringae</i>	Primary							●	0
<i>Xanthomonas axonopodis</i> pv. <i>citri</i>	Primary								0
<i>Xylella fastidiosa</i>	Primary								0

●	Previously recorded on this host	n	New to Lebanon	n: No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon	

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 8.2 Distribution of bacteria on Mandarin (*Citrus reticulata*)

Bacteria species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		3	0	0	3	1	2	12	21
<i>Agrobacterium tumefaciens</i>	Primary								0
<i>Pseudomonas syringae</i> pv. <i>syringae</i>	Primary								0
<i>Xanthomonas axonopodis</i> pv. <i>citri</i>	Primary								0
<i>Xanthomonas campestris</i>	Saprophyte						1	1	2
<i>Xylella fastidiosa</i>	Primary								0

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 8.3 Distribution of bacteria on Orange (*Citrus sinensis*)

Bacteria species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		16	0	0	3	4	11	51	85
<i>Agrobacterium tumefaciens</i>	Primary								0
<i>Pseudomonas syringae</i> pv. <i>syringae</i>	Primary								0
<i>Xanthomonas axonopodis</i> pv. <i>citri</i>	Primary								0
<i>Xanthomonas campestris</i>	Saprophyte							1	1
<i>Xylella fastidiosa</i>	Primary								0

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 8.4 Distribution of bacteria on Sour orange (*Citrus aurantium*)

Bacteria species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		0	0	0	0	0	2	1	3
<i>Agrobacterium tumefaciens</i>	Primary								0
<i>Pseudomonas syringae</i> pv. <i>syringae</i>	Primary								0
<i>Xanthomonas axonopodis</i> pv. <i>citri</i>	Primary								0
<i>Xylella fastidiosa</i>	Primary								0

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 8.5 Distribution of bacteria on Grapefruit (*Citrus paradisi*)

Bacteria species	Nature of association	Lebanon Districts							Total
		AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed		0	0	0	0	1	0	1	2
<i>Agrobacterium tumefaciens</i>	Primary								0
<i>Pseudomonas syringae</i> pv. <i>syringae</i>	Primary					1			1
<i>Xanthomonas axonopodis</i> pv. <i>citri</i>	Primary								0
<i>Xylella fastidiosa</i>	Primary								0

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

9. Results and Discussion: Viruses and Viroids

Based on all previous surveys conducted on Citrus crops in Lebanon, Citrus Tristeza virus (CTV) is considered a new host record for Mandarin. Hop stunt is also a new host record for Mandarin.

Citrus bent leaf viroid (CBLVd) is new to Lebanon on Lemon, on Mandarin and on orange.

Citrus viroid-III (CVd-III) is new to Lebanon on Mandarin and on orange.

A total of 1660 samples were tested. There were 850 samples from 85 orange sites, 550 samples from 55 Lemon sites, 210 samples from 21 mandarin sites, 30 samples from 3 sour orange sites and 20 samples from 2 grapefruit sites.

However, 123 sites (10 samples / site) were tested by RT-PCR. The sites were distributed as follows: (66 orange sites, 43 lemon sites, 12 mandarin sites and 2 sites of grapefruit).

Antisera Used for ELISA

Antisera specific to the following viruses were used in this survey:

CTV, *Citrus Tristeza Closterovirus*¹

CPsV, *Citrus Psorosis Ophiovirus*¹

¹Agritest, Italy

Primers used for PCR

CEVd, Citrus exocortis *Pospiviroid*, Amplified fragment (371) (Gross et al. 1982)

Hop stunt *Hostuviroid*, Amplified fragment (298-307 bp) (Sano et al. 2001)

CBLVd, Citrus bent leaf *Apscaviroid*, Amplified fragment (234bp) (Ashulin et al. 1991)

CVd-III, Citrus viroid-III *Apscaviroid*, Amplified fragment (269bp) (Sieburth et al. 2002)

CVd-IV, Citrus viroid-IV *Cocaviroid*, Amplified fragment (138bp) (Puchta et al. 1991)

9.1. Lemon (*Citrus limon*)

CTV was detected in lemon at 25.4% (14) of sites and CPsV at 47% (26) of sites (Table 9.1). Almost all viruses detected on lemon trees have been found in South Lebanon and Nabatiyeh (Tables 9.1 and 9.2).

The level of infection by CTV was higher than that reported by Saade et al. (2000) and D'Onghia et al. (1998) as well as for the rate of infection by CPsV cited by Saade et al. (2000).

Of the 55 sites tested by ELISA, 35 (63.6%) were infected by at least one virus. Of the ELISA-positive sites, 30 (85.7%) were infected by at least one virus. However, 5 sites (14.3%) have (CTV+CPsV) as mixed infection.

7 sites (16.2%) were infected by Citrus exocortis viroid (CEVd), 2 sites (4.6%) were infected by Citrus bent leaf viroid (CBLVd) and 1 site (2.3%) by Hop stunt viroid (HSVd). The level of infection of CEVd was less than that found by Saade et al. (2000) being 37.5%.

One site belonging to South Lebanon has a mix infection (CEVd+CBLVd).

The other viroids Citrus viroid-III (CVd-III) and Citrus viroid-IV (CVd-IV) were not encountered on lemon in Lebanon.

9.2. Mandarin (*Citrus reticulata*)

Out of 21 sites tested by ELISA, 7 sites (33%) were infected by at least one virus. CPsV and CTV were detected in 28.5% (6) and 9.5% (2) of the tested sites respectively on Mandarin (Table 9.2). High levels of virus infection were detected in mandarin trees from South Lebanon, while Akkar was the most district infected by viroids.

The level of infection CPsV was more to that reported by Saade et al. (2000) being 11%, however CTV was considered as new host record for mandarin in Lebanon.

One site in South Lebanon had mixed infection CTV+CPsV (Table 9.3).

Among the viroids tested by RT-PCR, 2 sites (16.6%) were infected by CEVd, 1 site by CBLVd (8.3%) and 1 site by CVd-III (8.3%) simultaneously. CBLVd and CVd-III are new for Lebanon on mandarin (Table 9.4).

One site in Akkar had mixed infection CEVd+CVd-III.

None of the following viroids was detected: HSVd and CVd-IV.

9.3. Orange (*Citrus sinensis*)

85 orange sites were tested by ELISA during this study. South Lebanon and Akkar showed the highest mean infection rate (Tables 9.5 and 9.6).

CPsV and CTV were detected in 21.1% (18) and 9.4% (8) respectively of the orange sites (Table 9.5). CPsV was the most widespread virus on orange trees confirming the previous study of Saade et al. (2000).

Of the 85 sites tested by ELISA, 21 (24.7%) were infected by at least one virus. Of the ELISA-positive sites, 16 (76.2%) were infected by only one virus; whereas the remaining sites 5 (23.8%) were infected by two viruses especially in South of Lebanon. North of Lebanon and Nabatiyeh were infected each one by a mix infection (Table 9.5).

Of the 66 sites tested by PCR, CEVd was detected in 11 sites (16.6%) followed by CBLVd and CVd-III detected in 3 sites (4.5%) and HSVd detected in 2 sites (3%).

2 sites belonging to Akkar were infected by CEVd+HSVd+CVd-III and 1 site was infected by CEVd+CBLVd in North Lebanon in the current survey (Table 9.6).

9.4. Sour orange (*Citrus aurantium*)

The sampling of Sour orange was done only from 3 sites during the survey. CTV and CPsV were found only in South of Lebanon. Viroids were not detected in this study.

9.5. Grapefruit (*Citrus paradisi*)

Two sites of grapefruit were surveyed and no samples contained CTV, CPsV, CEVd, HSVd, CBLVd, CVd-III or CVd-IV.

9.6. General Results and Discussion

The studies carried out in Lebanon on virus and viroids of citrus crops provide a comprehensive picture of their sanitary status. Laboratory testing of randomly collected citrus samples showed that most of the major viruses and viroids of citrus spp. (CTV, CPsPV, HSVd, CBLVd and CVd-III) occur in the Lebanese citrus groves.

Out of 166 sites tested by ELISA, 64 (38.5%) were infected by at least one virus, with overall rates ranging from 24.7% in orange to 63.6% in lemon. Intermediate infection levels were found in mandarin and sour orange (33.3%) each one.

From the above data, it can be inferred that Citrus Psorosis virus (CPsV) is by far the most widespread disease of citrus in Lebanon which is found in 51 sites (30.7% average infection). The disease is spread primarily by human via propagation of infected budwood and no vector is currently known. It has been observed that 50 year old sweet orange tree showing no bark lesions in the field produced trees with over 60% psorosis bark lesions (Roistacher and Calvin, unpublished). Thus, although psorosis may remain symptomless in certain host trees, the virus can be transmitted from a symptomless host and induce symptoms in progeny trees (Roistacher 1991).

Citrus Tristeza (CTV) is also highly widespread in the current survey; in the past, it was reported officially in Lebanon with an overall infection rate of 1.43% (D'Onghia et al. 1998), but its level has increased to 15% (25 infected sites). No apparent signs of tristeza decline were observed in trees in the field, but this does not exclude the possibility of a sudden outbreak, as shown in other countries (Kyriakou et al. 1996). *Aphis gossypii*, *Aphis citricola* and *Toxoptera aurantii* were identified during this survey.

Toxoptera citricida the most efficient CTV vector was not detected in the current survey.

According to our field observations in Lebanon, it seems that the existing strains are relatively mild strains confirming previous reports from other Mediterranean countries (Barbarossa & Savino 2004, Anfoka et al. 2005, Barzegar et al. 2005, Davino et al. 2005). This phenomenon does not prevent us to evaluate continually the sanitary status of citrus trees especially that almost all citrus trees in Lebanon are grafted on sour orange rootstocks.

In addition, citrus trees are natural hosts of at least five viroid species of the family *Pospiviroidae*: *Citrus exocortis viroid* (CEVd), *Citrus bent leaf viroid* (CBLVd), *Hop stunt viroid* (HSVd), *Citrus viroid-III* (CVd-III) and *Citrus viroid-IV* (CVd-IV) (Duran-Vila et al. 1988, 2000).

CEVd and specific variants of HSVd induce exocortis and cachexia diseases, respectively on sensitive citrus hosts (Semancik & Weathers 1972, Semancik et al. 1988). According to the current survey, *Citrus exocortis viroid* (CEVd) was detected in 20 out of 251 sites tested (8%), while *Hop stunt viroid* (HSVd) was detected only in 3 sites (1.2%). These viroids are distributed primarily by the introduction and propagation of infected budwood and subsequently by mechanical transmission.

Citrus bent leaf viroid (CBLVd) was found for the first time on orange, lemon and mandarin in Lebanon. CBLVd does not induce conspicuous specific disease, it can reduce tree size and crop yield (Ashulin et al. 1991, Hulton et al. 2000, Murchia et al. 2009).

Likewise, *Citrus viroid-III* (CVd-III) was present for the first time in orange, lemon and mandarin in Lebanon. Some CVd-III variants can induce dwarfing in citrus cultivars grafted on trifoliate orange (Ashulin et al. 1991, Semancik et al. 1997, Hulton et al. 2000).

Citrus viroid-IV (CVd-IV) was not encountered in Lebanon. According to the literature review, CVd-IV appears to be less widespread than the other viroids, can cause severe bark cracking on susceptible species (Putcha et al. 1991).

The control of viroids is based on prevention measures, using viroid-free bud wood as propagation material, appropriate sanitation, treatment of cutting tools and adequate indexing procedures (Duran-Vila & Semancik, 2003; Eiras et al. 2009).

The overall phytosanitary condition of citrus industry is still satisfactory. Despite the presence of several citrus diseases, CTV is one of the most dangerous threats for Lebanese citrus industry even though the trees were not apparently affected by the virus. In view of the danger of an epidemic spread of CTV, CPsV, CEVd and other viroids, a full certification program was initiated and a multiplication center for the international certified plant propagation material was established in Lebanon. Continuous surveys should be done in the citrus growing areas to control the symptoms, the potential vectors and the relative incidence of citrus graft transmissible diseases.

Table 9.1 Distribution of viruses on Lemon (*Citrus limon*)

Viruses	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	4	0	0	3	8	2	38	55
Citrus Psorosis virus (CPsV); <i>Ophiovirus</i>	1			1	6		18	26
Citrus Tristeza virus (CTV); <i>Closterovirus</i>	1			1	2	1	9	14

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: **SL:** CTV+CPsV: 3 samples; **NA:** CTV+CPsV: 2 samples

Table 9.2 Distribution of viroids on Lemon (*Citrus limon*)

Viroids	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	4	0	0	2	6	2	29	43
Citrus bent leaf viroid (CBLVd); <i>Apscaviroid</i>							2	2
Citrus exocortis viroid (CEVd); <i>Pospiviroid</i>					1	1	5	7
Citrus viroid-III (CVd-III); <i>Apscaviroid</i>								0
Citrus viroid-IV (CVd-IV); <i>Cocaviroid</i>								0
Hop stunt viroid (HSVd) <i>Hostuviroid</i> ;							1	1

●	Previously recorded on this host	n	New to Lebanon	n: No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon	

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: **SL:** CEVd+CBLVd

Table 9.3 Distribution of viruses on Mandarin (*Citrus reticulata*)

Viruses	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	3	0	0	3	1	2	12	21
Citrus Psorosis virus (CPsV); <i>Ophiovirus</i>				1		1	4	6
Citrus Tristeza virus (CTV); <i>Closterovirus</i>	1						1	2

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: **SL:** CTV+CPsV: 1 sample

Table 9.4 Distribution of viroids on Mandarin (*Citrus reticulata*)

Viroids	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	3	0	0	1	0	0	8	12
Citrus bent leaf viroid (CBLVd); <i>Apscaviroid</i>							1	1
Citrus exocortis viroid (CEVd); <i>Pospiviroid</i>	2							2
Citrus viroid-III (CVd-III); <i>Apscaviroid</i>	1							1
Citrus viroid-IV (CVd-IV); <i>Cocaviroid</i>								0
Hop stunt viroid (HSVd) <i>Hostuviroid</i> ;								0

●	Previously recorded on this host	n	New to Lebanon	n: No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon	

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: AK: CEVd+CVd-III: 1 sample

Table 9.5 Distribution of viruses on Orange (*Citrus sinensis*)

Viruses	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	16	0	0	3	4	11	51	85
Citrus Psorosis virus (CPsV); <i>Ophiovirus</i>	3				2	2	11	18
Citrus Tristeza virus (CTV); <i>Closterovirus</i>	1				1	1	5	8

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: **NL:** CTV+CPsV: 1 sample; **SL:** CTV+CPsV: 3 samples; **NA:** CTV+CPsV: 1 sample

Table 9.6 Distribution of viroids on Orange (*Citrus sinensis*)

Viroids	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	16	0	0	2	3	8	37	66
Citrus bent leaf viroid (CBLVd); <i>Apscaviroid</i>	1			1		1		3
Citrus exocortis viroid (CEVd); <i>Pospiviroid</i>	3				1	3	4	11
Citrus viroid-III (CVd-III); <i>Apscaviroid</i>	2				1			3
Citrus viroid-IV (CVd-IV); <i>Cocaviroid</i>								0
Hop stunt viroid (HSVd) <i>Hostuviroid</i> ;	2							2

●	Previously recorded on this host	n	New to Lebanon	n: No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon	

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: **NL:** CEVd+CBLVd: 1 sample;

AK: CEVd+Cachexia+CVd-III: 2 samples

Table 9.7 Distribution of viruses on Sour orange (*Citrus aurantium*)

Viruses	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	0	0	0	0	0	2	1	3
Citrus Psorosis virus (CPsV); <i>Ophiovirus</i>							1	1
Citrus Tristeza virus (CTV); <i>Closterovirus</i>							1	1

●	Previously recorded on this host	n	New to Lebanon	n: No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon	

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Mixed infection: **SL:** CTV+CPsV: 1 sample

Table 9.8 Distribution of viroids on Sour orange (*Citrus aurantium*)

Viroids	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	0	0	0	0	0	2	1	3
Citrus bent leaf viroid (CBLVd); <i>Apscaviroid</i>								0
Citrus exocortis viroid (CEVd); <i>Pospiviroid</i>								0
Citrus viroid-III (CVd-III); <i>Apscaviroid</i>								0
Citrus viroid-IV (CVd-IV); <i>Cocaviroid</i>								0
Hop stunt viroid (HSVd) <i>Hostuviroid</i> ;								0

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 9.9 Distribution of viruses on Grapefruit (*Citrus paradisi*)

Viruses	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	0	0	0	0	1	0	1	2
Citrus Psorosis virus (CPsV); <i>Ophiovirus</i>								0
Citrus Tristeza virus (CTV); <i>Closterovirus</i>								0

●	Previously recorded on this host	n	New to Lebanon	n: No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon	

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

Table 9.10 Distribution of viroids on Grapefruit (*Citrus paradisi*)

Viroids	Lebanon Districts							Total
	AK	BH	BE	ML	NA	NL	SL	
Total sites surveyed	0	0	0	0	1	0	1	2
Citrus bent leaf viroid (CBLVd); <i>Apscaviroid</i>								0
Citrus exocortis viroid (CEVd); <i>Pospiviroid</i>								0
Citrus viroid-III (CVd-III); <i>Apscaviroid</i>								0
Citrus viroid-IV (CVd-IV); <i>Cocaviroid</i>								0
Hop stunt viroid (HSVd) <i>Hostuviroid</i> ;								0

●	Previously recorded on this host	n	New to Lebanon	n:	No. of sites at which organism recorded
n	Previously recorded on this host and in this survey	n	New host in Lebanon		

Lebanon districts: **AK:** Akkar, **BH:** Baalbeck – Hermel, **BE:** Bekaa, **ML:** Mount Lebanon, **NA:** Nabatiyeh, **NL:** North Lebanon, **SL:** South Lebanon

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