Viruses, Fungi and Insect Pests Affecting Caper

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ABSTRACT

Capparis spinosa L. is a perennial shrub growing in the semi-arid areas of the Mediterranean basin and eastward into Iran. Caper use traces back to around ancient Egypt and Greece, used mainly for medicine and cosmetics, whereas the current major utilization is the unopened flower buds, named capers, for human consumption as a flavouring. Even though native caper shrubs grow on rocky cliffs and stone walls, in the last decades, commercial caper plantings have been developed in several Mediterranean countries for export of the pickled product, mostly to the USA and the UK. The move from a semi-wild to specialized cultivations has resulted in increasing pest problems in this crop. Since the 1970s, several pests, fungi, and viruses have been described that cause severe damage to caper leaves, flower buds and roots. In this paper, the major pathogens and insect pests of caper cultivation are reviewed.

Keywords: Capparis spinosa, control, damages, diseases, symptoms

INTRODUCTION

Capparis spinosa (L.) is a perennial shrub of the family Capparaceae that includes about 40 genera distributed principally in tropical and warm temperate regions (Porter 1967). The taxonomy of the largest genus, Capparis L., is controversial depending on the criteria adopted from diverse authors for the species delimitation. The occurrence of hybrids among plants of different varieties and species further complicates the classification. According to recent work, C. spinosa is considered the most common species in the Mediterranean region and it is further subdivided in subsp. spinosa and subsp. rupestris on the basis of morphological features of the leaves and the stipules (Fici 2001). Floral characters and molecular tools have been proposed to distinguish C. spinosa from other species (Innocenzo et al. 2002). Information from archeobotanical sources and ancient literary sources traced the use of caper seeds, leaves and roots for medicinal purposes and cosmetics back to ancient Greece. The use of capers as food is reported from Pliny (1st century A.D.), although the start of cultivation is more difficult to ascertain (Sozzi 2001; Megaloudi 2005). Caper is known mainly as a flavouring ingredient, particularly with the unopened buds pickled in salt brine or in vinegar to remove unpleasant bitter flavour and to favour long preservation. Also the fruits (caperberries) are used for culinary
purpose. Specialized cultivation of caper started around 1970 in Spain and Italy, with a maximum of about 4000 and 1000 ha in cultivation, respectively, in the 1990s. Actually, Morocco and Turkey are the leading world caper producers and exporters, mostly towards Central Europe, UK and USA. Currently Spain has moved most of its productions to Morocco, due to the high labour costs. In Italy, caper cultivation has been reduced, although the interest for caper cultivation is high for several important areas out of which are the possible use of marginal lands, low initial costs, higher profit margins as compared to other local crops, synergisms of the crop with tourism activities, and alternative use of capers in cosmetics and pharmacology. The designation of “protected geographical indication” (PGI) for the capron grown on the island of Pantelleria in 1996 (Commission Regulation No. 1107/96 of 12 June, 1996), increased the interest in regional varieties of Italian caper. In addition to the development of specialized cultivations techniques, useful information on propagation, cultural practices and postharvest technology of caper became available (Barbera 1993; Alkire 2000; Sozzi 2001). However, no systematic review of insect pests and diseases of caper have been published. In this paper, the current phytosanitary status of C. spinosa in the major production areas is reviewed with special emphasis to pests, viruses, and fungi. For each agent, a brief description of biological and epidemiological aspects, symptoms and damages on different plant parts, and control measures are given.

**VIRUSES**

The first assumption of a virus infection in caper was reported in 1938 in Italy by Ciferri who described leaf mosaic and reduction in size of wild plants grown on stone walls in Tuscany (Ciferri 1949). Later, a leaf yellow vein banding symptomatology was described on caper plants in Apulia (Italy) and was ascribed to a virus erroneously assigned to the genus *Carlavirus* (Majorana 1970). Subsequent studies ascertained the presence of two viruses: *Caper vein yellowing virus* (CVYV), associated with the vein yellowing symptoms and *Caper latent virus* (CapLV), often isolated from symptomless plants (Di Franco and Gallitelli 1985; Gallitelli and Di Franco 1987).

Recent surveys on caper diseases carried out in an important Italian production area (Sicily) and viral identification by molecular techniques established the presence of three viruses: *Caper latent virus* (CapLV), *Eggplant mottled dwarf virus* (EMDV), and *Cucumber mosaic virus* (CMV) (Tomassoli et al. 2006).

### Caper latent virus (CapLV)

CapLV is a member of *Carlavirus* (Brunt et al. 2000), a genus belonging to the family of *Flexiviridae* (Adams et al. 2004). The virus particles are slightly flexed, rod-shaped, and 662 nm long and 12 nm in diameter. They consist of a single-stranded circular RNA genome which encodes a single open reading frame encoding a protein of 35.7 kDa. The virus envelope that enclose the genome (about 11 Kb): the outer envelope is composed of glycoproteins, which are the major structural protein (CP) of 2004). The virus particles are slightly flexed, rod-shaped, and 662 nm long and 12 nm in diameter. They consist of a single-stranded circular RNA genome which encodes a single open reading frame encoding a protein of 35.7 kDa. The virus envelope that enclose the genome (about 11 Kb): the outer envelope is composed of glycoproteins, which are the major structural protein (CP) of 1970 in Spain and Italy, with a maximum of about 4000 and 1000 ha in cultivation, respectively, in the 1990s. Actually, Morocco and Turkey are the leading world caper producers and exporters, mostly towards Central Europe, UK and USA. Currently Spain has moved most of its productions to Morocco, due to the high labour costs. In Italy, caper cultivation has been reduced, although the interest for caper cultivation is high for several important areas out of which are the possible use of marginal lands, low initial costs, higher profit margins as compared to other local crops, synergisms of the crop with tourism activities, and alternative use of capers in cosmetics and pharmacology. The designation of “protected geographical indication” (PGI) for the capron grown on the island of Pantelleria in 1996 (Commission Regulation No. 1107/96 of 12 June, 1996), increased the interest in regional varieties of Italian caper. In addition to the development of specialized cultivations techniques, useful information on propagation, cultural practices and postharvest technology of caper became available (Barbera 1993; Alkire 2000; Sozzi 2001). However, no systematic review of insect pests and diseases of caper have been published. In this paper, the current phytosanitary status of *C. spinosa* in the major production areas is reviewed with special emphasis to pests, viruses, and fungi. For each agent, a brief description of biological and epidemiological aspects, symptoms and damages on different plant parts, and control measures are given.

### Eggplant mottled dwarf virus (EMDV)

The first evidence of a rhabdovirus, formerly named *Capsicum vein yellowing virus* (CVYV), was obtained by electron microscope observations of characteristic baccilliform or bullet-shaped particles (Di Franco and Gallitelli 1985). On the basis of serological relationship, the virus was later considered to be an isolate of *Pittosporum vein yellowing virus* (PVYY) (Nuzzaci et al. 1993), a plant rhabdovirus reported in *Pittosporum tohora* in Italy since 1957 (Corte 1957). More recently, a taxonomic scrutiny of the International Committee on Taxonomy of Viruses (ICTV) approved EMDV as a unique species within the *Rhabdoviridae* family (Tordo et al. 2004), and considered PVYY as a synonym. In absence of nucleotide characterization of caper rhabdovirus isolates, in the present review we will refer to EMDV (Brunt et al. 1996) as responsible for disease in caper. The *Rhabdoviridae* family comprises of over 150 viruses of vertebrates, invertebrates and plants. Plant rhabdoviruses are separated into two genera, *Cytorhabdovirus* and *Nucleorhabdovirus*, depending on the cellular site of virus replication; EMDV is classified as a nucleorhabdovirus because virus particles and viral inclusions were observed in the perinuclear spaces in large accumulations and in the nucleus, respectively. EMDV is a negative, ssRNA(-) virus and virions have a bacilliform morphology with particles of about 90 nm wide and 180-200 nm long. The distinctive feature of plant rhabdoviruses is the three layered envelope that enclose the genome (about 11 Kb): the outer layer is composed of glycoproteins, the middle layer of lipid membrane, and the inner core consists of nucleocapsid. First reported in Italy on eggplant (Martelli 1969), EMDV is widely distributed in the Mediterranean region and Middle East and causes disease in several crops of Solanaceae and Cucurbitaceae (Babaie and Izadpanah 2003; Aarambura et al. 2006; Mavric et al. 2006), other than in *P. tobara*, *C. spinosa* and *Pelargonium peltatum* (Russo et al. 1979).

EMDV caper strain also has been identified in Greece. On caper, EMDV causes vein clearing of young leaves that evolve into vein yellowing or necrosis in fully developed leaves (Fig. 1A). Plants with aged systemic infection show curling of leaves, short internodes, and severe dwarving and buds and fruits yields are much decreased. A recent survey in Italy revealed that EMDV incidence varies from island to island (0%-50%) and from place to place within the same island (Tomassoli et al. 2006). Although the spread of the virus is evident and new infected plants are periodically observed, the ways of virus transmission in the field are still unknown. EMDV is easily mechanically transmissible to experimental plants (*Nicotiana spp.*, *C. amaranticolor*, *Datura stramonium*, *Gomphrena globosa*) but is unlikely that virus transmission by contact could play an important role in the epidemiology of the virus. EMDV, and rhabdoviruses in general, are not transmitted by seeds or pollen whereas aphids (*Aphisidae*), leafhoppers (*Cicadellidae*), or plant hopper (*Delphacidae*) are reported as vectors in persistent and propagative manner (Tordo et al. 2004). The leafhopper *Agallia vorobjevi* DI. was recently reported to be a natural vector of EMDV in Iran (Babaie and Izadpanah 2003). Species of *Aglainae* are also reported to transmit *Potato yellow dwarf virus* (PYDV), the type member of the genus nucleorhabdovirus, and several *Aglainae* species are commonly present in Europe. Therefore, even if leafhoppers have never been described as pests of caper, species of *Cicadellidae* visiting caper plants could represent a...
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**Cucumber mosaic virus** (CMV)

CMV is the type member of *Cucumovirus* genus, family *Bromoviridae* (Roossinck et al. 1999). It is responsible for disease in more than 1000 species of plants worldwide and causes economic losses in vegetables, ornamentals, and fruit crops (Palukaitis et al. 1992). In 2004, *C. spinosa* was identified as a new host for CMV (Tomassoli et al. 2005). CMV is a ssRNA (+) tripartite genome virus (8621 nt) that is enclosed in small icosahedral virions (about 29 nm in diameter). Some strains of CMV contain a RNA satellite that can modulate disease symptoms in infected plants (Kaper and Waterworth 1977). CMV isolates have been divided into two major groups (group I and II), on the basis of serological and molecular techniques. Group I has been further divided in two subgroups, IA and IB by RFLP and phylogenetic analysis (Moury 2004). In caper, CMV has been exclusively detect in the Aeolian Archipelago (Tomassoli et al. 2006), and in some wild plants in Greece (Katis N., pers. comm.). All three subgroups were identified in caper and subgroup IB was predominant. CMV infected caper plants show chlorotic tips and mottling of young leaves (Fig. 1B), mosaic, vein banding and yellow rings or spots on fully expanded leaves that occasionally are malformed and reduced in size. CMV has sometimes been detected in asymptomatic plants, and molecular assays revealed the presence of subgroup II isolates, that are known to be less aggressive. Chronic infections produce shortening of internodes and zig-zag growth on the shoots. Co-infection of CMV and EMDV or CapLV is frequent and causes severe stunting of plant, thickening and malformation of leaves (Fig. 1C), and bud and flower distortion. In the Aeolian Islands CMV was present in all commercial fields visited with higher incidence (2-54%) than EMDV. In nature, CMV is transmitted by more than 80 aphid species in a non-persistent manner. This aspect, in addition to ubiquity and the large number of natural hosts among crops and wild species, guarantee a rapid and easy spread of the virus in fields (Palukaitis et al. 1992).

**Fig. 1 Viruses and fungi affecting caper plants.** (A) Vein yellowing caused by EMDV. (B) Chlorosis and mosaic of caper tips infected by CMV. (C) Leaf malformation in chronic infection with both EMDV and CapLV. (D) Basal rot of caper transplanting caused by *Fusarium solani*. (E) Wilting of caper branches caused by *Sclerotium rolfsii*. (F) Mycelium of *S. rolfsii* girdling basal caper branch.
Leveillula taurica
Leveillula taurica (Lév.) G. Arnaud, (Fam. Erysiphaceae,ord. Erysiphales; anamorph: Oidopsis taurica (Lév.) E.S. Salmon) is the causal agent of powdery mildew. The disease was observed on wild caper in the south-eastern Anatolia district of Turkey in 2002 and 2003, with incidence ranging from 35 to 93% (Kavak 2004). The fungus grows epiphytically on caper leaves, mostly on the lower surfaces but frequently expanding to the upper, until reaching petioles and branches. Haustoria extend into epidermal cells to obtain nutrition, causing chlorosis and necrosis of tissues and premature defoliation in case of severe attack. Specific diagnosis of L. taurica (Lev.) was based on the morphology of asexual and sexual structures. The fungus produced straight and generally unbranched conidiophores bearing lanceolate (primary conidia) or ellipsoidal (12-18 x 39-81 μm) conidia. Cleistothecia were yellow to dark brown or black in color, mostly round to broadly ovate (176-192 μm diam). They contained 3-27 broadly oval to ellipsoidal asci (25-45 x 53-98 μm), each containing two ascospores (15-23 x 25-44 μm). Appendages of cleistothecia were colorless and mycelial, irregularly branching, 35-80μm in length. The disease appeared in early summer and spread rapidly in summer and autumn, remaining visible throughout late season. The same species was observed on Capparis spinosa in 1990-91 in India during routine surveys of the Spiti Valley, Himachal Pradesh (Gupta and Bhardwaj 1998). L. taurica is a pathogen of such important solanaceous crops as tomato (Solanum lycopersicon) and eggplant (S. melongena), mainly in the dry areas of the Mediterranean basin, central Europe and the Near East (Dixon 1981). Infection is favoured by high temperatures (optimum 26°C) associated with high relative humidity. Control of powdery mildew is easily achieved by means of sulphur-based fungicides. In absence of registered chemicals for this crop, preventive measures that aim to reduce excessive humidity (weed removal, furrow irrigation, low nitrogen dosage) are the most effective cultural practices to control the disease.

Albugo capparidis

Albugo capparidis (de Bary) Kuntze (Fam. Albuginaceae, ord. Peronosporales) is the causal agent of white rust of caper. It has been commonly observed in Italy on wild caper plants along the Italian peninsula for some time (Ciferri 1949). On infected plants it causes hypertrophy of leaves and flower, peduncles, sometimes causing floral abortion. On the flowers the fungus causes distortions of floral organs (stamen, style, ovary) and lowering the buds’ commercial value. Overwintering structures of the fungus (oo- spores) were often localized at the base of flower. Albugo candida (Pers. ex Hook.), the most important species of the genus, commonly occurs worldwide on many cruciferous plants, especially on cabbages (Mukerji 1975). Infections are favoured by the presence of free water and cool temperature (optimum 15-20°C). Destroying infected plants is the best control practice of white rust on caper.

Other species

Several fungal species present on wild caper were listed by Ciferri in Italy in 1949, but this reference lacks detailed information on distribution, symptomatology and morphological description. These species include Ascochyta capparidis (Cast.) Sacc., Camarosporium susapanense Sacc. et Spec., Cercospora capparidis Sacc., Gloeosporium hians Pech., Hendersonia rupestris Sacc. et Spec., Leptosphaeria capparidis Pass., Phoma capparidina Pass., Phoma capparidis Pass., and Septoria capparidis Pass. Neoramarilalia capparidis, a new fungal species causing leaf spots on Capparis spinosa has been described in Hyderabad, Andhra Pradesh, India (Bagyanarayana et al. 1994).
INSECT PESTS

Caper plants are widely distributed in semiarid climates where they can represent the main food source and/or the recovery sites for a large cohort of phytophagous insects. The literature of entomocenosis of caper is quite limited, and most publications have referred to caper pests in specific regions. In total, 23 insect species have been reported as major and minor pests (Table 1). These insects have been categorized into four broad groups according to the plant part primarily attacked, i.e. root, foliage, bud, or fruit, although some insect pests are able to attack different parts of caper plants during all stages of growth. The insects reported are mainly poliphagous and/or oligophagous, with only two species that can be considered monophagous. Thus, only a few species can be classified as key pests, whereas the others occur on caper sporadically (Fernandez et al. 1986; Peri et al. 2004). Although the economic importance of an insect pest can vary greatly from one environment to another, as a general rule, heteropterans, lepidopterans, and dipterans comprise the key pests on caper.

Table 1 List of insect pests recorded on caper categorized according to the plant part primarily attacked.

<table>
<thead>
<tr>
<th>Attacked plant part</th>
<th>Phytophagous pest</th>
<th>Recorded area</th>
<th>Feeding habits, occurrence and economic importance*</th>
<th>Nature of damages</th>
<th>Ref**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>Coleoptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Foliage</td>
<td>Heteroptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homoptera</td>
<td>Acalles barbarus</td>
<td>Lucas</td>
<td>Italy</td>
<td>Oligophagous, occasional, minor pest</td>
<td>Mines into the wood</td>
</tr>
<tr>
<td></td>
<td>Bagrada hilaris</td>
<td>(Burmeister)</td>
<td>Italy, Malta, South Africa</td>
<td>Oligophagous, regular, key pest</td>
<td>Hollows, yellowing feeding punctures, and deformations</td>
</tr>
<tr>
<td></td>
<td>Nacara viridula</td>
<td>(L.)</td>
<td>Italy, Spain, Argentina</td>
<td>Poliphagous, occasional, minor pest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eurydema ventrale</td>
<td>Kol</td>
<td>Italy</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Eurydema ornata</td>
<td>L.</td>
<td>Spain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Holocotetes punctatus</td>
<td>L.</td>
<td>Carpocoris lunula F.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Bemisia tabaci</td>
<td>(Gennadius)</td>
<td>Turkey</td>
<td>Poliphagous, occasional, minor pest</td>
<td>Yellowish spots and deformation</td>
</tr>
<tr>
<td></td>
<td>Alata longitennis</td>
<td>(Gennadius)</td>
<td>Italy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Colotis suayi</td>
<td>(L.)</td>
<td>Italy</td>
<td>Poliphagous, occasional, minor pest</td>
<td>Yellowish spots, deformation, and development of sooty moulds on honeydew produced</td>
</tr>
<tr>
<td></td>
<td>Capparimyia savastani</td>
<td>(Martelli)</td>
<td>Italy, Malta, Algeria, Libya, Egypt, Israel, Oman, France, Pakistan, Tunisia, Jordan</td>
<td>Monophagous, regular, key pest</td>
<td>Deformation, drying up, and abortion</td>
</tr>
<tr>
<td></td>
<td>Asphondylia gennadii</td>
<td>(Marchal)</td>
<td>Italy, Cyprus, Malta, India, Indonesia</td>
<td>Oligophagous, occasional, key pest</td>
<td>Deformation, irregular development, and swelling</td>
</tr>
<tr>
<td></td>
<td>Syrphus decoratus</td>
<td>(Zel.)</td>
<td>Spain</td>
<td>Poliphagous, occasional, minor pest</td>
<td>Deformation, drying up, and abortion</td>
</tr>
<tr>
<td></td>
<td>Lampides boeticus</td>
<td>L.</td>
<td>Spain</td>
<td>Mines and deformation</td>
<td>4-7-14-15</td>
</tr>
</tbody>
</table>

*Feeding habits: Monophagous; Oligophagous; Poliphagous. Occurrence: occasional, regular. Economic importance: minor pest, key pest.

Root

Coleoptera

The only pest recorded on caper root is Acalles barbarus Lucas (Coleoptera: Curculionidae) (Liotta 1977) (Table 1). This little weevil was recovered from caper on the island of Pantelleria. Weevil larvae can occasionally cause damage to the root system, penetrating into the roots and excavating slender mines into the wood. Generally, A. barbarus attacks weak adult plants or plants previously damaged by other insects.

Foliage

Caper foliage can be attacked by a large phytophagous entomocenosis which includes both sap sucking (heteroptera and homoptera) and defoliator (lepidoptera and coleoptera) pests (Table 1). Most of these are considered minor pests (e.g. homoptera and coleoptera), whereas heteropteran and lepidopteran species can occur in large outbreaks that cause considerable damages to the plants.
Heteroptera

A few heteropterans in the family Pentatomidae have been recorded on caper (Table 1). All these insects, commonly named “stink bugs”, are polyphagous, feeding on different species of cultivated and native plants. The stink bugs recorded on caper plants include *Nezara viridula* (L.) on the islands of Salina and Ustica (Italy), in the Iberian Peninsula, and in Yemen (Peri et al. 1986; Priesner & Hosny, 2004). *Planococcus citri*, generally called citrus mealybug, is a polyphagous insect with a worldwide distribution. It is particularly dangerous on citrus. Citrus mealybug is a soft bodied insect with a small, 1-2 mm long, oval, segmented body covered with white fluffy wax. Citrus mealybug females pass through 3 nymphal stages, on the contrary, males have 4 nymphal stages. Females lay from 200 to 400 eggs, averaging 300 eggs in a lifetime. Eggs are laid in groups covered by ovisac wax threads, and hatch in 2-10 days. *P. citri* has 4-6 generations per year. On caper, *A. nerii* and *P. citri* colonize leaves and stems, preferring the internal part of the plant. The sucking of plant juices causes yellowish spots on leaves, deformation of infested plant parts, loss of vigour, in some cases loss of leaves, and death of young plants (Fig. 2F). Moreover the attack of *P. citri* can result in a major decline in vigour due to the growth of black sooty mold fungi on the honeydew produced by the pest. In case of severe infestations, homopteran pests can be controlled by spraying mineral oils.

Lepidoptera

Lepidopteran species which attack caper are generally polyphagous; they occur on caper in the dry season, when other potential host plants are not available (Fernandez et al. 1986).

Only pierid species are reported on caper, i.e. *Colotis evagore* Lucas in Spain, *Anaphaes aurora* F., *Colotis fausta fausta* Olivier, and *Colotis liagore* Klug. in Saudi Arabia (Pittaway 1979). The most severe attack can be caused by *Pieris brassicae* L., commonly called large white butterfly, and *P. rapae* L., the small white butterfly. *P. brassicae* is a cosmopolitan and highly polyphagous scale insect present in the Mediterranean basin, where it is particularly dangerous on olive, citrus, and other trees such as acacia, carob, mulberry, ivy, oleander, and palm. The female, firmly attached to substrate, has a hazel circular cover, 1.8 to 2.2 mm in diameter; the male has an elongated white cover and, the adult form is winged and is able to fly. Crawlers hatch and emerge from under the female cover and move around to find a suitable place to settle. Soon after, they start feeding, and a circular, waxy cover forms over their bodies. The female lays about 150 yellow eggs in about 5 to 12 days. The oleander scale usually has three generations per year. Individuals of all ages coexist on the same plant (Fig. 2E). Oleander scale usually overwinters as young females or older nymphs, but younger nymphs may also overwinter, becoming active again later in the spring. About 40 to 50 days are required to complete the life cycle.

Homoptera

Five species of homoptera recovered from caper have been reported: *Bemisia tabaci* (Gennadius) in Turkey, *Aecurolibus miloticus* Priesner & Hosny, *Brevicoryne brassicae* (L.), *Aspidiotus nerii* Bouché, and *Planococcus citri* Risso in Italy (Rapisarda 1985; Longo 1996; Peri et al. 2004; Bayhan et al. 2006). All these pests are polyphagous and feed on the sap of plants with their elongated rostrum. Usually they are considered minor pests, because the damage is not severe. However, heavy infestations of *A. nerii* and *P. citri* has been observed in the north-east zone and in the south-west zone of Pantelleria island, respectively (Peri et al. 2004).

*Aspidiotus nerii*, commonly known as oleander scale, is a cosmopolitan and highly polyphagous scale insect present in the Mediterranean basin, where it is particularly dangerous on olive, citrus, and other trees such as acacia, carob, mulberry, ivy, oleander, and palm. The female, firmly attached to substrate, has a hazel circular cover, 1.8 to 2.2 mm in diameter; the male has an elongated white cover and, the adult form is winged and is able to fly. Crawlers hatch and emerge from under the female cover and move around to find a suitable place to settle. Soon after, they start feeding, and a circular, waxy cover forms over their bodies. The female lays about 150 yellow eggs in about 5 to 12 days. The oleander scale usually has three generations per year. Individuals of all ages coexist on the same plant (Fig. 2E). Oleander scale usually overwinters as young females or older nymphs, but younger nymphs may also overwinter, becoming active again later in the spring. About 40 to 50 days are required to complete the life cycle.

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Planocebus citri, generally called citrus mealybug, is a polyphagous insect with a worldwide distribution. It is particularly dangerous on citrus. Citrus mealybug is a soft bodied insect with a small, 1-2 mm long, oval, segmented body covered with white fluffy wax. Citrus mealybug females pass through 3 nymphal stages, on the contrary, males have 4 nymphal stages. Females lay from 200 to 400 eggs, averaging 300 eggs in a lifetime. Eggs are laid in groups covered by ovisac wax threads, and hatch in 2-10 days. *P. citri* has 4-6 generations per year. On caper, *A. nerii* and *P. citri* colonize leaves and stems, preferring the internal part of the plant. The sucking of plant juices causes yellowish spots on leaves, deformation of infested plant parts, loss of vigour, in some cases loss of leaves, and death of young plants (Fig. 2F). Moreover the attack of *P. citri* can result in a major decline in vigour due to the growth of black sooty mould fungi on the honeydew produced by the pest. In case of severe infestations, homopteran pests can be controlled by spraying mineral oils.

Lepidoptera

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Viruses, fungi and insect pests affecting caper. Infantino et al.

Winds of females have two round black spots, whereas wings of males have only a single spot. Attacks of this pest on caper have been observed in Spain, California, and Turkmenistan (Murzin 1986; Fernandez García 1988; Kontaxis 1990). Damage is caused by larvae eating caper leaves. The larvae can be controlled with insecticides based on *Bacillus thuringiensis*, applied in late afternoon or early evening.

**Coleoptera**

The only pest of this order recorded on caper foliage is *Phyllotreta latevittata* Kutsch (Coleoptera: Chrysomelidae) (Longo 1996) (Table 1). This is a polyphagous beetle occasionally recovered from caper on the island of Pantelleria. The feeding adults cause small circular gouges in the surfaces of the leaves resulting in a peppered appearance. Large populations of feeding adults can occasionally devastate plantings, especially if the caper plants are in the seedling stage.

**Bud**

Caper bud can be attacked by several phytophagous insects (Table 1). Some of them can live on different caper parts, as in the case of the pentatomid bugs which can severely damage foliage and caper buds, causing hollows, yellowing chlorotic spots, and deformations (for more details refer to foliage pests). Other insect pests, such as dipteran and lepidopteran insects, attack mainly the buds, feeding on the internal tissues.

**Diptera**

Two dipteran species have been reported to feed on caper buds: the caper fly, *Capparimyia savastani* (Martelli) (Tephritidae), and the carob midge, *Asphondylia gennadii* (Marchal) (Cecidomyiidae). *C. savastani* (Fig. 2B) is a specific pest of this crop, present in Italy, France, Malta, Tunisia, Algeria, Libya, Egypt, Israel, Jordan, Oman, and Pakistan (Freidberg and Kugler 1989; Donati and Belcari 2003). The adult is very similar to the well known fruit flies *Ceratitis* spp. (e.g., **Mediterranean fruit fly**) from which it can be differentiated by several morphological characters such as: thorax yellowish with black spots and the anterior apical band of the wings with shallow hyaline areas (de Meyer and Freidberg 2005). The female lays its eggs in clusters of 3-5 inside buds and fruits. A number of females may lay in the

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**Fig. 2 Phytophagous pests of caper plants.** (A) Adult of *Bagrada hilaris* in feeding activity. (B) Adults of *Capparimyia savastani* in mating behaviour. (C) Caper buds deformed by larvae of *Asphondylia gennadii* (pointed out by black arrows). (D) Larva of *A. gennadii* recovered inside a caper bud (pointed out by a white circle). (E) Plants with heavy infestation of *Aspidiotus nerii* and (F) *Planococcus citri*. 

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same bud, where up to 7 eggs may be found (Longo 1996). Eggs hatch in 2-10 days. The larva is white with a typical fruit fly larval shape, e.g. cylindrical maggot-shape, elongate, anterior end narrowed, with anterior mouth hooks, and flattened caudal end. The last instar larva is usually 7 to 9 mm in length. Larvae complete their development inside buds in 10-18 days. Once developed, mature larvae emerge from the flower bud and pupate in the soil (Longo 1996). The larvae usually overwinters in cultural environments, burrowing a few centimetres deep in the soil. In laboratory conditions, caper fruit fly has 6 generations per year (Longo 1996). Damage is caused by the larvae which devour the buds from the inside; the attacked flower buds remain small and can dry up and drop off the plant. Yellow sticky traps or traps baited with attractive food have been employed to determine the flight periods of this pest and thus rationalize the application of insecticides or to apply a "lure and kill" strategy.

The carob midge, A. gennadii, is a polyphagous species that is widespread in the Mediterranean basin and in Asia; it has been reported from Italy (Peri et al. 2006), Cyprus (Orphanides 1975), Malta (Skuhra et al. 2002), India (Rangarajan and Mahadewan 1975), and Indonesia (Maryana et al. 2006). The adult has a thin body, about 4 mm long. The female lays its eggs inside caper buds. Embryonic development lasts about 3 days. Larvae complete their development inside buds feeding on the flower tissues; up to 15 individuals have been found in the same bud (Peri et al. 2006). Mature larvae pupate inside the buds. In Cyprus, using other host plants, 7 generations per year have been observed (Orphanides 1975). In the Mediterranean area it has been found in pods of Ceratonia siliqua L. and Calicotome villosa (L.) (Harris 1975; Orphanides 1975; Peri et al. 2006). The larvae devour the buds from the inside, causing deformations of the buds which develop irregularly (Fig. 2C, 2D). Even if the mode of feeding of the two species is similar, the symptoms of damage are easily distinguished: the buds attacked by the caper fly remain small, or are empty and can dry up and drop to the soil, whereas those attacked by the caper midge are swollen, deformed, and develop irregularly. For both species, the heaviest infestations are observed during the summer, when high temperatures and humidity cause an increase in population levels. In this case, the harvest of capers could be halted between the end of July and the middle of August. The control strategies adopted include the use of yellow sticky traps for mass trapping and monitoring the presence of the adults to determine their flight periods and rationalize the application of insecticides. For caper fly, some farmers adopt "lure and kill" strategy using ammonium-based-bottle-traps treated with synthetic pyrethroids. This strategy is mainly borrowed from that regularly. For both species, the heaviest infestations are observed during the summer, when high temperatures and humidity cause an increase in population levels. In this case, the harvest of capers could be halted between the end of July and the middle of August. The control strategies adopted include the use of yellow sticky traps for mass trapping and monitoring the presence of the adults to determine their flight periods and rationalize the application of insecticides. For caper fly, some farmers adopt "lure and kill" strategy using ammonium-based-bottle-traps treated with synthetic pyrethroids. This strategy is mainly borrowed from that strategy. Lepidoptera

The lepidopteran species feeding inside the buds include Cydia capparidana (Zel.) (Tortricidae) in Italy and Lampides boeticus L. (Lycaenidae) in Spain (Jordano Barbudo et al. 1988; Longo 1996; Peri et al. 2004). Larvae of both species bore into the inside of the buds and destroy the organs of the flower.

Fruit

Although there are no insect pests that feed exclusively on caper fruits, the fruits can be attacked by insects such as the pentatomid bugs previously described, that feed on many parts of the plant. Damage is the same as that caused to caper buds. Moreover, C. savastani females lay eggs in fruits and the larvae devour the internal tissues. The resulting fruits appear hollow and deformed.

CONCLUDING REMARKS

Caper diseases and insect pests have never been considered as limiting production factors for this crop. In fact in many production areas, caper is still harvested from wild species, and cultural environments not favourable for the majority of pathogens of cultivated crops. However, the move towards specialized cultivation systems and the consequent change of cultural practices could negatively affect the phytosanitary scenario of caper. In cactus pear (Opuntia ficus-indica), a crop grown in environments similar to those of caper, the change from informal to semi-formal to proper cultivation for the production of cladodes and fruits resulted in the outbreak of several diseases, mostly of fungal origin (Granata and Sidoti 2002). This increase in pest problems also is suggested to have occurred in the major Italian caper production areas where monoculture commercial crops started to show a progressive increase in pest and disease problems that raised local awareness of insect pests and pathogens. Consequently, surveys to monitoring the most important caper infectious agents have been recently done in Italy within the framework of a research project financially supported by Regional Agricultural Bureau of Sicilian Region to improve quality of caper plantations and management of insect pests and diseases. From the literature and from the experiences of the authors of this review it is suggested that at least five insects could be considered as “key pests” for caper. Three viruses have been identified in caper cultivations that resulted of economic importance because, being systematically distributed within the plant; they caused growth reductions and, as in the case of multiple infections, also reduction in quality and market value of the product. In addition, the presence of the virus render the plant more susceptible to both biotic and abiotic stresses. As an example, asymptomatic infection of CapLV hamper the establishment of the new root system in vegetatively propagated caper seedlings. Outbreaks of fungal diseases were observed less frequently, often associated with unusual weather conditions or improper cultivation practices. Knowledge of the most important insect pests and pathogens affecting any crop of agricultural interest is critical for the development of sustainable control strategies. This is particularly true for a “minor” specialty crop such as caper, for which the agricultural chemical industry is not interested in conducting the necessary research for registra- tion of chemicals specifically for that crop. Recent research has offered various alternative for development of more sustainable caper-pest management (Guarino 2007). To this end, organic farming shows promise for the protection of the environment and of the consumer’s health. Detecting a disease in the early stages of its development is critical to disease management, helping us in making management decisions to minimize disease risk or to prevent disease problems before they occur. In caper, scouting is favoured by the continuous bud maturation during summer period, so that caper fruits are harvested repeatedly at short time intervals. Knowledge of insect pests and disease affecting caper in the typical cultivation areas will also be important as caper cultivation is attempted in new environments, such as Australia (Trewanta and Trewanta 2005). Finally, global climate changes could also interfere directly or indirectly with agricultural environment, in the near future, particularly with plant diseases (Chrabakborty et al. 2000). If the trend towards global warming continues, there will be the opportunity for some pathogenic species considered of minor importance to become predominant in the changed environment.

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