The European Journal of Plant Science and Biotechnology ©2007 Global Science Books

Viruses, Fungi and Insect Pests Affecting Caper

Alessandro Infantino[1*] • Laura Tomassoli[1] • Ezio Peri[2] • Stefano Colazza[2]

[1] C.R.A.- Centro di Ricerca per la Patologia Vegetale -Via C. G. Bertero, 22 -00156 Rome, Italy
[2] S.En.Fi.Mi.Zo. Department - Section of Entomology, Acarology and Zoology, Università di Palermo, Viale delle Scienze, 13 90128 Palermo, Italy
Corresponding author: * **alessandro.infantino@entecra.it**

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

CONTENTS

INTRODUCTION 170
VIRUSES 171
Caper latent virus (CapLV) 171
Eggplant mottled dwarf virus (EMDV) 171
Cucumber mosaic virus (CMV) 172
FUNGI 173
Fusarium spp. 173
Sclerotium rolfsii 173
Leveillula taurica 173
Albugo capparidis 173
Other species 173
INSECT PESTS 174
Root 174
Coleoptera 174
Foliage 174
Heteroptera 175
Homoptera 175
Lepidoptera 175
Coleoptera 176
Bud 176
Diptera 176
Lepidoptera 177
Fruit 177
CONCLUDING REMARKS 177
ACKNOWLEDGEMENTS 177
REFERENCES 178

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 (Innocencio *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

Received: 30 July, 2007. Accepted: 11 December, 2007.

Invited Review

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 producions to Morocco, due to the high labour costs. In Italy, caper cultivation has been reduced, although the interest for caper cultivation remains high for several important reasons, among 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 caper 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 structural protein (CP) of 35.7 kDa encapsidating a single stranded monopartite RNA(+) (ssRNA) genome with an estimated size of 9.100 nucleotides. CapLV occurs endemically in commercial caper production areas in Italy (Tomassoli *et al*. 2006) and in wild plants growing in some Greek islands. No other information is available from the major producer countries (Turkey, Morocco and Spain). CapLV infected plants are symptomless and, until now, no disorders in growth, buds and fruits production or vegetative propagation have been observed when compared with healthy plants. In areas where caper propagation is done as cuttings, farmers rapidly spread CapLV from infected mother plants. Where seeds are traditionally used to establish new plantations (i.e. Pantelleria), the manner of dissemination still remains to be determined. A preliminary study, using caper plants grown from seeds of infected fruits, failed to prove seed transmission (Tomassoli, pers. obs). CapLV is mechanically transmissible to herbaceous indicator plants (*Nicotiana megalosiphon*, *N. benthamiana*, *Chenopodium amaranticolor*) but natural transmission during harvesting or pruning is doubtful. In nature, carlaviruses transmission from plant to plant is primarily caused by aphids in a non-persistent manner, and by white-fly for few viral species (Jones 2003). CapLV vectors have not been established yet; nevertheless, caper is reported to be visited by the aphid *Brevycoryne brassicae* (Longo 1996) and the whitefly *Aleurolobus niloticus* (Rapisarda 1985) that might serve as vectors.

Eggplant mottled dwarf virus (EMDV)

The first evidence of a rhabdovirus, formerly named *Capparis vein yellowing virus* (CVYV), was obtained by electron microscope observations of characteristic bacilliform 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* (PVYV) (Nuzzaci *et al*. 1993), a plant rhabdovirus reported in *Pittosporum tobira* 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 PVYV as synonym. In absence of full molecular 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; Aramburu *et al*. 2006; Mavric *et al*. 2006), other than in *P. tobira*, *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 evolves into vein yellowing or necrosis in fully developed leaves (**Fig. 1A**). Plants with aged systemic infection show curling of leaves, shorted internodes, and severe dwarfing 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*, *Gomprhena 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 (*Aphidae*), leafhoppers (*Cicadellidae*) or planthoppers (*Delphacidae*) are reported as vectors in persistent and propagative manner (Tordo *et al*. 2004). The leafhopper *Agallia vorobjevi* Dl. was recently reported to be a natural vector of EMDV in Iran (Babaie and Izadpanah 2003). Species of *Agallinae* are also reported to transmit *Potato yellow dwarf virus* (PYDV), the type member of the genus nucleorhabdovirus, and several *Agallinae* 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

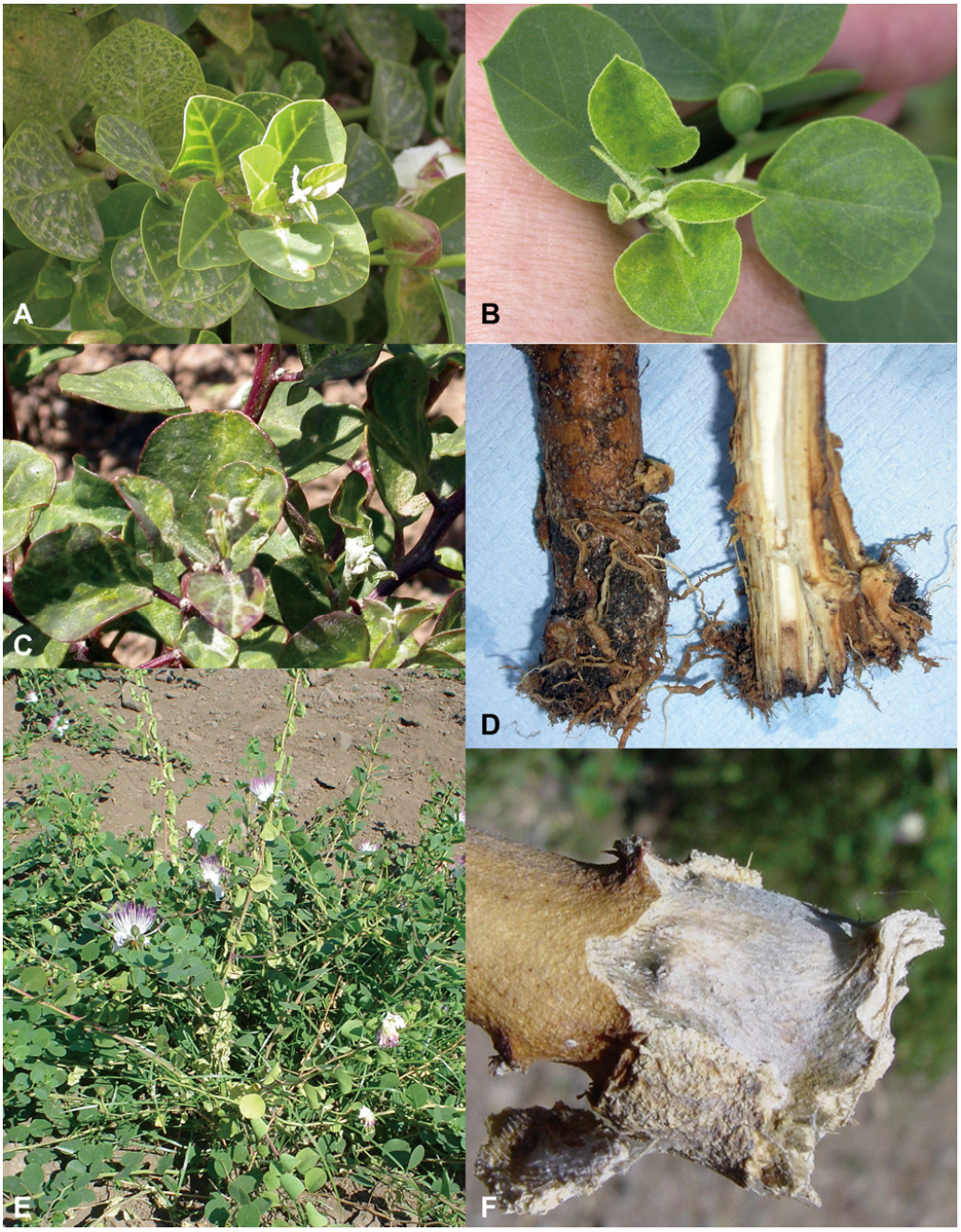

Fig. 1 Viruses and fungi affecting caper plants. (**A**) Vein yellowing caused by EMDV. (**B**) Chlorosis and mosaic of caper tips infected by CMV. (**C**) Leaf malformation in chronic infection with both EMDV and CapLV. (**D**) Basal rot of caper transplanting caused by *Fusarium solani*. (**E**) Wilting of caper branches caused by *Sclerotium rolfsii*. (**F**) Mycelium of *S. rolfsii* girdling basal caper branch.

potential vector of EMDV in caper.

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). According to our experience, although aphid colonization on caper shoot-tips is quite difficult to observe, aphid visiting and probing on caper plants could transmit the virus. CMV seed transmission is known in a few crops (squash, bean, lentil, lupin, and spinach) and several weeds. As with CapLV, preliminary studies have not identified seed-borne infection of CMV in caper seedlings.

Virus control is hampered by the inefficacy of traditional insecticides in reducing CapLV and CMV transmission by aphids and by the difficulty of producing adequate stocks of virus-free planting materials for new plantations. A better understanding of the epidemiology of each caper viruses is required, and more effort has to be devoted to developing an effective virus-testing and certification protocol to obtain an efficient small-scale production system for virus-free caper seedlings.

FUNGI

Diseases caused by fungi are less important than those due to insect pests and viruses. Several fungal species have been identified on cultivated caper affecting the roots and the foliar system, on adult plants or in propagation materials in nurseries. The most important are described below.

Fusarium spp.

Vegetative propagation is the most widely used technique for propagating caper, particularly when genetic identity with the source has to be maintained. Rooting of caper cuttings is difficult and is influenced by several factors, such as the age of the plant, the rooting media, and water stress. During the establishment of the new root system, caper cuttings are very susceptible to several fungi. Rotting of caper cuttings caused by *Fusarium solani* was frequently observed on Linosa Island of the Pelagian Archipelago (**Fig. 1D**). Damping-off of caper seedlings in seedbed or after transplanting caused by *Phytium* sp., *Verticillium* sp. and *Fusarium* sp. was observed in Spain (Luna Lorente and Vicente Pérez 1985). Use of sterilized soil and the avoidance of excessive watering are the most efficient methods to control these fungal diseases.

Sclerotium rolfsii

Sclerotium rolfsii Sacc. (telomorph: *Athelia rolfsii* (Curzi) C.C. Tu & Kimbr.), Fam. *Atheliaceae*, Ord. *Polyporales*) is the causal agent of Southern blight of caper. It was isolated for the first time in Italy in June 2005 on several caper plantations on the Aeolian Islands (Infantino *et al*. 2006). As many as 30% of plants were infected. On diseased plants, initial symptoms were yellowing and wilting on 1-5 branches from the ground up (**Fig. 1E**). With the progression of the disease, a whitish mycelium of the fungus was often observed at the base of affected shoots, that progressively died and were easily removed (**Fig. 1F**). The production of typical mustard-like microsclerotia in artificial media after isolation allowed the diagnosis of the fungus as *S. rolfsii*. Artificial inoculations of young caper plants with an isolate of the fungus in the laboratory reproduced typical symptoms of the disease in all plants and *S. rolfsii* was always reisolated from infected tissues, satisfying Koch's postulates. *S. rolfsii* has a broad host range and it is distributed worldwide. The fungus can persist in the soil as microsclerotia or on crop residues and weed hosts. *S. rolfsii* is favoured by wet soil followed by very hot temperatures, conditions that were met during the 2005 summer in the Aeolian Islands. Removal of crop debris, weed control, and reduction of any stress factor during cultivation are the only preventive measure that can be adopted for the disease. Other control measures (solarization, crop rotation) are not efficient.

Leveillula taurica

Leveillula taurica (Lév.) G. Arnaud, (Fam. *Erysiphaceae*, Ord. *Erysiphales*; anamorph: *Oidiopsis 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 structure. 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 sterility) lowering the buds' commercial value. Overwintering structures of the fungus (oospores) 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 suseganense* Sacc. et Speg., *Cercospora capparidis* Sacc., *Gloeosporium hians* Peck., *Hendersonia rupestris* Sacc. et Speg., *Leptosphaeria capparidis* Pass., *Phoma capparidina* Pass., *Phoma capparidis* Pass., and *Septoria capparidis* Pass. *Neoramularia capparidis*, a new fungal species causing leaf spots on *Capparis spinosa* has been described in Hyderabad, Andhra Pradesh, India (Bagyanarayana *et al*. 1994).

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

Attacked plant part	Phytophagous pest		Recorded area	Feeding habits, occurrence and economic importance*	Nature of damages	Ref**
Root	Coleoptera	*Acalles barbarus* Lucas	Italy	Oligophagous, occasional, minor pest	Mines into the wood	1
Foliage	Heteroptera	*Bagrada hilaris* (Burmeister)	Italy, Malta, South Africa	Oligophagous, regular, key pest	Hollows, yellowing feeding punctures, and deformations	2-3-4-5-6
		Nezara viridula (L.)	Italy, Spain, Argentina	Poliphagous, occasional, minor pest		
		Eurydema ventrale Kol	Italy			
		Eurydema ornata L.	Spain			
		Holcostetus punctatus L.				
		Carpocoris lunula F.				
	Homoptera	*Bemisia tabaci* (Gennadius)	Turkey	Poliphagous, occasional, minor pest	Yellowish spots and deformation	4-6-7-8
		Aleurolobus niloticus Priesner & Hosny	Italy	Oligophagous, occasional, minor pest		
		Brevicoryne brassicae (L.)				
		Aspidiotus nerii Bouchè		Poliphagous, occasional, minor pest	Yellowish spots, deformation, and development of sooty moulds on honeydew produced	
		Planococcus citri Risso				
	Lepidoptera	*Pieris brassicae* L.	Italy, Spain	Poliphagous, occasional, key pest	Large and irregular sized holes	4-6-9-10-11-12
		Pieris rapae (L.)	Spain, USA, Turkmenistan			
		Colotis evagore Lucas	Spain	Poliphagous, occasional, minor pest		
		Anaphaeis aurota F.	Saudi Arabia			
		Colotis fausta fausta Olivier				
		Colotis liagore Klug.				
	Coleoptera	*Phyllotreta latevittata* Kutsch	Italy	Poliphagous, occasional, minor pest	Small holes (shot holing)	4
Bud	Heteroptera	(See Foliage Heteroptera)				
	Diptera	*Capparimyia savastani* (Martelli)	Italy, Malta, Algeria, Libya,Egypt, Israel, Oman, France, Pakistan, Tunisia, Jordan	Monophagous, regular, key pest	Deformation, drying up, and abortion	4-6-13-14-15-16-17-18-19-20
		Asphondylia gennadii (Marchal)	Italy, Cyprus, Malta, India, Indonesia	Oligophagous, occasional, key pest	Deformation, irregular development, and swelling	
	Lepidoptera	*Cydia capparidana* (Zel.)	Italy	Monophagous, regular, key pest	Deformation, drying up, and abortion	4-7-21
		Lampides boeticus L.	Spain	Poliphagous, occasional, minor pest		
Fruit	Heteroptera	(See Foliage Heteroptera)				
	Diptera	*Capparimyia savastani* (Martelli)	(See Bud Diptera)		Mines and deformation	4-7-14-15

***Feeding habits:** Monophagous; Oligophagous; Poliphagous. **Occurrence**: occasional, regular. **Economic Importance**: minor pest, key pest.
** **References**: **1**: Liotta 1977; **2**: Carapezza 1981; **3**: Colazza *et al*. 2004; **4**: Longo 1996; **5**: Fernández *et al*. 1986; **6**: Peri *et al*. 2007; **7**: Bayhan *et al*. 2006; **8**:Rapisarda 1985; **9**: Fernández García 1988; **10**: Murzin 1986; **11**: Kontaxis 1990; **12**: Pittaway 1979; **13**: Freidberg and Kugler 1989; **14**: Donati and Belcari 2003; **15**: Peri *et al*. 2006; **16**: Harris 1975; **17**: Orphanides 1975; **18**: Skuhrava *et al.* 2002; **19**: Rangarajan and Mahadewan 1975; **20**: Maryana *et al*. 2006; **21**: Jordano Barbudo *et al*. 1987

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.

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 coleopteran) 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 Argentina (Fernandez *et al*. 1986; Peri *et al*. 2004); *Eurydema ventrale* Kol. on the island of Ustica (Peri *et al*. 2004); *Eurydema ornata* L., *Holcostethus punctatus* L., and *Carpocoris lunula* F. in Spain (Fernandez *et al*. 1986) (**Table 1**). *Bagrada hilaris* (Burmeister), the painted bug (**Fig. 2A**) (**Table 1**), is an oligophagous stink bug recorded on caper in some countries (Carapezza 1981; Colazza *et al*. 2004). Stink bug damage is caused by the feeding activity of both nymphs and adults. Damage is characterized by hollowed out plant parts, yellowing chlorotic spots, and deformations. Polyphagous stink bugs rarely represent a serious problem for caper, but the painted bug is one of the key pests of this crop. *Bagrada hilaris* is widespread in Southeast Asia and Africa, where it occurs in many countries including South Africa, Namibia, Senegal, and Angola (CAB l98l). In many parts of Asia and Africa, the painted bug is a major pest of caper crops, although it also has been recorded from beetroot, groundnut, potato, and papaya (Daiber 1991). In Europe it has been observed on the islands of Malta and Pantelleria (Carapezza 1981). On the island of Pantelleria, the bug was found about 25 years ago, and since then, it has established mainly on caper, becoming one of the main pests of this crop (Colazza *et al*. 2004). *B. hilaris* is a multivoltine species with several generations per year, according to climatic conditions (Singh and Malik 1993). In Italy, painted bug adults overwinter in protected areas, such as in the stone walls used to partition fields. Around May-June, the overwintering adults start to colonize the crop. Adult females can lay between 50 and 80 pale yellowish-white eggs individually or in small clusters of 2-4 on the leaves or underneath the soil. Eggs turn orange as they develop and, in laboratory conditions, larvae emerge after 5-8 days. Painted bugs complete their development in 5 stages (Colazza *et al*. 2004). Both adults and nymphs feed by sucking fluids from the foliage, the bud, and the fruit of the caper, causing chlorotic spots and deformations. The damage thresholds adopted for mustard crops of approximately 1 bug/m² in the early growing stage of the plant and 3 bugs/m² in the successive stages, have been suggested for caper (Daiber 1991). The control of painted bug populations is generally achieved by conventional chemical insecticides (e.g. pyrethroids, organophosphates, and carbamates). However, increasing crop damage caused by the painted bug is probably due to the appearance of pesticide resistance (Swaran Dhingra and Seema 1998; Guarino *et al*. 2007). Botanical insecticides, such as azadirachtin, rotenone, and natural pyrethrins, are under evaluation (Guarino 2007). Cultural practices, e.g. plough and break up the ground, destruction of residues of alternative host plants, can adversely affect painted bug population and increase the efficacy of chemical control.

Homoptera

Five species of homoptera recovered from caper have been reported: *Bemisia tabaci* (Gennadius) in Turkey, *Aleurolobus niloticus* Priesner & Hosny, *Brevicoryne brassicae* (L.), *Aspidiotus nerii* Bouchè, 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.

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 mould 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, *Anaphaeis aurota* 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 polyphagous insect with a worldwide distribution. *P. brassicae* attacks several plant species belonging to *Brassicacae*. On caper, this pest has been found in Southern Spain (Fernandez *et al*. 1986) and in Italy, on the islands of Pantelleria and Salina (Longo 1996; Peri *et al*. 2004). The adult has a 40-60 mm wingspan, the fore wings are white with a smoky apex, and the hind wings are white with a small black spot on the anterior border. The female also has 2 black rounded spots on the fore wings. Females lay eggs in clusters of 20-50 on the underside of the leaves of host plants. The egg is elongated, about 1.5 mm high and 0.6 mm at the base, ribbed and yellow. The mature larva is about 45-50 mm long, has a greyish green body with 3 longitudinal yellow lines, numerous bristles, and small black spots over all the body. The head is black in front, grey at the back, and with a black thoracic plate. The adult is diurnal and is active when the sun shines and the temperature is sufficiently high; otherwise, it remains under leaves or in other sheltered spots. At times, the butterflies can make mass migrations. The larvae first live in colonies, and cause superficial damage to the leaf epidermis. After the second moult, the larvae scatter into groups of 4-5 individuals. They are extremely voracious and perforate the foliage. Pupation lasts 10 to 15 days. *P. brassicae* has 2 generations per year, sometimes 3 in southern regions. Adults of *P. rapae* range from 40-45 mm wingspan; the wings are white with small dark spots on

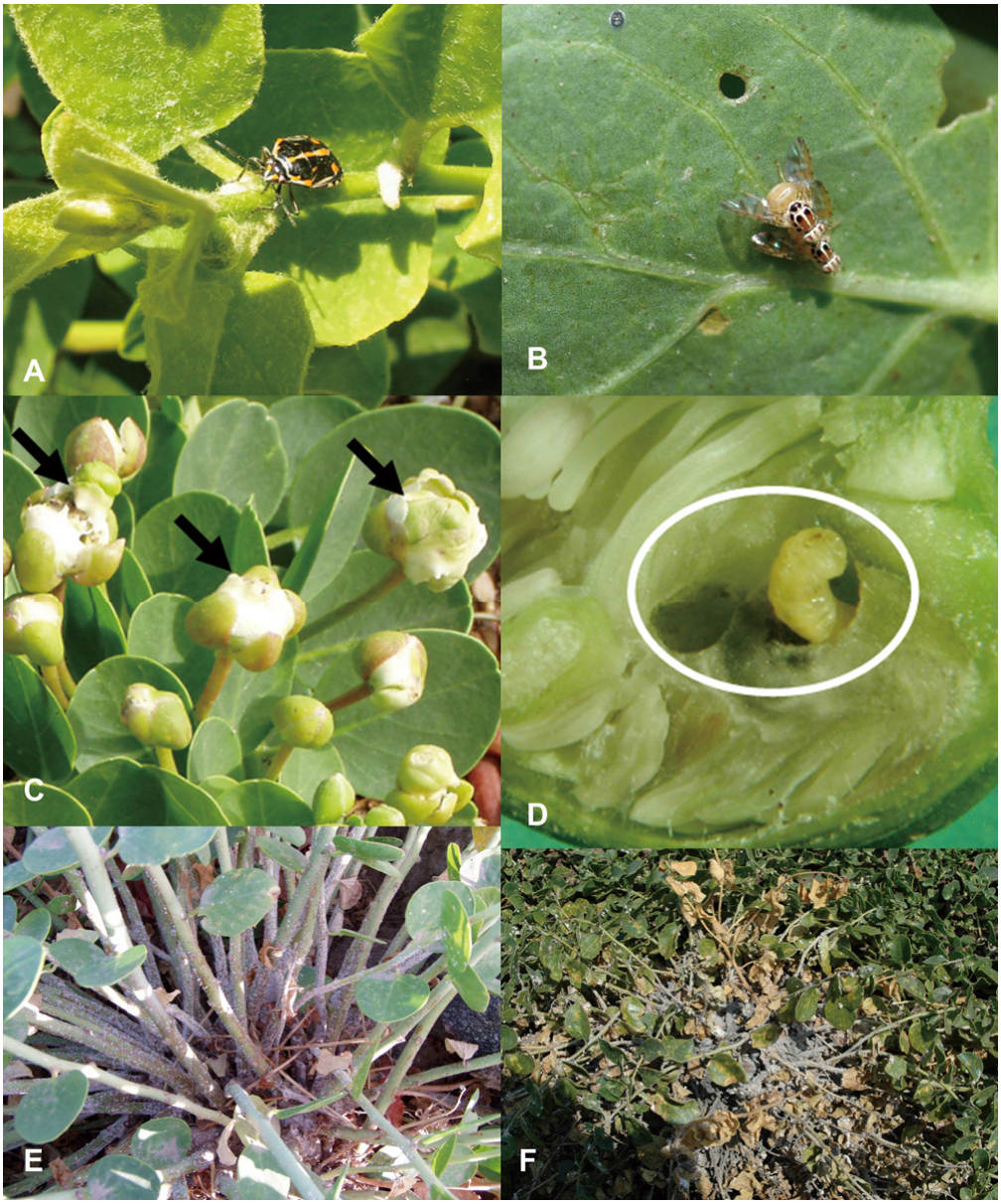

Fig. 2 Phytophagous pests of caper plants. (**A**) adult of *Bagrada hilaris* in feeding activity. (**B**) Adults of *Capparimyia savastani* in mating behaviour. (**C**) Caper buds deformed by larvae of *Asphondylia gennadii* (pointed out by black arrows). (**D**) Larva of *A. gennadii* recovered inside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

the apex of the anterior pair wings. 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 Garcia 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

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). This species usually overwinters as a pupa, buried 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 (Skuhrava *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 commonly used to control the Mediterranean fruit fly and olive fly, but its efficacy to control also caper fly is under evaluation. Moreover, the use of cultural practices such as ploughing and destruction of the attacked bud and fruits, can eradicate reservoirs of infestation of these insects after the end of the harvest and thus reduce the spread and increase of populations of these two pests for the remainder of the year.

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 attached 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, grown in cultural conditions and 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 registration 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 (Chrakaborty *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.

ACKNOWLEDGEMENTS

This work was financially supported by the project "Caratterizzazione, Miglioramento genetico-sanitario e Difesa del cappero

(*Capparis spinosa* L.) delle isole minori della Sicilia" funded by Regional Agricultural Bureau of Sicilian Region – IX Servizio allo Sviluppo, Unità Operativa 45 - Sperimentazione e Ricerca Applicata (L. 499/99).

REFERENCES

Adams MJ, Antoniw JF, Bar-Joseph M, Brunt AA, Candresse T, Foster GD, Martelli GP, Milne RG, Fauquet CM (2004) The new plant virus family *Flexiviridae* and assessment of molecular criteria for species demarcation. *Archives of Virology* **149**, 1045-1060

Alkire B (2000) Caper. New Factsheet. Available online: http://www.hort.purdue.edu/newcrop/cropfactsheets/caper.html

Aramburu J, Galipienso L, Tornos T, Matas M (2006) First report of *Eggplant mottled dwarf virus* in mainland Spain. *Plant Pathology* **55**, 565-565

Babaie Gh, Izadpanah K (2003) Vector transmission of *Eggplant Mottled Dwarf Virus* in Iran. *Journal of Phytopathology* **151**, 679-682

Bagyanarayana G, Braun U, Sutton BC (1994) *Neoramularia capparidis spec. nov*. *Mycotaxon* **51**, 35-36

Barbera G (1993) *Il Cappero*, Edagricole, Bologna, 101 pp

Bayhan E, Ulusoy MR, Brown JK (2006) Host range, distribution, and natural enemies of *Bemisia tabaci* 'B biotype' (Hemiptera: Aleyrodidae) in Turkey. *Journal of Pest Science* **79**, 233-240

Brunt AA, Crabtree K, Dallwitz MJ, Watson L, Zurcher EJ (1996) Eggplant mottled dwarf *nucleorhabdovirus*. *Plant Viruses Online: Descriptions and Lists from VIDE Database*. Available online: http://image.fs.uidaho.edu/vide/descr320.htm

Brunt AA, Foster GD, Morozov SY, Zavriev SK (2000) *Carlavirus*. In: Van Regenmortel MHV, Fauquet CM, Bishop DHL, Carstens EB, Estes MK, Lemon SM, Maniloff J, Mayo MA, McGeock DJ, Pringle CR, Wickner RB (Eds) *Virus Taxonomy, 7th Report of the International Committee on Taxonomy of Viruses*, Academic Press, San Diego, USA, pp 969-975

CAB-International (1981) *Bagrada hilaris*. Distribution map 417, Distribution Maps of Plant Pests, Commonwealth Agricultural Bureau International, Nosworthy Way, Wallingford, Oxfordshire, OX10 8DE, UK

Carapezza A (1981) Gli Eterotteri dell'Isola di Pantelleria (Insecta, Heteroptera). *Il Naturalista siciliano* S. IV, **V** (3-4), 73-91

Chrakaborty S, Tiedemann AV, Teng PS (2000) Climate change: potential impact on plant diseases. *Environmental Pollution* **108**, 317-326

Ciferri R (1949) Rassegna di parassiti e malattie del cappero (*Capperis spinosa* L.) in Italia. *Notiziario sulle malattie delle piante* **3**, 33-35

Colazza S, Guarino S, Peri E (2004) *Bagrada hilaris* (Burmeister) (Heteroptera: Pentatomidae) fitofago dannoso al cappero nell'isola di Pantelleria. *Informatore Fitopatologico* **53 (12)**, 30-34

Corte A (1957) Una nuova virosi del *Pittosporum*. *Rivista della Ortofloricoltura Italiana* **52**, 197-202

Daiber KC (1991) Insects and nematodes that attack cole crops in Southern Africa – a research review. *Journal of Plant Diseases and Protection* **99**, 430-440

de **Meyer M, Freidberg A** (2005) Revision of the fruit fly genus *Capparimyia* (Diptera, Tephritidae). *Zoologica Scripta* **34 (3)**, 279-303

Di Franco A, Gallitelli D (1985) Rhabdovirus-like particles in caper leaves with vein yellowing. *Phytopathologia Mediterranea* **24**, 234-236

Dixon GR (1981) *Vegetable Crop Diseases*, McMillan Publishers Ltd., London and Basingstoke, 404 pp

Donati M, Belcari A (2003) A note on insect pests of the caper plant in Jordan, with special reference to *Capparimyia savastani* (Martelli) (Diptera, Tephritidae). *Studia dipterologica* **10 (2)**, 395-400

Fernandez Garcìa E (1988) Spring and summer hosts for *Pieris rapae* in Southern Spain with special attention to *Capparis spinosa*. *Entomologia Experimentalis et Applicata* **48**, 173-178

Fernandez J, Jordano D, Rodriguez J (1986) *Capparis spinosa*: a resource for insects during summer food shortage in Southern Spain. In: Velthuis HHW (Ed) *Proc. 3rd European Congress of Entomology*, Nederlandse Entomologische Vereniging, Amsterdam, pp 259-262

Fici S (2001) Intraspecific variation and evolutionary trends in *Capparis spinosa* L. (*Capparaceae*). *Plant Systematics and Evolution* **128**, 123-141

Freidberg A, Kugler J (1989) Diptera: Tephritidae. *Fauna Palaestina, Insecta* **4**, 1-212

Gallitelli D, Di Franco A (1987) Characterization of Caper Latent Virus. *Journal of Phytopathology* **119**, 97-105

Granata G, Sidoti A (2002) Survey of diseases discovered on *Opuntia ficus-indica* in producer countries. *Acta Horticolturae* **581**, 231-237

Guarino S (2007) IPM of Painted Bug populations affecting caper bush: from laboratory experiments to field applications. PhD Thesis, University of Palermo, 116 pp

Guarino S, Peri E, Lo Bue P, La Pillo A, Colazza S (2007) Impiego di insetticidi di origine vegetale per il contenimento delle popolazioni di *Bagrada hilaris* nei cappereti panteschi. *Informatore Fitopatologico* **57 (7-8)**, 53-58

Gupta AK, Bhardwaj LN (1998) Additional host of *Leveillula taurica* (Lev.) G Arnaud from India. *Indian Phytopathology* **51**, 104-106

Harris KM (1975) The taxonomic status of the carob gall midge, *Asphondilia gennadii* (Marchal), comb. n. (Diptera, Cecidomyiidae), and other *Asphondilia* species recorded from Cyprus. *Bulletin Entomological Research* **65**, 377-380

Infantino A, Pucci N, Di Giambattista G, Tomassoli L (2006) *Capparis spinosa* - a new host for *Sclerotium rolfsii*. *Plant Pathology* **55**, 580

Innocencio C, Alcaraz F, Calderón F, Obón C, Rivera D (2002) The use of floral characters in *Capparis* sect. *Capparis* to determine the botanical and geographic origin of capers. *European Food Research Technology* **214**, 335-339

Jones DR (2003) Plant viruses transmitted by whiteflies. *European Journal of Plant Pathology* **109**, 195-219

Jordano Barbudo D, Rodriguez Gonzalez J, Fernandez Haeger J (1988) *Capparis spinosa* (Capparidaceae): On oviposition substrate for *Lampides boeticus* Linnaeus, in southern Spain (Lepidoptera: Lycaenidae). *Nota Lepidopterologica* **10**, 218-223

Kaper JM, Waterworth HE (1977) *Cucumber mosaic virus* associated RNA 5: causal agent for tomato necrosis. *Science* **196**, 429-431

Kavak H (2004) Epidemic outbreaks of powdery mildew caused by *Leveillula taurica* on *Capparis spinosa* in Turkey. *Plant Pathology* **53**, 809

Kontaxis DG (1990) Pest of caper, *Capparis spinosa*. Some new records for California. *Phytopathology* **80**, 1026

Liotta G (1977) *Acalles barbarus* Lucas su *Capparis spinosa* a Pantelleria. Nota bio-etologica. *Il Naturalista Siciliano* (S. IV) **1**, 39-45

Longo S (1996) La mosca del cappero. *Informatore Agrario* **51 (5)**, 65-69

Luna Lorente F, Vicente Pérez M (1985) La tapenera o alcaparra: cultivo y aprovechamiento. *Publicaciones de Agricultura práctica, Ministerio de Agricultura, Pesca y Alimentación, Madrid (España)*, 127 pp

Majorana G (1970) La reticolatura fogliare del cappero: una malattia associata ad un virus del gruppo S della patata. *Phytopathologia Mediterranea* **9**, 106-110

Martelli GP (1969) Bacilliform particles associated with mottled dwarf of eggplant (*Solanum melongena* L.). *Journal of General Virology* **5**, 319-320

Maryana N, Anastasia D, Prima R (2006) *Asphondylia* sp. (Diptera: Cecidomyiidae) infesting Chili pods in Bogor, West Java, Indonesia. *Proceedings of the 6th International Congress of Dipterology, 23-28 September 2006, Fukuoka, JAPAN*, p 157

Mavric I, Tusek Znidaric M, Virscek Marn M, Dolnicar P, Mehle N, Lesemann DE, Ravnikar M (2006) First report of *Eggplant mottled dwarf virus* in potato and tomato in Slovenia. *Plant Pathology* **55**, 566-566

Megaloudi F (2005) Wild and cultivated vegetables, herbs and spices in Greek antiquity (900 B.C. to 400 B.C.). *Environmental Archaeology* **10.1**, 71-80

Moury B (2004) Differential selection of genes of *Cucumber Mosaic Virus* subgroups. *Molecular Biology and Evolution* **21**, 1602-1611

Mukerji KG (1975) *Albugo candida*. *CMI Descriptions of Pathogenic Fungi and Bacteria* No. **460**

Murzin VS (1986) Diurnal Lepidoptera (Rhopalocera) of the Badkhyzskii Reserve (Turkmen, SSR). *Trudy Vsesoyuznogo Entomologisheskogo Obshchestva, Akademiya Nauk SSSR* **67**, 125-130 (In Russian)

Nuzzaci M, De Stradis A, Rana GL, Camele I (1993) Identità sierologica tra i due virus dell'ingiallimento nervale del cappero e del pittosporo. *Petria* **3**, 99-107

Orphanides GM (1975) Biology of the carob midge complex, *Asphondylia spp*. (Diptera, Cecidomyiidae) in Cyprus. *Bulletin of Entomological Research* **65**, 381-390

Palukaitis P, Roossinck MJ, Dietzgen RG, Francki RIB (1992) *Cucumber mosaic virus*. *Advances in Virus Research* **41**, 281-348

Peri E, Lo Bue P, Federico R, Ammavuta G, Spatafora F, Colazza S (2006) *Asphondylia gennadii* (Marchal) fitofago dannoso al cappero nelle isole minori della Sicilia (Diptera: Cecidomyiidae). *Informatore Fitopatologico* **56 (11)**, 26-30

Peri E, Lo Bue P, Guarino S, Colazza S (2004) Piante aromatiche e medicinali: l'entomocenosi del cappero in Sicilia. *Atti del 2° Convegno Nazionale Piante Mediterranee*, Agrigento, pp 105-110

Pittaway AR (1979) The butterflies and hawk-moths of Eastern Saudi Arabia. *Proceedings of the British Entomological Natural Historical Society* **12**, 90-101

Porter CL (1967) *Capparaceae*. In: *Taxonomy of Flowering Plants* (2nd Edn), W.H. Freeman and Company, S. Francisco and London, p 270

Rangarajan AV, Mahadewan NR (1975) Incidence of gallmidge, *Asphondylia capsici* Barnes on chilli in Tamil. *Indian Journal of Entomology* **36 (1)**, 66-67

Rapisarda C (1985) Presenza in Italia di *Aleurolobus niloticus* Priesner & Hosny, nuovo parassita delle piante di cappero (Homoptera: Aleirodidae). *Bollettino di Zoologia agraria e Bachicoltura* S II, **18**, 75-86

Roossinck MJ, Bujorski J, Ding SW, Hajimorad R, Hanada K, Scott S, Tousignant M (1999) Family *Bromoviridae*. In: van Regenmortel MHH, Fauquet CM, Bishop DHL, Carstens EB, Estes MK, Lemon SM, Maniloff J, Mayo MA, McGeock DJ, Pringle CR, Wickner RB (Eds) *Virus Taxonomy – 7th Report of the Interna-tional Committee on Taxonomy of Viruses*, Academic Press, San Diego, CA, pp 923-935

Russo M, Castellano MA, Martelli GP (1979) Rhabdovirus-like particles in English ivy (*Hedera helix*) and ivy-leafed geranium (*Pelargonium peltatum*). *Phytopathologische Zeitschrift* **96**, 122-131

Singh Harvir, Malik VS (1993) Biology of painted bug (*Bagrada crucifera-*

rum). *Indian Journal of Agricultural Sciences* **63**, 672-674

Skuhrava M, Skuhravy V, Ebejer MJ (2002) Gall midges (Diptera: Cecidomyiidae) of Malta. *Entomologica* **36**, 25-43

Sozzi G (2001) Caper bush: Botany and horticulture. *Horticultural Reviews* **27**, 125-188

Swaran Dhingra, Seema (1998) Relative toxicity of some important insecticides with particular reference to change in susceptibility level of *Bagrada cruciferarum* Kirk. during the last quarter century. *Journal of Entomological Research* **22**, 307-311

Tomassoli L, Zaccaria A, Barba M (2005) *Capparis spinosa*, a new host of *Cucumber mosaic virus* in Italy. *Plant Pathology* **54**, 263

Tomassoli L, Zaccaria A, Barba M (2006) Virus distribution and incidence on *Capparis spinosa* L. in Sicilian Islands. *Proceedings of the 12th Congress of the Mediterranean Phytopathological Union*, 11-15 June Rhodes Island, Greece, pp 125-126

Tordo N, Benmansour A, Calisher C, Diezgen RG, Fang RX, Jackson AO, Kurath G, Nadin-Davies S, Tesh RB, Walker PJ (2004) Rhabdoviridae. In: Fauquet CM, Mayo MA, Maniloff J, Desselberger U, Ball LA (Eds) *Virus Taxonomy, VIIIth Report of the ICTV*, Elsevier/Academic Press, London, pp 623-644

Trewanta J, Trewanta S (2005) Producing capers in Australia. Viability study. Publication No. 05/132, Rural Industries Research and Development Corporation, 17 pp