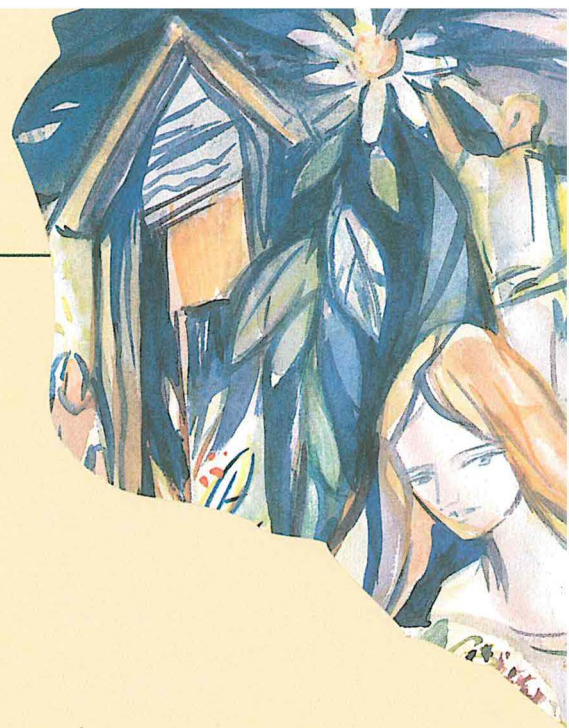


PLANT PROTECTION CENTRE

October 1996



Pest Risk Assessment (PRA) for  
the Vegetable Leaf Miner  
*Liriomyza sativae*

Commissioned by the Norwegian  
Agricultural Inspection Service

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# Pest Risk Assessment (PRA) for the Vegetable Leaf Miner, *Liriomyza sativae*

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## **1. Endangered Area**

The endangered area is Norway.

## **2. Identity and Geographic and Regulatory Criteria**

Name: *Liriomyza sativae* (Blanchard)

Synonyms: *Liriomyza pullata* (Frick)

*Liriomyza canomarginis* (Frick)

*Liriomyza minutiseta* (Frick)

*Liriomyza munda* (Frick)

*Liriomyza guytona* (Freeman)

*Liriomyza propepusilla* (Frost)

Taxonomic position: Insecta: Diptera: Agromyzidae

Common names: Vegetable leaf miner, Serpentine Vegetable leaf miner, Cabbage leaf miner,  
Tomato leaf miner (English)

EPPO A1 list: No. 152

EC Annex designation: I/A1

Norway: A list (Quarantine pests. Limit of tolerance: 0 %)

Significance: Has never been reported in Norway.

## **3. Methods for Detection and Identification**

### **3.1 Methods for Detection**

#### Symptoms

Feeding punctures appear as white speckles between 0,13 and 0,15 mm in diameter (Smith et al., 1992). Oviposition punctures are smaller (0,05 mm) and more uniformly round.

Mines are usually white with dampened black and dried areas. (These are the same symptoms listed by Smith et al. (1992), for three similar quarantine pests: *Amauromyza maculosa*, *Liriomyza huidobrensis* and *L. trifolii*. The symptoms are also the same for *L. bryoniae*).



Mines are typically serpentine, tightly coiled and of irregular shape, increasing in width as larvae mature (Smith et al., 1992).

#### The pest

Eggs in plant tissue or prepupae and pupae either on the foliage or in the soil just beneath the surface, are almost impossible to detect by visual inspection. Mines and larvae can be detected by specifically examining both sides of the lower leaves of the plant. The bigger the mines and larvae are, the easier can they be detected.

### **3.2 Methods for Identification**

An exact characterisation on the basis of morphological characteristics of the pupae, larvae and mines is impossible, and it takes too long to wait for the adults to emerge from the pupae (de Goffau, 1991).

Adult flies may initially be identified by morphological characteristics after a simplified key (Smith et al., 1992). All identifications should be confirmed by a specialist.

Only adult males of *L. sativae* (and also adult males of *L. bryoniae*, *L. huidobrensis*, *L. strigata* and *L. trifolii*) can be identified with certainty on the basis of their genitalia (Oudman, 1992). Female adults, pupae and larvae can only be identified on the level of groups of species (*L. trifolii* and *L. sativae* versus *L. bryoniae*, *L. huidobrensis* and *L. strigata*). All identifications should be confirmed by a specialist.

The identification of the *Liriomyza* species is very important and misidentifications have occurred more or less often. Lindquist & Casey (1983) reported that Fogg (1981) conducted experiments in a greenhouse with a leafminer identified in 1980 as *L. sativae*. However, subsequent identifications from the same insect colony have been as *L. trifolii*. Further, the specimens that Fogg submitted were lost in shipment and are no longer available.

Electrophoretic methods have been developed to distinguish *L. sativae* from *L. bryoniae* and *L. huidobrensis* (Oudman, 1992). The method can be used for each developmental stage of the pest (larvae, pupae and adults). This has to be done in a laboratory by a specialist. An electrophoretic method to distinguish *L. sativae* from *L. trifolii* (they belong to the same group) will probably be developed within a short time (Collins pers. comm.).

#### Sticky traps

Yellow sticky traps can be used to catch adult flies in quarantine rooms and greenhouses.

#### Water traps

Yellow water traps can be used for the same purpose as yellow sticky traps.

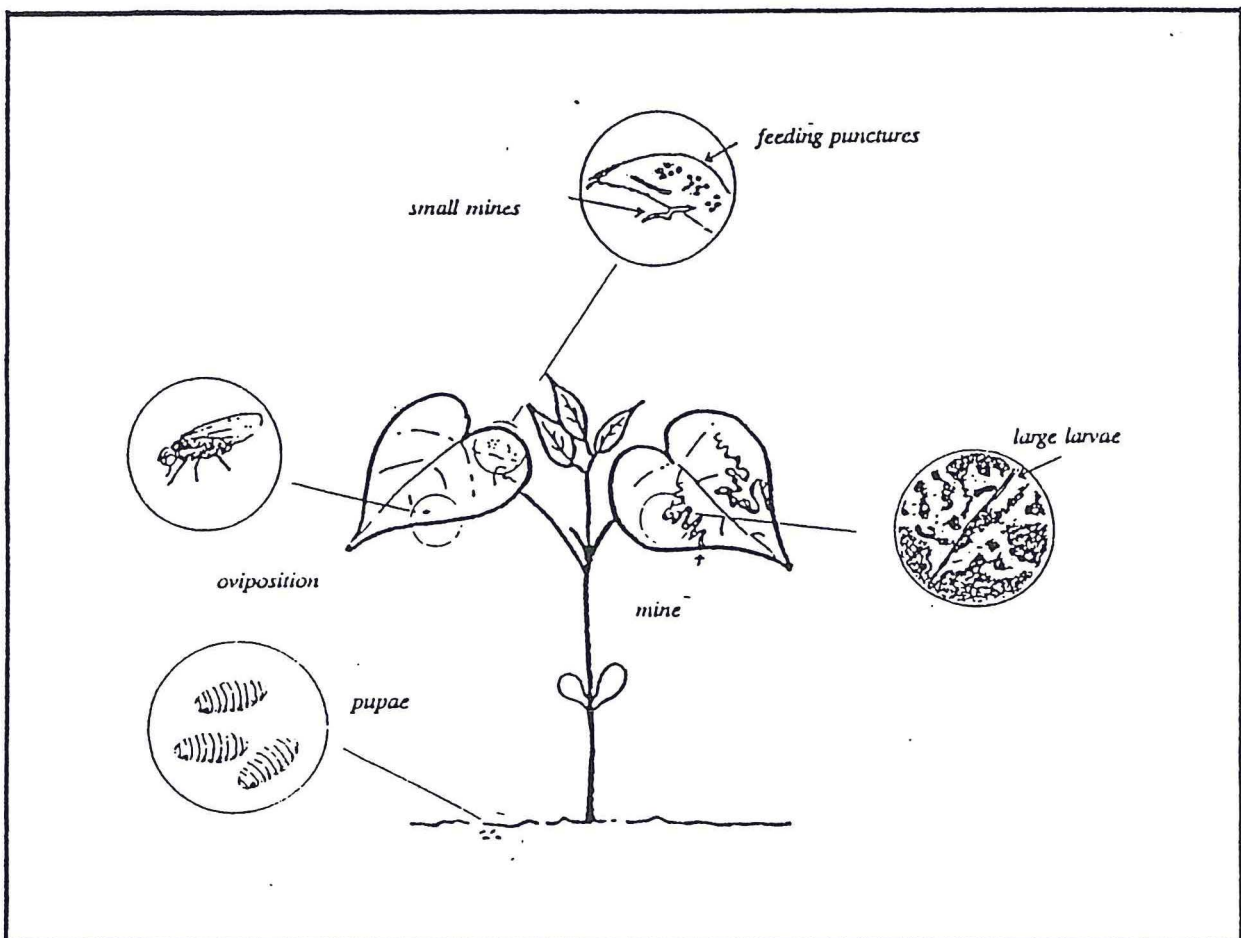
## 4. Establishment Potential

### 4.1. Biological Information of the Pest

#### 4.1.1 Life Cycle

A generalized lifecycle of leafminers (*Liriomyza* spp.) is shown in figure 1. Peak emergence of adults occurs before midday (Smith et al., 1992). Mating takes place from 24 h after emergence and a single mating is sufficient to fertilize all eggs laid.

In the southern USA the life-cycle is probably continuous throughout the year (Smith et al., 1992). There is a noticeable first generation which reaches a peak in April. *L. sativae* completes its life cycle in 24-28 days during the winter in California (December-January) when the heaviest attacks on crops occur.



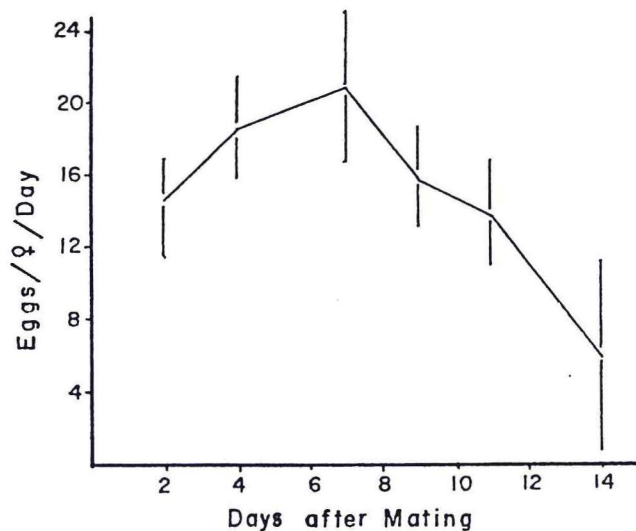
Figur 1. Generalized lifecycle for leaf miners (*Liriomyza* spp.) (Enkegaard, 1990).



Adults of *L. sativae* live between 15 and 30 days (Smith et al., 1992). On average, females live longer than males. Female flies puncture the leaves of the host plant causing wounds which serve as sites for feeding or oviposition. Males also feed at these puncture sites.

The number of feeding punctures and eggs varies according to temperature and host plant (Smith et al., 1992). About 15 % of punctures made by *L. sativae* contain viable eggs. McClanahan (1980) reported that oviposition (on bean plants) started soon after mating and persisted for two weeks (fig. 2). Mean total eggs per female were 228.7 on beans. It is not difficult to see how leaf miner numbers can build up rapidly.

Experiments in rearing *L. sativae* made by Petitt & Wietlisbach (1994) with cohorts at 25°C, showed that peak oviposition occurred between ages 2 to 6 days and was consistent enough across these ages so that the cohort could be provided with the same number of plants for oviposition on each of these days without under- or overcrowding of larvae in the leaves. Cohorts with adults younger than age 2 days and older than 6 days require fewer plants in which to oviposit. Through age 9 days about 210 offspring per female, can be expected.



Figur 2. Oviposition by *Liriomyza sativae*. Mean total eggs per female was 228.7 (McClanahan, 1980).

Eggs are inserted just below the leaf surface (Smith et al., 1992). Eggs hatch in 2-5 days dependent on temperature (Smith et al., 1992).

The larva feeds primarily in the palisade layer of the leaf (Johnson et al., 1992). Three larval instars develop in the leaf and the mines become progressively larger with each moult (Smith

et al., 1992). First instar larva are colourless on hatching, turning pale yellow-orange. Later instars are yellow-orange.

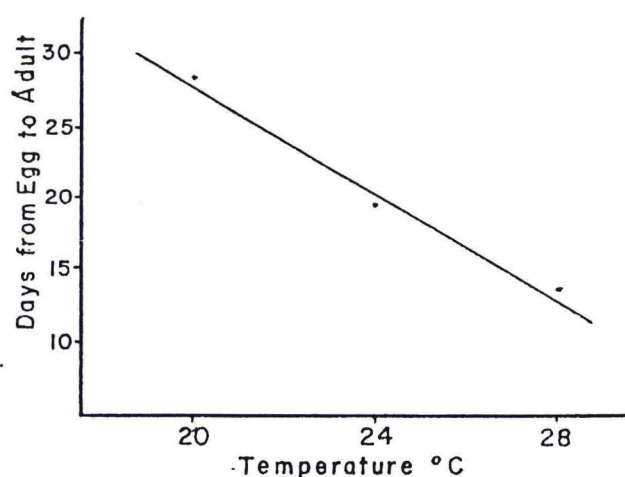
The duration of larval development varies with temperature and host plant, but is generally 4-7 days at mean temperatures above 24°C (Smith et al., 1992). At temperatures above 30°C the mortality rate for immature stages rises sharply.

The larva makes an exit hole in the leaf surface at the end of the mine, through which it emerges to pupate (Smith et al., 1992). Pupation normally takes place in the soil just beneath the surface, or in the darkest accessible area. However, Johnson et al. (1984) reported that some larvae pupate on the calyx end of the fruit and on leaflets. Pupariation is adversely affected by high humidity and drought. The colour of the pupa is variable, pale yellow-orange often darkening to golden brown as it gets older (Smith et al., 1992).

Adults emerge from the puparia in about seven to ten days depending on the temperature (Johnson et al. 1984).

#### 4.1.2. Development, Diapause and Hibernation

The development of *L. sativae* in relation to temperature was investigated by McClanahan (1980). The period from oviposition to emergence of adults was found for temperatures of 20°C, 24°C and 28°C. Figure 3. shows the linear relationship found within this range. Development at 28°C was about twice as fast as it was at 20°C. The same data may be expressed as rate of development against temperature, and regression analysis indicates a very close fit to linearity ( $r=0.998$ ). McClanahan (1980) predicted by substitution (in the equation  $y=0.0046x-0.0576$ ) that no development would occur at 12.5°C or lower.



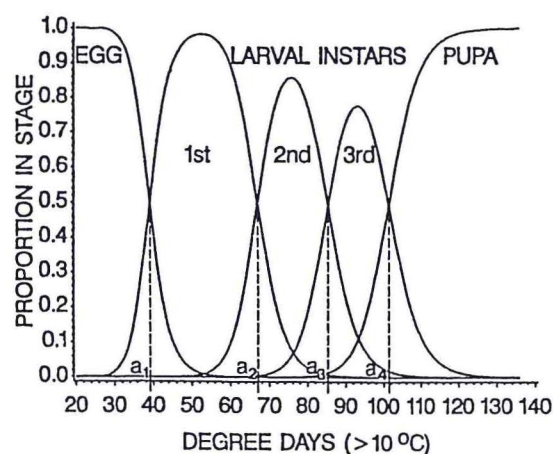
Figur 3. Development of *Liriomyza sativae* at various constant temperatures (McClanahan, 1980).



The time taken from egg to adult can also be calculated as a day-degree requirement (McClanahan, 1980). The best agreement for the three temperatures (20°C, 24°C and 28°C) was achieved with a base temperature of 12.3°C, and 220.8 ± 2.3 day-degrees were required. It is readily apparent that *L. sativae* is well adapted to the greenhouse environment.

According to Petitt et al. (1991) the lack of data on temperature-dependent development of instars of *L. sativae* is an impediment to research on biological control of this pest because parasitoids will likely interact differently with each instar. Development times of eggs and instars of *L. sativae* were determined at constant temperatures of 20, 25, 30 and 35 ± 1°C on *Phaseolus lunatus* L. 'Henderson'. Development rates of eggs and larvae increased linearly with temperature up to 35°C. More than 91 % of the variation in development rate of first and second instars was explained by temperature, whereas temperature explained only 42 % of the variation in third-instar development rate. A part of the variation in development rate of third instars may be explained by the fact that the designated end point of this stadium (emergence of third instars from leaves) occurred only during photophase. Overall, 99.9 % of larvae emerged from leaves after 95 degree-days (DD) (threshold temperature, 10°C).

The constant temperature data were used to parametrize a stochastic phenology model for *L. sativae* (Petitt et al., 1991). The model predicted that 50 % of the population would advance beyond the egg and first-, second- and third-instars stages by 39.2, 67.0, 85.5 and 101.2 DD, respectively (fig. 4). The model predicted peak proportions of the population to be in first, second and third stadia at 52.7, 76.1 and 93.2 DD (fig. 4). Pooled data from two fluctuating temperature experiments resulted in very similar estimates of timing of peak stage proportions (51.3, 74.4 and 94.1 DD, respectively). Degree-day values at peak stage proportions were used successfully to determine the temperatures required to advance members of cohort to a particular stadium at a given time, thereby facilitating experiments examining interactions of parasitoids with each larval instar.



Figur 4. Expected proportions of *Liriomyza sativae* in each stage as functions of degree-day time. Parameter values ( $a_i$ ) are the maximum likelihood estimates from the constant temperature data set for the time when one-half of the population is in stage  $i$  or below (Petitt et al., 1991).

McClanahan (1980) found that over the winter the growth of *L. sativae* populations (on tomato) seemed to indicate that daylength is a factor that influences fecundity of the species. Through the months of December to March, adults punctured the leaves, but fewer eggs were laid.

Petitt & Wietlisbach (1994) investigated the effect of relative humidity on pupal survival at 25°C. Of the 68 *L. sativae* pupae exposed to 20, 40, 60, 70, 80, 90 and 95% RH 49, 81, 90, 97, 100, 99 and 94% survived, respectively. The differences among all treatments were significant. However, when only the 70, 80, 90 and 95% RH were included, differences were not significant. In the range 70-95 % RH and 25°C the survival of *L. sativae* pupae was 94% or more.

There is no available information on the possibilities for *L. sativae* to overwinter in areas with cold winters or any information on diapause. However, *L. sativae* can be compared with *L. trifolii*, which has not been found to have adapted to survive outdoors in areas with cold winters and no evidence of pupal diapause has been found (Minkenberg, 1988).

#### 4.1.3. Host Plants Reported

*L. sativae* is a polyphagous species, having been reared from over 50 species of cultivated and wild hosts (Chambers & Kouskolekas, 1985). Some of the more important economic plants are Cucurbitaceae (gherkin, cucumber, melon), Fabaceae (various bean species), Solanaceae (pepper, tomato, potato, eggplant), Chenopodiaceae (spinach), Compositae (aster, *Chrysanthemum morifolium*) and Umbelliferae (celery). Host plants reported are listed in table 2, Appendix (Chambers & Kouskolekas (1985) did not name the 50 species mentioned above).

The crops attacked by *L. sativae* are mainly in the three families Cucurbitacea, Leguminosae (Fabaceae) and Solanaceae (Deeming, 1992).

#### Wild Host Plants in Norway

The following species are found in Norway (table 2, Appendix):

*Amaranthus*, *Aster* sp., *Lathyrus*, *Medicago sativa*, *Pisum sativum*, *Tropaelum majus*, *Vicia faba* (Lid, 1987).

#### Cultivated Host Plants in Norway

Several of the host plants of *L. sativae* are cultivated in Norway, either in greenhouses, outdoors or both (table 2, Appendix).

In greenhouses important host plants for the pest are cucumber and tomatoes among the vegetables, and *Chrysanthemum* and *Dahlia* hybrids among the ornamental plants.

Outdoors there are several field vegetables which are reported as host plants for *L. sativae*: bean species, celery, gherkin, pea, potato and spinach. Ornamental plants, reported as host plants for *L. sativae*, are also grown outdoors as annuals, cut flowers or perennials, eg. *Amaranthus*, *Aster* sp., *Chrysanthemum* sp., *Dahlia* hybrids and *Zinnia* (table 2, Appendix)



During the summer several of the host plants listed in table 2, Appendix, are grown in private gardens, both vegetables and ornamental/bedding plants.

#### **4.1.4. Migration, Dispersal and Transport**

##### **Dispersal by natural means**

Adult flies are capable of limited flight (Smith et al., 1992). Gratwick (ed., 1992) reported that *L. trifolii* can fly over 100 metres in a few hours but left undisturbed, they tend to aggregate on individual leaves. *L. sativae* is probably capable of flying the same distance. It is therefore likely that dispersal and subsequent infestation may occur, from one greenhouse to the open field or to other greenhouses nearby, or from the open field to greenhouses and between outdoor crops.

Tryon et al. (1980) conducted experiments on a commercial vegetable and ornamental transplant range, to determine attraction of various trap colors and monitor dispersal of *L. sativae* into the range. Significantly more adult flies were captured on yellow traps than on yellow-green, orange, green and blue. Significantly more flies were trapped on cards located on the periphery of the range nearest the prevailing wind and within 100 ft of commercial tomato farms. Fly movement onto the transplant production range and infestation within production houses reflected both proximity of source and prevailing wind direction.

Studies of intercrop movement of the two leafminers *L. trifolii* and *L. sativae* made by Trumble (1981) showed that these two species tend to segregate on the basis of host preference, with *L. sativae* preferring tomatoes and *L. trifolii* preferring celery, even though both tomatoes and celery are suitable hosts. However, when a tomato field nearby a celery field was removed, *L. sativae* readily migrated from tomato to celery.

Zehnder & Trumble (1984) determined host preferences of *L. sativae* and *L. trifolii* and their associated parasites from adjacent plantings of celery and tomatoes in California. The results indicated that although *L. sativae* can complete development on celery and populations can be sustained at low levels, tomato is the preferred host. *L. sativae* densities will not be high in celery if tomatoes or other preferred hosts are in the immediate vicinity. Additionally, a change in *Liriomyza* composition in celery is not likely after termination of a nearby tomato planting.

##### **Dispersal by human activity**

Dispersal over long distances is on planting material or in soil of host species in trade (Smith et al., 1992). Cut flowers can also represent a danger as a means of dispersal. For example, the vase life of chrysanthemums is sufficient to allow completion of the life-cycle. The pest may also be dispersed on equipment and containers which have not been properly cleaned.

#### 4.1.5. Adaptability

##### The Pest

*L. sativae* has high adaptability due to the high reproduction rate and fast development on suitable host plants.

The spread of *L. sativae* has so far not been very fast compared to the story of *L. trifolii* and *L. huidobrensis* who, during the last 20-30 years, have invaded new territories and become established in many countries all over the world. This shows a high adaptability for these two species to establish in environments with nonsimilar climatic conditions compared to the area of origin. However, *L. sativae* seems to be moving, and new countries are relatively often added to the EPPO Distribution List for *L. sativae*. The question now is whether *L. sativae* will establish in some of the European countries, like *L. trifolii* and *L. huidobrensis* have managed successfully. There has not been found any evidence of pupal diapause in *L. sativae* (as in *L. huidobrensis*) and it is therefore unlikely that the pest has adapted to survive outdoors in areas with cold winters.

##### Host plant range

High adaptability to new host plants has so far not been reported for *L. sativae* to the same extent as *L. huidobrensis* and *L. trifolii*. Spencer (1973) reported that crop plants attacked by *L. sativae* are mainly in the three families Cucurbitaceae, Fabaceae and Solanaceae. The list of host plants presented in this assessment, table 2, Appendix, includes hosts in 9 families (Seymour (pers. comm.), EPPO database (1996)).

Studies of intercrop movement of the two leafminers *L. trifolii* and *L. sativae* made by Trumble (1981) and Zehnder & Trumble (1984) showed that when a tomato field nearby a celery field was removed, *L. sativae* readily migrated from tomato to celery. Sharma et al. (1980) reported that during the two squash-production seasons in the Imperial Valley (California), *L. sativae* is more prevalent in the fall than in the spring. Large populations build up on cotton and spill into cucurbits when the cotton is ready for harvest.

##### Geographical range

*L. sativae* is known from the Americas, Caribbean and Pacific (Deeming, 1992). Deeming (1992) reported that *L. sativae* is firmly established in the southern part of the Arabian Peninsula and may have a wider Old World distribution. In 1994 *L. sativae* was found in India and Thailand (Asia), and it has recently been found in Cameroon and Sudan (Africa) (EPPO Reporting Service 1996, no. 6). *L. sativae* is still absent in Europe, but researchers dealing with quarantine pests in many European countries are now following the movements of *L. sativae* closely.

*L. sativae*, under different names, has been recognized as a serious pest on a variety of crops in Argentina, Peru, Venezuela, Alabama, California, Florida, Texas and Hawaii (Spencer, 1973). It is possibly the most injurious species known in both North and South America. Its significance as a pest can vary greatly from year to year and also from locality to locality, but it seems to be accepted that the damage caused has increased appreciably since the first widespread use of DDT in the immediate post-war years.



### **Tolerance to low temperatures**

The results from McClanahan (1980) and Petitt et al. (1991) shows that temperature is a factor causing large differences in the development rate of *L. sativae* (fig. 3 & 4). The theoretical temperature-threshold for development of *L. sativae* was 12.5°C (McClanahan, 1980).

All stages are killed within a few weeks by cold storage at 0°C (Smith et al., 1992). Smith et al. (1992) reported that newly laid eggs are the most resistant stage (but then the pupal stage was probably not considered).

There is no available information on the possibilities for *L. sativae* to overwinter in areas with cold winters or any information on diapause. However, *L. sativae* can be compared with *L. trifolii*, which has not been found to have adapted to survive outdoors in areas with cold winters and no evidence of pupal diapause has been found (Minkenberg, 1988). Reinfestations of *L. sativae* in greenhouses in spring from outdoor populations are therefore unlikely in temperate areas.

## **4.2. Geographical Distribution**

### **4.2.1. World Distribution**

#### **The Pest**

Europe: Absent. Finland (intercepted), United Kingdom (intercepted).

Africa: Cameroon, Sudan, Zimbabwe.

Asia: India, Oman, Thailand, Yemen.

North America: Canada (under glass in Ontario), Mexico (unconfirmed), United States (Hawaii, outside in southern and western states, in glasshouses in Ohio, Maryland and Pennsylvania).

Central America and Caribbean: Antigua and Barbuda, Bahamas, Barbados, Costa Rica, Cuba, Dominica, Dominican Republic, Guadeloupe, Jamaica, Martinique, Mountserrat, Nicaragua, Panama, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, Trinidad and Tobago.

South America: Argentina, Brazil, Chile, Colombia, French Guiana, Peru, Venezuela.

(EPPO Reporting Service 1996, no. 6. EPPO/PQR Database, version 3.2, dated 1996-02. Smith et al., 1992.)

#### **Host Plants**

The host plants of this highly polyphagous species are present in almost every country of the world, in glasshouses, outdoors or both.

### **4.2.2. Occurrence in Norway**

#### **The Pest**

*L. sativae* has never been found/reported in greenhouses or outdoors in Norway.

## Host Plants

Several host plants are present in Norway, ornamental plants, vegetables and weeds. In glasshouses host plants are available during the whole year, and during the summer suitable hosts are found both in greenhouses and outdoors, including weeds (table 2, Appendix). Greenhouses (with host plants) are present in all parts of the PRA-area, but some regions have higher density of greenhouses than others, like the south-west coastal area and the south-eastern part of Norway.

## 4.3. Control Measures of the Pest

### 4.3.1. Phytosanitary Regulations

*L. sativae* is included in the Norwegian list of quarantine pests (A list), with a tolerance limit of 0 %.

Control at entry: The Norwegian Agricultural Inspection Service carries out inspections at different arrival places for plant commodities to Norway.

As mentioned previously (chap. 3.1), the chance of detecting *L. sativae* during the inspections both at the place of origin (phytosanitary certificate) and arrival might be very small, depending on which life stage(s) of the pest is present.

EPPO (Smith et al., 1992) recommends that planting material (except seeds) of celery, *Cucumis*, lettuces, tomatoes, and propagating material (except seeds) of *Capsicum*, carnations, celery, chrysanthemums, *Cucumis*, *Gerbera*, *Gypsophila*, lettuces, *Senecio hybridus* and tomatoes from countries where the pest occurs must have been inspected at least once a month for the previous 3 months and found free of the pest. A phytosanitary certificate should be required for cut flowers and vegetables with leaves.

All stages are killed within a few weeks by cold storage at 0°C (Smith et al., 1992). Newly laid eggs however, are the most resistant stage and it is recommended that cuttings of infested ornamental plants be maintained under normal glasshouse conditions for 3-4 days after lifting to allow eggs to hatch. Subsequent storage of the plants at 0°C for 1-2 weeks should then kill of the larvae of leaf miner species.

### 4.3.2. Chemical Measures

Chemical control of *L. sativae* (and other leaf miners) has proven difficult because of the development or rapidly developing resistance to the currently available insecticides and a number of effective compounds are also becoming unavailable because of health, safety and environmental concerns.

Some insecticides, particularly pyrethroids, are effective but leaf miner resistance can sometimes make control difficult (Smith et al., 1992).

Larvae and eggs would be the most important stage to target for chemical control. Larvae can be controlled with abamectin and cyromazine. Pyrazophos and triazophos are also effective



against larvae. No effective chemical has been reported against the eggs. Dichlorvos is most effective against the adults, deltamethrin is also effective.

Among the insecticides mentioned above, only dichlorvos and deltamethrin are permitted for use in the PRA area, which means that there are no effective insecticides available against the larvae. Deltamethrin is not registered for greenhouse vegetables in Norway. The time of application for dichlorvos (in Norway) is 4 days and 14 days for deltamethrin (Anon., 1995). Even 4 days makes the use impossible in vegetables during the harvesting period, when for example tomatoes and cucumber are being harvested every day or every second day at the most intense time of harvesting.

Chemical control of *L. sativae* in the PRA area is very difficult because of the reasons mentioned above, and due to the time of application, the use on vegetables is almost impossible at the onset of harvest.

### 4.3.3. Insecticide Resistance

Insecticide resistance of *Liriomyza* spp. was first confirmed in Florida in the latter half of the 1940's (Saito, 1994). Sharma et al. (1980) reported that *L. sativae* had become quite troublesome on squash in California. Because *L. sativae* has a wide host range and is continuously exposed to insecticides, it has become very resistant and hence difficult to kill.

Susceptibility to the pyrethroids permethrin and fenvalerate was determined for several populations of *L. sativae* and *L. trifolii* from various crops in Hawaii (Mason et al., 1987). Susceptibility varied significantly among populations of both species. Populations with a history of extensive insecticide use had 2- to 71-fold higher LC<sub>50</sub>'s than did *L. sativae* population from a site with minimal insecticide use, suggesting that some resistance to pyrethroids had developed in *L. sativae*.

The two pyrethroids examined in Hawaii (Mason et al., 1987), had at that time, recently been registered in Hawaii for leafminer control and had had limited use. Both *L. sativae* and *L. trifolii* became established in Hawaii before widespread use of these compounds in the continental United States. Thus, direct selection by pyrethroids had been minimal, but cross resistance may have developed from the prior use of chlorinated hydrocarbon insecticides, because DDT and some pyrethroids have similar modes of action.

During 1978 and 1979, watermelon growers in the Kahuka area of Oahu (Hawaii) suffered serious crop losses due to *Liriomyza* induced damage (Johnson et al., 1989). Some growers reported that pesticides were applied for leaf miner control daily over a two and one-half month period on individual watermelon plantings. In 1984, the only registered compound effective in controlling the leaf miners was fenvalerate. Failure in individual insecticides such as oxamyl and naled probably resulted from development of insecticide resistance in the *Liriomyza* spp. and destruction of efficient natural enemies.



#### 4.3.4. Biological Measures

*L. sativae* is historically considered as a secondary pest on fresh market tomatoes in southern California (Johnson et al., 1980a) and Mexico (Trumble & Alvarado-Rodriguez, 1993), and on glasshouse and field-grown tomato, cucumber, melons and other vegetables in Indiana (York, 1988). Repeated applications of broad spectrum insecticides resulted in leaf miner population increase and reduction in natural parasitization.

A world list of all known parasites and predators of the 26 economically important species of *Liriomyza* is given by Grenouillet et al. (1993). The list includes the biogeographical area where the recording has been done. 40 species of hymenopterous parasitoids from 4 families attack *L. sativae*. The four families are Eulophidae (20 species), Braconidae (9 species), Pteromalidae (2 species) and Eucoilidae (9 species).

Surveys of the populations and the parasitoids of *L. sativae* on late-season tomatoes were conducted for two years (1978 and 1979) in two locations of Alabama by Chambers & Kouskolekas (1985). The three most prevalent parasitoids and their percent occurrence were 1) *Opius dimidiatus* (Ashmead) (Braconidae) 33.3 %, 2) *Chrysonotomyia* sp. (Eulophidae) 20.8 % and *Halticoptera* sp. (Pteromalidae) 19.5 %.

In Alabama *L. sativae* larvae were most heavily parasitized early in the growing season, with 60 to 85 % of the collected larvae being parasitized at one location (Chambers & Kouskolekas, 1985). Percent parasitism declined as the seasons progressed, reaching a low by mid-August. The difference between early and late season parasitization rates observed may be, at least in part, due to the chemical control spray programs that were intensified in August. Early in the season there is little insect pressure so few or no insecticidal applications are made. In the absence of toxic spray treatments, the parasites are more likely to reach the upper limits of their field densities and potential as regulatory factors. But as spray programs are initiated at fruit set for control of fruit-feeding insects, the leaf miners parasite complex is reduced to levels that prevent them from being significant in the later season.

Johnson et al. (1980b) reported that the predominant species that parasitize *L. sativae* varies according to the agroecosystem and geographic location. Johnson & Hara (1987) reviewed the predominant parasitoids reared from four major *Liriomyza* spp. infesting 12 different host crops in North America and Hawaii. No single parasitoid species was found to be the predominant biological control agent in most crops. *Diglyphus begini* (Ashmead), *Halticoptera circulus* (Walker) and *Chrysonotomyia punctiventris* (Crawford) were either the first or second most reared species in 60.9, 26.1 and 21.7 % of the studies, respectively. Because of uneven distribution of parasitoids among crops, it is suggested that effective biological control may depend on matching the 'most effective' parasitoid species complex with a given *Liriomyza* host and crop.

*L. sativae* larval populations in bell pepper (*Capsicum annuum* L.) foliage were parasitized by representatives of eight Hymenoptera species at two study sites in South Texas (Chandler, 1983). *Chrysonotomyia* sp. (Eulophidae) was the most common species collected at both locations in each of six growing seasons. Distinct population peaks were not observed among the individual parasite species during the season.



#### 4.3.5. Cultural Measures

Seedlings can be covered with insect nets (0.8 mm) during the hardening period before planting to avoid attack (Anon., 1994). This is used against leaf miners on a limited scale in the Netherlands (de Goffau, 1991).

Growers have a choice of many types of insect exclusion screens for greenhouses (Bethke et al., 1994). Before selecting materials for screening greenhouses, growers need to consider the price of the material (including installation), the type and economic value of the crop being grown, the pests to be excluded and the effect the screening will have on greenhouse conditions.

Weeds inside or around the greenhouse or field can be infected, and might cause an outbreak and must be removed. Waste of infested plants must be buried in the ground or sealed up with plastic film for over a month. When cropping is finished, pupae must be exterminated by fumigating the soil or the field must be left without plants for more than 20 days before the next cropping.

#### 4.3.6. Monitoring

Continuous observations in greenhouses with yellow sticky traps and/or water traps and visual inspections of the plants/seedlings should be used to detect imminent outbreaks of *L. sativae*.

Weeds are favoured by pests before cultivated plants are attacked (Rubin, 1990). The use of black plastic nets, herbicides or manual weeding will leave a few weeds that are monitored routinely and are important as an information source for the grower to decide, on the basis of their infestation, the need for biological/chemical treatment in the greenhouse.

#### 4.3.7. Integrated Pest Management Measures

Integrated pest management (IPM) is a pest control strategy emphasizing crop protection by using all available methods, including cultural, physical, mechanical, biological and chemical control methods (Wadill et al., 1981). Insects, diseases and nematodes were monitored on snap beans (*Phaseolus vulgaris* L.) in four experiments in Florida. Insecticide costs were reduced by 48 and 83 % in two field tests where field monitoring was utilized in making management decisions.

Biological control is being used extensively in the IPM program in The Land at EPCOT Center in central Florida (Petitt, 1992). Cultural and mechanical control are also important in this IPM program. *L. sativae* is controlled by the parasitoid *Opius dissitus* and the control program has been successful in many crops such as eggplant, tomato, beans, cucumber and other cucurbits. *L. sativae* densities are so low that damage is insignificant. Rapid increase in the *L. sativae* population after treatments with non-selective insecticides have provided some evidence that the parasitoid is responsible for suppression of *L. sativae*. Currently work is underway in screen cages in the greenhouse to determine required release rates. Releases of *O. dissitus* are also being made in exterior bedding plants in The Land.

An IPM program based on intensive sampling, parasite release, use of the mating disruption technique, and applications of microbial pesticides and abamectin was developed for the fresh market tomatoe industry in Sinaloa, Mexico (Trumble & Alvarado-Rodriguez, 1993). The IPM program for tomatoes was compared with conventional practices and an unmanaged control in each of three major agricultural valleys in autumn and winter crops, and in two valleys for spring plantings. The amount of marketable fruit production was similar for all treatments in the autumn plantings, but significantly higher in the IPM program during the winter and spring plantings. Net profits (value of fruit at harvest minus the cost of control) were substantially higher in the lower input IPM plots than in conventional treatments. The IPM programs offers substantial long-term benefits in comparison with the conventional approach.

#### **4.4. Conclusion on Establishment Potential**

There is a great potential for *L. sativae* to establish in greenhouses and protected crops in the PRA area. There are also a possibility for establishment outdoors during the summer, but *L. sativae* is probably not capable of overwintering in the PRA area (table 7 & 8, Appendix).

### **5. Spread Potential after Establishment**

#### **5.1. Distribution of Host Plants in Norway**

##### **Wild Host Plants**

The distribution of wild host plants of *L. sativae* in the PRA area (table 2, Appendix) is as follows:

*Amaranthus*, *Aster* sp. 4 species, (including escapes), *Lathyrus* is distributed in all parts of Norway (18 species, with some differences in distribution among the species), *Medicago sativo* meadows, roads and waste disposal sites, *Pisum sativum*, *Tropaelum majus* and *Vicia faba* are escapes (Lid, 1987).

##### **Cultivated Host Plants**

Host plants of *L. sativae* are grown in greenhouses in all parts of Norway all year round (table 2, Appendix). During the summer several host plants listed in table 2, Appendix, are grown outdoors as field vegetables/crops or annuals/perennials.

#### **5.2. Spread Potential within Norway**

##### **Spread by human activity**

In Norwegian greenhouse structures there is often a great variety of different species and cultivars of ornamental plants. Different greenhouse vegetables or greenhouse vegetables and ornamental plants is also quite common. This means that many greenhouses grow at least one host plant of *L. sativae* (table 2, Appendix).



The single grower is not capable of producing all the different species and cultivars the market demands, and an extensive trade with other countries and/or between Norwegian growers is very important. The potential for spread of plant material or soil infested with *L. sativae* within Norwegian greenhouses is therefore great.

### **Spread by natural means**

Spread of *L. sativae* between greenhouses is only likely to happen in areas where there is a great concentration of greenhouses, like in Rogaland and Buskerud county. However, the long distances between greenhouses in many other areas in Norway lower the possibility of natural spread in these areas. During the summer several host plants are available outdoors (vegetables, annuals, perennials, weeds (table 2, Appendix), and therefore the spread potential by natural means are greater at this time of the year.

### **5.3. Natural Enemies of *L. sativae* in Norway**

*Diglyphus begini* (Ashmead) has been found in Jostedalen (Compton, 1981) and at Ås (Hågvar et al., 1994), and is probably distributed in Southern Norway (Hofsvang, pers. comm.). *Halticoptera circulus* (Walker) is present in Norway (Compton, 1981).

The presence of *Chrysonotomyia punctiventris* (Crawford), *Chrysonotomyia* sp., *Ganaspidium utilis* (Cynipidae), *Halticoptera* sp. (except *H. circulus*) or *Opius dimidiatus* (Ashmead) has not been investigated so far.

### **5.4. Conclusion on Spread Potential**

After establishment in the PRA area, the spread potential within greenhouse environments of *L. sativae* is great. The spread potential outdoors is probably limited to the surrounding vegetation (vegetables, annuals, perennials and weeds) close to infested greenhouses, and could act as a source of re-infestation.

## **6. Potential Economic Importance**

### **6.1. Type of damage**

Damage is caused by larvae mining into leaves and petioles (Smith et al., 1992). The photosynthetic ability of the plants is often greatly reduced as the chlorophyll-containing cells are destroyed. Severely infested leaves may fall, exposing plant stems to wind action, and flower buds and developing fruit to scald. The presence of unsightly larval mines and adult punctures in the leaf palisade of ornamental plants can further reduce crop value. In young plants and seedlings, mining may cause considerable delay in plant development, leading to plant loss.

## 6.2. Crop Losses

*L. sativae* is reported as economically damaging on a wide range of vegetables in the USA including tomatoes, potatoes and *Cucurbita* (Smith et al., 1992). The damage threshold of *L. sativae* in tomatoes is one active leaf miner per three terminal leaflets or 25 miners per 18 leaflets. Tomatoes can tolerate a 30% infestation of pre-bloom leaves and 60 % post-bloom. *L. sativae* has been reported to cause a 30% defoliation in an 80-ha field of tomatoes in the USA. Cucurbit crops severely attacked in the seedling stage by *L. sativae* can be totally destroyed. This species transmits a number of plant viruses, including celery mosaic potyvirus.

Larval mining causes greater injury than feeding punctures and egg-laying wounds (Johnson et al., 1984). Field studies showed that photosynthetic rates within mined tissues are reduced by about 62% as compared with unmined tissue. It has been estimated that about 18% mining injury results in a 60% reduction of total leaflet photosynthesis. However, researchers have had difficulties in demonstrating reduction in tomato yields as a result of *L. sativae* infestations. This might be explained by physiologists that suspect that tomato plants produce more assimilates than are actually required for growth and fruit production.

In Chandler Mountain, Alabama in 1976 and 1977, premature defoliation of tomato plants caused by *L. sativae* resulted in a loss of the late-season crop of tomatoes (Chambers & Kouskalas, 1985). Growers sprayed at 2- to 3-day intervals with insecticides to control the pest.

During 1978 and 1979, watermelon growers in the Kahuku area, Hawaii, suffered serious crop losses due to *Liriomyza* induced damage (*L. sativae* & *L. trifolii*) (Johnson et al., 1989). Watermelon production in the Kahuku area was reduced by about a third during 1978 and 1979.

The production of plants and vegetables in greenhouses in Norway is economically important. In 1995 the total production-value of vegetables (cucumber and tomatoes, host plants of *L. sativae*), was 221.191.000 NOK (table 1, Appendix). The production-value of ornamental host plants (pot plants, cut flowers, nursery plants) was 73.028.000 NOK (table 1, Appendix). The number of man-labour years involved in the greenhouse-production (vegetables and ornamental plants) of host plants of *L. sativae* in Norway, has been estimated to 493 (table 1, Appendix).

The production-value of host plants of *L. sativae* grown outdoors during the summer was 560.090.000 NOK in 1995 (table 1, Appendix). The number of man-labour years involved in outdoor production (vegetables/crops) of the same host plants of has been estimated to 2.449 (table 1, Appendix).

## 6.3. Loss of Export Markets

Exportation of plant material from Norway to other countries is limited. However, the Norwegian Horticultural Growers Association is working to increase the export of different products, such as seedlings of different species. In 1994 Norwegian growers exported about 877.000 rooted seedlings of four species (Tærum, pers. comm.).



#### 6.4. Increase in Control Costs

The costs of eradicating *L. huidobrensis* from Norway in 1995 has been estimated to a total value of 2.010.500,- NOK for the three growers involved (Norwegian Horticultural Growers Association). The total costs of eradication can be specified as follows:

1) Loss of plant material:	1.251.389,- NOK
2) Disinfection/Cleaning/Pesticides:	469.779,- NOK
3) Work in connection with destruction of plant material:	272.625,- NOK

Finland had a campaign of eradicating *L. trifolii* in 1980 and another in 1982 (Rautapää, 1984). In 1980 eradication from eight greenhouses resulted in total costs of 380.000 Fmk for the government, and in 1982 the corresponding figure for four greenhouses was 280.000 Fmk. The range of costs of chemical control in greenhouses growing vegetables and chrysanthemums while «living with» *L. trifolii* were estimated to be 0,8-8,8 million Fmk, depending on whether 10 or 100 % of the growing area was to be treated respectively.

Rautapää (1984) found that when all the costs for exclusion measures were summed (eradication + quarantine) and compared with the costs of «living with» the pest, the ratio would be 1:3 to 1:13 depending on the use of insecticides. The secondary effects of additional use of insecticides on biological control or marketing difficulties because of residues were not included in this comparison. In this case the most economical way of avoiding problems caused by *L. trifolii* was to invest in pre-entry quarantine measures and prevent its spread into the country.

The best solution for Norwegian growers will probably be to eradicate *L. sativae*, as done successfully with *L. trifolii* in 1980 and *L. huidobrensis* in 1995.

#### 6.5. Effects of ongoing Integrated Pest Management (IPM) Programmes

Tomatoes in Norway are grown with minimum use of pesticides, where only 0.048 kg of active ingredients per 1.000 m<sup>2</sup> is used (Sæthre & Hofsvang, 1995). The pesticide situation in cucumbers was a total use of 0.607 kg active ingredients per 1.000 m<sup>2</sup> (Sæthre & Hofsvang, 1996). Establishment of *L. sativae* in Norwegian greenhouses would present a serious threat to the present and very positive pesticide-situation for greenhouse vegetables in Norway.

There are no IPM-programmes for ornamental plants in Norwegian greenhouses at present, but for the future IPM-programmes in ornamentals are one of the important aims both for growers and researchers in plant protection. Establishment of *L. sativae* in the PRA area would make a threat to this aim.

## 6.6. Environmental damage

Establishment of *L. sativae* in the PRA area would probably result in an increase in the use of insecticides in a few years in Norwegian greenhouses. Such an increase in the use of pesticides is not desired by all those involved in horticulture in Norway, including the growers, researchers in plant protection and the Norwegian authorities.

Documentation on environmental damage like impact of ecosystem health caused by *L. sativae* in its existing geographic range, has not been found.

## 6.7. Conclusion on Potential Economic Importance

The damage caused by *L. sativae* is of great economic importance and includes aesthetic and physiological damage, delay in plant development, time of flowering, number and/or quality of flowers and might in some cases also cause entire crop losses (young seedlings and cellery). Planned and ongoing IPM-programmes would be negatively affected according to the level of pesticide use in Norwegian greenhouses today.

## 7. Introduction Potential

### 7.1. Entry

Before entry, the pest has to be associated with the pathway at the origin (countries which Norway import from). How likely the pest is to be associated with the pathway at the origin and carried into the PRA area (Norway) is not easy to predict. However, the story of dispersal of *L. sativae* is not as dramatic as the story of *L. trifolii* and *L. huidobrensis*, but confirm that the possibility for association is still high.

### 7.2. Import of Host Plants to Norway

Importation of host plants of *L. sativae* to Norway is listed in table 3-5, Appendix. Plant commodities liable to carry *L. sativae* are listed in the EPPO/PQR database (1996) (table 6, Appendix), and includes among others, *Apium graveolens*, *Capsicum annum*, *Cucumis*, *Lycopersicon esculentum*, ornamental and vegetable plants.

### 7.3. Number of Consignments and Use

There are no statistics available on the number of consignments of imported plant material to Norway. The amount of importation and use of plant material in the PRA area, such as plants for further cultivation and saleable decoration plants, flowering pot plants and nursery plants, cuttings and small plants of cut flowers, are shown in table 1-2 and 3-5, Appendix.



#### **7.4. Survival of the Pest under the Environmental Conditions of Transport**

The many interceptions of *L. sativae* in different countries, proves that the pest is able to survive in transit and also to infest new crops at the place of destination. Transport of host plant material is fast (often sent by air) and very common nowadays. The life cycle of the pest is of sufficient duration to extend beyond time in transit.

#### **7.5. Detection of the Pest at Entry Inspection**

Eggs in plant tissue or prepupae and pupae either on the foliage or in the soil are almost impossible to detect by visual inspection. Mines and larvae can be detected, but low infestations are easily overlooked. According to Minkenberg (1988), in several countries, *L. trifolii* was only noticed by Plant Protection Services after the alarm had been given by growers who could not control a leafminer infestation chemically, and this is probably likely to occur with other *Liriomyza*'s as well.

#### **7.6. Pest Movement into Norway by Natural Means**

No documentation has been found that confirms or suggests that *L. sativae* can enter Norway naturally.

#### **7.7. Conclusion on Introduction Potential**

There is a great potential for introduction of *L. sativae* on infected plant material imported to Norway.

### **8. Overall Conclusion for Pest Risk Assessment**

The conclusion of the pest risk assessment for *L. sativae* is that this pest is of sufficient economic importance and has a great potential for introduction, establishment and spread in Norwegian greenhouses, to justify phytosanitary measures.

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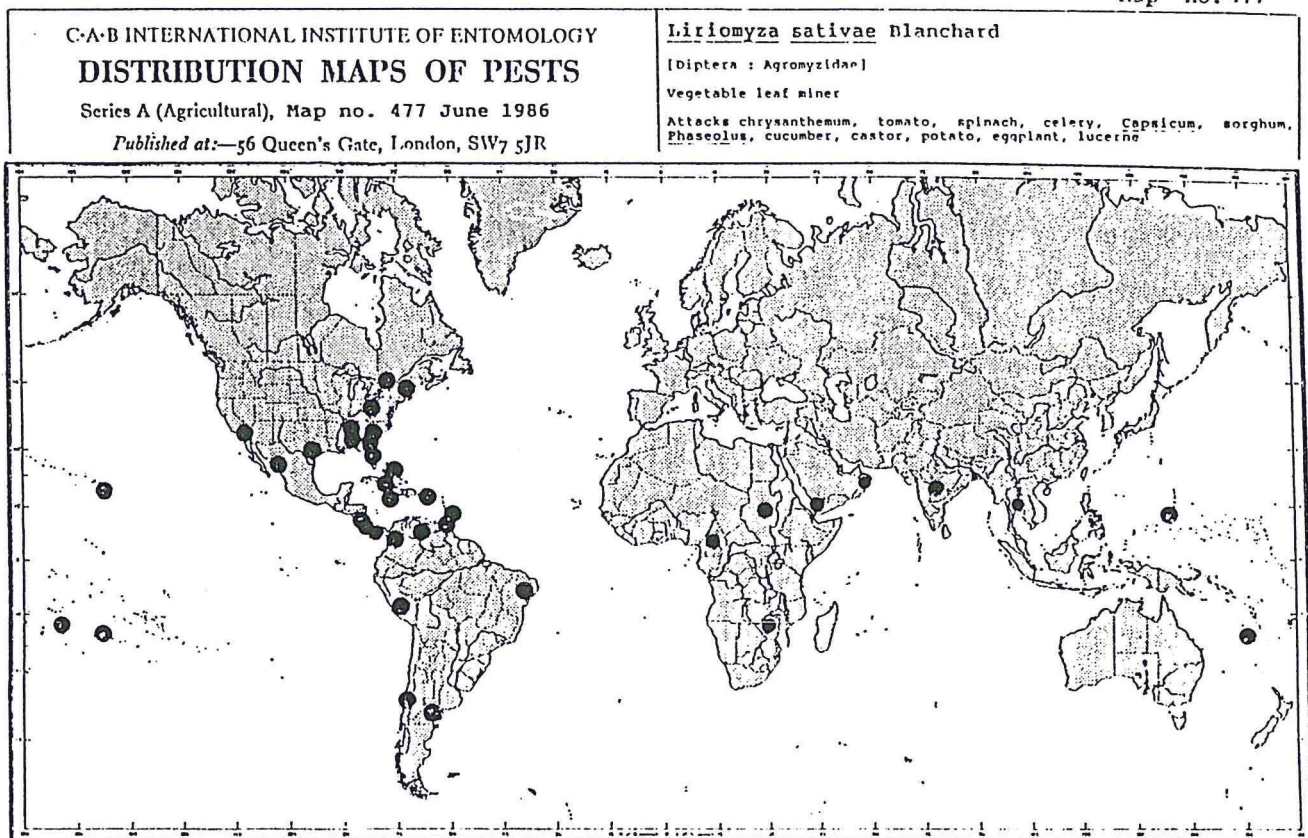
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*For list of countries in which this pest is known to occur, see overleaf*

Figur 5. The world distribution of *Liriomyza sativae*.  
Modified Distribution Maps of Pests, see text page 10 (CAB International Institute of Entomology, Series A (Agricultural), Map no. 477, June 1986).

Table 1. Economically important host plants of *Liriomyza sativae*, production in Norway, production value (NOK) and man-labour years.  
Data from the Norwegian Horticultural Growers Association.

Economically important hosts of <i>Liriomyza sativae</i>	Production in Norway		Production-value (1.000 NOK)	Man-labour years
<i>Spinacia oleracea</i>	200 daa	250 tonns	1.000	6
<i>Aster novi-belgii</i>	0,1 mill pot plants		1.100	1,5
<i>Chrysanthemum morifolium</i>	2,9 mill. pot plants	5,0 mill. cut flowers	66.753	73
<i>Chrysanthemum</i> sp.	0,4 mill. nursery plants		1.500	2
<i>Dahlia</i> hybrids	0,6 mill. nursery plants		3.300	3
<i>Dahlia</i> sp.				
<i>Cucumis sativus</i> greenhouse	238 daa	9,4 tonns	108.319	170
outdoors	638 daa	1,8 tonns	8.730	38
<i>Phaseolus vulgaris</i>	926 daa	796 tonns	2.969	17
<i>Pisum sativum</i>	8.322 daa	3,8 tonns	8.738	152
<i>Lycopersicon esculentum</i>	340 daa	19,4 tonns	112.872	243
<i>Solanum tuberosum</i>	183.500 daa	368.600 tonns	535.266	2.192
<i>Tropaelum majus</i>	0,1 mill. nursery plants		375	0,5
<i>Tropaelum</i> sp.				
<i>Apium graveolens</i>	750 daa	1,5 tonns	13.117	44



Table 2. Host plants of *Liriomyza sativae*. The table consists of plants where *L. sativae* has been reported (found), and are based upon data from Seymour (pers. comm.), Eppo database (1996).

Host plants for <i>Liriomyza sativae</i>	Occurrence in Norway	Major hosts = *** Minor hosts = ** Not classified = □
Amaranthaceae <i>Amaranthus</i>	annual/wild	□
Chenopodiaceae <i>Spinacia oleracea</i>	field vegetable	**
Compositae <i>Aster novi-belgii</i> <i>Aster</i> sp. <i>Chrysanthemum morifolium</i> <i>Dahlia hybrids</i> <i>Zinnia</i>	perennial annual/perennial/wild greenhouse greenhouse/annual annual/perennial	** □ ** ** □
Cucurbitaceae <i>Cucumis melo</i> <i>Cucumis sativus</i> <i>Cucurbita pepo</i> <i>Cucurbita</i> sp.	field vegetable/greenhouse (mostly privat growing) greenhouse/field vegetable field vegetable (mostly privat growing) greenhouse/field vegetable	** ** *** □
Euphorbiaceae <i>Ricinus communis</i>		**
Fabaceae <i>Lathyrus</i> <i>Medicago sativa</i> <i>Phaseolus lunatus</i> <i>Phaseolus</i> sp. <i>Phaseolus vulgaris</i> <i>Pisum sativum</i> <i>Vicia faba</i> <i>Vigna</i>	wild/(annual/vegetable) meadow/wild  field vegetable/privat growing field vegetable/privat growing field vegetable/privat growing/wild wild/(field vegetable)	** ** ** □ ** ** ** **
Solanaceae <i>Capsicum annum</i> <i>Lycopersicon esculentum</i> <i>Solanum melongena</i> <i>Solanum tuberosum</i>	vegetable, privat growing greenhouse/privat growing privat growing field crop/privat growing	** *** ** ***
Tropaeolaceae <i>Tropaelum majus</i>	annual/wild	□
Umbelliferae <i>Apium graveolens</i>	field vegetable	**

Table 3. Norwegian import of saleable plants and plants for further cultivation from different countries in 1994. The last column describes the situation for *Liriomyza sativae* in the respective countries.

Data from The Norwegian Horticultural Growers Association, EPPO/PQR Database, version 3.2, dated 1996-02. EPPO Reporting Service 1996, No. 6. Smith et al., 1992.

Country	Decoration Plants		Flowering Pot Plants		Sum	<i>Liriomyza sativae</i> A, B, C, X, E, I or N *)
	Saleable	For Further Cultivation	Saleable	For Further Cultivation		
Denmark	3.602.799	6.686.297	3.214.820	5.040.517	18.544.735	N
Holland	581.485	66.640	131.666	120.294	900.085	N
Belgium	50.793	17.075	860.381	0	928.294	N
Germany	0	0	1.007.038	143.650	1.150.688	N
Finland	0	0	0	0	0	I
France	0	0	0	195.796	194.500	N
Israel	0	0	0	337.260	337.800	N
Sweden	0	0	0	0	0	N
Spain	0	0	0	17.800	17.800	N
Guatemala	0	0	0	0	0	X
Costa Rica	0	66.390	0	0	66.300	X
Sri Lanka	0	253.815	0	0	253.816	N
Polen	0	0	0	0	0	N
USA	0	0	0	27.040	27.040	B
Sum	4.235.077	7.090.217	5.213.911	5.882.357	22.421.013	

\*) : A=Present, widespread, B=Present, restricted distribution, C=Present, few reports,  
X=Present, no distribution detail, E=Eradiated, I=Intercepted only, N=Never reported.

Table 4. Importation of cuttings and small plants of cut flowers (only host plants of *Liriomyza sativae*) from Holland in 1994. The last column describes the situation of *L. sativae* in Holland.

Data from The Norwegian Horticultural Growers Association, EPPO/PQR Database, version 3.2, dated 1996-02. EPPO Reporting Service 1996, No. 6. Smith et al., 1992.

	Importation of cuttings and small plants of Cut Flowers	<i>Liriomyza sativae</i>
Country	<i>Chrysanthemum</i> sp.	A, B, C, X, E, I or N *)
Holland	211.450	N
Sum	211.450	

\*) : A=Present, widespread, B=Present, restricted distribution, C=Present, few reports,  
X=Present, no distribution detail, E=Eradiated, I=Intercepted only, N=Never reported.



Table 5. Importation of economically important host plants of *Liriomyza sativae*. Production of pot plants, nursery plants and cut flowers, and import of saleable pot plants, cuttings and small plants (1994).

Data from the Norwegian Horticultural Growers Association.

Economically important hosts of <i>Liriomyza sativae</i>	Production in Norway of saleable plants (numbers)	Import of saleable plants to Norway (numbers)	Import of cuttings or young plants to Norway (numbers)
<i>Aster sp.</i>	160.000	145.592	51.418
<i>Chrysanthemum morifolium</i>	2.903.600	0	675.532
<i>Dahlia</i>	600.000	0	130.164
<i>Chrysanthemum morifolium</i>	5.000.000		211.450

Table 6. Plant commodities liable to carry *Liriomyza sativae* (EPPO/PQR Database, version 3.2, dated 1996-02).

Plants	Cut Flowers/Branches	Fruits/Vegetables
<i>Apium graveolens</i>	Ornamental plants	<i>Apium graveolens</i>
<i>Capsicum annum</i>		Vegetable plants
<i>Cucumis</i>		
<i>Lycopersicon esculentum</i>		
Ornamental plants		
Vegetable plants		

Table 7. Normal air temperatures for the year (i.e. the average for each month for the period 1961-1990) measured at five meteorological stations in the coastal area of southern Norway (NORPRE, Plant Protection Centre).

Month	Locality and Temperature (°C)				
	Tomb	Lier	Tjølling	Landvik	Særheim
January	-4,8	-5,5	-3,0	-1,6	0,5
February	-4,6	-5,0	-3,1	-1,9	0,4
March	-0,8	-0,4	0,4	1,0	2,4
April	4,2	4,8	4,6	5,1	5,1
May	10,3	11,0	10,5	10,4	9,5
June	14,7	15,7	15,0	14,7	12,5
July	16,1	17,1	16,7	16,2	13,9
August	15,0	15,7	15,5	15,4	14,1
September	10,6	11,3	11,7	11,8	11,5
October	6,0	6,6	7,6	7,9	8,6
November	0,6	0,6	2,5	3,2	4,4
December	-3,0	-3,5	-1,1	0,2	2,0



Table 8. Number of days with minimum air and soil temperatures below 0°C and minimum daily air and soil temperature in these periods at five locations in the coastal area of southern Norway (NORPRE, Plant Protection Centre).

Locality	Year	Days with mean air temperature below 0°C	Minimum mean daily air temperature (°C)	Days with mean soil temperature below 0°C	Minimum mean daily soil temperature (°C)
				<u>1 cm depth</u>	
Tomb <sup>1)</sup>	1991	77	-10,2	79	-6,7
Tomb	1992	75	-10,3	50	-1,8
Tomb	1993	90	-13,6	89	-1,5
Tomb	1994	87	-19,9	70	-0,7
Lier	1991	28	-6,8	38	-4,8
Lier	1992	92	-11,0	76	-4,5
Lier	1993	102	-14,8	97	-1,4
Lier	1994	107	-20,0	3	-0,02
Tjølling <sup>2)</sup>	1991	45	-10,2	18	-2,4
Tjølling	1992	58	-8,3	0	-
Tjølling	1993	73	-13,2	0	-
Tjølling	1994	73	-14,5	1	-0,4
				<u>10 cm depth</u>	
Landvik	1991	-	-	51	-1,9
Landvik <sup>3)</sup>	1992	34	-6,2	19	-1,1
Landvik <sup>4)</sup>	1993	52	-12,2	12	-1,0
Landvik	1994	57	-8,3	0	-
Særheim	1991	20	-6,1	17	-1,7
Særheim	1992	8	-3,7	0	-
Særheim	1993	27	-5,4	0	-
Særheim	1994	36	-5,2	19	-0,3

<sup>1)</sup> Lacking data for 4 days in March

<sup>2)</sup> Lacking data for 8 days in March and April

<sup>3)</sup> Lacking data for 6 days in January and February

<sup>4)</sup> Lacking data for 5 days in November