PLANT PROTECTION CENTRE

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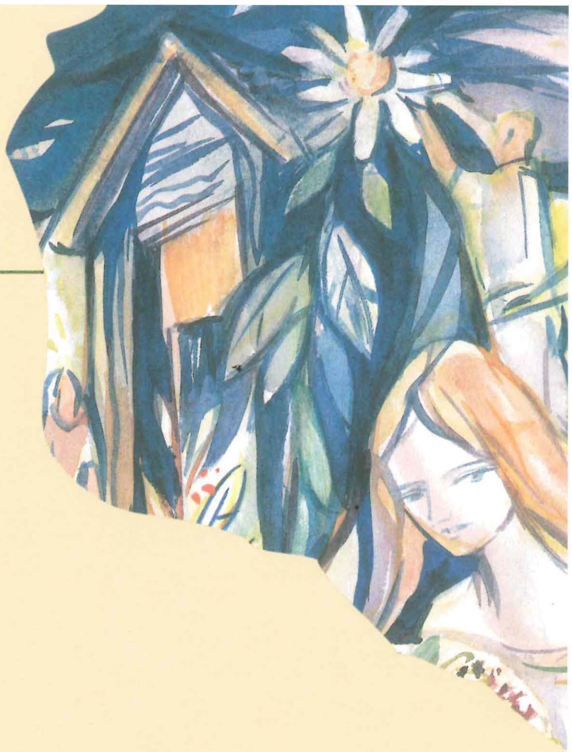

Pest Risk Assessment (PRA) for the American Serpentine Leaf Miner *Liriomyza trifolii*

Commissioned by the Norwegian Agricultural Inspection Service

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1. Endangered Area

The endangered area is Norway.

2. Identity and Geographic and Regulatory Criteria

Name: *Liriomyza trifolii* (Blanchard)
Synonyms: *Liriomyza allivora* Frick
Taxonomic position: Insecta: Diptera: Agromyzidae
Common names: American serpentine leaf miner, Chrysanthemum leafminer (English)
Mineuse du gerbera (French)
Floridaminierfliege (German)
EPPO A2 list: No. 131
EC Annex designation: I/A2
Norway: A list (Quarantine pests. Limit of tolerance: 0 %)
Significance: Two known infestation in two different greenhouses in the southern part of Norway in 1980. Eradicated.

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 quarantene pests: *Amauromyza maculosa, Liriomyza huidobrensis* and *Liriomyza sativae*. 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 simpliefied key (Smith et al., 1992). All identifications should be confirmed by a specialist.

Only adult males of *L. trifolii* (and also adult males of *L. bryoniae, L. huidobrensis, L. strigata* and *L. sativae*) 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*).

Electrophoretic methods has been developed to distinguish *L. trifolii* from *L. bryoniae* and *L. huidobrensis* (Oudman 1992). The identification can be done on each developmental stage of the pests (larvae, pupae and adults). This has to be done in a laboratory by a specialist. An electrophoretic method to distinguish *L. trifolii* from *L. sativae* (they belong to the same natural 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 quarantene rooms and greenhouses.

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

4. Establishment Potential

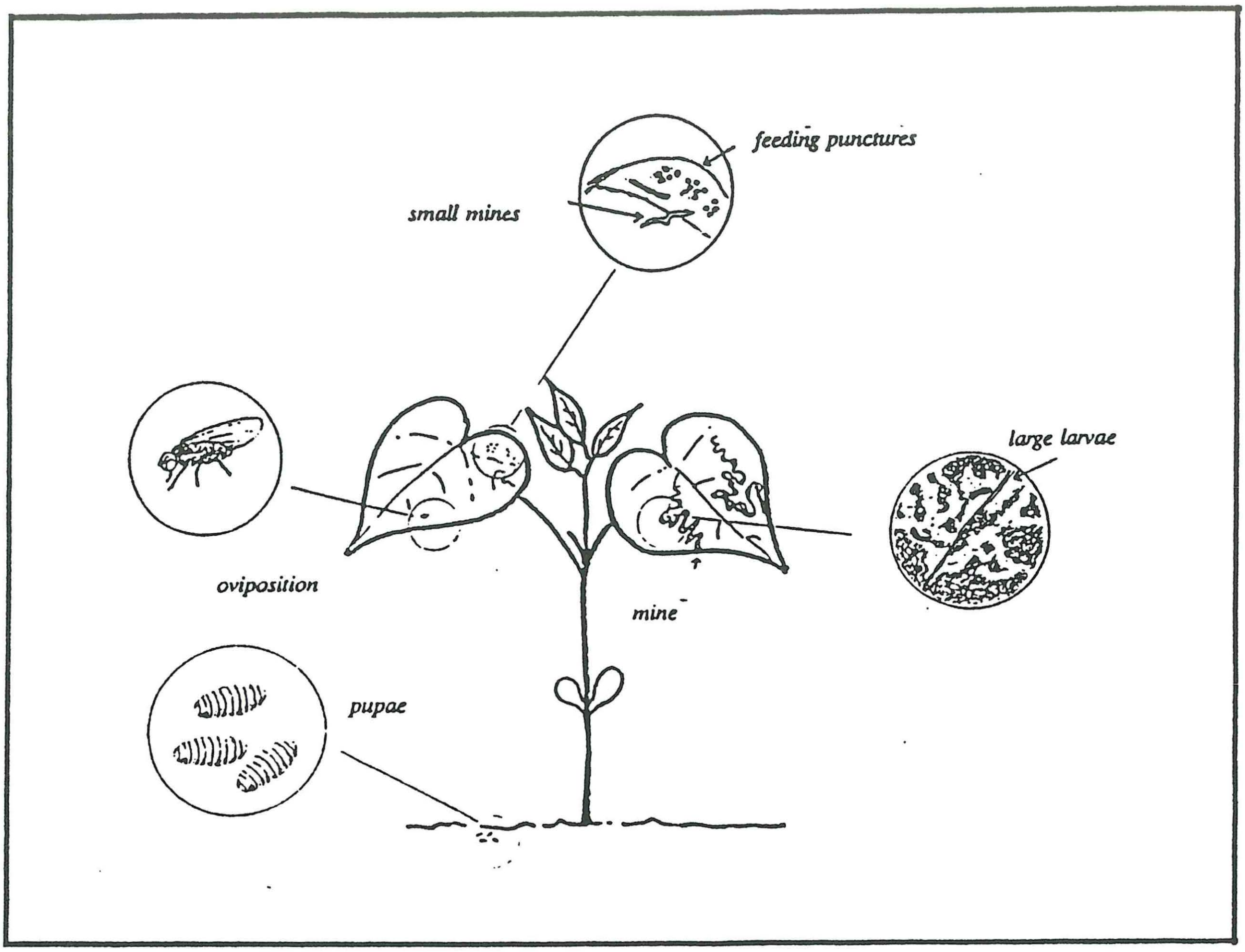
4.1. Biological Information of the Pest

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 usually takes place within the day of emergence (Minkenberg, 1990). Unfertilized females are unable to produce fertile eggs.

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. In southern

Florida, *L. trifolii* has two or three complete generations followed by a number of incomplete, overlapping generations.



Figur 1: Generalized lifecycle for leafminers (Liriomyza spp.) (Enkegaard, 1990).

Adults of *L. trifolii* 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.

Feeding and oviposition occurs throughout the daylight hours but *L. trifolii* feeds and oviposits most frequently around midday (Minkenberg, 1990). 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. trifolii* contain viable eggs.

Eggs are inserted just below the leaf surface (Smith et al., 1992). *L. trifolii* females laid 25 eggs each in celery at 15°C and 400 eggs at temperatures around 30°C. One female of *L. trifolii* laid 493 eggs in peas and another laid 639 eggs in chrysanthemums.

Eggs hatch in 2-5 days according to temperature (Smith et al., 1992). Developmental time is shown for some temperatures and host plants in table 4, Appendix.

The larva feeds in the leaf on the mesophyll layer producing a contorting mine (Minkenberg, 1990). In chrysanthemum, *L. trifolii* larvae prefer to feed the palisade mesophyll. The larva which is originally colourless, darkens to yellow as it matures. Three larval instars develop in the leaf and the mines become progressively larger with each moult. The duration of larval development also varies with temperature and host plant, but is generally 4-7 days at mean temperatures above 24°C. However, the larval stage may be as short as 3 days or as long as 26 days (table 4., Appendix).

The larva makes an exit hole in the leaf surface at the end of the mine, through which it emerges to pupate (Minkenberg, 1990). The larval emergence from leaves occurs primarily in the morning. The opening can be in the upper or lower leaf surface. Pupation normally takes place in the soil just beneath the surface, or in the darkest accessible area. Developmental time for the pupal stage varies with temperature and host plant (table 4., Appendix), and the pupa is orange-yellow and turns brown as it gets older.

4.1.2. Development, Diapause and Hibernation

The development of *L. trifolii* in relation to temperature is discussed by Minkenberg (1990). Temperature is a factor causing large differences in the development of *L. trifolii* and its reproduction. The host plant is a second factor with a considerable impact on the performance of *L. trifolii*. Other distinct characteristics of the host plant influencing performance of *L. trifolii* are its cultivar and its growing conditions, e.g. the amount of fertilizers applied.

According to Minkenberg (1990) the developmental time of *L. trifolii* on tomato at 25°C is as follows (table 5, Appendix):

Eggs:	2.7 days
Larvae:	4.6 days
Pupae:	9.3 days
Total:	16.6 days

The egg stage was proportionally 12-16 %, the larval stage 24-29 % and the pupal stage was 55-61 % of the total time spent as an immature on tomato (table 5, Appendix) (Minkenberg, 1990). Proportionally longer egg and larval stages and shorter pupal stages have been found on bean, chrysanthemum and celery. *L. trifolii* larvae were seen feeding both night and day except during moulting.

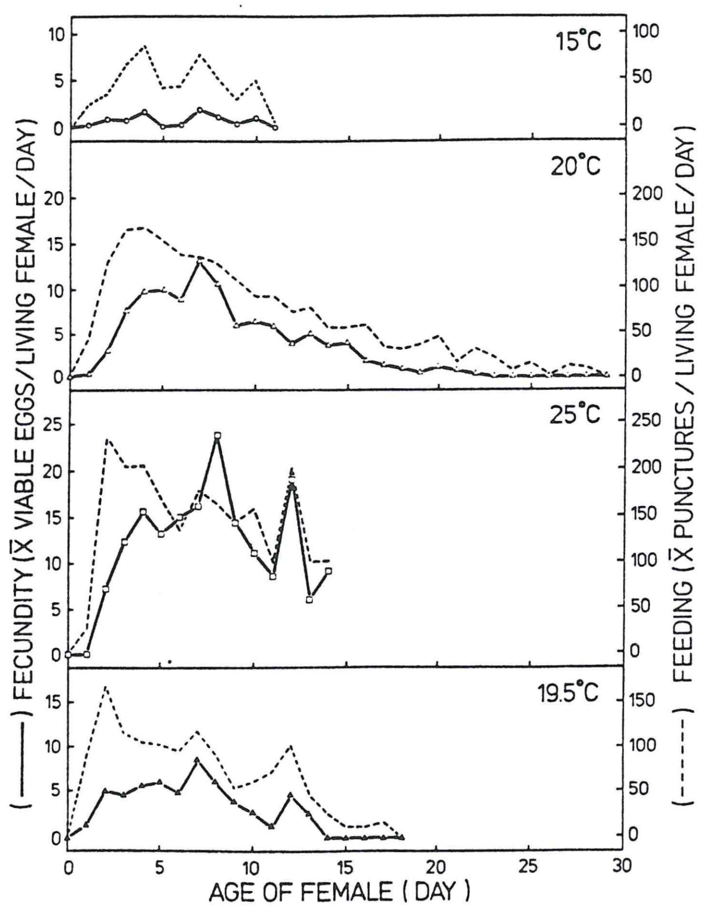
The threshold temperature for oviposition was estimated by Minkenberg (1990) to 12,6°C (table 6, Appendix). The threshold temperature for development of the eggs was estimated to 6,9°C, and through the larval stage a threshold temperature of 8,2°C was estimated. The theoretical temperature-threshold for total development was 9,0°C. *L. trifolii* is not known to enter diapause.

Based on the observations and estimates (25°C) made by Minkenberg (1990) (table 5 & 6, Appendix) the degree-days required for development of *L. trifolii* could be estimated as follows:

Egg:	48.9 degree-days
Larvae:	77.3 degree-days
Pupae:	139.5 degree-days
Total:	265.7 degree-days

The estimates above are made by the author, and are not based on observations in laboratory or field.

Olivera et al. (1994) found that the oviposition behaviour of *L. trifolii* seems to be markedly reduced at low temperatures, when very few eggs are laid. Other authors, mentioned by Olivera et al. (1994), has found a total absence of ovipositing at temperatures of less than 12°C. However, at increased temperatures, the feeding habits and oviposition activity of females also increased, with optimal behaviour at 30°C (table 3, Appendix). These and previous data are in keeping with the species tropical origin.



Figur 2. Gross reproduction and feeding of Liriomyza trifolii at three constant temperatures and one alternating temperature (Minkenberg, 1990).

Minkenberg (1990) found that on tomato most feeding punctures per female occurred at 20° C and with the least at 15° C. However, feeding rate (averaged punctures/female/day) was greatest at 25° C. The feeding activity of a female was age dependent and increased sharply during the first days of her life to a peak at Day 2 or 4, after which the feeding rate declined with age (fig. 2).

Mean fecundity was 79 eggs at 20° C and only 5 at 15° C (Minkenberg, 1990). Mean oviposition rate varied from nine eggs per day at 25° C to six at 20° C and one at 15° C. Oviposition rate showed a slow increase with a peak at Day 7 or 8, after which a slow decrease followed, with the exception of the 15° C treatment where egg production was constantly low (fig. 2).

Minkenberg (1990) reports that the optimum temperature for population growth is near 25° C. The generation time decreases with temperature from 48 days at 15° C to 24 days at 25° C. At 20° C a population may multiply more than 25 times per generation.

4.1.3. Host Plants Reported

L. trifolii is a highly polyphagous species, and feeds on a large number of flowers, vegetables and weeds (Parella, 1983). The long list of host plants seems to increase as the pest invades new territories. Some of the more important economic plants are Cucurbitaceae (gherkin, cucumber, melon), Fabaceae (various bean species), Solanaceae (pepper, tomato, potato, eggplant), Caryophyllaceae (*Dianthus* spp., *Gypsophila* spp.), Chenopodiaceae (spinach, beet) Compositae (thistle, endive, aster, *Chrysanthemum* spp., *Gerbera* spp., lettuce), Cruciferae (Chinese cabbage, radish), Umbelliferae (carrot, celery, parsley) and Verbenaceae (*Verbena* spp.). Host plants reported are listed in table 2, Appendix.

Although *L. trifolii*'s name is derived from a host in the Leguminosae (Fabaceae), evidence from Florida indicates that its most favoured host family is the Compositae (Spencer, 1973).

Wild Host Plants in Norway
The following species are found in Norway (table 2, Appendix):
Aster sp., *Capsella bursa-pastoris, Chenopodium album, Chrysanthemum* sp., *Dianthus* sp., *Epilobium* sp., *Gypsophila* sp., *Gypshophila paniculata, Medicago sativa, Pisum sativum, Plantago lanceolata, Plantago major, Ranunculus* sp., *Senecio jacobaea, Senecio vulgaris, Solidago* sp., *Trifolium, Tropaelum majus, Vicia faba* (Lid, 1987).

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

In greenhouses important host plants for the pest are cucumber, lettuce and tomatoes among the vegetables, and *Alstromeria, Chrysanthemum, Dahlia* hybrids, *Dianthus*, *Gerbera* sp., *Gypshophila paniculata, Gypsophila* sp. among the ornamental plants.

Outdoors there are several field vegetables which are reported as host plants for *L. trifolii*: bean species, carrot, celery, gherkin, chinese cabbage, lettuce, onion, parsley, pea, potato, radish, spinach and sugarbeet. Ornamental plants, reported as host plants for *L. trifolii*, are also grown outdoors as annuals, cut flowers or perennials, eg. *Antirrhinum* sp., *Aster* sp., *Chrysanthemum* sp., *Dahlia* hybrids, *Dianthus* sp., *Gypsophila* sp., *Ranunculus* sp., *Tagetes* sp., *Tropaelum, Verbena* hybrids and *Zinnia.* (See table 2, Appendix, for complete list.)

During the summer several of the host plants listed in table 2, Appendix, are grown in privat 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. 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.

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. trifolii* prefering celery and *L. sativae* prefering tomatoes. However, when celery fields were harvested, *L. trifolii* readily moved into tomato plantings.

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 has not been properly cleaned.

Minkenberg (1988) mentioned several reasons for the rapid spread of *L. trifolii* (and other insect species) throughout the world:

- The insects escape chemical control in their country of origin because of a reduced susceptibility to pesticides.
- It also demonstrates the dramatic consequences of an 'insecticide-use policy' that disregards development of insecticide resistance.
- An effective control method was not available at the time of its arrival in most countries, which facilitated its establishment.
- An incorrect assessment of the pest situation. Initial diagnosis was delayed due to superficial similarity with the damage caused by indigenous leafminers.
- 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.

4.1.5. Adaptability

The Pest
L. trifolii has high adaptability due to the high reproduction rate and fast development on suitable host plants.

Since 1970 the pest has invaded new territories and established in many countries all over the world (Minkenberg, 1988). This shows high adaptability to environments with nonsimilar climatic conditions compared to the area of origin. However, there has not been found any evidence of pupal diapause in *L. trifolii* (as in *L. huidobrensis*) and this makes it unlikely that the pest has adapted to survive outdoors in areas with cold winters.

Host plant range
The host plant range of *L. trifolii* has increased during the last thirty years as the pest has entered new areas. Considering the differences in flora between origin and outbreak areas, the pest seems to have high adaptability to new host plants. Spencer (1973) confirmed records on ten families, Saito (1994) mentioned that *L. trifolii* attacks about 25 families (he does not name the families). The list of host plants presented in this assessment, table 2, Appendix, includes hosts in 17 families (Seymour (pers. comm.), EPPO database (1996), Baufeld & Motte (1992), Powell (1981)), but according to Saito (1994) the number of host families is probably higher.

Geographical range
The leafminer *L. trifolii* was originally a nearctic and neotropical species, and is thought to be endemic to Florida (US) (Minkenberg, 1988). By 1970 its range had extended northwards through the eastern USA as far as Ontario (Ca), and southwards to the Bahamas, Guyana and Venezuela. In the EPPO region *L. trifolii* was first detected in the Netherlands in 1976 (Smith et al., 1992).

L. trifolii has become a serious pest on ornamental and vegetable crops in the Netherlands, France, Italy, South Africa, Canada, Israel, Colombia, Spain and the USA (Green et al., 1985). It is also found sporadically in Denmark, the United Kingdom and Germany.

Minkenberg (1988) reported that *L. trifolii* has been known in Japan since 1949. The distribution was limited to the northern region of Japan and the pest occurred only on leguminous plants. It was not considered as a pest. This has later turned out to be another species *L. congesta* (Saito, 1994), and *L. trifolii* has only been reported in Japan since 1990, where it is concidered as a serious pest.

Tolerance to low temperatures
Outdoors in Japan, the largest number of *L. trifolii* adult flies are observed from late July to early August, and they are not seen in the winter (Saito, 1994). On the other hand, *L. trifolii* continue infesting all year round in greenhouses, and at least 7-8 generations are likely to occur. Serious damage to outdoor crops is from summer to autumn in Japan.

De Goffau (1991) reported that in the Netherlands *L. trifolii* is considered clearly more sensitive to cold than *L. huidobrensis* .

The results from Minkenberg (1990), Olivera et al. (1994) and Saito (1994) shows that temperature is a factor causing large differences in oviposition behaviour, oviposition rate and development rate of *L. trifolii* (table 3, 4 & 5, Appendix). The theoretical temperature-threshold for total development of *L. trifolii* was 9,0°C and threshold temperature for oviposition 12,6 (Minkenberg, 1990) (table 6, Appendix). At temperatures less than 12,0°C there was a total absent of ovipositing (Olivera et al., 1994).

The effect of temperature (15°, 20°, 25° and 19,5°C) on mortality of different stages of *L. trifolii* was also discussed by Minkenberg (1990) (table 7, Appendix). He found that mortality showed no constant relationship with temperature. Highest total mortality (73 %) occurred at 15°C, whereas most immatures reached adulthood near 20°C. At the alternating temperature (16°-22° C) mortality was relatively low and 64 % of the eggs survived to adulthood.

Adult emergence of *L. trifolii* is delayed at low temperatures (Smith et al., 1992). In the laboratory *L. trifolii* survived cold storage at 4,5°C for 8 weeks.

Newly laid eggs in chrysanthemums survived for up to 3 weeks in cold storage at 0°C (Minkenberg, 1988). Under the same conditions eggs incubated for 36-48 h were killed after one week. All larval instars were killed after 1-2 weeks at 0°C. Pupae died after exposure to 1,1°C for 20 days, but some adults emerged at 14-26° C from pupae that had been kept at 1,1°C for 15 days. It is concluded that *L. trifolii* is most tolerant to low temperatures at the pupal stage.

The leafminer *L. trifolii* was originally a nearctic and neotropical species, and is thought to be endemic to Florida (US) (Minkenberg, 1988). Populations of *L. trifolii* originating from Florida can probably not survive in areas where the winters are severe with sub-zero temperatures for extended periods. In southern England, however, a few pupae remained viable outdoors for over two months during the winter, but no evidence of pupal diapause was found. This non-diapausing form has been exported and occurs in Canada, northern USA, and western, northern and eastern Europe, but only in heated glasshouses. Reinfestations in spring from outdoor populations are therefore unlikely in temperate areas.

4.2. Geographical Distribution

4.2.1. World Distribution

The Pest

Europe: Austria, Belgium, Denmark (eradicated), Finland (eradicated), France, Greece, Italy, Malta, Netherlands, Norway (eradicated), Poland, Portugal, Romania, Slovenia, Spain, Sweden (eradicated), Switzerland, United Kingdom (eradicated), earlier Yugoslavia.
Asia: Cyprus, India, Israel, Japan, Lebanon, Philippines, Taiwan, Turkey.
Africa: Egypt, Ethiopia, Kenya, Mauritius, Nigeria, Reunion, Senegal, South Africa, Tanzania, Tunisia.
North America: Canada (outside and under glass in Ontario), Mexico, United States (outside in New Mexico, California, most eastern states from Florida northward to New Jersey, Wisconsin and Iowa, under glass in other southern states).
Central America and Caribbean: Bahamas, Barbados, Costa Rica, Dominican Republic, Guadeloupe, Guatemala, Martinique.
South America: Brazil, Colombia, French Guiana, Guyana, Peru, Venezuela.

(EPPO/PQR Database, version 3.2, dated 1996-02. Smith et al., 1992.)

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

4.2.2. Occurrence in Norway

The Pest
In the southern part of Norway (Akershus and Vest-Agder county), in 1980, there have been two known infestations of *L. trifolii* in two commercial greenhouses. One of the growers had imported chrysanthemum cuttings from the Canary Islands in 1980. The other grower had attack of *L. trifolii* on *Gerbera*.

Eradication: Immediate action was taken by the Norwegian authorities with a policy of eradication based partly on destruction of infected material and partly on treatment with pesticides. The eradication campaign was successful.

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 there are also some regions with higher densitiy 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

In 1981 (16.01) *L. trifolii* was included in the Norwegian list of quarantine pests (A list), with a limit of tolerance 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. trifolii* 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 and tomatoes, and plant material (except seeds and pot plants) of *Capsicum*, carnations, chrysanthemums, *Gerbera, Gypsophila* and *Senecio hybridus* from countries where the pest occurs must either have been inspected at least every month during the previous 3 months and found free from the pest, or have been treated by a recommended control method.

According to Minkenberg (1988) the case of *L. trifolii* clearly shows the powerlessness of plant protection services in most countries. Many insects escape national quarantine procedures, despite careful inspection of the steadily increasing volume of traded plant material.

4.3.2. Chemical Measures

Chemical control of *L. trifolii* (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 becoming unavailable because of health, safety and environmental concerns (Bethke et al., 1994).

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 egg. Dichlorvos is most effective against the adults, deltamethrin are also effective.

To control *L. trifolii* in young seedlings after planting effective insecticides must be sprayed several times at intervals of 7-10 days (Saito, 1994). When the plant is young and small, granular systemic insecticides are also effective. For glasshouse lettuce a single treatment when the pest is detected may be sufficient, but it may be necessary to repeat the treatment at 3-5 days intervals (Anon., 1994).

Among the insecticides mentioned above, only dichlorvos and deltamethrin is permitted for use in the PRA area, which means that there are no effective insecticides available against the larvae. The time of application for dichlorvos (in Norway) is 4 days and for deltamethrin is 14 days (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. trifolii* 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). Among this genus, *L. trifolii* developed resistance to insecticides very quickly, and its resistant level was very high. For example, in California, ca. 20-fold resistance to permethrin had been documented 2 years after its registration in 1979. In Canada, it was confirmed that susceptibility to pyrazophos dropped approximetely 15-fold in one year. The average effective field-life of an insecticide used against this species in Florida had been less than 3 years. *L. trifolii* in Japan also showed high resistance to insecticides.

Observations from Japan, from a population of *L. trifolii* reared in the laboratory without chemical application (18 generations), suggests that the susceptibility may not be restored even if the threatment of insecticides is restricted for long time (Saito, 1994).

4.3.4. Biological Measures

Celery is an important agricultural commodity in California, with annual returns exceeding $ 145 million on 8500 ha (Trumble, 1990). During the mid- to late 1970's. introduction of *L. trifolii* began causing substantial economic losses. In response to the loss of efficacy of many agricultural chemicals for leafminer control, and the potential for rapid development of insecticide resistance, interest increased in the development of a biological control or resistance management program that would maximize pest suppression while minimizing insecticide input. The appeal of such a program was enhanced by reports that many insecticides were generating outbreaks of *Liriomyza* species.

Parasitoids registrered for leafminer control in celery by Trumble (1990), included species in the families Eulophidae: *Diglyphus* spp. (69 % of total parasitoids), *Chrysonotomyia punctiventris* (Crawford) (16 %), *Chrysocharis parksi* (Crawford) (9,1 %), *Chrysocharis ainsliei* (Crawford) (1 %); Pteromalidae: *Halticoptera circulus* (Walker) (4 %) and Braconidae: *Opius* spp. (>1%). Naturally occurring parasitoids combined with documenting of injury threshold levels and low pesticide input have given promising results for reduced pesticide input in the future. Particularly if this could be combined with leaf miner-resistant cultivars.

In greenhouse chrysanthemums a combined program utilizing both the entomopathogenic nematode, *Steinernema carpocapsae*, and the parasitoid, *Diglyphus begini* (Ashmead), as biocontrol agents for *L. trifolii* are under development (Sher & Parella, 1996). Neither agent alone however, has proven to be control- or cost-effective in ornamental greenhouse production of chrysanthemums. During the work both positive and negative aspects of the combined use is seen. Once the major positive and negative effects on both the nematode and wasp populations due to their interactions are determined, this information can be used to properly develop a spray and release timing schedule for the two agents.

Biological control of *L. trifolii* on yardlong beans with release of the two parasitoids *Chrysocharis oscinidis* (Ashmead) and *Ganaspidium utilis* (Cynipidae) has shown that leaf miner damage was very low compared with the infestation observed earlier year on Pohnpei (Freely Associated States of Micronesia) (Suta & Esguerra, 1993).

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 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 of *L. trifolii* and must be removed (Saito, 1994). 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 next cropping.

4.3.6. Resistant Plants

Resistance of selected interspecific *Lycopersicon* hybrids to *L. trifolii* has shown promising results (Erb et al., 1993), but there is still a way to go before the level of resistance is transfered to *L. esculentum* (tomato).

The potential for resistance to *L. trifolii* in *Apium* L. species was evaluated and discussed by Trumble and Quiros (1988). The results indicated substantial antibiosis in some of the species, and further selection of parental plants from the wild species *A. panul* and *A. chilense* for high fertility and absence of chromosomal aberriations were suggested. Further investigations would determine if the resistant traits is dominant or recessive, and the presence of undesirable chemicals. This information will provide the background data required before undertaking a large-scale celery breeding program for leafminer resistance.

4.3.7. Monitoring

Continous 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. trifolii.*

4.3.8. Integrated Pest Management Measures

The use of multiple tactics to control *L. trifolii* (including cultural, physical, mechanical, biological and chemical controls) is a common sense approach, and one that provides long term control without selecting for resistance to any of the control options (Sher & Parella, 1996). While this appears very reassuring, it is clear that many chrysanthemum-growers (USA) are relying solely on the use of abamectin to keep this pest under control. Many growers apply the material on a weekly basis. The product cannot survive when used in such a way given the propensity of *L. trifolii* to develop resistance to insecticides.

In Italy integrated pest control in greenhouse chrysanthemums is being developed to reduce the number of insecticide treatments, with the natural enemy *Diglyphus isaea* (Walker) to control leafminers and *Orius* spp. to control thrips (Del Bene et al., 1994). The necessary conditions for this to be successful are: 1) Regular sampling to ascertain pest and parasite-predator impact. 2) A period of non-marketability for the crop when biological control could be tried (the first 4-6 weeks of crop growth, because the foliage on the plants at this time is not present when the final flowers are cut). 3) The availability of good insecticides (abamectin) which offer effective pest control when biological control fails.

In the Netherlands an IPM programme is being developed for leafy and tuberous crops, such as lettuce and radish (van der Linden, 1993). Biological control of leafminers in lettuce is possible, but the use of natural enemies or selective chemicals against other pests and diseases is strictly necessary.

In Israel the development of an IPM programme for greenhouse crops has included tests of different screens aimed to minimize pest immigration from outside (Berlinger et al., 1993). In experiments the immigrant populations of *L. trifolii,* whiteflies, western flower thrips and aphids were significantly lower than outdoors and in most cases it was below the acceptable economic damage threshold. Preliminary results showed that the indoor pest populations must be controlled and this can be done in most cases by parasitoids and predators. However, against other pests «safe» insecticides must be tested and integrated into this IPM system.

4.4. Conclusion on Establishment Potential

There is a great potential for *L. trifolii* to establish in the greenhouse environment in the PRA area. There are also a possibility for establishment outdoors during the summer. Experiences from other parts of Europe indicates that overwintering of *L. trifolii* in the PRA area is most unlikely.

5. Spread Potential after Establishment

5.1. Distribution of Host Plants in Norway

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

Aster sp. 4 species, (including escapes), *Capsella bursa-pastoris* is distributed in all parts of Norway, *Chenopodium album* is usually in crops, gardens and around waste disposal sites, *Chrysanthemum* sp. 2 species, 1 is distributed up to Finnmark county and 1 around waste disposal sites, *Dianthus sp.* is distributed in all parts of Norway (5 species, with some differences in distribution among the species), *Epilobium* sp. is distributed in all parts of Norway (18 species with some differences in distribution among the species), *Gypsophila paniculata* is escaped , *Gypsophila sp.* one species is distributed in all parts of Norway and one around waste disposal sites, *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* is escaped, *Plantago lanceolata* is distributed up to Finnmark county, *Plantago major* is distributed in all parts of Norway, *Ranunculus* sp.is distributed in all parts of Norway (31 species, with some differences in distribution among the species), *Senecio jacobaea* up to Trøndelag county, *Senecio vulgaris* all parts of Norway around fields,gardens and waste disposal sites, *Solidago* sp. 2 species, *Trifolium* is distributed up to Finnmark county (19 species, with some differences in distribution among the species), *Tropaelum majus* is escaped, *Vicia faba* is escaped (Lid, 1987).

Cultivated Host Plants
Host plants of *L. trifolii* 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 almost every greenhouse grows at least one host plant of *L. trifolii* (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. trifolii* within Norwegian greenhouses is therefore great.

Spread by natural means

Spread of *L. trifolii* 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. trifolii* in Norway

Diglyphus begini (Ashmead) has been found in Jostedalen (Compton, 1981) and at Ås (Hågvar et al., 1994), and is probably distributed in the Southern Norway (Hofsvang, pers. comm.). *Diglyphus isaea* (Walker) has been found in the Southern parts of Norway (Trandem, pers. comm.). *Halticoverpa* circulus (Walker) and *Chrysonotomyia formosa* is present in Norway (Compton, 1981).

The presence of *Chrysonotomyia punctiventris* (Crawford), *Chrysocharis parksi* (Crawford), *Chrysocharis ainsliei* (Crawford), *Chrysocharis oscinidis* (Ashmead), *Ganaspidium utilis* (Cynipidae), *Hemiptarsenus semialbiclavus* (Girault) or *Opius* spp., has not been investigated so far.

The nematode *Steinernema carpocapsae* has so far not been found in Norway (Haukeland pers. comm.).

5.4. Conclusion on Spread Potential

After establishment in the PRA area, the spread potential within greenhouse environments of *L. trifolii* 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 to reinfest greenhouses during the the summer.

6. Potential Economic Importance

6.1. Type of damage

The damage caused to plants by *L. trifolii* is both aesthetic and physiological (Green et al., 1985). The leaf punctures caused by the adults develop in expanding leaves to blemishes called stipplings and larval mining causes an unsightly brown to brownish-white leaf mine which greatly detracts from the visual appearance of the leaf. As larval mining kills the leaf cells, it reduces the photosynthetic capacity of the leaf. Therefore, leafminer damage can delay the development of plants, particularly at the seedling stage, and at the time of flowering. The number and/or quality of flowers may also be reduced.

In chrysanthemums, wounds caused by the feeding and oviposition of *L. trifolii*, provides an ingress bacterial leaf spot, *Pseudomonas cichorii,* (Matteoni & Broadbent, 1988). The number of leaf spots that developed on plants exposed to the leaf miner before inoculation was linearly related to the number of wounds caused by the leaf miner. *P. cichorii* requires wet conditions for disease development. Overhead irrigation (routine in propagation stages of chrysanthemum production, as well as during production of seasonal pot mums under crowded conditions) or even pesticide spraying may disseminate bacteria and provide conditions favourable for infection.

Alternaria leaf blight, incited by *Alternaria cucumerina* (Ellis & Everh.), is an important disease of muskmelon, *Cucumis melo,* in the south-eastern United States (Chandler & Thomas, 1991). In laboratory experiments Chandler & Thomas found that *L. trifolii* puncture wounds significantly increased the incidence of infection of *C. melo* by *A. cucumerina.* Although it is well established that muskmelon leaves can be infected by *A. cucumerina* without the presence of leaf miner punctures, these studies demonstrate that these punctures provide wound sites that enhance the infection process.

6.2. Crop Losses

In young plants and seedlings, mining may cause considerable delay in plant development leading to plant loss (Smith et al., 1992). *L. trifolii* is now the major pest of chrysanthemums in North America. Vegetable losses in the USA are also considerable, for example losses for celery were estimated at US$ 9 million in 1980.

On Guam, in the Mary Islands, *L. trifolii* was accidently introduced in the late 1970's (Schreiner et al., 1986). This resulted in serious crop losses to fresh pole beans (*Phaseolus vulgaris*) and yard-long beans (*Vigna unguiculata*) which are among the principle vegetable crops grown on Guam.

The production of plants and vegetables in greenhouses in Norway is economically important. In 1995 the total production-value of vegetables (lettuce, cucumber and tomatoes, all host plants of *L. trifolii*), was 265.980.000 NOK (table 1, Appendix). The production-value of ornamental host plants (pot plants, cut flowers, nursery plants) was 145.160.000 NOK (table 1, Appendix). The number of man-labour years involved in the greenhouse-production (vegetables and ornamental plants) of host plants of *L. trifolii* in Norway, has been estimated to 643,5 (table 1, Appendix).

The production-value of vegetables/crops (only host plants of *L. trifolii*) grown outdoors during the summer was 945.104.000 NOK in 1995 (table 1, Appendix). The number of man-labour years involved in outdoors production (vegetables/crops) of the same host plants of *L. trifolii* has been estimated to 3.602 (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.), and one of these species was *Dianthus caryophyllys,* a host plant of *L. trifolii* (table 1 & 2, Appendix).

6.4. Increase in Control Costs

There are no information available of the costs of eradicating *L. trifolii* from Norway in 1980, but the costs of eradicating *L. huidobrensis* 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 of 2.010.500,- NOK, 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 one campain of eradicating *L. trifolii* in 1980 and another in 1982 (Rautapää, 1984). In 1980 eradication from eight greenhouses caused total costs of 380.000 Fmk to the government, and in 1982 the corresponding figure with 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.

Rautapää (1984) found that when all the costs caused by 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 the pest, as done in 1980.

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^2 is used (Sæthre & Hofsvang, 1995). Greenhouse lettuce is also grown with minimum use of pesticides (Sæthre & Hofsvang, 1996). For lettuce grown in water-culture (Grand Rapid) the total amount of active ingredients used per 100.000 lettuces was 0.008 kg, and 0.11 kg active ingredients per 1.000 m^2 for ordinary grown lettuce. The pesticide situation in cucumbers was a total use of 0.607 kg active ingredients per 1.000 m^2. Establishment of *L. trifolii* in Norwegian greenhouses would present a serious threat to the present and very positiv pesticide-situation for greenhouse vegetables in Norway.

There are no IPM-programmes for ornamental plants in Norwegian greenhouses at the moment. However, a project with the aim to increase the use of biological control in ornamental plants and cucumber is going on in Norway.

6.6. Environmental damage

Establishment of *L. trifolii* 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. trifolii* in its existing geographic range has not been found.

6.7. Conclusion on Potential Economic Importance

The damage caused by *L. trifolii* 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, lettuce and cellery). The effects on ongoing and planned IPM-programmes would be negative according to the level in use of pesticides 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. trifolii* shown in figur 3 (Appendix) (which presumably began on chrysanthemum cuttings exported from Floridan multiplication farms to Colombia from around 1968 (Minkenberg, 1988)), confirm that the possibility for association is still high.

7.2. Import of Host Plants to Norway

Importation of host plants of *L. trifolii* to Norway is listed in table 8-10, Appendix. Interceptions of *L. trifolii* in other countries has most commonly occurred on imported *Chrysanthemum*, but also on *Gerbera, Gypsophila* and other mainly floricultural plant species (Minkenberg, 1988). Plant commodities liable to carry *L. trifolii* are listed in the EPPO/PQR database (1996) (table 11, Appendix), and includes among others, *Chrysanthemum morifolium, Dianthus caryophyllus, Gerbera jamesonii, Gypsophila paniculata, Senecio cruentus*, ornamental and vegetable plants, fruits and vegetables. *Chrysanthemum* sp., *Dianthus caryophyllus* and *Gypsophila paniculata* are imported to the PRA area from countries where *L. trifolii* is present, with a restricted distribution and from countries were it is present/widespread (table 8-10, Appendix).

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 8-10, Appendix.

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

The many interceptions of *L. trifolii* 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 plant material (host plants of *L. trifolii*) 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.

7.6. Pest Movement into Norway by Natural Means

No documentation has been found that confirms or opens the possibility that movement by natural means could be a way for *L. trifolii* to enter Norway.

7.7. Conclusion on Introduction Potential

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

8. Overall Conclusion for Pest Risk Assesment

The conclusion of the pest risk assessment for *L. trifolii* is that this pest is of sufficient economic importance, and has a great potential for introduction, establishment and spread, for phytosanitary measures to be justified.

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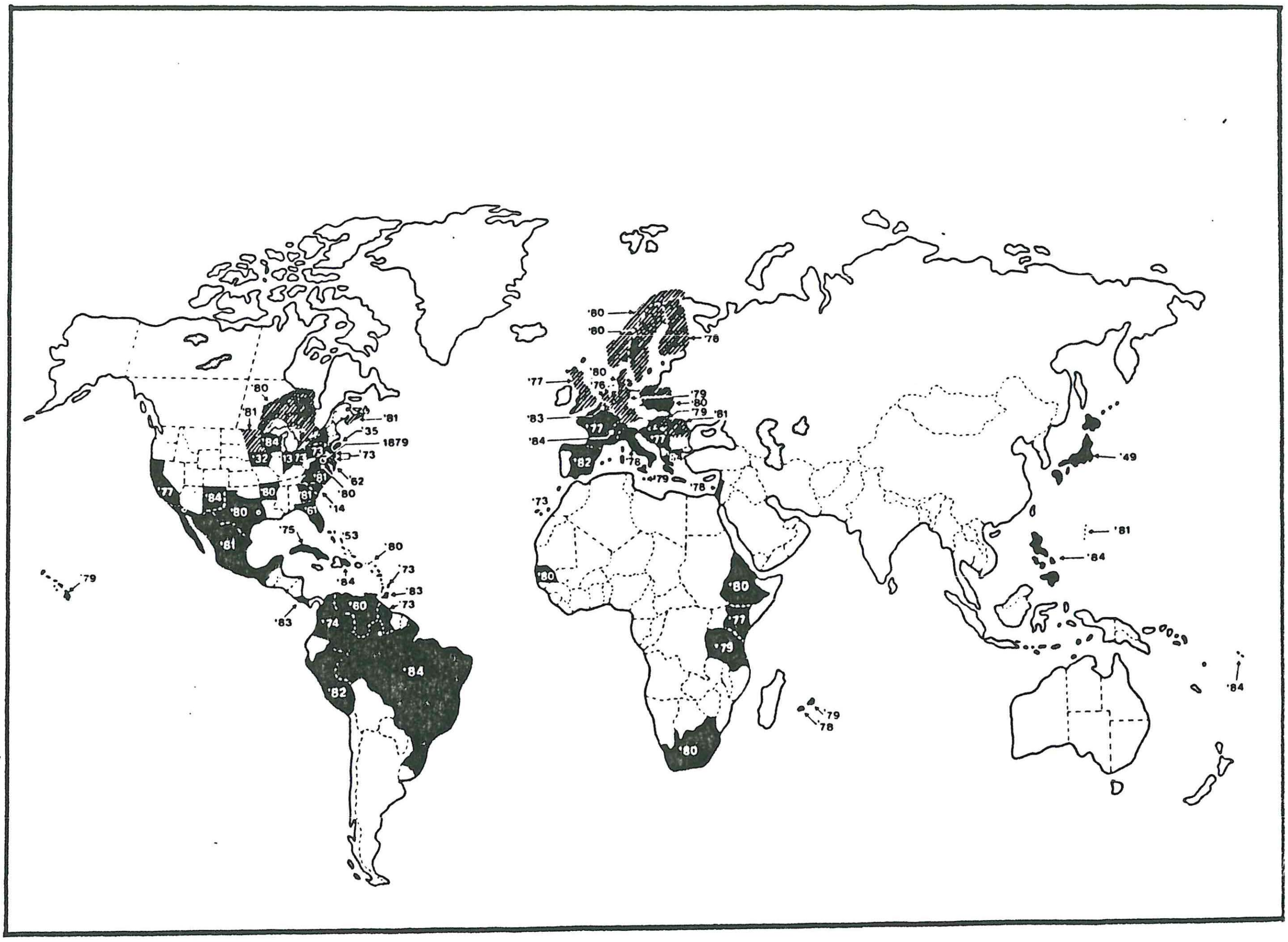
Appendix



Figur 3. The world distribution of *Liriomyza trifolii*. Years of first record are indicated and shaded areas are records only from greenhouses. Note that *L. trifolii* has now been eradicated in a few European countries (Minkenberg, 1990).

Table 1. Economically important host plants of *Liriomyza trifolii*, production in Norway, production value (NOK) and man-labour years in the production.

Data from the Norwegian Horticultural Growers Association.

Economically important hosts of *Liriomyza trifolii*	Production in Norway		Production-value (1.000 NOK)	Man-labour years
Allium cepa	5.060 daa	120,4 tonns	66.323	173
Allium porrum	1.454 daa	2.941 tonns	28.410	90
Alstromeria sp.	2,0 mill. cut flower		13.120	13
Anthirrhinum sp.	0,05 mill. nursery plants		300	0,5
Apium graveolens	750 daa	1,5 tonns	13.117	44
Apium petroselinum	250 daa	1 mill. bunches	11.620	14
Aster novi-belgii	0,1 mill pot plants		1.100	1,5
Aster sp.	0,06 mill nursery plants		660	0,5
Beta vulgaris	553 daa	2.386 tonns	4.915	17
Bidens sp.	0,1 mill nursery plants		375	1
Brassica campestris	3.246 daa	12,1 tonns	48.532	95
Brassica oleracea	16.206 daa	34,0 tonns	111.503	398
Chrysanthemum frutescens	0,08 mill. cut flowers 1,5 mill. nursery plants		7.393	8,5
Chrysanthemum morifolium	2,9 mill. pot plants 5,0 mill. cut flowers		66.753	73
Chrysanthemum sp.	0,4 mill. nursery plants		1.500	2
Cucumis sativus greenhouse outdoors	238 daa 638 daa	9,4 tonns 1,8 tonns	108.319 8.730	170 38
Dahlia hybrids *Dahlia* sp.	0,6 mill. nursery plants		3.300	3
Daucus carota	12.039 daa	35,9 tonns	95.414	352
Dianthus caryophyllus	0,3 mill. cut flowers		2.250	2
Dianthus sp.	1,7 mill. nursery plants		8.275	9
Gerbera sp.	0,8 mill. pot plants		10.800	11
Gypsophila paniculata	2,4 mill cut flowers		15.144	15
Lactuca sativa greenhouse outdoors	15,0 mill. heads	2,6 tonns	44.789 4.977	75
Lycopersicon esculentum	340 daa	19,4 tonns	112.872	243
Phaseolus vulgaris	926 daa	796 tonns	2.969	17
Pisum sativum	8.322 daa	3,8 tonns	8.738	152
Raphanus sativus	1 mill. bunches		3.590	14
Senecio cruentus	0,08 mill. pot plants		800	1
Spinacia oleracea	200 daa	250 tonns	1.000	6
Solanum tuberosum	183.500 daa	368.600 tonns	535.266	2.192

Table 1. Continued. Economically important host plants of *Liriomyza trifolii*, production in Norway, production value (NOK) and man-labour years in the production.

Data from the Norwegian Horticultural Growers Association.

Economically important hosts of *Liriomyza trifolii*	Production in Norway	Production-value (1.000 NOK)	Man-labour years
Solidago sp.	0,01 mill nursery plants	110	-
Tagetes sp. (erecta hybrids)	2,0 mill. nursery plants	7.500	11
Tropaelum majus	0,1 mill. nursery plants	375	0,5
Verbena sp.	0,5 mill. nursery plants	5.125	3
Zinnia	0,05 mill. nursery plants	280	-

Table 2. Host plants of *Liriomyza trifolii*. The tabel consists of plants where *L. trifolii* has been reported (found), and are based upon data from Seymour (pers. comm.), Eppo database (1996), Baufeld & Motte (1992) and Powell (1981).

Host plants for *Liriomyza trifolii*	Occurrence in Norway	Major hosts = *** Minor hosts = ** Not classified = ¤
Alstromeriacea		
Alstromeria sp.	greenhouse	¤
Caryophyllaceae		
Dianthus caryophyllus	greenhouse/annual	**
Dianthus sp.	greenhouse/annual/perennial/wild	¤
Gypsophila paniculata	greenhouse/perennial/wild	**
Gypsophila sp.	greenhouse/perennial/wild	¤
Chenopodiacea		
Beta vulgaris	field vegetables	**
Chenopodium album	weed	¤
Spinacia oleraceae	field vegetables	**
Compositae		
Aster novi-belgii	perennial	**
Aster sp.	annual/perennial/wild	¤
Bidens sp.	annual	**
Calendula officinalis	annual/perennial	¤
Chrysanthemum frutescens	greenhouse/annual/(perennial)	¤
Chrysanthemum morifolium	greenhouse	***
Chrysanthemum sp.	greenhouse/annual/perennial/wild	¤
Dahlia hybrids	greenhouse/annual	**
Dahlia sp.	greenhouse/annual	¤
Gerbera jamesonii	greenhouse	**
Gerbera sp.	greenhouse	¤
Helianthus bispinatus		¤
Lactuca sativa	greenhouse/field vegetables	**
Senecio cruentus	greenhouse/annual	**
Senecio jacobaea	weed	¤
Senecio vulgaris	weed/wild	¤
Solidago sp.	perennial/wild	¤
Spilanthus acmello		¤
Tagetes sp.	annual	¤
Zinnia	annual/perennial	**
Cruciferae		
Brassica chinensis	field vegetable	**
Brassica oleracea	field vegetable	¤
Capsella bursa-pastoris	weed	¤
Raphanus sativus	field vegetables/privat growing	¤
Cucurbitaceae		
Cucumis melo	field vegetables/greenhouse/mostly privat growing	**
Cucumis sativus	greenhouse/field vegetable	**
Cucurbita pepo	field vegetables (mostly privat growing)	**

Table 2. Continued. Host plants of *Liriomyza trifolii*. The tabel consists of plants where *L. trifolii* has been reported (found), and are based upon data from Seymour (pers. comm.), Eppo database (1996), Baufeld & Motte (1992) and Powell (1981).

Host plants for *Liriomyza trifolii*	Occurrence in Norway	Major hosts = *** Minor hosts = ** Not classified = ¤
Labiatae		
Ocimum basilicum	greenhouse/annual	¤
Fabaceae		
Arachis hypogaea		**
Lathyrus sp.	wild/(annual/vegetable)	**
Medicago sativa	meadow/wild	**
Phaseolus coccineus		**
Phaseolus lunatus		¤
Phaseolus vulgaris	field vegetables/privat growing	**
Pisum sativum	field vegetables/privat growing/wild	**
Trifolium	wild	**
Vicia faba	wild(field vegetables)	¤
Vigna		**
Liliacaea		
Allium cepa	field vegetables	**
Allium porrum	field vegetables	**
Allium sativum	(field vegetables)	**
Malvaceae		
Hibiscus esculentus		¤
Onagraceae		
Epilobium sp.	wild	¤
Plantaginacaeae		
Plantago lanceolata	weed	¤
Plantago major	weed	¤
Ranunculaceae		
Ranunculuc repens	wild	¤
Ranunculus sp.	perennial/wild	¤
Schrophulariaceae		
Antirrhinum sp.	annual	¤
Solanaceae		
Capsicum annuum	greenhouse	¤
Lycopersicon esculentum	greenhouse/privat growing	**
Solanum dulcamara		¤
Solanum tuberosum	field crop/privat growing	**
Tropaeolaceae		
Tropaelum majus	annual/wild	**
Tropaeolum sp.	annual/wild	¤

Table 2. Continued. Host plants of *Liriomyza trifolii*. The tabel consists of plants where *L. trifolii* has been reported (found), and are based upon data from Seymour (pers. comm.), Eppo database (1996), Baufeld & Motte (1992) and Powell (1981).

Host plants for *Liriomyza trifolii*	Occurrence in Norway	Major hosts = *** Minor hosts = ** Not classified = ¤
Umbelliferae		
Anethum graveolens		¤
Anthriscus cereifolium		¤
Apium graveolens	field vegetables	***
Apium petroselinum		¤
Daucus carota	field vegetables	¤
Verbenaceae		
Verbena sp.	greenhouse/annual	¤

Table 3. Effect of temperature on the oviposition behaviour of *Liriomyza trifolii* females on phaseolus bean (*Phaseolus vulgaris*), cv. Aiguillon. Relative humidity ranged from 60-70 %, photoperiod was 12L: 12D (Olivera et al., 1994).

Temperature (° C)	Number of feeding points for 10 females	Number of larvae for 10 females	Number of larvae per number of feeding points
18° C	182,3 (16) c	5,8 (16) c	0,0311 (22) b
23° C	2011,1 (32) b	113,7 (32) b	0,0577 (38) a
30° C	3679,2 (48) a	202,3 (48) a	0,0546 (36) a
Chi2 (friedman)	32,000 ***	32,000 ***	9,500 ***

***: Significant at the 1 % level.
(...): Sum of ranks with 16 replications.
a, b, c: Significantly different at the 5 % level by Nemenyi's test.

Table 4. Mean developmental time in days of *Liriomyza trifolii* at different temperatures and host plants, and estimated lower threshold temperatures (Saito, 1994).

Host plant	Stage	Temperature (°C) 15	20	25	30	35	Threshold temperature (°C)
Celery	Egg	10,0	4,4	2,3	2,4	2,0	12,9
	Larva	25,8	12,0	8,0	6,8	5,4	8,4
	Pupa	28,2	13,5	8,4	6,7	6,7	11,0
	Total	64,0	29,8	18,7	15,9	14,0	11,0
Tomato	Egg	6,6	3,1	2,7			6,9
	Larva	10,7	7,2	4,6			7,9
	Pupa	26,8	15,0	9,3			10,0
	Total	44,0	25,3	16,6			9,1
Bean	Egg	9,8	4,8	3,1	2,5	2,8	10,5
	Larva	10,3	5,3	4,0	3,5	3,0	8,3
	Pupa	32,7	15,0	9,7	7,0		10,7
	Total	52,8	25,1	16,8	13,0		10,3

Table 5. Developmental time in days of *Liriomyza trifolii* at three constant temperatures and one alternating temperature (mean ± SE, range) on tomato (Minkenberg, 1990).

	Temperature (°C)			
Stage	15	20	25	19,5 (16-22)
Egg	6,6 ± 0,06 (6,2-7,0)	3,1 ± 0,02 (2,9-3,4)	2,7 ± 0,02 (2,7-3,0)	3,8 ± 0,01 (3,5-4,5)
First larval	3,3 ± 0,18 (2,5-4,5)	2,8 ± 0,08 (0,5-3,7)	1,4 ± 0,05 (1,2-2,0)	3,4 ± 0,04 (2,5-4,3)
Second larval	3,7 ± 0,28 (2,7-5,0)	2,1 ± 0,06 (1,7-3,2)	1,4 ± 0,08 (1,0-2,2)	2,2 ± 0,03 (1,3-2,7)
Third larval	3,7 ± 0,14 (3,0-4,8)	2,3 ± 0,10 (0,5-3,5)	1,8 ± 0,15 (0,8-3,5)	2,4 ± 0,05 (1,7-5,2)
Pupal	26,8 ± 0,26 (25,8-28,5)	15,0 ± 0,05[a] (13,7-17,0)	9,3 ± 0,10 (8,8-10,5)	16,8 ± 0,06 (15,8-19,2)
Total	44,0 ± 0,64 (41,0-47,0)	24,6 ± 0,09[a] (23,7-27,0)	16,6 ± 0,33 (15,0-20,9)	28,5 ± 0,12 (26,9-33,9)
N	11	34 a86	17	98

Table 6. Estimated temperature tresholds for development and oviposition of *Liriomyza trifolii* on tomato (Minkenberg, 1990).

	Estimated threshold temperature (°C)
Development:	
Egg	6,9
First instar	8,8
Second instar	8,9
Third instar	6,1
Pupa	10,0
Total	9,1
Oviposition:	12,6

Table 7. Percentage mortality of *Liriomyza trifolii* stages at different temperatures (Minkenberg, 1990).

	Temperature (° C)			
Stage	15	20	25	19,5 (16-22)
Egg	23	20	21	12
First larval	45	22	18	5
Second larval	29	9	19	2
Third larval	0	1	15	20
Total	73	48	60	36
N eggs	40	140	42	152

Within-instar mortality of individuals entering the instar is given for immatures and total mortality is from egg to adult.

Table 8. Norwegian import of saleable plants and plants for further cultivation from different countries in 1994. The last column describes the situation of *L. trifolii* in the respective countries.
Data from The Norwegian Horticultural Growers Association, EPPO/PQR Database, version 3.2, dated 1996-02. EPPO Reporting Service 1994, No. 5. Smith et al., 1992.

	Decoration Plants		Flowering Pot Plants			*Liriomyza trifolii*
Country	Saleable	For Further Cultivation	Saleable	For Further Cultivation	Sum	A, B, C, X, E, I or N *)
Denmark	3.602.799	6.686.297	3.214.820	5.040.517	18.544.735	E
Holland	581.485	66.640	131.666	120.294	900.085	B
Belgium	50.793	17.075	860.381	0	928.294	B
Germany	0	0	1.007.038	143.650	1.150.688	B
Finland	0	0	0	0	0	E
France	0	0	0	195.796	194.500	A
Israel	0	0	0	337.260	337.800	A
Sweden	0	0	0	0	0	E
Spain	0	0	0	17.800	17.800	B
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	
Polen	0	0	0	0	0	B
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=Eradicated, I=Intercepted only, N=Never reported.

Table 9. Import to Norway of cuttings and small plants of cut flowers (only host plants of *L. trifolii*) from different countries in 1994. The last column describes the situation of *L. trifolii* in the respective countries.

Data from The Norwegian Horticultural Growers Association, EPPO/PQR Database, version 3.2, dated 1996-02. EPPO Reporting Service 1994, No. 5. Smith et al., 1992.

	Importation of cuttings and small plants of Cut Flowers				*Liriomyza trifolii*
Country	*Alstromeria*	*Chrysanthemum* sp.	*Dianthus caryophyllus*	*Gypsophila paniculata*	A, B, C, X, E, I or N *)
Holland	3.163	211.450	106.500	24.995	B
Germany	0	0	20.000	0	B
Israel	0	0	0	24.370	A
Sum	3.163	211.450	126.500	49.365	

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

Table 10. Importation of economically important host plants of *Liriomyza trifolii*. Production in Norway 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 *Liriomyza trifolii*	Production in Norway of saleable plants (numbers)	Import of saleable plants to Norway (numbers)	Import of cuttings or young plants to Norway (numbers)
Aster	160.000	145.592	51.418
Chrysanthemum morifolium	2.903.600	0	675.532
Dahlia	600.000	0	130.164
Gerbera sp.	787.940	0	21.940
Senecio (cruentus)	114.600	9.478	0
Alstromeria	2.000.000		3.163
Chrysanthemum frutescens	80.000		
Chrysanthemum morifolium	5.000.000		211.450
Dianthus caryophyllus	300.000		126.500
Gyphsophila paniculata	2.400.000		49.365

Table 11. Plant commodities liable to carry *Liriomyza trifolii* (EPPO/PQR Database, version 3.2, dated 1996-02).

Plants	Cut Flowers/Branches	Fruits/Vegetables
Apium graveolens	*Chrysanthemum morifolium*	*Apium graveolens*
Capsicum annum	*Dianthus caryophyllus*	*Beta vulgaris*
Chrysanthemum morifolium	*Gerbera jamesonii*	*Brassica*
Cucumis	*Gypsophila paniculata*	*Lactuca sativa*
Dianthus caryophyllus	*Senecio cruentus*	Vegetable plants
Gerbera jamesonii	Ornamental plants	
Gypsophila paniculata		
Lactuca sativa		
Lycopersicon esculentum		
Senecio cruentus		
Ornamental plants		
Vegetable plants		

Table 12. 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).

	Locality and Temperature (°C)				
Month	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 13. 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)
				1 cm depht	
Tomb [1]	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 [2]	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
				10 cm depht	
Landvik	1991	-	-	51	-1,9
Landvik [3]	1992	34	-6,2	19	-1,1
Landvik [4]	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

[1] Lacking data for 4 days in March
[2] Lacking data for 8 days in March and April
[3] Lacking data for 6 days in January and February
[4] Lacking data for 5 days in November