Pest risk assessment of the Vegetable Leafminer (*Liriomyza sativae)* in Norway

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Pest risk assessment of the Vegetable Leafminer (*Liriomyza sativae*) in Norway

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SUMMARY

Liriomyza sativae Blanchard is a pest species that originates from Central and North America, but since the 1990s it has spread with plants to many parts of the world. In the tropics, subtropics and warmer parts of the temperate zone it has been established in the field, while in a colder climate it can develop as a pest only in greenhouses. The pest has a wide host plant range. In Europe the pest has been reported in most countries; predominantly on vegetables imported from Asia in recent years. So far it has not with certainty been encountered in Norway.

The pest risk assessment was initiated by the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) Panel on Plant Health.

The VKM Panel on Plant Health gives the following main conclusions of the risk assessment: 1) *L. sativae* has never with certainty been encountered in Norway. 2) The overall probability of entry of *L. sativae* into Norway and the overall probability of establishment in greenhouses of *L. sativae* in Norway are both rated as high with medium levels of uncertainty. 3) In the absence of statutory control the probability for *L. sativae* to be spread quickly in greenhouses in the PRA area by trade of host plants is rated as high. The uncertainty of this assessment is low. 4) *L. sativae* can be spread in the field around infested greenhouses during the summer, but it can not overwinter in the field in Norway. The level of uncertainty of this assessment is low. 5) The part of the PRA area where presence of *L. sativae* might result in economically important losses (the endangered area) in greenhouses is assessed to be all of Norway. 6) *L. sativae* is likely to have moderate economic impact in the greenhouses in the PRA area with current phytosanitary measures. Without any such regulations *L. sativae* is likely to have major economic impact on the greenhouse industry of the PRA area. The levels of uncertainty of these assessments are low. 7) The non-commercial and environmental consequences in the PRA area are likely to be low. The level of uncertainty of this assessment is low.

CONTRIBUTORS

Persons working for VKM, either as appointed members of the Committee or as *ad hoc* experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed an *ad hoc* group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority. The members of the *ad hoc* group are acknowledged for their valuable work on this opinion.

The members of the *ad hoc* group are:

VKM members

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ASSESSED BY

The report from the *ad hoc* group has been evaluated and approved by

VKM Panel on Plant Health:

Leif Sundheim (chair), May Bente Brurberg, Trond Hofsvang, Christer Magnusson, Trond Rafoss, Brita Toppe, Anne Marte Tronsmo, and Bjørn Økland.

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CONTENTS

1. BACKGROUND

Among the three polyphagous *Liriomyza*-species that are quarantine pests in Norway (*L. huidobrensis*, *L. sativae* and *L. trifolii*), *L. sativae* has the highest temperature preferences (Kang *et al*. 2009). It has been established in many tropical, subtropical and warmer parts of the temperate areas all over the world (except Australia). In addition there are regular outbreaks in greenhouses in most parts of the world. The larvae of *L. sativae* are highly polyphagous, being able to develop inside the leaves of plants in many plant families, including cultivated plants like many vegetables, ornamentals and cotton. Under favorable climatically conditions generations follow in quick succession, and serious damage has been reported in many agricultural and ornamental crops.

The global distribution of *L. sativae* (Appendix 1) has changed considerably since the last PRA was made for the pest in Norway (Sæthre 1996). Due to the recent spread of the species in many parts of the world, it has probably been established in more tropical and subtropical countries than is presently documented in international literature, especially in Africa and Asia, and it will probably reach new countries in the near future. In Europe the pest has been reported in many countries, predominantly in vegetables from Asia in border controls. Due to different levels of investigation and policies in different countries, the current distribution map of the species in Europe and the rest of the world (EPPO 2006) is not well documented, and the information must be used with caution.

The species has never with certainty been encountered in Norway. Only in one case of *Liriomyza* sp. found in 2001 the flies were identified as possibly *L. sativae*. However, the large number of encounters in other European countries during the last years (Appendix 2) has made the Norwegian Food Safety Authority on the alert concerning the species.

The report from the *ad hoc* group has been initiated, evaluated and approved by VKM Panel on Plant Health. The pest risk assessment was adopted by the panel on a meeting at December 10th 2009.

Be aware that the current document is a pest risk assessment, and not a Pest Risk Analysis (PRA). A PRA consists of both a risk assessment and a risk management part. VKM performs purely the risk assessment, whereas the Norwegian Food Safety Authority is responsible for the risk management. However, since this pest risk assessment is part of a PRA process, the current document refers to the PRA term in several contexts, like the identification of the PRA area and referrals to former PRAs. This is in accordance with the international standard ISPM No. 11 (FAO 2004).

2. INITIATION

2.1. Initiation points

2.1.1. PRA initiated by the identification of a pest

Initiated by the Norwegian Scientific Committee for Food Safety, a previous Norwegian PRA is being re-evaluated. The pest has recently been established in many countries all over the world during the last few years. Also, the taxonomy of the pest has recently been investigated. Consequently, the timing of the PRA initiation is due to new knowledge about the pest.

2.2. Identification of PRA area

The PRA area is Norway.

2.3. Information

Information sources utilised for this pest risk assessment are published material available in international scientific journals, books and reports, as well as personal communications with persons involved in the area, geographical data, unpublished results, and information from the Norwegian Food Safety Authority that have been made available to the risk assessors. Where these information sources have been used, this is indicated in the text by references enclosed in brackets.

The current pest risk assessment is made according to the international standard ISPM No. 11 (FAO 2004).

2.3.1. Previous PRAs

Commissioned by the former Norwegian Agricultural Inspection Service, the former Norwegian Crop Research Institute (Planteforsk) in 1996 did a PRA on *Liriomyza sativae* (Sæthre 1996). The biology of the species was given, and available control measures and the potential economic importance were evaluated.

The PRA was followed up by an investigation of possible *Liriomyza* species being present in greenhouses and the field in Norway in 1996 (Sæthre 1997) and 2003-2005 (Johansen *et al*. 2004, 2006).

Important information is also found in the two EPPO documents “EPPO Data Sheet on Quarantine Pests. *Liriomyza sativae*” (EPPO 1997) and “EPPO Diagnostic. *Liriomyza* spp.” (EPPO 2005).

2.4. Conclusion of initiation

The pest of concern is the dipterous pest *Liriomyza sativae*. The work was initiated by the Norwegian Scientific Committee for Food Safety, and the initiation point for the pest risk assessment is the re-evaluation of a previous PRA for Norway. The PRA area is Norway.

3. PEST RISK ASSESSMENT

3.1 Pest categorization

3.1.1. Identity of pest

3.1.1.1 Scientific name

Liriomyza sativae Blanchard, 1938

3.1.1.2 Synonyms

Liriomyza pullata Frick, 1952

Liriomyza canomarginis Frick, 1952

Liriomyza minutiseta Frick, 1952

Liriomyza munda Frick, 1957

Liriomyza guytona Freeman, 1958

Liriomyza propepusilla Frost

3.1.1.3 Common names

Vegetable leafminer

Serpentine vegetable leafminer

Cabbage leafminer

Tomato leafminer

3.1.1.4 Taxonomic position

Class: Insecta; Order: Diptera; Family: Agromyzidae; genus: *Liriomyza*.

While *L. sativae* populations all over the world today are treated as one species, Scheffer & Lewis (2005) concluded that the presence of several mitochondrial clades in the species is suggestive of cryptic species. However, most of the diversity appeared in the native areas in the Americas, while all the invasive populations belonged to the same phylogenetic clade.

L. sativae is taxonomically also very closely related to *L. trifolii*, another invasive species. This sometimes poses a problem in identification at border controls, especially if only female specimens are found. Shiao (2004) gives valuable information on how to separate the two species morphologically.

As a conclusion, due to the difficult taxonomy of the species and several very closely related species, all information concerning *L. sativae* has to be evaluated with caution.

3.1.2 Presence or absence in PRA area

L. sativae has never with certainty been discovered at the Norwegian border. However, as flies in some encounters have only been identified to *Liriomyza* sp., it is possible that the species is more common than it seems today (Table 1, 2).

Table 1. Imports to Norway the last five years stopped due to records of *Liriomyza* spp. by import control (Norwegian Food Safety Authority).

Year	Pest species	Plant species	Country of origin
2004 – 2007: no records			
2008	*L.* sp.	*Exacum* sp.	Denmark
	L. huidobrensis	*Exacum* sp.	Denmark
	L. huidobrensis	*Exacum* sp.	Denmark
	L. sp.	*Solidago* sp.	Zimbabwe
	L. sp.	*Verbena* sp.	The Netherlands
2009: no records			

Table 2. An import of *Liriomyza* sp. into Norway, identified to *L. sativae* or *L. trifolii* (Norwegian Food Safety Authority and Norwegian Institute for Agricultural and Environmental Research)

Year	Number of imports	Number of infested shops	Host plant	Country of origin
2001	1	1	*Spinacia oleracea*	Sri Lanka

3.1.3 Regulatory status

In Norway *L. sativae* is currently treated as a quarantine pest.

3.1.4 Potential for establishment and spread in PRA area

According to EPPO reports on notifications of non-compliance for *L. sativae* for the years 2002-2009 (EPPO Reporting Service 2002 – September 2009), it is obvious that there is a high probability that plants containing *L. sativae* now and then is sought imported into Norway. The occurrence of *L. sativae* is most common in vegetables from Asia (Appendix 2). Due to the availability of relevant host species and suitable climatic conditions, there is a potential for establishment and spread of *L. sativae* all year round in greenhouses in the PRA area. If not eradicated, the species would be able to exist in greenhouses all year round, but in the field it would only survive during the summer. Chen & Kang (2005) suggest a northern overwintering range limit under natural conditions in China to be the -2 °C isotherm of the minimum mean temperature in January. In that case, data from Aune (1993) and three meteorological stations in Norway (Table 3) should indicate that *L. sativae* could be able to overwinter outdoors in the warmest coastal areas of Southern Norway. However, the northern latitude Chen & Kang (2005) suggest in China is 34° N, which correspond to south of Crete and Cyprus in Europe and Southern Syria in Asia, far south of Norway. This large difference can be explained by the more Atlantic climate in Europe compared to the continental climate in China. Furthermore, Zhao & Kang (2000) reported that no pupae of *L. sativae* were able to survive prolonged exposure to 0 °C for 7 days which would make it very unlikely that *L. sativae* would survive during winter even in the mildest parts of Norway.

The mean temperature along the coast of Southern Norway during May – August is around 15 °C, as shown by the mean temperature for three meteorological stations during 1995-2009 (Ås near Oslo in South-Eastern Norway, Særheim near Stavanger in South-Western Norway and Kvithamar near Trondheim in Middle Norway) in Table 3. During 3 months (90 days) at 15 °C, *L. sativae* should be able to go through two full generations, as reported by Haghani *et al.* (2007).

Table 3. Monthly mean temperatures (°C) for the years 1995 – 2009 at three sites in coastal Southern Norway (Landbruksmeteorologisk tjeneste (LMT), Bioforsk).

	Jan	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**June-Aug**
Særheim	2.4	6.4	9.4	12.3	14.7	15.3	12.5	8.7	14.1
Ås	-2.8	5.0	10.0	14.0	16.1	15.7	11.3	6.1	15.3
Kvithamar	-0.8	5.2	9.1	12.7	15.1	14.8	10.9	6.3	14.2

While *L. huidobrensis* is often found in flowers imported into European greenhouses, *L. sativae* is most often found in vegetables that are imported for sale in food shops. Compared to *L. huidobrensis*, this makes it more difficult for *L. sativae* to get established on host plants in Norway. In conclusion, *L. sativae* could be locally detected in greenhouses in the PRA area. The pest could also be spread outdoors in the field around infested areas during the summer, but the species will not survive the winter in the field.

3.1.5 Potential for economic consequences in PRA area

Yield losses of the three New World *Liriomyza* spp. (*L. huidobrensis*, *L. sativae* and *L. trifolii*) can be significant and the three species are regarded as serious pests of numerous ornamental and agricultural plants (Parrella 1987, Murphy & La Salle 1999).

Losses of up to 70 % in tomato crops have been reported (Murphy & LaSalle 1999). Semi-field studies in vegetables in Vietnam have shown that the action threshold for *L. sativae* varies with host plants. To avoid crop loss, control methods, e.g. the use of an insecticide, should be applied when the number of mines per leaf exceeds 5 in French bean, 1 in cowpea, 6 in pack-choi cabbage, 6 in cucumber and 15 in tomato (Arild Andersen & Tran Thi Thien An, unpublished). Parrella (1987) refers to a threshold in tomato field in California which calls for treatment when an average of 10 pupae per sampling tray per day accumulate over a 3-4 day period.

3.1.6 Conclusion of pest categorization

L. sativae is not present in the PRA area.

Due to the availability of hosts and a climate, there is a potential for establishment and spread of *L. sativae* in greenhouses in the PRA area. All evidence indicates that the species would be able to exist in the field in the summer, but it can not survive the winter.

The pest could cause significant loss or damage to plants in greenhouses in the PRA area.

Thus, the current pest risk assessment is continued.

3.2. Assessment of the probability of introduction and spread

3.2.1 Probability of entry of the pest

3.2.1.1 Identification of pathways

Pathway A. Import of host plants with eggs, larvae or pupae

L. sativae might be imported into the PRA area with host plants originating from infected areas. This is shown by the previous history of the pest, especially the high number of infestations detected in vegetables at European borders (Appendix 2). In the PRA area the pest has never been stopped at the border as interceptions on known host plants for planting imported from other countries (Table 1), but possibly it has been found once on imported vegetables in a shop (Table 2).

Adults of *L. sativae* copulate on the host plants, and the females make so-called pinholes by inserting their ovipositor into the leaves to feed on the plant fluids that run from the wounds. Later they lay eggs inside the leaf in some of the pinholes. Larvae hatch from the eggs and create a so-called mine by eating tissue inside the leaf. When fully grown, the larvae leave the mine and pupate either on the outside of the leaf or drop to the ground before they pupate. The next generation of flies emerges from the pupae. Thus, the plant host species offers *L. sativae* all it needs concerning environment and development. A small infestation can be difficult to discover, since it often can consist only of pinholes, eggs and possibly some larvae in small mines. Also, sometimes the mines are easy to spot from only one side of the leaf, and can easily be overlooked.

The full range of natural host species to date is reported in Appendix 3.

The global distribution of *L. sativae* is shown in Appendix 1.

Pathway B. Import of soil/growing media with pupae

L. sativae might be imported into the PRA area with soil/growing media originating from infected areas. *L. sativae* has the potential to contaminate soil and growing medium as pupae, and the pest has a potential to survive significant periods of time in potting media. The developmental time for pupae depends on the temperature, and varies from 9.5-10.2 days at 25 °C and 19.7-35.8 days at 15 °C (Sakamaki *et al*. 2003, Haghani *et al*. 2007). If *L. sativae* is present in soil or growing media it is very unlikely to be detected and there is a high probability to survive existing pest management procedures.

Pathway C. Natural spread of adult flies from other European countries by air.

L. sativae might enter the PRA area by natural spread of adult flies by air from infected areas in other European countries. Wind-borne migration has been shown to exist in many insect taxa, including Diptera species (Gatehouse 1997).

3.2.1.2 Probability of the pest being associated with the pathway at origin

The ratings of probabilities and uncertainties for *L. sativae* being associated with the pathways at origin are given for each pathway in Table 4. The probabilities varies according to factors like

- prevalence of the pest in the source area
- occurrence of the pest in a life-stage that would be associated with commodities, containers, or conveyances
- volume and frequency of movement along the pathway
- seasonal timing
- pest management
- cultural and commercial procedures applied at the place of origin

Table 4. Estimates of the probability of *Liriomyza sativae* being associated with each pathway at origin in relation to geographical source. The probability of the pest is ranked according to the following scheme: Very unlikely; Unlikely; Moderately likely; Likely; Very likely. Uncertainty for each estimate is given in brackets, and is ranked according to the following scheme: Low; Medium; High.

	Pathway	**Europe (EU/Switzerland)**	**USA and Canada**	**South and central America**	**Africa**	**Asia**
A	Import of host plants with eggs, larvae, pupae or adult flies	Moderately likely (low uncertainty)	Unlikely (low uncertainty)	Unlikely (medium uncertainty)	Moderately likely (medium uncertainty)	Moderately likely (low uncertainty)
B	Import of soil/growing media with pupae	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)
C	Natural spread of adult flies by air	Very unlikely (medium uncertainty)	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)	Very unlikely (low uncertainty)

<u>Pathway A. Import of host plants with eggs, larvae or pupae</u>

Generally this is considered as the most probable pathway of entry of *L. sativae* into the PRA area. Due to high import of host plants to Norway from Europe, Africa and Asia, the probability of *L. sativae* being associated with host plants from these regions is rated as higher than from the rest of the world.

<u>Pathway B. Import of soil/growing media with pupae</u>

The import of soil and organic growing media into the PRA area is prohibited from countries outside Europe (Landbruks- og matdepartementet 2000). Import of growing medium (except *Sphagnum*) from European countries need to be followed by a Phytosanitary Certificate. Therefore, the probability for the pest being associated with this pathway at origin is considered as very unlikely from all parts of the world.

<u>Pathway C. Natural spread of adult flies from other European countries by air.</u>

Natural spread of *L. sativae* by aerial dissemination of adult flies is possible as strong winds could potentially move the pest over great distances from other European countries like

Sweden, Denmark, Germany and Poland into the PRA area. Such weather events occur sometimes when there are strong southern or south-eastern winds in Northern Europe. However, so far the probability for the pest being associated with this pathway is considered as very unlikely. This is due to the fact that the following two unusual situations must coincide: A relatively high population density of *L. sativae* must have been established in the field in a nearby country, and the weather conditions in the area must favor a spread of the population to Norway. This situation could change if *L. sativae* is established in greenhouses in other countries in Northern Europe.

Because of the long distances from most parts of the world to Norway, pathway C is only possible from (Northern) Europe.

3.2.1.3 Probability of survival and multiplying during transport or storage

There is a high probability for *L. sativae* to survive and multiply during transport or storage of host plants (pathway A). This is due to the fact that all the developmental stages of the pest (eggs, larvae, pupae and adult flies) will be able to utilize the host plant for their successful development, and the temperature need of the plants is suitable also for all stages of the pest. The level of uncertainty in these assessments is low.

There is a low probability for *L. sativae* to survive and multiply during transport or storage of soil or growing media (pathway B). This is due to the fact that pupae can survive periods of approximately 1-2 weeks in soil, away from their host plants. The level of uncertainty in these assessments is low.

3.2.1.4 Probability of pest surviving existing pest management procedures

The likelihood of the pest to survive existing pest management procedures will vary from very unlikely to very likely depending on the commodity and the phytosanitary measures applied. For all pathways and all geographical origins the ability for the pest to remain undetected will be affected by the method of inspection by the exporting country's NPPO and if required by the Norwegian regulations. Similarly, the likelihood of the pest surviving any phytosanitary measures required by Norwegian legislation will depend on the effectiveness of their application and their efficacy. For each pathway ratings of the probability for survival, and uncertainties of the ratings, are given below. So far the Norwegian authorities are of the opinion that *L. sativae* does not exist in Norway.

<u>Pathway A. Import of host plant species accompanied by eggs, larvae, pupae or flies</u>

It is moderately likely that *L. sativae* will survive existing pest management procedures given by Landbruks- og matdepartementet (2000). One possible entry into Norway is presented in Table 2. The pest may be present on plants even if the plants originate from an area in which there is an official statement that *L. sativae* does not occur. It is also moderately likely that the pest will remain undetected on plants that are inspected and tested prior to export to the PRA area from greenhouses in areas where the pest occurs. The uncertainties of these assessments are low.

Pathway B. Import of soil or growing media accompanied by pupae in the soil

If *L. sativae* is present in soil or growing media it is very unlikely to be detected and there is a high probability to survive existing pest management procedures. The uncertainties of these assessments are low.

Pathway C. Natural spread of adult flies by air

Free movement of insects with wind is impossible to control. Consequently, there is a possibility that *L. sativae* might be wind-borne into the country if the species has an outbreak in a nearby country, or if the species in the future is established in greenhouses or the field in nearby countries. The uncertainty of this assessment is low.

3.2.1.5. Probability of transfer to a suitable host

Due to the polyphagy of *L. sativae*, the probability of transfer to a suitable host after arrival in the PRA area is high, whatever the way of entry. Regarding the pathway of host plants, the pest is already present on a suitable host. It is very likely that the pest would be transferred to other hosts in Norwegian greenhouses and garden centres. The conditions in greenhouses and garden centers with close spacing of plants favour the dispersal of the pest. Furthermore, *L. sativae* is very likely to transfer to a suitable environment, when sold to the consumer. The environments of parks and private gardens, at least along the coast of Norway, are very likely to support the pest during summer.

It is highly likely that *L. sativae* could be transferred from plants in greenhouses to host plants in natural environments during the summer**.**

3.2.1.6. Summarised probability of entry for each pathway

Pathway A. Import of host plants with eggs, larvae or pupae

The likelihood of *L. sativae* to be imported into the PRA area by import of host plants is rated as high, with low level of uncertainty. This pathway is rated as the most likely pathway for entry of *L. sativae* into the PRA area.

Pathway B. Import of soil/growing media with pupae

The likelihood of *L. sativae* to be imported to the PRA area with contaminated soil is rated as low, with a high level of uncertainty.

Pathway C. Natural spread of adult flies from other European countries by air.

The likelihood of *L. sativae* to enter the PRA area by aerial dissemination of adult flies is rated as low, with a high level of uncertainty. However, if the species becomes established in nearby countries like Germany, Poland, Denmark or Sweden in the future, such entries will be much more probable.

3.2.2 Probability of establishment

The probability of establishment of *L. sativae* in the PRA area will vary with the availability of suitable hosts, suitability of the environment, biological characteristics of the pest, and the effects of existing pest management practices. The significance and the uncertainty for each of these topics are addressed in the following paragraphs (4.2.2.1 – 4.2.2.4).

3.2.2.1 Availability of suitable hosts, alternate hosts and vectors in the PRA area

L. sativae has a very broad host range across a wide range of plant genera and there is an abundant availability of suitable hosts in the PRA area. The uncertainty surrounding this data is low. Under natural conditions the pest has infested at least 103 plant species in 84 plant genera worldwide (Appendix 3), representing over 29 plant families (Table 5). Of these, many grow naturally or in greenhouses in Norway. Wild plants growing in Norway that has been confirmed infested in other countries are among others chickweed (*Stellaria media*), yarrow (*Achillea millefolium*), buttercups (*Ranunculus acris*), and sow thistles (*Sonchus arvensis*), although the topic has not been systematically investigated.

Table 5. Plant families that contain host species for *Liriomyza sativae* (Spencer 1990, Sæthre 1996, Andersen et al. 2002, 2008, EPPO databases on quarantine pests, and EPPO reporting service 2002 – September 2009)

Scientific name	Scientific name	Scientific name	Scientific name
Asteraceae	*Caryophyllaceae*	*Malvaeceae*	*Scrophulariaceae*
Alliaceae	*Convulvulaceae*	*Moringaceae*	*Solanaceae*
Alstromeriaceae	*Cucurbitaceae*	*Oxalidaceae*	*Tropaeolaceae*
Amaranthaceae	*Euphorbiaceae*	*Plantaginaceae*	*Verbenaceae*
Apiaceae	*Fabaceae*	*Poaceae*	*Violaceae*
Brassicaceae	*Gentianaceae*	*Polemoniaceae*	
Campanulaceae	*Lamiaceae*	*Primulaceae*	
Cannabaceae	*Linaceae*	*Ranunculaceae*	

3.2.2.2 Suitability of environment

The environmental conditions in greenhouses in the PRA area are considered to be suitable for *L. sativae* all year round, with a low level of uncertainty. Outdoors the environmental conditions are considered to be suitable for *L. sativae* during the summer in some parts of the PRA area, with a low level of uncertainty. *L. sativae* will not be able to overwinter in the field even in the mildest areas in Norway. The assessments behind these conclusions are given below.

Climate is an important factor that affects establishment of *L. sativae*, and climate suitability of the PRA area is therefore analysed in this section. The global distribution of the pest according to EPPO is shown in Appendix 1.

The monthly mean temperature in most parts of coastal Southern Norway in October – May (exemplified by Særheim, Ås and Kvithamar, Table 3) is lower than the lowest developmental temperature of *L. sativae* of about 10 °C (Hagnhani *et al*. 2007). Consequently, *L. sativae* could develop in the field only during four months each summer, but would have to stay in the pupal stage for the remaining eight months each winter.

The present distributions show that the polyphagous quarantine *Liriomyza* species cannot successfully overwinter under natural conditions in the temperate areas. However, *Liriomyza* species have dispersed far beyond their apparent overwintering range limit, and in much higher-latitude regions with severe winter conditions, by opportunistic exploitation of protected microhabitats (Kang *et al.* 2009). The climatic conditions necessary for the development of *L. sativae* has been investigated mainly in Asia during the quick spread of the species towards the north in recent years, and is reported below.

L. sativae is common in many countries in Asia (Chen *et al*. 2003, Andersen *et al*. 2008). In China, Zhao & Kang (2000) suggested that *L. sativae* can overwinter in the field north to a latitude of approximately 34° N, with an isotherm of minus 2 °C in January. North of 34° N the species will have to overwinter in greenhouses and infest the fields each year. The species has also been established several places in Japan north to Kyoto, at a latitude of approximately 35° N (Abe & Kawahara 2001, Tokumaru & Abe 2003, Sakamaki *et al*. 2005, Tokumaru *et al*. 2007). However, at least in the winter 2000/2001 *L. sativae* could not overwinter outside greenhouses near Kyoto (Tokumaru *et al*. 2007).

The lower threshold temperature for development of the different larval stages and the pupal stage in different *L. sativae* populations were found to be 9.8 – 11.0 °C by Haghani *et al.* (2007), 11.0 – 11.7 °C by Sakamaki *et al*. (2003), and 10.7 °C by Tokumaru & Abe (2003). Taking into account the mean temperatures in coastal Norway in the period October – May (Table 5), this means that there will be almost no development of the species in the field during these eight months.

In conclusion, all scientific data suggest that *L. sativae* will not be able to overwinter in the field even in the mildest areas in Norway. However, when growing host plants continuously in greenhouses, the species will be able to develop large populations. The number of generations will vary with the temperature. At 20 °C the life-cycle takes 29.9 days, and 12 generations would develop per year, while at 25 °C the life-cycle is 16.5 days (Tokumaru & Abe 2003), and 22 generations would develop per year.

3.2.2.3 Cultural practices and control measures

After establishment in greenhouses in the PRA area, the pest will be sought eradicated, so it is unlikely that the pest will be established in greenhouses over long periods of time.

Also the managed environment outside greenhouses in parts of the PRA area is favourable for the spread of *L. sativae* during the summer months. It is unlikely that existing pest management practice in the PRA area will prevent spread of the pest in greenhouses or in the field. *L. sativae* also has many host plants among commonly grown vegetables in Norway. Thus, if infested greenhouses are in the vicinity of agricultural fields, *L. sativae* could be spread in fields. However, so far such a situation has not been reported. Based on biological characteristics, it is likely that the pest during summer could survive pest management practices in the field in Norway. The uncertainty surrounding these questions is low.

<u>Likelihood of the existing pest control management practice to prevent establishment of the pest in greenhouses</u>

In Norway, dimethoate, thiacloprid, abamectin, spinosad and several pyrethroids are recommended pesticides against *L. sativae* and other leafmining flies (Mattilsynet 2009). In addition, two parasitic wasp species and one nematode species are on the current list of biological agents against leafmining flies in Norway. Since eradication would be the chosen strategy upon potential incidents of *L. sativae* in the PRA area, the effectiveness of these pest control methods would not be tested. However, due to the experience from control programs in other countries (e.g. Hossain & Poehling 2006), we find it unlikely, with low uncertainty, that these pest management practises currently available in greenhouses, garden centres, parks, private gardens and fields in the PRA area would prevent establishment of *L. sativae.*

Likelihood to survive eradication programs in the PRA area, based on the biological characteristics of the pest.

L. sativae has so far not been encountered in Norway, but due to similarities in biology with the two other quarantine *Liriomyza* species, *L. huidobrensis* and *L. trifolii*, it is reasonable to assume that *L. sativae* would act similarly to them. So far, eradication has been the chosen strategy with all incidents of *L. huidobrensis* and *L. trifolii* into the PRA area. Important parts of the eradication program have been full sanitation of infested greenhouses (immediate destruction of all plant material, and heat treatment of the soil) and no growing of potential host plant species for a certain period of time. Due to the successful eradications of *L. huidobrensis* and *L. trifolii* after all incidents in the PRA area, we find it unlikely that *L. sativae* could survive eradication programs in greenhouses in the PRA area. The uncertainty is low. In the field it is highly unlikely that *L. sativae* can be eradicated by any means during the summer, but during the following winter it will die out.

Suitability of the managed environment in the PRA area for pest establishment

The managed environment around Norwegian greenhouses, garden centres, private gardens and public greens are all favourable to the spread of *L. sativae* during summer. The uncertainty is low. In greenhouses and garden centres, host plants are abundantly available. Trade networks, which are common between Norwegian greenhouses and garden centres, favour a wider establishment of the pest. In parks, private gardens and natural areas, the environment is also considered favourable due to availability of hosts and conductive climate. Mutual use of equipments at different sites, are examples of management practises that will support the spread of *L. sativae.* Once entered into the environment, spread is favoured by the short generation time and the ready availability of host plants.

3.2.2.4 Other characteristics of the pest affecting the probability of establishment

It is likely that the reproductive strategy of the pest and duration of its life cycle could aid establishment, and it is likely that a population could spread in the field during the summer months. The pest is highly adaptable and has been introduced into many new areas outside its area of origin. In parts of the temperate zone *L. sativae* infests crops in the field in summer even if it cannot overwinter outside greenhouses. This is due to repeated colonization from infested greenhouses every spring. The uncertainty is low for these assessments.

Probability of the reproductive strategy of the pest and the duration of its life cycle to aid establishment.

L. sativae has a reproduction strategy that most likely would favour quick spread in the field during summer, and all year round in greenhouses. In greenhouses, at 20 °C the life-cycle takes 29.9 days, and theoretically 12 generations could develop per year, while at 25 °C the life-cycle is 16.5 days (Tokumaru & Abe 2003), and 22 generations could develop per year. This rapid development of successive generations is part of the explanation for the quick build-up of huge population. Another important factor both in the greenhouses and in the field is the wide host plant range that makes it probable for the pest to find host plants everywhere and the development of resistance to many insecticides in many populations. The uncertainty of this assessment is low.

3.2.3 Probability of spread after establishment

There is a high probability for *L. sativae* to be spread quickly in the PRA area by trade of host plants. The uncertainty of this assessment is low. Planting of infested plants will bring the pest from the greenhouses into the environment.

<u>Spread by natural means</u>

L. sativae has the opportunity for natural spread in the PRA area during the summer, and it is highly likely that this spread would be rapid. It is assumed that *L. sativae* in this respect could act similar to *L. huidobrensis*, which in the field in Norway can spread in a circle with diameter at least 1 km during the three summer months (Andersen & Hofsvang 2010).

Long-distance dispersal by natural means includes movement by aerial dissemination of adult flies during major weather events such as wind driven rain and turbulent air. So far this has not been observed in Norway.

<u>Spread by human assistance</u>

There are very high probabilities for *L. sativae* to be spread quickly by human-mediated means in the PRA area, most significantly through the commercial movement of infected plants for planting. The uncertainty of this assessment is low.

3.2.4 Conclusion on the probability of introduction and spread

<u>Probability of entry</u>

The overall probability of entry of *L. sativae* into the PRA area is rated as high, with medium level of uncertainty. This assessment is based upon identification of pathways, import volume, the probability of the pest being associated with the pathway at origin, the probability of survival and multiplying during transport or storage and the probability of transfer to a suitable host after arrival.

<u>Probability of establishment</u>

The overall probability of establishment in greenhouses of *L. sativae* in the PRA area is rated as high, with medium level of uncertainty. This assessment is based on an abundant availability of suitable hosts, suitability of the environment, biological characteristics of the pest, and the effects of existing pest management practices.

The overall probability of spread of *L. sativae* outdoors in the PRA area is rated as moderate, with medium level of uncertainty. This assessment is based on the experience during the situation with *L. huidobrensis* in 2002 (Andersen & Hofsvang 2010).

Probability of spread after establishment

The probability for *L. sativae* to be spread quickly in greenhouses in the PRA area by trade of host plants is rated as high. The uncertainty of this assessment is low. Planting of infected plants will bring the pest from the greenhouses into the environment. This can also happen if adult flies escape from the greenhouses through doors or windows. In parts of the PRA area where climate events are favourable, and where there is an abundance of continuous hosts, natural spread is likely to be high during the summer months. During the winter, all out-door populations will die out in the PRA area.

3.3. Assessment of potential economic consequences

3.3.1 Pest effects

L. sativae has never been reported from Norway, neither on imported plant material nor in the field. A future establishment in Norwegian greenhouses and plant centres is expected to have considerable effect as the species has the potential to affect plant growth and yield, cf. 4.1.5.

3.3.2 Analysis of economic consequences

3.3.2.1 Analysis of commercial consequences

To assess a potential economical consequence of an infestation of *L. sativae* in Norwegian greenhouses is difficult. However, one cannot exclude an incidence equivalent to the spread of *L. huidobrensis* in 2002 which was estimated to cost 40-50 million NOK (Miljøverndepartementet 2007).

3.3.2.2 Non-commercial and environmental consequences

Appearance of *L. sativae* in natural areas in the PRA area could be a local threat to closely related species, mainly *L. bryoniae* and *L. strigata*, by competing over host plants. In addition it would cause locally high infestations in host plants. However, since the species will be eradicated during the winter, the threat to the environment, both plants and animals, is valuated as low.

3.3.3 Conclusion of the assessment of economic consequences

It is concluded that *L. sativae* can cause significant damage to plants, both vegetables and ornamentals. In addition to the directs crop losses, *L. sativae* will cause indirect economic consequences as the Norwegian Food Safety Authority will instruct that all plants material in an infested unit should be destructed. The significances of direct and indirect losses depend on how fast an infestation is discovered and how fast a potential spread by trade is stopped. So far, *L. sativae* has never been observed in Norway.

3.3.3.1 Endangered area

The PRA area where presence of *L. sativae* might result in economically important losses is identified as Norwegian greenhouses and plant centres.

4. CONCLUSION OF THE PEST RISK ASSESSMENT

Pest status of the PRA area

The pest of concern in this pest risk assessment is the Agromyzid fly *Liriomyza sativae*. The PRA area is Norway. *L. sativae* is not present, and the pest is a quarantine species in the PRA area. So far it has never with certainty been encountered in Norway.

Probability of introduction and spread

The overall probability of entry of *L. sativae* into the PRA area is rated as high, with a medium level of uncertainty. This assessment is based upon identification of pathways, import volume, the probability of the pest being associated with the pathway at origin, the probability of survival and multiplying during transport or storage and the probability of transfer to a suitable host after arrival.

The overall probability of establishment of *L. sativae* in greenhouses in the PRA area is rated as high, with a medium level of uncertainty. The probability of establishment in the field is rated as high during the summer months, but its ability to overwinter in the field in the PRA area is evaluated as very low, with a low level of uncertainty. This assessment is based on an abundant availability of suitable hosts, suitability of the environment in at least parts of the PRA area, and biological characteristics of the pest.

Conclusion regarding endangered areas

The part of the PRA area where presence of *L. sativae* in greenhouses might result in economically important losses (the endangered area) is assessed to be all of the country of Norway. This area must be regarded as a maximum estimate for the endangered area. In the field, the species would need a summer temperature of at least 15 °C to develop populations of a certain size to become a pest. This could happen in coastal areas of Southern and Middle Norway.

Conclusion of the assessment of economic consequences

The pest *L. sativae* is likely to have moderate economic impact on the plant centres and greenhouses in the PRA area with current phytosanitary measures. Without any such regulations *L. sativae* would likely have major economic impact on the greenhouse industry of the PRA area. The level of uncertainty of this assessment is low.

L. sativae is likely to have a low economic impact on outdoor crops in parts of the PRA area.

The non-commercial and environmental consequences to natural environments in the PRA area are likely to be low, with a low level of uncertainty.

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Appendix 1

Appendix 1. Distribution of Liriomyza sativae (EPPO 2009).

Country	Widespread	Limited distribution	Few records	No details	Absent
Europe					
Turkey		X			
Asia					
Vietnam	X				
China		X			
India		X			
Israel		X			
Japan		X			
Thailand		X			
Uzbekistan		X			
Yemen			X		
Indonesia				X	
Iran				X	
Jordan				X	
Malasia				X	
Oman				X	
Sri Lanka				X	
Africa					
Zimbabwe		X			
Cameroon				X	
Nigeria				X	
Sudan				X	
America					
Argentina	X				
Carribean	X				
Martinique	X				

St. Vincent and the Grenadines	X				
Bahamas		X			
Barbados		X			
Brazil		X			
Canada		X			
Chile		X			
Colombia		X			
Jamaica		X			
Peru		X			
USA		X			
Venezuela		X			
Antigua and Barbuda				X	
Costa rica				X	
Cuba				X	
Dominican Republic				X	
French guiana				X	
Guadeloupe				X	
Mexico				X	
Montserrat				X	
Netherlands Antilles				X	
Nicaragua				X	
Panama				X	
Puerto Rico				X	
Saint Lucia				X	
St. Kitts-Nevis				X	
Trinidad and Tobago				X	
Oceania					
American Samoa	X				
Samoa	X				
Guam		X			

Cook Islands		X			
New Caledonia		X			
Pacific Islands		X			
French Polynesia				X	
Micronesia				X	
Northern Mariana Islands				X	
Vanuatu				X	

Appendix 2

Appendix 2. EPPO report on notifications of non-compliance for *Liriomyza sativae* (records of *Liriomyza* spp. are not included) (EPPO Reporting Service 2002 – September 2009)

Year	Consignment	Type of commodity	Country of origin	Destination
2009	*Ocimum*	Vegetables (leaves)	Thailand	United Kingdom
	Ocimum americanum	Vegetables (leaves)	Thailand	France
	Ocimum americanum	Vegetables (leaves)	Thailand	Sweden
	Ocimum americanum	Vegetables (leaves)	Thailand	France
	Ocimum sanctum, Ocimum basilicum	Vegetables (leaves)	Egypt	France
	Ocimum basilicum	Vegetables (leaves)	India	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum	Vegetables (leaves)	Thailand	United Kingdom
	Ocimum americanum	Vegetables (leaves)	Thailand	France
	Ocimum americanum	Vegetables (leaves)	Thailand	Sweden
	Ocimum americanum	Vegetables (leaves)	Thailand	France
	Ocimum sanctum, Ocimum basilicum	Vegetables (leaves)	Egypt	France
	Ocimum basilicum	Vegetables (leaves)	India	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum basilicum	Vegetables (leaves)	Thailand	Sweden
	Ocimum	Vegetables (leaves)	Thailand	United Kingdom
	Ocimum americanum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Israel	Netherlands
	Gypsophila	Cut flowers	Ethiopia	Netherlands
	Ocimum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum americanum	Vegetables (leaves)	Thailand	Sweden
	Ocimum basilicum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	Sweden

2008	*Ocimum americanum*	Vegetables (leaves)	Thailand	Sweden
	Ocimum	Vegetables (leaves)	Thailand	Sweden
	Ocimum basilicum	Vegetables (leaves)	Israel	Czech Republic
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum basilicum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	Sweden
	Ocimum basilicum	Vegetables (leaves)	Thailand	United Kingdom
	Ocimum canum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum americanum	Vegetables (leaves)	Thailand	Denmark
	Ocimum americanum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Israel	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum basilicum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum sanctum	Vegetables (leaves)	Thailand	France
	Ocimum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum americanum	Vegetables (leaves)	Thailand	Denmark
	Ocimum basilicum, *Ocimum americanum,* *Ocimum*	Vegetables	Thailand	Netherlands
	Ocimum basilicum, *Dendrobium*	Vegetables (leaves) and cut flowers	Thailand	Denmark
2007	*Ocimum*	Vegetables (leaves)	Thailand	United Kingdom
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum basilicum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum, *Ocium canum*	Vegetables (leaves)	Thailand	Netherlands
	Ocium canum	Vegetables (leaves)	Thailand	Netherlands
	Gypsophila	Cut flowers	Israel	Netherlands
	Ocimum	Vegetables (leaves)	Thailand	Sweden
	Ocimum	Vegetables (leaves)	Thailand	Belgium

	Ocimum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum americanum	Vegetables (leaves)	Thailand	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Israel	Czech Republic
	Ocimum basilicum	Vegetables (leaves)	Israel	Netherlands
	Ocimum basilicum	Vegetables (leaves)	Thailand	Czech Republic
	Ocimum basilicum	Vegetables (leaves)	Thailand	France
	Ocimum basilicum	Vegetables (leaves)	Thailand	Netherlands
2006	*Gypsophila*	Cut flowers	Israel	Netherlands
	Ocimum	Vegetables	Thailand	Sweden
	Ocimum	Vegetables	Thailand	Belgium
	Ocimum americanum	Vegetables	Thailand	Netherlands
	Ocimum basilicum	Vegetables	Israel	Czech Republic
	Ocimum basilicum	Vegetables	Thailand	France
	Ocimum basilicum	Vegetables	Thailand	Netherlands
	Gypsophila	Cut flowers	Israel	Netherlands
	Ocimum sanctum	Vegetables	Thailand	Netherlands
	Cassia	Vegetables	Thailand	Czech Republic
	Gypsophila	Cut flowers	Israel	Netherlands
	Ocimum americanum	Vegetables	Thailand	France
	Ocimum basilicum	Vegetables	Thailand	Netherlands
	Ocimum sanctum	Vegetables	Thailand	Netherlands
2005	*Ocimum basilicum*	Vegetables	Thailand	Netherlands
	Lisianthus	Cut flowers	Brazil	Netherlands
	Ocimum basilicum, *Solanum melongena*	Vegetables	Thailand	United Kingdom
	Gypsophila	Cut flowers	Tanzania	Netherlands
	Gypsophila	Cut flowers	Israel	Netherlands
	Ocimum basilicum	Vegetables	Thailand	Ireland
2004	*Ocimum basilicum*	Vegetables	Israel	Ireland
	Ocimum basilicum	Vegetables	Israel	Netherlands
	Ocimum basilicum	Vegetables	Thailand	Ireland
	Ocimum	Vegetables	Thailand	Denmark
	Ocimum americanum	Vegetables	Thailand	Ireland
	Ocimum basilicum	Vegetables	Thailand	France

	Ocimum basilicum	Vegetables	Thailand	Netherlands
	Ocimum basilicum	Vegetables	Thailand	Sweden
2003	*Coriandrum sativum*	Vegetables	Egypt	Denmark
	Ocimum canum	Vegetables	Thailand	Denmark
	Amaranthus tricolour	Cut flowers	Sri Lanka	France
	Ocimum	Vegetables	Israel	France
	Mentha	Vegetables	Vietnam	France
2002	*Amaranthus*	Vegetables	Nigeria	United Kingdom

Appendix 3

Appendix 3. Host plants for *Liriomyza sativae* (Sæthre 1996, Andersen et al. 2002, 2008, EPPO databases on quarantine pests, and EPPO reporting service 2002 – September 2009).

Host species	**Major host = A; Minor host or not classified = B**
Abelmoschus esculentus	B
Achillea	B
Allium ampeloprasum	B
Allium cepa	B
Allium sativum	B
Alstromeria	B
Amaranthus tricolour	B
Amaranthus sp.	B
Anemone sp.	B
Anthirrhinum sp.	B
Apium graveolens	B
Aster novi-belgii	B
Aster sp.	B
Bellis sp.	B
Benincasa hispida	B
Beta vulgaris	A
Brassica campestris	B
Brassica chinensis	B
Brassica juncea	B
Brassica oleracea	B
Brassica rapa	B
Calendula sp.	B
Callistephus chinensis	B
Cannabis sativa	B
Capsicum annuum	B
Carduus sp.	B
Carthamus sp.	B
Cassia sp.	B

Chrysanthemum frutescens	A
Chrysanthemum morifolium	A
Chrysanthemum sp.	A
Cichorium endivia	B
Cineraria sp.	B
Cirsium arvense	B
Citrullus lanatus	B
Coriandrum sativum	B
Cucumis melo	B
Cucumis sativus	B
Cucurbita pepo	B
Dahlia pinnata	B
Dahlia hybrids	B
Datura sp.	B
Daucus carota	B
Dendranthema x *grandiflorum*	B
Dendranthema sp.	B
Dianthus barbatus	B
Dianthus caryophyllus	B
Dianthus chinensis	B
Dianthus cv. Gypsy	B
Dianthus sp.	A
Diascia sp.	B
Eustoma sp. (syn. *Lisianthius* sp.)	B
Exacum sp.	B
Galinsoga sp.	B
Gazania sp.	B
Gerbera sp.	B
Glechoma hederacea	B
Gossypium sp.	B
Gypsophila paniculata	A
Lactuca sativa	A
Lagenaria siceraria	B
Lathyrus sp.	B

Liatris sp.	B
Linum sp.	B
Lobelia sp.	B
Luffa acutangula	B
Luffa aegyptica (syn. *L. cylindrica)*	B
Lycopersicon esculentum	B
Matricaria sp.	B
Matthiola incana	B
Medicago sativa	B
Mentha sp.	B
Nicotiana alata	B
Ocimum americanum	B
Ocimum basilicum	B
Ocimum canum	B
Ocimum sanctum	B
Ocimum sp.	B
Oxalis sp.	B
Petasites hybridus	B
Petroselinum crispum	B
Petunia hybrids	B
Phaseolus lunatus	B
Phaeolus vulgaris	B
Phlox drummondii	B
Pisum sativum	B
Primula obconica	B
Primula polyantha	B
Primula sp.	B
Ranunculus sp.	B
Raphanus sativus	B
Ricinus communis	B
Saponaria sp.	B
Senecio vulgaris	B
Solanum melongena	B
Solaunum nigrum	B

Solanum tuberosum	A
Solidago sp.	B
Solidaster sp.	B
Sonchus sp.	B
Sorghum vulgare	B
Spinacia oleracea	A
Stellaria sp.	B
Tagetes erecta	B
Trachelium sp.	B
Tropaeolum majus	B
Verbena hybrids	A
Vicia faba	B
Vigna sp.	B
Viola sp.	B
Zinnia sp.	B