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VKM Report 2017: 24

# Risk Assessment of Tomato leaf miner moth (*Tuta absoluta*)

**Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety**

Report from the Norwegian Scientific Committee for Food Safety (VKM) 2017: 24  
Risk assessment of Tomato leaf miner moth (*Tuta absoluta*)

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15.06.2017

ISBN: 978-82-8259-281-9

Norwegian Scientific Committee for Food Safety (VKM)

Po 4404 Nydalen

N – 0403 Oslo

Norway

Phone: +47 21 62 28 00

Email: [vkm@vkm.no](mailto:vkm@vkm.no)

[www.vkm.no](http://www.vkm.no)

[www.english.vkm.no](http://www.english.vkm.no)

Suggested citation: VKM. (2017) Risk assessment of Tomato leaf miner moth (*Tuta absoluta*). Scientific Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety, ISBN: 978-82-8259-281-9, Oslo, Norway.

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# **Risk assessment of tomato leaf miner moth (*Tuta absoluta*)**

## **Authors preparing the draft opinion**

Leif Sundheim (chair), Daniel Flø (NIBIO), Trond Rafoss, Micael Wendell (VKM)

(Authors in alphabetical order after chair of the working group)

## **Assessed and approved**

The opinion has been assessed and approved by Panel on Panel of Plant Health. Members of the panel are: Trond Rafoss (chair), Guro Brodal, Åshild Ergon, Christer Magnusson, Arild Sletten, Halvor Solheim, Leif Sundheim, Anne Marte Tronsmo, Bjørn Økland. (Panel members in alphabetical order after chair of the panel)

## **Acknowledgment**

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed a working group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority. Project leader from the VKM secretariat has been Micael Wendell. The members of the working group Leif Sundheim, Trond Rafoss (Panel on Plant Health) and Daniel Flø (NIBIO) are acknowledged for their valuable work on this opinion. The Panel on Plant Health is acknowledged for comments and views on this opinion.

VKM would like to thank senior consultant Pernille Røed Larsen, The Norwegian Horticultural Growers Association for providing valuable information on the structure and geography in the Norwegian greenhouse tomato production. VKM would also thank the greenhouse production consultant Nick Starkey from Grotek Consulting ApS for valuable information regarding both the Danish and the Norwegian *T. absoluta* infestation as well as Scandinavian pest management strategies. Furthermore, VKM would like to thank technical officer Dr. Philip Morlay from the British Tomato Grower Association for valuable input regarding British pest management strategies.

## **Competence of VKM experts**

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

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# Summary

Since 2006, the Tomato leaf miner moth (*Tuta absoluta*) has become the most serious pest in commercial tomato production, both in open fields, tunnels and in greenhouse production, thru out of Europe. *Tuta absoluta* was detected for the first time in Norway in April 2017, in a tomato nursery in Jæren in Klepp municipality, Rogaland County. Since then, the pest has been detected in three additional greenhouses in close proximity to the first outbreak.

The Norwegian Food Safety Authority is in the process of doing a cost-benefit analysis of the economy in a potential eradication of the *T. absoluta* outbreaks in Rogaland County.

Surveillance has been commenced to investigate the possibility of further spread. In anticipation of the results of the survey, the Norwegian Food Safety Authority wishes to initiate the process of obtaining basic data and risk assessments that are needed to perform a cost-benefit analysis, and therefore wishes to ask, inter alia, relevant knowledge-support

The Norwegian Scientific Committee for Food Safety (VKM) has been asked by the Norwegian Food Safety Authority to 1) estimate the damage to the Norwegian tomato industry if the outbreak is not eradicated, 2) Other detrimental impacts, 3) assess the uncertainties related to the questions above and 4) assess the likelihood of a new introductions to Norwegian tomato nurseries due to the imports of plants and fruits.

VKM has appointed a working group consisting of two members of the Panel on Plant Health, one external expert and the VKM secretariat to answer the request. The Panel on Plant Health has reviewed and revised the draft prepared by the working group and finally approved the risk assessment of tomato leaf miner moth (*Tuta absoluta*).

*Tuta absoluta* is a night active moth with a high reproduction capacity that allows the pest population to increase rapidly. Females can lay up to 260 eggs on the underside of leaves or on stems and to a lesser extent on fruits. After hatching in the morning larvae normally start mining within one hour. There are four larval stages, and if food is available and the climate favourable, larvae feed almost continuously and generally do not enter diapause. Fully-fed larvae pupate mainly on the leaves and in the soil, depending on the environmental conditions.

The larvae of *T. absoluta* feed on all parts of the plants, as well as on the fruit. This results in significant yield losses, since damaged tomatoes cannot be marketed.

*Tuta absoluta* originates from South America, but the pest has spread throughout Europe (discovered in Spain 2006) and Africa (discovered in Algeria 2008) and now discovered in Norway April 2017.

*Tuta absoluta* is a major pest in all countries where it has been established, and crop losses between 50-100% have been reported from South America and Spain. In infested countries,

the cost of tomato production has increased as a result of new pest control and monitoring strategies, both at production but also during the post harvest process.

Control measures already applied by Norwegian tomato growers against other insects will partly control *T. absoluta*. If no precise control measures are applied against *T. absoluta*, damage to the Norwegian tomato production industry is expected to be high with a low uncertainty. The estimated yield losses in Norway are expected to be about 1 to 5%. However, this estimation is assessed with a high uncertainty and if the pest is early detected and controlled. If not, yield losses are expected to be much higher.

The increase in chemical as well as biological pesticide application is assessed to be high, with low uncertainty. The number of insecticide applications are expected to be increased fourfold. The use of predatory bugs (*Macrolophus pygmaeus*) as well the use of pheromone traps (Delta and water traps) for monitoring are both expected to be doubled. Moreover, the amount of mating disruption pheromone dispensers are going to be considerable. All estimated amounts are assessed with a high uncertainty.

The available data on the climate in Rogaland County indicates that outdoor populations of *T. absoluta* may multiply outdoors during the summer months on tomato, potato and other suitable solanaceous host plants in the major tomato growing districts of Jæren and the islands in the Ryfylke fjord.

The available data indicate that the climate along the coastal counties may support outdoor populations of *T. absoluta* during the summer months on tomato, potato and other suitable solanaceous plants.

The data indicates that the winter climate in Jæren and on the coast of Rogaland is slightly too cold for winter survival of *T. absoluta*. However, on some islands winter temperatures may not reach sub-zero temperatures some years, which would make the probability of survival higher.

Infestation of *T. absoluta* results in yield losses, besides reduction in crop quality. Losses will affect the farmer's income directly (e.g. crop and quality loss) and indirectly (e.g. higher production cost due to increased pest management and monitoring programs). In addition, the society in general will in the end be affected by fewer commodities or to a higher cost than expected.

Production of other host plants (e.g. potatoes) in the area near to an infested greenhouse should be avoided. It is not likely that *T. absoluta* will affect the potato yield. However, potatoes, and other host plants, may facilitate spread of *T. absoluta*.

An increased use of pesticides for controlling *T. absoluta* may also negatively affect the perception of Norwegian tomatoes among Norwegian consumers.



Pallets, packing materials and carriage equipment used in transport are the most important pathways for entry of the pest in Norway. Import of tomatoes from the heavily infested countries is also a pathway as well as plant for planting imported to the hobby gardener.

The probability of entry of *T. absoluta*, from countries outside the assessed area is considered as likely. The uncertainty of this conclusion is medium. The overall assessment behind this conclusion is that *T. absoluta* is frequently associated with several pathways for entry (imported tomato fruits, plants for planting to the hobby gardener as well as packing material), the pest survives during transport and storage, and there are no existing pest management procedures applied to consignments that might contain *T. absoluta*.

To prevent entry of *T. absoluta* from other countries into Norway, it is important to avoid import of infested tomatoes or other fruits of *Solanaceae* as well as infested plants for planting. *Tuta absoluta* is not regulated in the exporting countries from where Norway import tomatoes and other fruits from *Solanaceae*, or plants for planting. Fruits in trade should show no signs of insect damage, and plants for planting should be imported from pest free production areas.

Pallets, packing material used in transport are potential pathways for entry. To prevent introduction of the pest into the assessed area those consignments should be pest free. Importing countries should guarantee that crates, that are returned to the tomato growers, are free from the pest.

The only known Danish *T. absoluta* infestation, outside Odense, was due to importation of organic tomatoes from Spain into the packinghouse of the producer. Therefore, extra control measures might be necessary for imported organic tomato consignments.

It is important that the tomato industry openly share information between growers to avoid spread between greenhouses.

If no control measures are taken, the tomato growers may suffer considerable losses.

**Key words:** VKM, risk assessment, Norwegian Scientific Committee for Food Safety, Norwegian Food Safety Authority, *Tuta absoluta*, Tomato leaf miner moth, Sør-amerikansk tomatmøll, entry, establishment, pathway, yield loss, control measures, pest management, plant health, tomato production, greenhouses, economic consequences.

# Sammendrag på norsk

Siden den søramerikansk tomatmøllen, *Tuta absoluta*, for første gang kom til Europa i 2006, har den blitt en av de mest alvorlige skadedyrene for kommersiell tomatproduksjon, både på åpne felt, i tunneler og i drivhusproduksjon. *Tuta absoluta* ble i april 2017 påvist for første gang i Norge i et tomatgartneri på Jæren. De tre andre tomatgartneriene i nærheten har også fått påvist smitte.

Mattilsynet er i gang med en kost-nytteanalyse for å avgjøre om det er samfunnsøkonomisk lønnsomt å sette i verk offentlige utryddingstiltak mot det pågående utbruddet av søramerikansk tomatmøll, *Tuta absoluta*, på Jæren.

Det er igangsatt kartlegging for å undersøke eventuell videre spredning. I påvente av resultatene fra kartleggingen ønsker Mattilsynet å starte prosessen med å innhente grunnlagsdata og risikovurderinger som trengs for å gjøre en kost-nytteanalyse, og ønsker derfor å spørre bl.a. kunnskapstøtteinstitusjonene og næringen om de kan bidra med dette.

Mattilsynet ba VKM om å 1) vurdere skade i tomatnæringen dersom utbruddet ikke utryddes, 2) beskrive sannsynlighet for etablering på friland eller annen skade, 3) beskrive usikkerheten i svarene og 4) anslå sannsynligheten for at smitten introduseres på ny i norske tomatgartnerier som følge av import av planter og frukt.

VKM utnevnte en prosjektgruppe bestående av to medlemmer av VKMs faggruppe for plantehelse, en ekstern ekspert og VKMs sekretariat til å besvare oppdraget. Faggruppen for plantehelse har gjennomgått og revidert utkastet fra prosjektgruppen og godkjent den endelige rapporten.

*Tuta absoluta* er en nattaktiv møll med høy reproduksjonskapasitet som gjør at skadedyrpopulasjonen øker raskt. Hunnene kan legge opp til 260 egg på undersiden av bladene eller på stenglene, men også på selve frukten. Etter klekkingen om morgenen starter larvene normalt å lage små ganger innen en time. Det er fire ulike larvestadier, og hvis mattilgangen er god og klimaet er gunstig, lever larvene nesten kontinuerlig og går vanligvis ikke inn i noen dvaleperiode. Fullmettede larver forpupper hovedsakelig på blader og i jord, avhengig av miljøforholdene.

Larvene av *Tuta absoluta* gresser på alle deler av plantene, så vel som på selve tomatfrukten. Dette resulterer i betydelige avlingstap, siden skadede tomater ikke kan selges.

Opprinnelig kommer *Tuta absoluta* fra Sør-Amerika, men den har spredd seg over hele Europa (oppdaget i Spania 2006) og Afrika (oppdaget i Algerie 2008) og nå for første gang oppdaget i Norge i april 2017.

*Tuta absoluta* er en stor skadegjørere i alle land hvor det er etablert, og avlingstap mellom 50 til 100 prosent har blitt rapportert fra både Sør-Amerika og Spania. I infiserte land har kostnaden for tomatproduksjon økt som et resultat av nye bekjempelses- og overvåkingsstrategier, både ved produksjon, men også etter innhøsting.

Ulike tiltak som norske tomatprodusenter allerede har tatt i bruk mot andre insekter, vil kun delvis kontrollere *Tuta absoluta*. Dersom det ikke pålegges nøyaktige tiltak mot *Tuta absoluta*, forventes det stor skade på norsk tomatnæring. Dette anslås med en lav grad av usikkerhet. Det estimerte avlingstapet i Norge forventes å være om lag 1 til 5 prosent. Estimater har imidlertid stor usikkerhet, og vil kun være gjeldende hvis møllen oppdages og kontrolleres tidlig. Hvis ikke, forventes avlingstapet å bli mye høyere.

Økningen i bruk av kjemiske og biologiske plantevernmidler estimeres å være høy, med en lav usikkerhet. Bruk av insektmidler forventes å økes fire ganger. Bruken av rovinsektet (*Macrolophus pygmaeus*) samt bruk av feromonfeller for overvåking, forventes å bli doblet.

Videre vil bruk av parringsforstyrrende feromondispensere bli betydelig. Alle estimatene vurderes med stor usikkerhet.

Klimaet i Rogaland fylke indikerer at utendørspopulasjoner av *Tuta absoluta* kan etablere seg under sommermånedene på tomat, potet og andre egnede planter fra søtvierfamilien.

Ytterligere kan klimaet langs kystområdene støtte utendørs populasjoner av *Tuta absoluta* i sommermånedene på tomat, potet og andre egnede planter fra søtvierfamilien.

Vinterklimaet på Jæren og langs Rogalandskysten er litt for kaldt for vinteroverlevelse av *Tuta absoluta*. Men på noen øyer holder vintertemperaturene seg over null, noe som vil gjøre sannsynligheten for overlevelse høyere.

Angrep av *Tuta absoluta* vil gi store avlingstap, i tillegg til reduksjon i avlingskvalitet. Tap vil påvirke produsentens inntekter direkte (for eksempel avling- og kvalitetstap) og indirekte (for eksempel høyere produksjonskostnad på grunn av økt skadeforvaltning og overvåkingsprogrammer). I tillegg kan samfunnet bli påvirket av færre tomater eller til en høyere kostnad enn forventet.

Produksjon av andre vertsplanter (f.eks. poteter) i området nær et utbrudd, bør unngås. Det er ikke sannsynlig at *Tuta absoluta* vil påvirke potetproduksjonen med avlingstap. Imidlertid kan poteter og andre vertsplanter bidra til ytterligere spredning av *Tuta absoluta*.

Økt bruk av plantevernmidler kan også påvirke oppfatningen av norske tomater blant norske forbrukere negativt.

Lastepaller, emballasjemateriell og annet transportutstyr er blant de viktigste innførselsveiene for *Tuta absoluta* tili Norge. En annen viktig innførselsvei er import av tomater fra land med en høy forekomst av møllen og planter importert til hobbygartnere.

Det anses som sannsynlig at *Tuta absoluta* vil bli introdusert på ny som følge av import. Usikkerheten i denne konklusjonen er middels stor. Den overordnede bedømmelsen bak konklusjonen er at *Tuta absoluta* ofte er forbundet med flere spredningsveier for innførsel (importerte tomatfrukter, planter til hobby gartnere samt emballasje materiell). *Tuta absoluta* overlever fint under transport og lagring, og det er ingen skadedyrreducerende tiltak som brukes på forsendelser som kan tenkes inneholde *Tuta absoluta*.

For å forhindre en ny introduksjon av *Tuta absoluta*, er det viktig å unngå import av smittede tomater eller andre frukter fra søtvierfamilien samt smittede planter til hobby garnerer. Tomater, eller andre frukter fra søtvierfamilien som selges, bør ikke vise tegn på insektskader. Planter skal importeres fra produksjonsområder som er fri for skadedyr.

Paller og pakkematerialet som brukes i transport er de viktigste innførselsveierne for *Tuta absoluta*. For å hindre innføring av skadedyr i det vurderte området, bør også disse forsendelsene være skadedyrfrie. Importerende land skal garantere at kasser, som returneres til tomatbrukerne, er frie for smitte.

Det eneste kjente danske *Tuta absoluta*-angrepet skyldtes import av økologiske tomater fra Spania til den danske produsentens pakkeri. Det kan derfor være nødvendig med ekstra tiltak for importerte økologiske tomatforsendelser.

Det er viktig at tomatindustrien åpent deler informasjon mellom produsenter for å unngå spredning mellom veksthusene.

# Background as provided by the Norwegian Food Safety Authority

The Norwegian Food Safety Authority is in the process of doing a cost-benefit analysis of the economy in a potential eradication of the *T. absoluta* outbreaks in Jæren, Rogaland County. Surveillance is on-going to determine if *T. absoluta* is further spread outside the current outbreak area. While anticipating the results from the mapping of the outbreaks, The Norwegian Food Safety Authority has initiated a process of collecting baseline data and risk assessment necessary for a cost benefit analysis. The Norwegian Food Safety Authority has also contacted research institutes, VKM and the grower organizations for this purpose. The relevant questions to VKM are listed in the Terms of reference below.

*Tuta absoluta* is currently not regulated in the Norwegian Plant Health Regulations. The pest is on the EPPO A2 list. *Tuta absoluta* is present in numerous countries in the region and is not a regulated pest in the EU plant health regulations.

In April 2017 *T. absoluta* was first detected in Norway in a tomato greenhouse in Klepp municipality, Rogaland County. Since then, the pest has been detected in three additional greenhouses in close proximity to the first outbreak. For the time being The Authority considers *T. absoluta* as a potential quarantine pest and has provisionally obliged the growers to implement measures to avoid further spread of the pest, without asking for complete sanitation. To determine if *T. absoluta* has been spread to other areas, The Authority has asked all commercial tomato growers in Norway to use pheromone traps and report suspicious findings.

Senior scientist Nina Svae Johansen from NIBIO has previously issued two statements related to this discovery in Norway: "Statement regarding the *T. absoluta* at Wiig Gartneri AS" (7.4.17) and "Statement on the effectiveness of combating *T. absoluta* with available methods and the risk of spread to horticultural premises in the vicinity of the farm where the attack has been detected" (30.4.17).

Nina Svae Johansen has also developed a contingency plan for greenhouse tomatoes, together with an overview of chemical and biological resources (4.5.17). The Authority will forward this to VKM. Furthermore, the Norwegian Food Safety Authority is aware of a previous express PRA from Germany (2010) and a PRA from the Netherlands Potting (2009), revised by Potting (2013).

# Terms of reference as provided by the Norwegian Food Safety Authority

## **1) Damage to the tomato industry<sup>1</sup> if the outbreak is not eradicated.**

- a) Dissemination scenario – how fast will the pest be spread from the currently infested greenhouses, and what is the expected infested area within 5 – 10 years?
- b) What yield losses can be expected?
- c) What increase in pesticide application and use of biological control can be expected?
- d) What increase in other pest control measures can be expected?
- e) What other significant damages could an establishment of *T. absoluta* inflict on the tomato growers?

## **2) Other damages**

- a) What is the probability of establishment of outdoor populations of *T. absoluta* during the summer in Rogaland and other tomato districts?
- b) What is the probability of the pest overwintering outdoors in Rogaland and in other tomato districts?
- c) What is the probability of damage from outdoor populations of *T. absoluta* on other crops, for example potato?

## **3) What is the uncertainty in the responses to the questions above – «most probable» scenario contra «worst»/ «best case».**

## **4) What is the probability of new introductions of the pest into Norwegian tomato greenhouses as a consequence of import of plants for planting and fruit? What are the potential pathways with the current production practices used by the tomato growers?**

<sup>1</sup> Including both traditional tomato production with stop of production in winter and greenhouses producing tomatoes all year

# Assessment

## 1 Introduction

### 1.1 Purpose and scope

This document presents an opinion prepared by the VKM Panel of Plant Health (hereafter referred to as the Panel), in a response to an urgent request from the Norwegian Food Safety Authority. The opinion is an assessment of *T. absoluta* in Norway.

### 1.2 Information collection

#### 1.2.1 Previous Pest risk assessments

Potting (2013) Pest risk assessment for *T. absoluta* by the NAPPO of Nederland is regarded as relevant for the PRA area. The greenhouse environment is similar in Norway to the greenhouse environments in continental Europe. The critical question is whether the outdoor climates in tomato growing areas of Rogaland County and other counties with greenhouse tomato cultivation in Norway are more severe than in countries in Europe where *T. absoluta* survives the winter.

In January of 2009 adult *T. absoluta* moths were detected in a Dutch tomato packing facility, which had received a consignment of infected tomato from Spain (Potting, 2013). The Dutch PRA considers tomato, potato and Solanaceae weeds and ornamental Solanaceae (*Petunia* spp. and *Schizanthus* spp.) as potential host plants (Potting, 2013). Tomato fruits from infested areas and especially vine tomato, which may contain all stages of the pest, are considered pathways with medium to high probability of *T. absoluta* entry. Transport equipment such as containers, packing crates and transport vehicles are considered pathways with medium probability of the pest entry. Tomato or aubergine plants for planting and other Solanaceae plants for planting are considered to have low probability of *T. absoluta* entry, as relatively small amounts are imported to the Netherlands from infested area. The Dutch PRA concludes that *T. absolutais* considered likely to survive in protected cultivation in the Netherlands with continuous tomato production. Dispersal from infested greenhouses to un-infested greenhouses may be possible during the summer, and transient field populations may enter greenhouses as the moth is attracted to light at night (Potting, 2013). Without changing clothes it is moderately likely that the moth may spread by visiting people. The pest is moderately likely to spread from production greenhouses to packing facilities, but the PRA concludes that spread from consumers to production greenhouses is unlikely (Potting, 2013).

An Express PRA on *T. absoluta* has been published in Germany. As large volumes of tomato are imported into the country from Spain and the Netherlands, the PRA considers the probability of introduction to be high (Kehlenbeck et al., 2010). The pest has already been detected at Baden-Württemberg in Germany. Infestations of Dutch production sites in close vicinity to the German tomato growing districts at the Lower Rhine is of concern. Further introduction of the pest into Germany could lead to extensive damage due to yield losses and additional plant protection costs for tomato growers and damage to bed and balcony plants of Petunia. *Tuta absoluta* is likely to be spread during summer months, but overwintering will be limited to greenhouses due to the climatic conditions in Germany (Kehlenbeck et al., 2010). The German PRA considers tomato to be the main host for *T. absoluta*, but the pest may damage potato foliage, eggplant (*Solanum melongena*), pepino (*S. muricatum*), ornamental plants of the Solanaceae (e.g. *Petunia*, *Datura*) and several wild plants of the Solanaceae, like *S. nigrum* and *Datura stramonium* (Kehlenbeck et al., 2010). The pest has already been detected at Baden-Württemberg in Germany. Infestations of Dutch production sites in close vicinity to the German tomato growing districts on the Lower Rhine is of concern. Further introduction of the pest into Germany could lead to extensive damage due to yield losses and additional plant protection costs for tomato growers and damage to bed and balcony plants of Petunia. *Tuta absoluta* is likely to be spread during summer months, but overwintering will be limited to greenhouses due to the climatic conditions in Germany (Kehlenbeck et al., 2010). The German PRA considers tomato to be the main host for *T. absoluta*, but the pest may damage potato foliage, eggplant (*Solanum melongena*), pepino (*S. muricatum*), ornamental plants of the Solanaceae (e.g. *Petunia*, *Datura*) and several wild plants of the Solanaceae, like *S. nigrum* and *Datura stramonium* (Kehlenbeck et al., 2010).

### **1.2.2 Literature search strategy**

This section describes the literature search conducted for retrieving the scientific documentation available for this opinion.

A literature search was conducted with the species name "*Tuta absoluta*" with default settings, in Science Direct, ISI Web of Knowledge, Pub Med. and Google scholar.

### **1.2.3 Data collection**

Data on import volume (tonnes) of tomatoes and tomato yield in Norway, were obtained from Statistics Norway (SSB, 2017).

Information on occurrence of *T. absoluta* was obtained from Norwegian Food Safety Authority.



### **1.3 Ratings of probabilities and uncertainties**

The conclusions for probability of entry, establishment and spread of the pest are presented and rated separately, following a fixed scale: unlikely, moderately likely, likely. The descriptors for these qualitative ratings are shown in Appendix **1**.

For the assessment conclusion on entry, establishment, spread and impact, the levels of uncertainty are rated separately, following a fixed scale: low, medium, high. The descriptors for these qualitative ratings of uncertainty are given in Appendix **2**.

## 2 Pest identity and status

### 2.1 Identity of pest, name and taxonomic position

The name of the pest is: *Tuta absoluta* (Povolny, 1994)

Synonym: *Phthorimaea absoluta* (Mayrick, 1917)

Common name in Norwegian: Sør-Amerikansk tomatmøll

Common names in English: South American tomato moth, tomato borer, tomato leaf miner, South American tomato pinworm

EPPO code: GNORAB

The pest is an arthropod.

Class: Insecta, Lepidoptera, Gelechiidae

### 2.2 Assessed area

Norway.

### 2.3 Current distribution

**Table 1.** Current distribution of the pest (CABI, Invasive Species Compendium 2017).

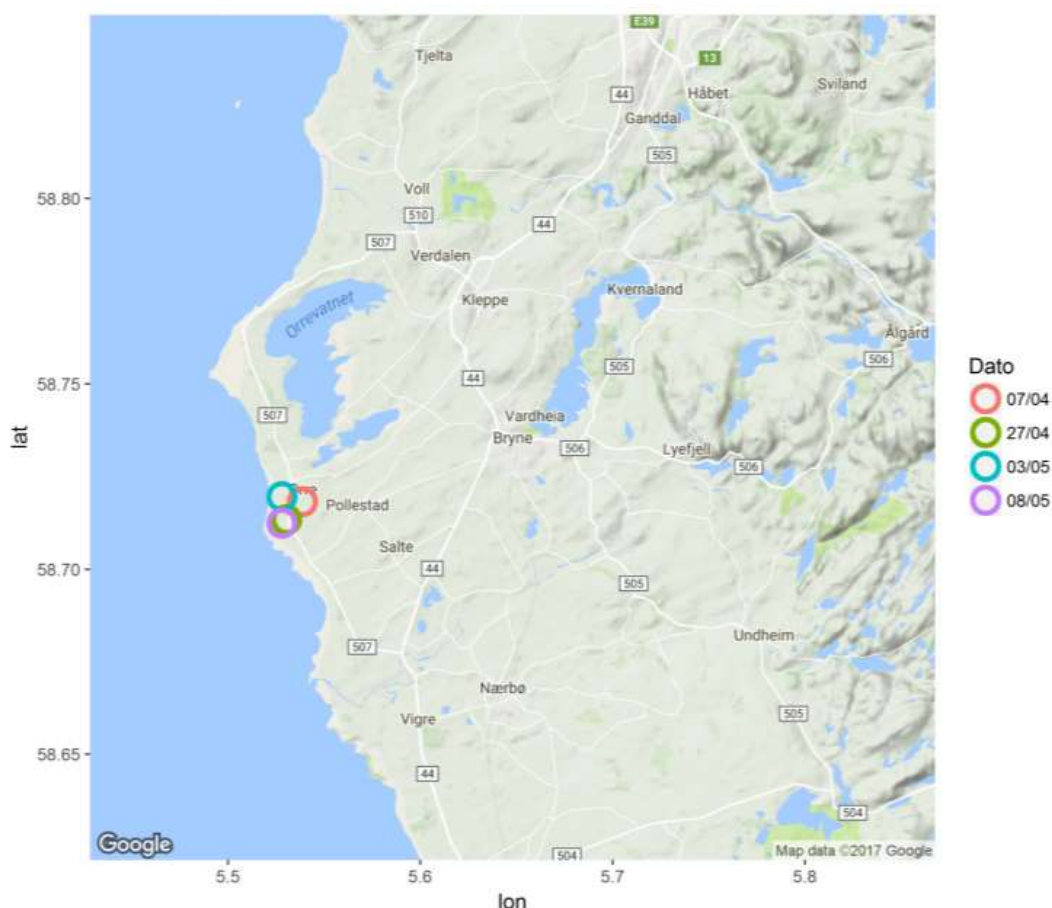
Continent	Distribution	Comments on the pest status in the different countries where it occurs
<b>Africa</b>	<i>Tuta absoluta</i> is widespread in Africa.	First discovered in Algeria 2008
<b>America</b>	The pest originates in Central-America and is widespread in South-America	The native range of <i>T. absoluta</i> is Central-America.
<b>Asia</b>	During the last ten years the pest has spread in Asia, including India, Iran, Israel, Syria, Turkey and many other countries.	

Continent	Distribution	Comments on the pest status in the different countries where it occurs
<b>Europe</b>	The pest is present in most countries of Europe.	<i>T. absoluta</i> is widespread in Spain, where it first was detected in 2006. Since then it has spread across Europe. In 2008 the pest was detected in France (restricted distribution), and in 2009 it was found in Portugal, The Netherlands, United Kingdom (present, personal communication Philip Morlay, June 2017), Germany (under eradication), Romania, Russia (restricted distribution) and several other countries. The pest is under eradication in Denmark (personal communication Nick Starkey, June 2017), and in Norway it was first detected in 2017.
<b>Oceania</b>	Not present	

## 2.4 Occurrence of the pest in the assessed area

The pest was detected in a tomato greenhouse, April 2017 in Klepp municipality, Rogaland County (Figure 1). Later the pest has been found in three more greenhouses close to the first outbreak.

The pest has damaged tomato plants in two of the properties. In the other two properties, with no visible damage (personal communication Hilde Paulsen), the pest was detected by pheromone traps. All tomato growers in Norway have been advised to use pheromone traps in the on-going survey to determine the distribution of the pest in the country.



**Figure 1.** Overview map of the locations where *T. absoluta* was discovered in April 2017 in Klepp municipality. Coloured circles indicate the location of the four greenhouses infested with *T. absoluta* (different colours indicate date of discovery).

## 2.5 Regulation status

The pest is not regulated by the Norwegian NPPO. *Tuta absoluta* was added to the EPPO A1 list in 2004. *Tuta absoluta* is on the EPPO A2 list of pests recommended for regulation as quarantine pests.

### 2.5 Biological information

*Tuta absoluta* is a night active moth with a high reproduction capacity that allows the pest population to increase rapidly. Females can lay up to 260 eggs (EPPO, 2005) on the underside of leaves or on stems and to a lesser extent on fruits. After hatching in the morning larvae normally start mining within one hour. There are four larval stages, and if food is available and the climate favourable, larvae feed almost continuously and generally do not enter diapause. Fully-fed larvae pupate mainly on the leaves and in the soil, depending on the environmental conditions. The pupae (length 5-6 mm) are normally protected by a thin, silky cocoon. After about 5 days at 30°C the pupa becomes dark brown

and the adult moth (6-7 mm) is ready to emerge. The development cycle on tomato depends on the temperature. At 14°C the average development time is 76.3 days, at 19.7°C the development time is 39.8 days and at 27.1°C the development time is 23.8 days (EPPO, 2005 ). *Tuta absoluta* originates from South America, but the pest has spread throughout Europe (discovered in Spain 2006) and Africa (discovered in Algeria 2008) and now discovered in Norway April 2017.

# 3 Assessment of the probability of introduction and spread

## 3.1 Probability of entry of the pest

The overall probability of entry for *T. absoluta* is regarded as likely, with medium uncertainty.

Pallets, packing materials and carriage equipment used in transport are the most important pathways for entry of the pest in Norway. Import of tomatoes from the heavily infested countries is also a pathway as well as plant for planting imported to the hobby market.

### 3.1.1 Identification of pathways for entry

Three pathways are considered as likely and moderately likely for entry of *T. absoluta* into Norway; packing material, fruits of tomatoes and import of Tomato, and other Solanaceae, plants for planting by the hobby gardeners.

Imported tomato plants for planting in commercial greenhouses are also discussed (Table 2).

**Table 2.** Possible pathways for entry of *Tuta absoluta* into Norway.

Possible pathways	Short description	Pathway regulated in Norway? (Yes/No)	Pest already intercepted on the pathway? (Yes/No)
Packing materials that have been contaminated with the pest.	Likely pathway for introduction of the pest	No	No
Tomato fruits imported from countries where <i>T. absoluta</i> is present	Likely pathway for introduction of the pest	Yes from 16/4-3/9 unregulated from 4/9-15/4	No
Imported tomato plants for planting in commercial greenhouses	No imports from <i>T. absoluta</i> infested countries	Yes	No
Tomato, and other Solanaceae, plants for planting by the hobby gardeners.	There is considerable import of tomato plants and other Solanaceae plants for the Norwegian hobby market.	Yes	No

### 3.1.1.1 Tomatoes, fresh or chilled

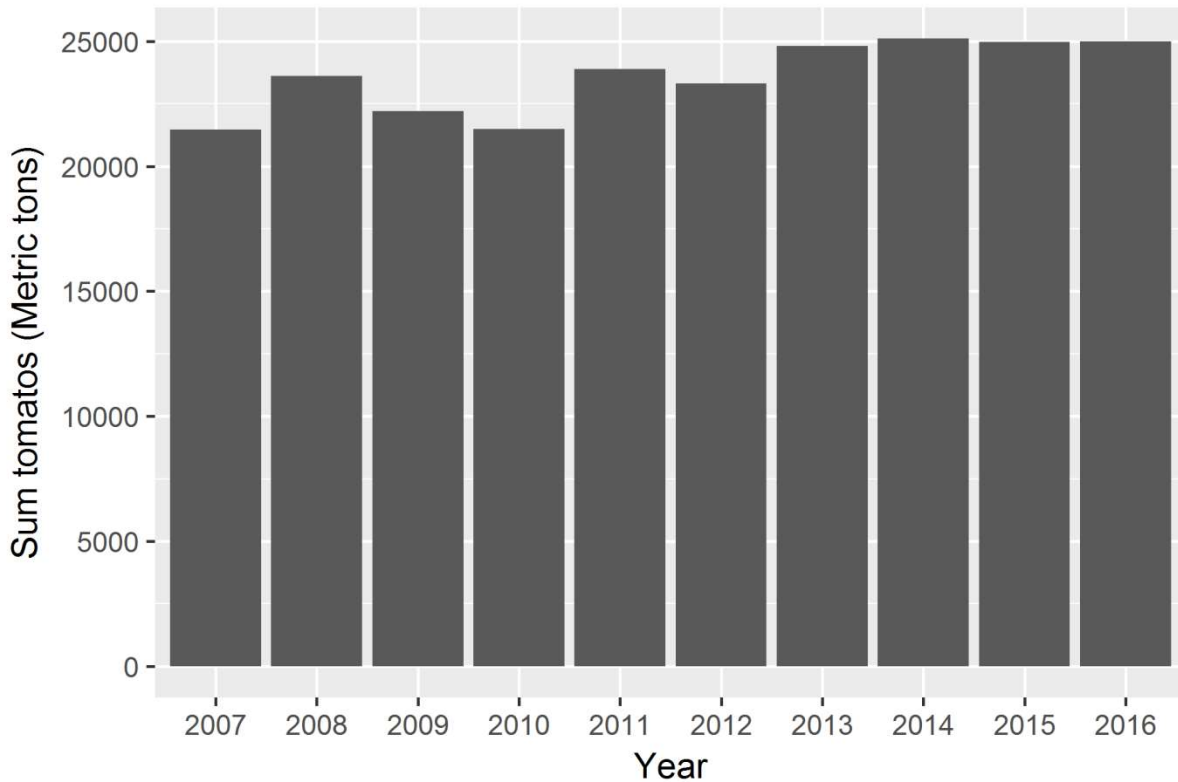
The probability of entry by *T. absoluta* to Norway is considered as moderately likely, with a low level of uncertainty for the commodity "Tomatoes, fresh or chilled".

The frequency and volume of tomato import facilitates the entry of *T. absoluta* to Norway. However, all the tomato importers are situated far from the tomato greenhouses in Rogaland and, therefore, the probability of entry is moderately likely. The probability of entry of *T. absoluta* will depend on the origin, volume and frequency of imports of tomatoes, and the pest's ability to seek out a suitable habitat (greenhouse).

During the past 10 years Norway imported on average  $23.587 \pm 1.438$  metric tons of tomatoes annually (Figure 2). Fresh tomatoes are imported under the commodity codes heading 07.02, which is further split into eight subclasses depending on time of import (Table 3).

**Table 3.** Summarized imports for the past ten years (2007-2016) for each period.

Nr	Commodity Code 07.02	Commodity name	Metric ton
<b>Tomatoes, fresh or chilled.</b>			
1	.0010	From 1. November - 31. May	0
2	.0011	From 1. November - 9. May	170.355
3	.0021	From 10. May – 10. June	0
4	.0022	From 10. May - 31. May	6.465
5	.0023	From 1. June - 10. July	10.585
6	.0030	From 11. July - 14. October	354.535
7	.0040	From 15. October - 31. October	130.145
8	.0090	From 1. June – 31. October	0



**Figure 2.** Bar plot of annual Norwegian tomato imports the past 10 years (2007-2016) (tons) showing a steady import of tomatoes.

### ***3.1.1.2 Plants for planting (commercial growers)***

The probability of entry by *T. absoluta* to Norway is considered as unlikely, with a medium level of uncertainty for plants for planting (commercial growers).

According to The Norwegian Horticultural Growers Association (personal communication Pernille Røed Larsen, June 6, 2017.) there is, or has been a limited import of tomato plants from «Sigg Plant» in Finland to commercial greenhouses in eastern Norway. The uncertainty is therefore in the discrepancy between the information from The Norwegian Horticultural Growers Association and the lack of documented data on imports of tomatoes plants for planting.

### ***3.1.1.3 Packing material***

The probability of entry by *T. absoluta* into domestic greenhouses by packing material is considered as likely, with a medium level of uncertainty.

According to Potting (2013) transport equipment associated with tomato fruits from infested areas have been reported as a pathway. Outbreaks both in Netherland and the UK have been linked to movement of infested packing material (i.e. crates and containers). All life



stages of *T. absoluta* can survive transport between countries and greenhouses, especially the cocoons which will stick to any surfaces.

Packing material such as pallets and crates used for transport are reused, and shipped between production sites, storage facilities and redistributors. Crates that are returned to tomato producers from e.g. packing operations could contain *T. absoluta*.

#### **3.1.1.4 Tomato, and other Solanaceae, plants for planting (hobby market)**

The probability of entry of *T. absoluta* into domestic tomato greenhouses with the pathway tomato and other Solanaceae plants for planting (hobby market) is considered as moderately likely, with a high level of uncertainty.

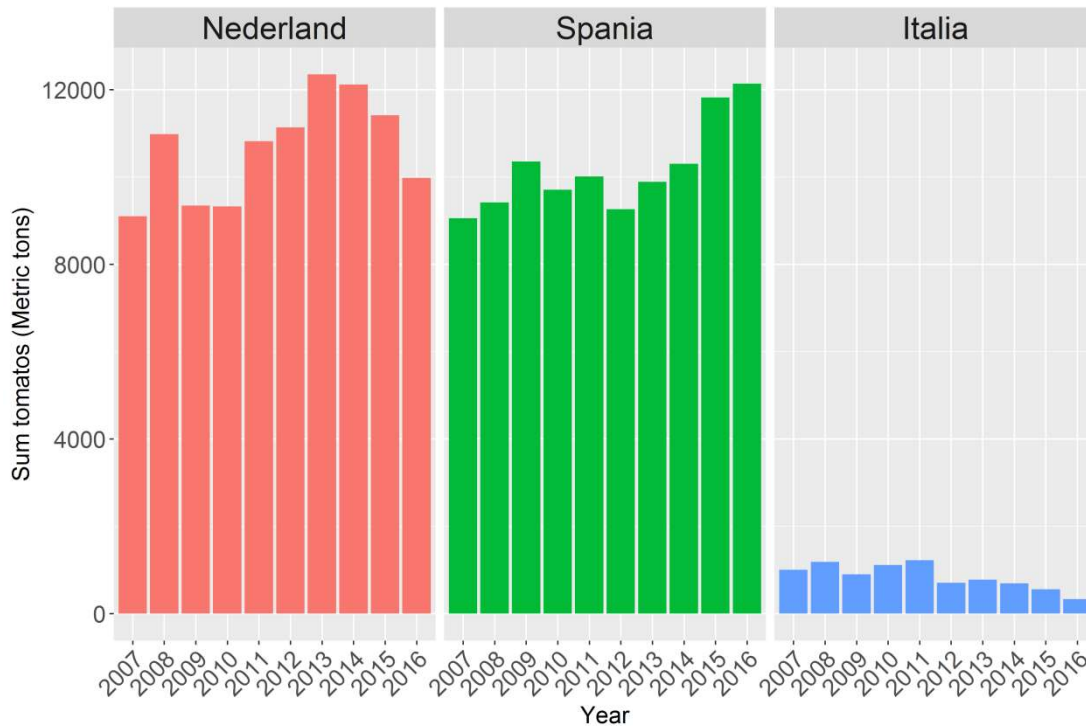
There is a considerable volume of tomato plants as well as other Solanaceae plants for planting imported for the private market (personal communication, Hilde Paulsen, 12 June 2017). Most tomato plants for planting are imported from Denmark and the Netherlands (personal communication, Hilde Paulsen, 12 June 2017). *Tuta absoluta* is present in the Netherlands and has been under eradication in Denmark.

#### **3.1.2 Probability of the pest being associated with the pathway at the origin**

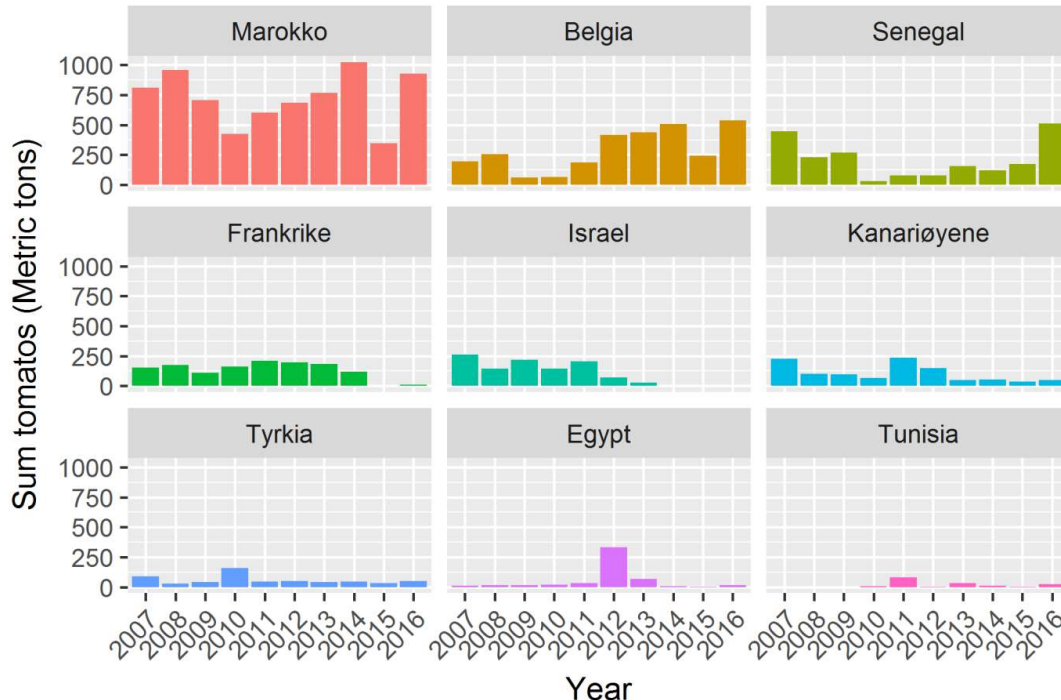
The probability of *T. absoluta* being associated at origin with the pathway "Tomatoes, fresh or chilled" is considered as likely, with a low level of uncertainty.

Greenhouse populations of *T. absoluta* in the Netherlands are limited. However, populations in Spain and Italy are more prevalent. Most of the imported tomatoes (88%) come from two countries; the Netherlands and Spain, where *T. absoluta* is present (Table 4 and Figure 3). Several other top exporting countries also have *T. absoluta* present (Figure 4). Moreover, *T. absoluta* is present in 36 out of the 55 countries exporting tomatoes to Norway (Table 4).

The probability that *T. absoluta* is associated with "Tomato, and other Solanaceae, plants for planting for the private market" is regarded as unlikely with a high uncertainty.



**Figure 3.** Bar plot of the three biggest exporters (names in Norwegian) of tomatoes to Norway during the past 10 years in descending order; Nederland, Spain and Italy (presented as tons/year).



**Figure 4.** Bar plot of the top 4th to 12th tomato exporters (names in Norwegian) (4-12 from table 4) to Norway (presented as tones/year).

**Table 4.** List of exporting countries (names in Norwegian), sum of 10 year imports to Norway in descending order, and the status of *T. absoluta* in the exporting country (EPPO, 2017).

Number	Exporting country	Sum tomatoes 10 years (Kg)	<i>Tuta absoluta</i>
1	Nederland	106555.7	Present
2	Spania	101952.0	Present
3	Italia	8506.7	Present
4	Marokko	7256.6	Present
5	Belgia	2907.9	Present
6	Senegal	2095.7	Present
7	Frankrike	1324.7	Present
8	Israel	1073.4	Present
9	Kanariøyene	1060.9	Unknown
10	Polen	990.5	Absent
11	Tyrkia	579.5	Present
12	Egypt	518.6	Present
13	Palestina (2013-)	220.0	No data
14	Sverige	164.2	Absent
15	Tunisia	163.0	Present
16	Portugal	150.2	Present
17	Tyskland	108.5	Transient, under eradication
18	Ecuador	31.6	Present
19	Makedonia	31.2	No data
20	Danmark	25.6	Absent, intercepted only
21	Hellas	23.2	Present
22	Albania	21.8	Present
23	Chile	16.7	Present
24	Sør-Afrika	14.2	Present
25	Etiopia	13.4	Present
26	Canada	13.2	No data
27	Costa Rica	9.5	Present
28	Namibia	8.9	No data
29	Brasil	5.3	Present
30	Elfenbeinskysten	4.4	No data
31	Zambia	3.2	Present
32	Singapore	2.9	No data
33	Bulgaria	2.5	Present
34	Argentina	2.3	Present

Number	Exporting country	Sum tomatoes 10 years (Kg)	<i>Tuta absoluta</i>
35	Storbritannia	2.2	Present
36	Estland	1.7	No data
37	Kina	1.5	No data
38	Peru	1.5	Present
39	Saudi-Arabia	1.3	Present
40	Colombia	1.0	Present
41	Liechtenstein	0.6	No data
42	Tsjekkia	0.6	Transient, under eradication
43	Mexico	0.5	Present
44	USA	0.5	Present
45	Sri Lanka	0.4	No data
46	New Zealand	0.3	No data
47	Kenya	0.3	Present
48	Russland	0.3	Present
49	Indonesia	0.2	No data
50	Georgia	0.2	Present
51	Kypros	0.2	Present
52	Vietnam	0.2	No data
53	Jamaica	0.1	No data
54	India	0.1	Present
55	Hviterusland	0.1	Present
<b>Sum</b>	55	235871.8	36

### 3.1.3 Probability of survival during transport and storage

The probability of *T. absoluta* surviving transport and storage is regarded as likely with a medium level of uncertainty.

*Tuta absoluta*'s ability to survive transport is evident in the species history during the past ten years. The pest has spread from South America across Africa, parts of Asia and into Europe. Tomatoes are shipped all year and relatively rapidly throughout the year. In addition, populations of *T. absoluta* are prevalent in most tomato exporting countries (Table 4), and all life stages of *T. absoluta* could survive transport. Especially pupas, which are sheltered by a cocoon, are less vulnerable. Tomatoes are handled carefully and products like vine tomato would provide shelter for the pest.

### **3.1.4 Probability of the pest surviving existing pest management strategies**

There are no existing pest management procedures.

### **3.1.5 Conclusions on the probability of entry**

In conclusion, the probability of entry of *T. absoluta*, from countries outside the assessed area is considered as likely. The uncertainty of this conclusion is medium.

The overall assessment behind this conclusion is that *T. absoluta* is frequently associated with several pathways for entry (imported tomato fruits, plants for planting to the hobby gardener as well as packing material), the pest survives during transport and storage, and there are no existing pest management procedures applied to consignments that might contain *T. absoluta*.

## **3.2 Probability of establishment**

### **3.2.1 Suitability of environment**

The probability of *T. absoluta* to establish populations outdoors is regarded as unlikely, with a medium level of uncertainty.

The probability of *T. absoluta* to establish populations in greenhouses is regarded as likely, with a low level of uncertainty.

*Tuta absoluta* is most likely a chill susceptible species i.e. it lacks cold hardiness. Although *T. absoluta* has a supercooling point of between -18.2 to -16.7°C (Van Damme et al., 2015), it most likely dies, when exposed to subzero temperatures for extended periods. Experiments by Van Damme et al. (2015) indicated that at least half of a pupal or adult population of *T. absoluta* can survive for 2 weeks at zero Celsius. Also, 29 % of pupas survived a cold period with a minimum temperature of -1.7°C, and a mean of 7.3°C. Even though *T. absoluta* has low physiological ability to survive low temperature, it probably exhibits some freeze avoiding behavior that needs to be considered in management, especially adult moths that stay above ground.

A large area of Europe, where *T. absoluta* has established, has a temperate oceanic climate. This climate type is also found along the southern coast of Norway, in the area where *T. absoluta* was discovered in April 2017 (Figure 5). This area along the coast of Norway has relatively warm winters, with a mean minimum temperature for the coldest month (January) between 0°C and -5°C (Figure 6). For example, data from Sola weather station (met.no) show that the winter minimum for 2013-14, 2014-15 and 2016-17 stayed above -5°C (Figure 7). This area has a low mean diurnal range, because of the close proximity to the ocean. Seasonal extremes of temperature are absent giving relatively cool summers and mild

winters. In this area one can expect that temperatures decrease more rapidly from the coast towards the inland than northward along the coast (Figure 6).

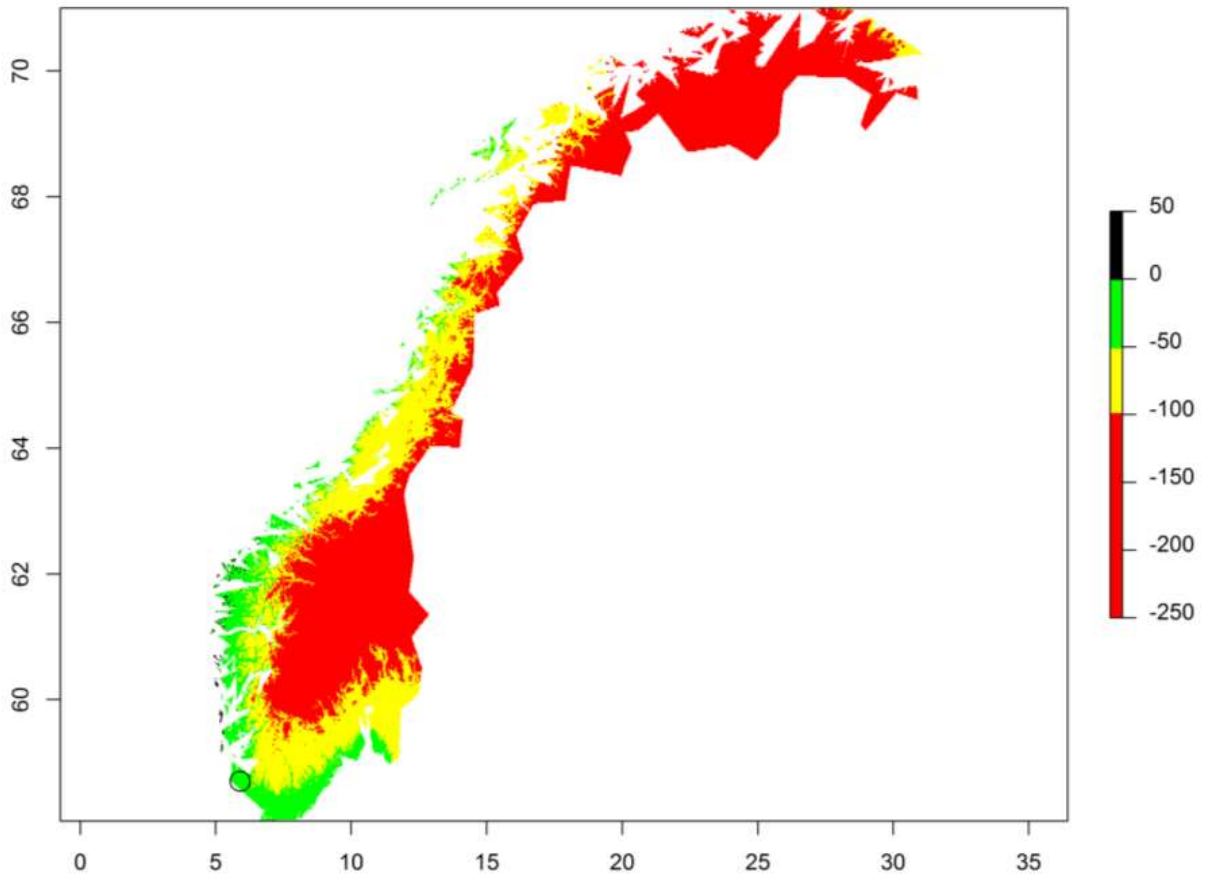
Establishment in Norwegian greenhouses is likely due to similarity in greenhouse climate settings between Norwegian greenhouses and greenhouses in continental Europe where the *T. absoluta* is prevalent.

Establishment outdoors is unlikely, however, summer abundance of *T. absoluta* outdoors will vary according to the severity of the preceding winter temperature in greenhouses. In years with mild winters (i.e. daily mean temperature not below 0°C) *T. absoluta* could possibly survive outdoors along the coast in certain areas. Potentially *T. absoluta* can complete one or two generations per year along the coast in southern Norway (Figure 8) using the settings from (Potting, 2013). Manipulation of the limiting low temperature threshold (DV0) caused a shift in distribution with larger areas along the coast becoming suitable (Figure 9) and making three generations per year possible in Østlandet.

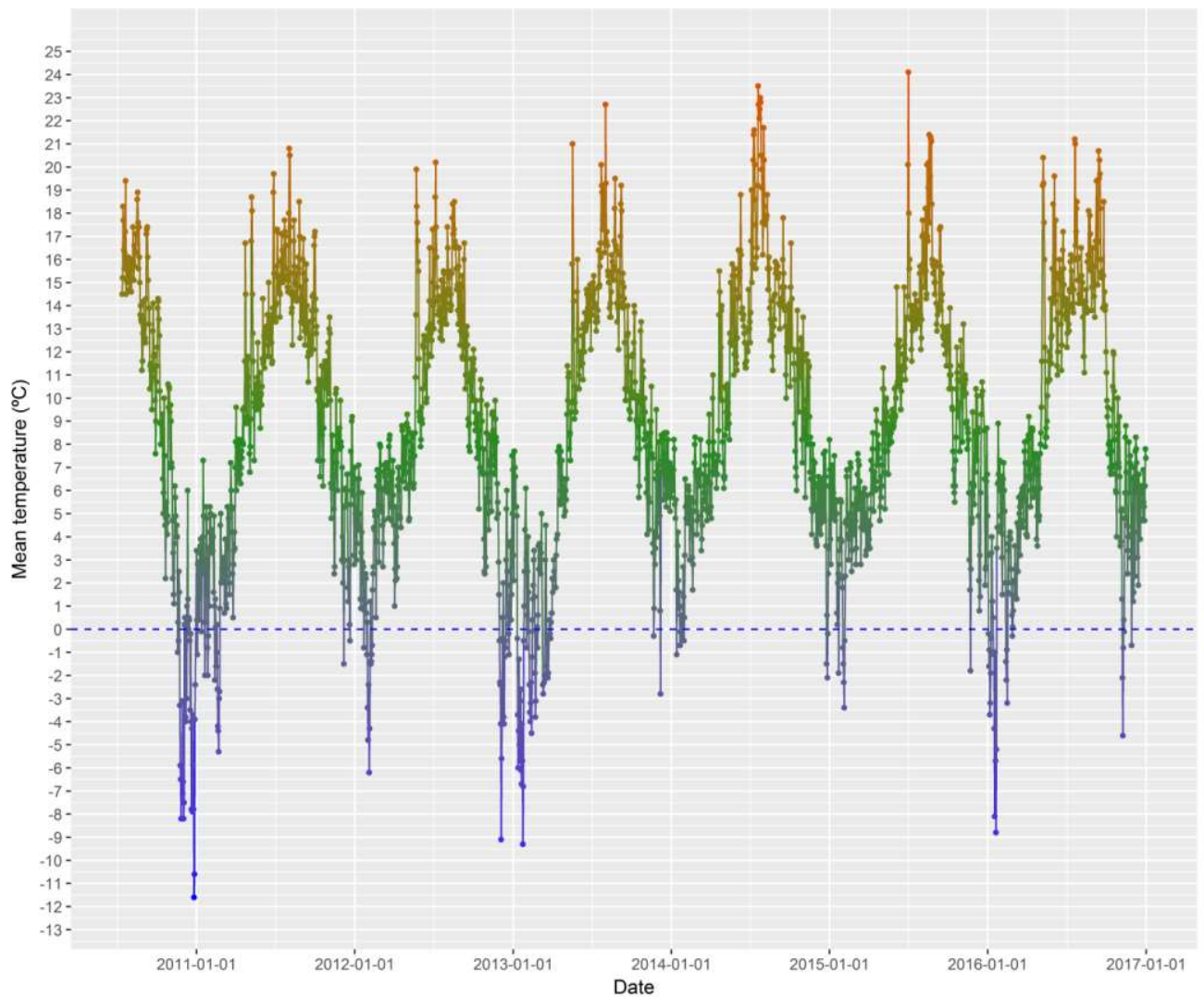
We assume that minimum temperature is the most limiting abiotic factor, and we have not considered precipitation or other climate variables.



**Figure 5.** Map of Europe showing temperate oceanic climate (green area) according to Köppen-Geiger climate classification. Green= Cfb, Temperate oceanic climate; coldest month averaging above 0°C

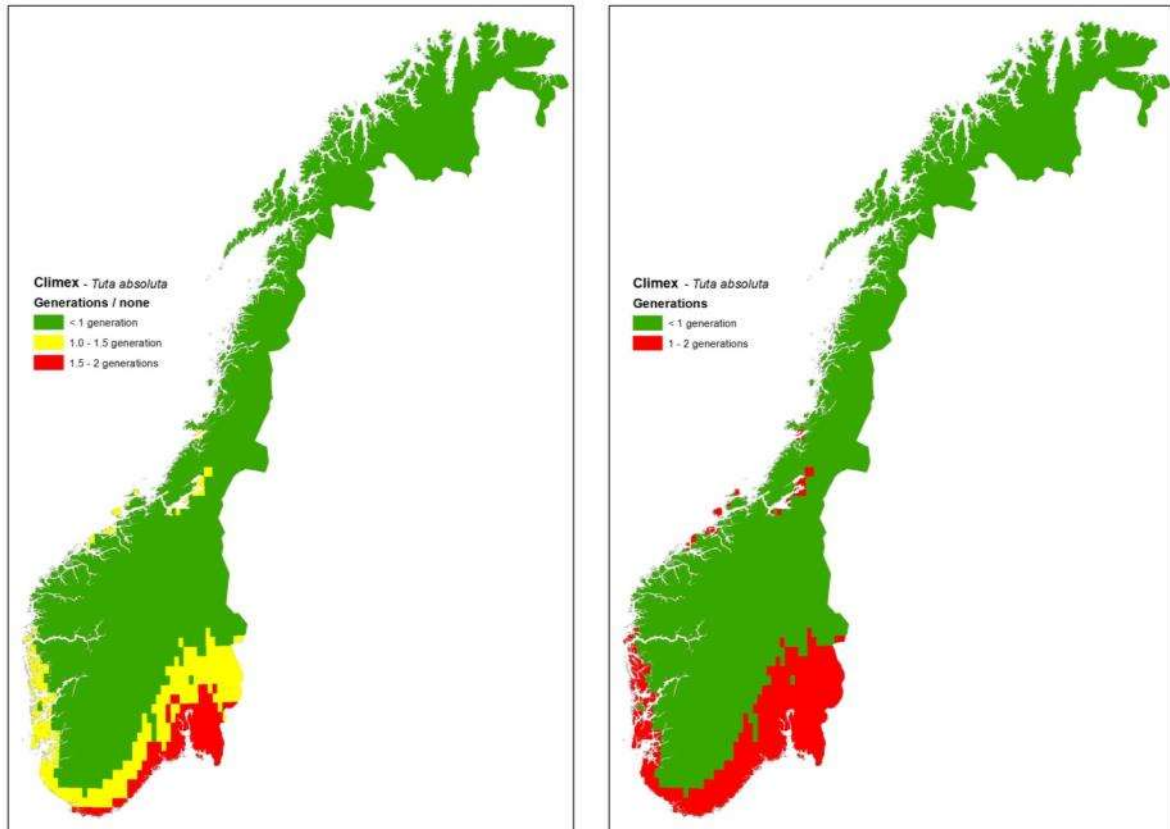


**Figure 6.** Map of Norway showing mean minimum temperature ranges for January (Black= 5 to 0°C, Green = 0 to -5°C, Yellow= -5 to -10°C, Red=below -10°C). Black circle indicates approximate area of the four greenhouses infested with *T. absoluta* (Data from worldclim).



**Figure 7.** Daily mean temperature from Sola meteorological station (less than 20 km from where *T. absoluta* was found), from the period 13.07.2010- 31.12.2016. Data illustrates mild winters (2014 and 2015) only reaching -3 and -3.5°C, respectively. Dashed blue line indicates zero Celsius. Data downloaded from the Norwegian Meteorological Institute (eKlima).





**Figure 8.** Number of generations calculated by Climex using parameter settings of Potting et al. (respectively classed in 3 and two classes for the number of generations). Climatology average 1961 – 1990.

Parameters used in Climex model1:

*Moisture index:* SM0=0.1; SM1=0.4; SM2=0.7; SM3=2

*Temperature index:* DV0=8; DV1=20; DV2=25; DV3=35

*Cold Stress:* TTCS=3; THCS=-0.001; DTCS=15; DHCS=-0.001; TTCSA=0; THCSA=0

*Heat Stress:* TTHS=35; THHS=0.0015; DTHS=0; DHHS=0

*Dry Stress:* SMDS=0.1; HDS=-0.01

*Wet Stress:* SMWS=2; HWS=0.002

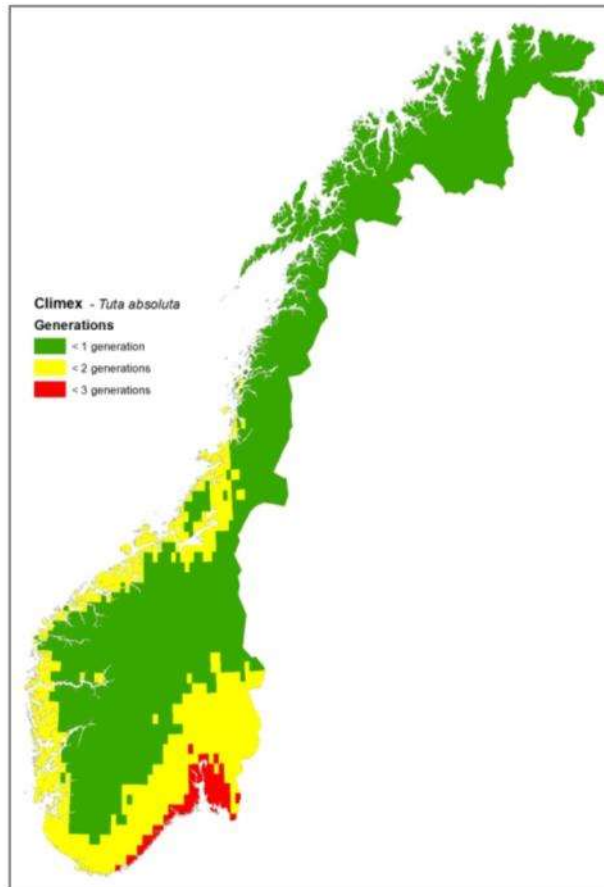
*Day Degree Accumulation above DVO:* DVO=8; DV3=35; MTS=7

*Day Degree Accumulation above DVCS:* DVCS=8; \*DV4=100

*Day Degree Accumulation above DVHS:* DVHS=35

*Degree-days per generation:* PDD=460

Lowering the lower temperature threshold for development (DV0) from 8 to 7 degrees Celcius changes the estimation of the number of generations like in Figure 9.



**Figure 9.** Number of generations calculated by Climex using modified parameter settings of Potting et al. Where DV0 is changed from 8 to 7 according to (ref) (respectively classed in 3 and two classes for the number of generations). Climatology is based on the thirty year average from the period 1961 – 1990.

### 3.2.2 Cultural practises and control measures

The Norwegian Horticultural Growers Association has provided information on the structure of the tomato production in Norway.

About 80-90% of the domestic tomato in Norway is produced in Rogaland County. The greenhouses are located on the plains of Jæren and on the island in the Ryfylke fjord, north of Stavanger. Two greenhouses are located Vestfold County, two are in Buskerud County, and one commercial greenhouse is located in each of the counties Aust-Agder, Telemark, Akershus, Hedmark and Nord-Trøndelag.

A few Norwegian growers import a limited amount of tomato plants for planting from Finland. Growers in Rogaland County do not import of tomato plants for planting.

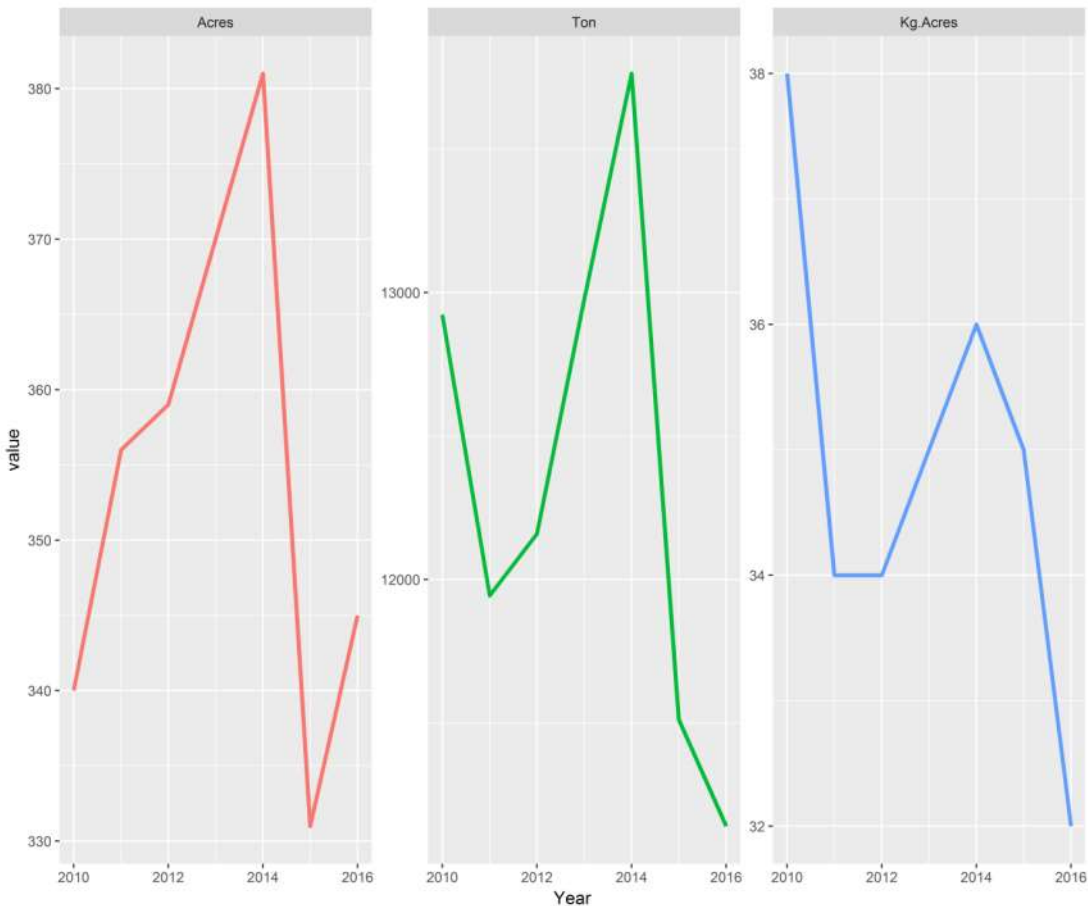
Rockwool is the substrate for 90 % of the domestic tomato production, while a few growers use perlite, coconut fibres or peat as substrate. The larvae of *T. absoluta* may pupate in Norwegian greenhouses.

All commercial tomatoes are produced in greenhouses. Hobby growers produce tomatoes in the open and in greenhouses for their own consumption.

### 3.2.3 Potential hosts in the assessed area

Greenhouse tomato is the main host of *T. absoluta*, but the pest can establish on potato foliage, eggplant/aubergine (*Solanum melongena*), (*Petunia* spp.), several other ornamentals in the Solanaceae family and a number of wild plants of the Norwegian flora (Table 5).

According to data from SSB (2017), in 2015 there were 78 greenhouses producing tomatoes in Norway with a total production area of 466.000 m<sup>2</sup> (46.6 ha). Most of the production area is located in the area around Stavanger, Rogaland. In the period 2010-2016, 331 to 381 acres (1339509 m<sup>2</sup> to 1541852 m<sup>2</sup>) were grown per year with a mean tomato production of 34.86 kg per acre (Figure 10).



**Figure 10.** Area (acres) and yield (metric ton and kilogram) of greenhouse tomatoes in the period 2010-2016 in Norway. Note that the y-axis is scaled differently between figure panels

**Table 5.** Potential host of *T. absoluta* in Norway.

Host Scientific name (common name)	Presence in PRA area (Yes/No)	Comments (e.g. total area, major/minor crop in the PRA area)	Reference
<b><i>Lycopersicon esculentum</i> (tomat).</b>	Yes	Tomato is the main host of <i>T. absoluta</i> . Tomato is cultivated in greenhouses and in fields in the PRA area. Occasionally tomato is growing in the nature in the PRA area.	(Lid and Lid, 2005)
<b><i>Solanum tuberosum</i> (potet) is reported to be host, but the pest has not been found on this host in the PRA area.</b>	Yes	Potato is commonly grown in the areas of greenhouse tomato production in the PRA area.  Potato is occasionally growing in the nature in the PRA area. In the best climatic zones of South and West Norway potato can survive several years in the nature.	(Lid and Lid, 2005)
<b><i>Solanum nigrum</i> (svartsøtvier)</b>	Yes	<i>Solanum nigrum</i> is an introduced weed in the PRA area. Occasionally the weed is growing on roadsides, and on nutrient deficient soil.	(Lid and Lid, 2005)
<b><i>Solanum melongena</i> (aubergine)</b>	No	Only grown in greenhouses.	
<b><i>Datura stramonium</i> (piggeple) is a common weed in cultivated fields.</b>	Yes	<i>Datura stramonium</i> , a weed in cultivated fields in the PRA area up to Nord-Trøndelag. The weed is also growing on roadsides and on nutrient deficient soil. The weed has been detected north to Finnmark.	(Lid and Lid, 2005)
<b><i>Capsicum annum</i> (paprika)</b>	Yes	Grows occasionally on garbage deposits and in nature.	(Lid and Lid, 2005)
<b><i>Physalis</i> spp.</b>	Yes	Ornamental, occasionally growing in the nature.	(Lid and Lid, 2005)
<b>Other <i>Solanum</i> spp.</b>	Yes	Several <i>Solanum</i> spp. are commonly growing in the nature.	(Lid and Lid, 2005)
<b><i>Petunia</i> spp.</b>	Yes	Ornamental, occasionally in the nature.	(Lid and Lid, 2005)

### **3.2.4 Conclusions of establishment**

The probability of establishment of outdoor populations of *T. absoluta* is regarded as unlikely with medium uncertainty.

The probability of establishment of greenhouse populations of *T. absoluta* is regarded as very likely with medium uncertainty.

## **3.3 Probability of spread**

### **3.3.1 Identification of pathways of spread**

#### ***3.3.1.1 Natural spread***

Dispersal from infested greenhouses to uninfested greenhouses during summer months may be possible in Rogaland, possibly using potato crops as a stepping stone at long distances. *Tuta absoluta* has a high reproductive potential, and the pest is a strong flyer. Passive dispersal by wind is important for the pest.

The Canadian Food Inspection Agency (<http://www.inspection.gc>) reports adult flights of *T. absoluta* up to 100 kilometres. Moths are easily transported long distances by wind, so the actual flight distance is probably shorter than 100 kilometres. According to Roques et al. (2016) *T. absoluta* increased its radius by approximately 600 km per year the first nine years after introduction to Spain in 2006. This rapid spread is caused by stratified dispersal, most likely by movement of host plants and other tomato commodities, and/or wind. The rate of *T. absoluta* dispersal is unknown. The estimated spread rate of accidentally-introduced insect pest species to Europe is 3.5 km/year and for species associated with herbaceous plants the spread rate is estimated to 4.8 km/year, however the spread rate of alien species first recorded after 1989 has been estimated to 37.0 km/year (Roques et al., 2016). We, therefore, assume that the spread rate of *T. absoluta* would be somewhere in-between these two extremes (from 3.5 to 37km/year).

If *T. absoluta* were to establish permanently in Norwegian greenhouses, it could probably spread south east along the coast, in a narrow band of suitable climate (black and green colours in Figure 6), and in the worst case scenario it could spread through Rogaland, Vest-Agder and Aust-Agder counties the first five years provided that there were available greenhouse tomato crops (Figure 11).

Spread northward along the coast will probably be slower due to fjords and higher elevations and less suitable or unsuitable climate. There are no commercial tomato greenhouses north of Rogaland County. Spread inland, away from the coast, is unlikely due to lower temperatures and higher elevations.



**Figure 11.** Best and worst case dispersal scenario (excluding stratified dispersal and wind) of *T. absoluta* in Norway after five years based on a spared rate of 3.5 km/year (3.5 km/year x 5, yellow circle) and 37.0 km/year (37.0 km/year x 5, red circle).

**3.3.1.2 Human assisted spread**

*Tuta absoluta* is spread by infested tomato lots, packing materials; such as crates and pallets as well as other commodities that may carry the pest.

**3.3.2 Conclusions on the probability of spread**

The probability of spread is regarded as likely during summer months in the best climatic zones along the coast of Norway, with high uncertainty

The probability of human assisted spread is likely, with medium uncertainty

# 4 Potential damage to the tomato industry (without the use of control measures)

## 4.1 What yield losses can be expected

Control measures already applied by Norwegian tomato growers against other insects will partly control *T. absoluta*. If no precise control measures are applied against *T. absoluta*, damage to the Norwegian tomato production industry is expected to be high with a low uncertainty. The estimated yield losses in Norway are expected to be about 1 to 5%. However, this is assessed with a high uncertainty and if the pest is early detected and controlled.

The larvae of *T. absoluta* feed on all parts of the plants, as well as on the fruit. This results in significant yield losses, since damaged tomatoes cannot be marketed. During the last decade the pest has been spreading from South America to Africa, Middle East and Europe (Table 1) (Brévault et al., 2014; CABI, 2017; Tropea Garzia G et al., 2012).

*Tuta absoluta* is a major pest in all countries where it has been established, and crop losses between 50-100% have been reported from South America and Spain (EPPO, 2005 ). Unpublished data from an infested organic greenhouse tomato production, in Denmark, confirms losses up to 100% (personal communication Nick Starkey, 7 June 2017). However, Norwegian tomato production systems differs from those in Spain and South America, which are more similar to the greenhouse production systems in UK and the Netherlands that were assessed by Potting (2013). Yield losses between 1 to 5% were expected in the Netherlands (Potting, 2013). The same number (about 5% of losses) are valid for UK, through meticulous planning and use of IPM techniques (personal communication Philip Morley, June 7, 2017). The estimated yield losses in Norway are expected to be in the same range as in the Netherlands and UK. However, this is assessed with a high uncertainty.

Furthermore, in infested countries, the cost of tomato production has increased as a result of new pest control and monitoring strategies, both at production but also during the post harvest process (Tropea Garzia G et al., 2012).

If a greenhouse production of organic tomatoes is infested by *T. absoluta*, the pest may cause greater damage than in conventional production due to fewer control measures available.

## 4.2 What increase in pesticide application and use of biological control can be expected

The increase in chemical as well as biological pesticide application is assessed to be high, with low uncertainty.

The number of insecticide applications are expected to be increased fourfold. The use of predatory bugs (*Macrolophus pygmaeus*) as well the use of pheromone traps (Delta and water traps) for monitoring are both expected to be doubled. Moreover, the amount of mating disruption pheromone dispensers are going to be considerable. All estimated amounts are assessed with a high uncertainty.

In Norway, only 13 % of the tomato greenhouse production area in 2015 was under chemical control at least once (SSB, 2017). Infested greenhouses or other infested areas will probably have to use chemical control during the entire production area.

Potting (2013) have assessed the use of insecticides in a worst-case scenario based on an all year around production system with the pest present in the greenhouses throughout the year. In this scenario nine generations of *T. absoluta* needs to be controlled (Potting, 2013). Each generation were assumed to be treated with two applications for satisfactory control. A total 18 pesticide treatments were then needed. However, in the Netherlands some insecticide applications are already applied to control other lepidopteran species. Therefore, 13-15 extra insecticide applications due to a *T. absoluta* were assumed to provide control.

More than 90% of the Norwegian tomato producers use biological control and pollination with bumblebees (*Bombus terrestris*) (Svae Johansen, 2017a). Bumblebees are widely used as pollinators in the Norwegian greenhouse production of tomatoes. An increased use of chemical control will lead to a more challenging biological control and the pesticides will negatively affect the bumblebees.

Sex pheromones of *T. absoluta* have been identified and they are commercially available and proven effective in monitoring the pest (Proffit et al., 2011). Pheromone lures that are attached to sticky cards or other traps are used by tomato producers to monitor as well as disrupt the mating activity of different pests. Monitoring the prevalence of *T. absoluta* by pheromone traps to find first adults are vital to effectively control of *T. absoluta*. In Norway 1-2 Delta traps and 1-2 water traps per 1000 m<sup>2</sup> are usually applied. These traps are usually loaded with fresh pheromone lures every 4-6 weeks. To be able to control *T. absoluta* it is possible that the traps have to be loaded every third week (personal communication Nick Starkey, June 14, 2017).

Furthermore, a mating disruption pheromone confusing the males and ultimately preventing reproduction of the insect (Michereff Filho et al., 2000) may be effective (<http://www.biogard.it>). The product may persists in the greenhouse for up to 6 months and unpublished reports from an early UK trial are positive (personal communication Philip Morley, June 7, 2017). However, the effect may be reduced as ventilation rates increases



during summer time. It is estimated a dosage of 800-1000 of dispensers/ha (<http://www.biogard.it>). To effectively controlled *T. absoluta* the dispensers will need to be replaced 2-3 times during a season (personal communication Nick Starkey, June 14, 2017). This gives in total a need of 2400-3000 dispenses/ha seasonally.

When *T. absoluta* arrived in the UK in 2009, it soon became the most important pest of the tomato producing greenhouse industry. Several different applied projects ultimately led to the development of an integrated pest management (IPM) strategy for control of *T. absoluta* (HDC Factsheet 02/14). This strategy uses *Macrolophus pygmaeus*, physical control measures and a combination of the chemical insecticides; Conserve, Coragene and Steward. Both the biological control agent and the three insecticides are registered by label (Conserve and Steward) or off label (Coragen) in Norwegian tomato production (Svae Johansen, 2017a; Svae Johansen, 2017b). The three insecticides used in the IPM strategy are from different Insecticide Resistance Action Committee (IRAC) Mode of Action Classification Groups. This is to avoid development of resistance in *T. absoluta*. However, during 2016 *T. absoluta* intercepted from southern Europe, were already resistant to Coaragen and Spinosad, and resistance to Converse had already been confirmed from UK (personal communication Philip Morley, 7 June 2017). Spinosad is often being introduced through the irrigation system in hydroponic crops in UK. Resistant populations of *T. absoluta* have already been reported from south of Europe (Roditakis et al., 2015). *Tuta absoluta* is a difficult moth to control. Effectiveness of chemical control is limited due to the insect's nature and its rapid capability of development of insecticide resistant strains. This indicates that the *T. absoluta* population recently detected in Norway may already be resistant to some of the insecticides mentioned above.

Other techniques such as the use of nematodes, which were sprayed on leaves, or *Bacillus thuringensis* have also been used, although this method provides less effective control than the chemical control measures discussed above.

The predatory mirid bug, *Macrolophus pygmaeus*, are one of the most useful biological control agents used by tomato growers. It is used to control greenhouse whitefly, tobacco whitefly, two spotted spider mites, trips, butterflies and *T. absoluta*. However, it must be used wisely, as it is expensive. Normally a Norwegian greenhouse producer of tomatoes uses 2-3 introductions of 0.5 clusters per m<sup>2</sup> seasonally. The clusters should consist of at least 50 predatory bugs that are sprinkled on the leaves or on clean rockwool slabs. To effectively control *T. absoluta* the rates of clusters needs to be doubled to 2-3 introductions of 1 cluster per m<sup>2</sup> (personal communication Nick Starkey, June 14, 2017). However, this might lead to an explosion of *Macrolophus pygmaeus* during summertime. *Macrolophus pygmaeus* are under such circumstances a pest itself and needs to be controlled chemically by 1 to 2 applications.

## **4.3 What increase in other pest control measures can be expected**

### **4.3.1 Risk reduction options to prevent entry**

To prevent entry of *T. absoluta* from other countries into Norway, it is important to avoid import of infested tomatoes or other fruits of Solanaceae as well as infested plants for planting. *Tuta absoluta* is not regulated in the exporting countries from where Norway import tomatoes and other fruits from Solanaceae, or plants for planting. As mentioned by Potting (2013) fruits in trade should show no signs of insect damage, and plants for planting should be imported from pest free production areas.

Pallets, packing material used in transport are potential pathways for entry. To prevent introduction of the pest into the assessed area those consignments should be pest free. Potting (2013) also identified movement of carriage equipment from infested areas as an important pathway. Importing countries should guarantee that crates, that are returned to the tomato growers, are free from the pest.

The only known Danish *T. absoluta* infestation, outside Odense, was due to importation of organic tomatoes from Spain into the packinghouse of the producer (personal communication Nick Starkey, June 7, 2017). Therefore, extra control measures might be necessary for imported organic tomato consignments.

### **4.3.2 Risk reduction options to prevent establishment and damage to crop**

In southern Europe *T. absoluta* has been able to spread via field grown tomatoes and other suitable host plants. Therefore, monitoring the prevalence of *T. absoluta* by pheromone traps to find first adults are vital to efficiently control *T. absoluta*. This should be done in all tomato producing greenhouses as a routine and more frequently if *T. absoluta* has been reported in the area.

To avoid spread between greenhouses, it is important to avoid introduction from another packinghouse of tomatoes, pallets, packing materials and carriage equipment into a greenhouse or packinghouse.

### **4.3.3 Risk reduction options to prevent further spread**

Production of other host plants (e.g. potatoes) in the area near to an infested greenhouse should be avoided. It is not likely that *T. absoluta* will affect the potato yield. However, potatoes, and other host plants, may facilitate spread of *T. absoluta*.

To prevent further spread within the assessed area it is important to avoid infested tomatoes as well as infested consignments.

It is important that the tomato industry openly share information between growers to avoid spread between greenhouses.

To limit spread between greenhouses, it is important to avoid introduction of other tomatoes, plants for planting (plantlets), pallets, packing materials and carriage equipment into a greenhouse or pack house from another pack house/greenhouse.

#### **4.3.4 Other control options**

Closing all ventilation openings with mesh will prevent *T. absoluta* from flying into the greenhouse. Installing a double door at the entrance of the greenhouse is another control measure.

It is important to prevent the pest to establish in newly planted greenhouse compartments. The greenhouse and its soundings should be free from old plants, host plants, to prevent an infestation from previous cultures to the new crop. Removal of early-infested leaves are only possible when plants are young. A strict control of used material should be managed preventing mixing of boxes between the different greenhouse compartments. It is important to keep the greenhouse free from plant litter.

Other control options to prevent establishment and spread of *T. absoluta* are crop removal when temperature are below 10°C (Potting, 2013) or as suggested by Svae Johansen (2017c) to stop the water supply to the plants and kill off the pest by increase heating in the greenhouse to 45°C during 1-3 days. Svae Johansen (2017c) further suggests that the greenhouses should be left empty for 4-6 weeks depending on greenhouse temperature.

Destruction of plant material as well as cleaning of greenhouse compartments, pack house and carriage equipment are important control measures.

If possible, a crop rotation system with crops not known to be host for *T. absoluta* should be planted.

There is also possible with controlling the pest in greenhouses by use of UV-light to attract the moth to glue-traps.

### **4.4 What other significant damages could an establishment of *T. absoluta* inflict on the tomato growers**

If no control measures are taken, the tomato growers may suffer considerable losses.

Infestation of *T. absoluta* results in yield losses, besides reduction in crop quality. Losses will affect the farmer's income directly (e.g. crop and quality loss) and indirectly (e.g. higher production cost due to increased pest management and monitoring programs). In addition, the society in general will in the end be affected by fewer commodities or to a higher cost than expected.

An increased use of pesticides for controlling *T. absoluta* may also negatively affect the perception of Norwegian tomatoes among Norwegian consumers.

# 5 Conclusions (with answers to the terms of reference)

## 5.1 Damage to the tomato industry<sup>1</sup> if the outbreak is not eradicated:

a) *Dissemination scenario – how fast will the pest be spread from the currently infested greenhouses, and what is the expected infested area within 5 – 10 years?*

There is high uncertainty regarding the range of active flight of *T. absoluta*, but based on the rapid, passive dissemination of the pest in Europe, there is high probability that *T. absoluta* will have established populations in most of the tomato greenhouses in Jæren and on the Ryfylke islands if the current outbreak in Rogaland County and possible outbreaks in the future are not eradicated. Similarly, there is also medium probability that *T. absoluta* will have established populations in most of the other Norwegian tomato greenhouses.

b) *What yield losses can be expected?*

Control measures already applied by Norwegian tomato growers against other insects will partly control *T. absoluta*. If no precise control measures are applied against *T. absoluta*, damage to the Norwegian tomato production industry is expected to be high with a low uncertainty. The estimated yield losses in Norway are expected to be about 1 to 5%. However, this is assessed with a high uncertainty and if the pest is early detected and controlled.

c) *What increase in pesticide application and use of biological control can be expected?*

Based on the experience from *T. absoluta* outbreaks in Rogaland greenhouses and in greenhouses of continental Europa, an increase in pesticide application in Norwegian tomato greenhouses can be expected. This is assessed with a low uncertainty.

The number of insecticide applications are expected to be increased fourfold. The use of predatory bugs (*Macrolophus pygmaeus*) as well the use of pheromone traps (Delta and water traps) for monitoring are both expected to be doubled. Moreover, the amount of mating disruption pheromone dispensers are going to be considerable. All estimated amounts are assessed with a high uncertainty.

d) *What increase in other pest control measures can be expected?*

Reduced effect of biological control is a consequence of increased application of chemical pesticides in control of *T. absoluta*.

Closing all ventilation openings with mesh will prevent *T. absoluta* from flying into the greenhouse. Installing a double door at the entrance of the greenhouse is another control measure

*e) What other significant damages could an establishment of *T. absoluta* inflict on the tomato growers?*

Norwegian tomato production is known for its very limited use of chemical pesticides. If the *T. absoluta* outbreak is not eradicated the consumer confidence in domestic tomato may be damaged.

Infestation of *T. absoluta* results in yield losses, besides reduction in crop quality. Losses will affect the farmer's income directly (e.g. crop and quality loss) and indirectly (e.g. higher production cost due to increased pest management and monitoring programs). In addition, the society in general will in the end be affected by fewer commodities or to a higher cost than expected.

## 5.2 Other damages

*a) What is the probability of establishment of outdoor populations of *Tuta absoluta* during the summer in Rogaland and in other tomato districts?*

The available data on the climate in Rogaland County indicates that outdoor populations of *T. absoluta* may multiply outdoors during the summer months on tomato, potato and other suitable solanaceous host plants in the major tomato growing districts of Jæren and the islands in the Ryfylke fjord.

The available data indicate that the climate along the coastal counties may support outdoor populations of *T. absoluta* during the summer months on tomato, potato and other suitable solanaceous plants.

*b) What is the probability of the pest overwintering outdoors in Rogaland and in other tomato districts?*

The data indicates that the winter climate in Jæren and on the coast of Rogaland is slightly too cold for winter survival of *T. absoluta*. However, on some islands winter temperatures may not reach sub-zero temperatures some years, which would make the probability of survival higher.

*c) What is the probability of damage from outdoor populations of *Tuta absoluta* on other crops, for example potato?*

As concluded above *T. absoluta* may multiply outdoors on suitable hosts. However it is unlikely that *T. absoluta* will do damage on potato tubers and other solanaceous crops. This is assessed with a low uncertainty.

**There is low uncertainty in the response to the questions 2 a-b.**

### **5.3 What is the uncertainty in the responses to the questions above – «most probable» scenario contra «worst»/ «best case».**

The uncertainties are given for each of the questions.

### **5.4 What is the probability of new introductions of the pest into Norwegian tomato greenhouses as a consequence of import of plants for planting and fruit? What are the potential pathways with the current production practices used by the tomato growers?**

In conclusion, the probability of entry of *T. absoluta*, from countries outside the assessed area is considered as likely. The uncertainty of this conclusion is medium.

The overall assessment behind this conclusion is that *T. absoluta* is frequently associated with several pathways for entry (imported tomato fruits, plants for planting to the hobby gardener as well as packing material), the pest survives during transport and storage, and there are no existing pest management procedures applied to consignments that might contain *T. absoluta*.

<sup>1</sup>Including traditional tomato production with stop of production in winter and nurseries producing tomato all year.

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# Appendix I

Table x: Rating of the probability of entry, establishment and spread

Rating	Descriptors
Unlikely	<p>The likelihood would be low because:</p> <ul style="list-style-type: none"> <li>• rarely associated with the pathway at the origin</li> <li>• low survival rate during transport or storage</li> <li>• strongly limited by current pest management procedures</li> <li>• considerable limitations for transfer to a suitable habitat/crop in the risk assessment</li> <li>• limited availability of suitable habitat/crop</li> <li>• unsuitable environmental conditions over the majority of the risk assessment area</li> <li>• occurrence of other obstacles preventing establishment</li> <li>• effective barriers to spread exist</li> <li>• the suitable habitats/crops are occasionally present</li> </ul>
Moderately likely	<p>The likelihood be moderate because:</p> <ul style="list-style-type: none"> <li>• is frequently associated with the pathway at the origin</li> <li>• survives at a low rate during transport or storage</li> <li>• affected by the current pest management procedures</li> <li>• some limitations for transfer to a suitable habitat/crop</li> <li>• suitable habitats/crops are abundant in few areas of the risk assessment area</li> <li>• environmental conditions are suitable in few areas of the risk assessment area</li> <li>• no obstacles to establishment occur</li> <li>• partially effective barriers to spread exist</li> <li>• the suitable habitats/crops are abundant in few parts of the risk assessment area</li> </ul>
Likely	<p>The likelihood would be high because:</p> <ul style="list-style-type: none"> <li>• regularly associated with the pathway at the origin</li> <li>• mostly survives during transport or storage</li> <li>• partially affected by the current pest management procedures</li> <li>• very few limitations for transfer to a suitable habitat/crop</li> <li>• suitable habitats/crops are widely distributed in some areas</li> <li>• environmental conditions are suitable in some areas</li> <li>• no obstacles to establishment occur</li> <li>• the pest has already in some areas</li> <li>• no effective barriers to spread exist</li> <li>• the suitable habitats/crops are widely present in some parts of the risk assessment area</li> </ul>

# Appendix II

Table x: Ratings used for describing the level of uncertainty

Rating	Descriptors
Low	No or little information or no or few data are missing, incomplete, inconsistent or conflicting. No subjective judgment is introduced. No unpublished data are used.
Medium	Some information is missing or some data are missing, incomplete, inconsistent or conflicting. Subjective judgment is introduced with supporting evidence. Unpublished data are sometimes used.
High	Most information is missing or most data are missing, incomplete, inconsistent or conflicting. Subjective judgment may be introduced without supporting evidence. Unpublished data are frequently used.