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A risk analysis for fire ants in the Netherlands

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TABLE OF CONTENTS

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SUMMARY

Fire ants are regularly found during import inspections in the Netherlands. *Solenopsis invicta*, *S. geminata* and *S. richteri* are known invasive exotics that cause nuissance in large parts of the world. The Invasive Alien Species Team (of the Ministry of Economy, Agriculture & Innovation) commissioned a risk analysis for fire ants in the Netherlands. This analysis must clarify the number of import in the Netherlands, the possibility of establishment, the consequences for humans and nature, and how they can be exterminated.

Fire ants can become dominant species after introduction in suitable habitat and climate zones outside their natural range. This is due to their aggressive foraging behaviour, high reproduction speed, and resilience against predators and competitors. Because of their high abundances and opportunistic foraging, they can have a substantial impact on natural occurring species communities. They may also be a nuisance to humans; their sting is painful and can occasionally lead to an anafylactic shock. Additionally, they can damage crops, farm animals, and agricultural machinery. The establishment of fire ants can lead to import restrictions by other countries.

To obtain an overview of the occurrence of fire ants in the Netherlands, all records and museum specimens were checked. For *S. geminata*, 21 records are given of which most relate to import interceptions, except for one establishment in a flat building in Amsterdam. For S. invicta three import interceptions are described. Several individuals of *S. gayi* were found during an import insepction, but this species is not considered in the remainder of this report, because it is not known as an invasive alien.

It is unlikely that fire ants can establish themselves in the outdoor environment of the Netherlands. A published model study shows that the climate in the Netherlands is too cold for successful reproduction in *S. invicta.* Since *S. geminata* is even more thermophilic then *S. invicta*, the change of settlement of this species in the Netherlands is even smaller. However, establishments in permanently heated buildings are possible, and fire ants can cause nuisance there. Such establishments can often easily be solved by extermination of the nests. Imports of ant nests should, however, always be avoided. Identification of ant species is difficult, and there are many potential invasive alien ant species. A risk analysis always explores the current characteristics of a species. There is, however, always a possibility that small changes in the behaviour or the genetic material can cause an exotic species to become a successful species in a region that was presumed not suitable for survival.

SAMENVATTING

Geregeld worden brandmieren aangetroffen tijdens importinspecties. *Solenopsis invicta*, *S. geminata* en *S. richteri* zijn notoire invasieve exoten die in grote delen van de wereld voor veel overlast zorgen. Dit was voor het Team Invasieve Exoten (van het Ministerie van EL&I) de aanleiding om een risicoanalyse voor brandmieren in Nederland uit te laten voeren. Deze moet inzicht geven in het aantal importen in Nederland, of ze zich hier kunnen vestigen, welke gevolgen eventuele vestigingen zullen hebben voor mens en de natuur, en op welke wijze ze eventueel bestreden kunnen worden.

Brandmieren kunnen in geschikt habitat en klimaatzones dominante soorten worden na introductie buiten hun natuurlijke areaal. Dit komt door hun aggresieve foerageergedrag, hoge reproductiesnelheid en hun grote weerstand tegen predatoren en concurrerende soorten. Door hun hoge dichtheden en opportune foerageergedrag kunnen ze een negatieve invloed hebben op natuurlijk voorkomende levensgemeenschappen. Ook kunnen ze de mens tot overlast zijn omdat ze een pijnlijke steek hebben die soms leidt tot anafylactische shock. Daarnaast kunnen ze schade aanbrengen aan vee, landbouwgewassen of -apparaten en ervoor zorgen dat een land met importrestricties van andere landen te maken krijgt als de brandmieren zich vestigen.

Om inzicht te krijgen in het voorkomen van brandmieren in Nederland zijn de waarnemingen en collectiemateriaal van verscheidene instanties beoordeeld. Er konden 21 waarnemingen van *Solenopsis geminata* gevonden worden, vrijwel allemaal importintercepties, en slechts één vestiging in een flat in Amsterdam. Van *Solenopsis invicta* werden drie waarnemingen verzameld, alle importintercepties. Ook is eenmaal *Solenopsis gayi* aangetroffen tijdens een importinterceptie, maar deze soort wordt verder niet behandeld in het rapport, omdat deze nergens ter wereld als invasieve exoot bekend is.

In Nederland is het onwaarschijnlijk dat brandmieren zich buiten kunnen vestigen. Een in de literatuur beschikbare klimaatanalyse laat zien dat *S. invicta* zich niet kan voortplanten in Nederland, omdat het klimaat te koud is. *Solenopsis geminata* is nog meer een warmteminnende soort dan *S. invicta*, dus voor deze soort is het Nederlandse klimaat helemaal ongeschikt. Vestigingen van een nest in permanent verwarmde gebouwen is wel mogelijk en de mieren kunnen daar overlast veroorzaken. Dergelijke vestigingen kunnen gemakkelijk en met succes worden bestreden. Import van mierennesten moet echter wel streng in de gaten gehouden worden. Mieren zijn soms moeilijk op naam te brengen en er zijn vele potentiële invasieve mierensoorten. Een risicoanalyse gaat doorgaans uit van de onveranderlijkheid van een soort. Het blijft echter mogelijk dat een kleine verandering in gedrag of genetisch materiaal ervoor kan zorgen dat een exoot toch succesvol kan aanslaan in een nieuw leefgebied waarvan werd aangenomen dat het niet geschikt zou zijn.

1 INTRODUCTION

The Red imported fire ant (RIFA) *Solenopsis invicta* Buren, 1972 is a species native to South America. The nests of this ant have been shown to be easily transported into other countries, whereafter successful establishment and spread might occur. Nowadays it can be found as an exotic species in the USA, Australia, Taiwan, China, Malaysia, and the Philippines. All introduced populations are found in warm and low vegetation in arid, tropical or sub-tropical areas or, occasionally, indoor settings. In these countries it is commonly considered a pest species; the arrival of RIFA causes problems for the human health, economy and indigenous ecosystems. This species has therefore been included in the list of 100 of the "World's Worst invaders" (IUCN/SSC Invasive Species Specialist Group 2009).

All fire ant species (*Solenopsis* sensu stricto) may cause painful stings, and are aggressive towards humans and animals, sometimes with serious consequences to human health and native species assemblages. The introduction and establishment of any of these species is thefore regarderd as unwanted. Especially *Solenopsis geminata* (Fabricius, 1804), a cosmopolitan tramp species, is known to cause similar nuisance as RIFA.

In the Netherlands, a nest of RIFA has been found once in 2002 in the soil of imported ficus plants from the USA and on several other occasions workers were encountered during import inspections. *Solenopsis geminata* has established itself once indoors and has regularly been found during import inspections. Because of the often reported invasive character and potential harmfulness, the Invasive Alien Species Team (*Team Invasieve Exoten*) of the Ministery of Agriculture, Nature and Food Quality (*Ministerie van Landbouw, Natuur en Voedselkwaliteit*) commissioned EIS-Nederland to conduct a risk assessment of *Solenopsis* species. This report contains a literature study on the distribution, biology, ecology and known occurrences in the Netherlands of *Solenopsis* with emphasis on *S. invicta* and *S. geminata*. The report furthermore discusses the possible introduction pathways and the risk of establishment of *Solenopsis* species in the Netherlands.

Figuur 1. The Red imported fire ant *Solenopsis invicta*
(photo: April Nobile / www.antweb.org).

2 RESEARCH METHODS

Apart from *Solenopsis invicta*, other *Solenopsis* species might show similar characteristics concerning introduction potential and the effects on human health and ecosystems, and are therefore discussed here as well. It is important to explain first which species are considered in this report. There are 202 *Solenopsis* species described, and they vary in morphology and behaviour, and three 'lineages' can be recognised. Although in some classic works official subgenera names are not used for these groups (Trager 1991, Bolton 1995, Pitts *et al.* 2005), the three distinct groups can easily be characterised (Tschinkel 2006).

- The first group comprises 20 described and several hybrids (and very likely several undescribed) species of **true fire ants** which all originate from the New World. The subgenus name *Solenopsis* or *Solenopsis* sensu stricto can be used for these species. These ants have polymorphic workers (i.e., minor and major workers). The nests of most species can be polygynous (having more than one reproductive queen) and reproduction and colony growth can be very rapid.
- The second group comprises many species of smaller ants that are often referred to as **thief ants** and which are occasionally placed in a separate subgenus: *Diplorhoptrum*. These ants are cosmopolitan and in the Netherlands one indigenous species is found in relatively warm and dry ecosystems: *Solenopsis fugax* (Latreille, 1798) (Van Loon 2004, Seifert 2007). Thief ants are kleptoparasites constructing their nest close to or inside nest of other species of ants from were they steal their brood. Nests are often polygynous.
- The third 'group' contains one to possibly three *Solenopsis* species: **the social parasite *Solenopsis daguerrei*** (Santschi, 1930) and possibly the social parasites *S. phoretica* (Davis & Deyrup, 2006) en *S. enigmatica* (Deyrup & Prusak, 2008). This species was previously given the genus name *Labauchena* and this is now sometimes used as its subgenus name. *Solenopsis daguerrei* has no worker caste and future queens need to take over control of the nest of other fire ants (a.o. *S. invicta* and *S. richteri* Forel, 1909) in order to establish themselves.

This report discusses *Solenopsis* sensu stricto with emphasis on *S. invicta* and *S. geminata* as these are widely recognised as pest species being harmful for human health, economy and ecosystems. Although thief ants are also often introduced (like *S. molesta* (Say, 1836) and *S. papuana* Emery, 1900 – e.g., Morrison 1996, McGlynn 1999, Julie & Lee 2001), only the true fire ants, *Solenopsis* sensu stricto, are considered.

2.1 CONSULTED LITERATURE

There exists a vast amount of literature on fire ants and especially so on RIFA. These reports and articles mainly originate from the USA as RIFA is considered a major pest in the southern states of this country. An excellent up-to-date overview is given by Walter R. Tschinkel (2006) in his book: *The Fire Ants*. This book provided the majority of the facts on *Solenopsis invicta* that are presented in this report. In addition many other articles on other *Solenopsis* species were used.

2.2 CONSULTED SPECIALISTS

Several specialists from the Netherlands were questioned on their experiences with RIFA.

- **G. (Bert) Vierbergen** from the Plant Protection Service, Wageningen (part of the Ministery of Agriculture, Nature and Food) provided data on the 'official' imports of *Solenopsis* species in the Netherlands.
- **Mike Brooks & Bruce Schoelitsz** from the KAD, Wageningen (*Kenniscentrum Dierplagen*) provided the occurrence data from the archive of their institute that is specialized in the extermination of pest animals.
- **Peter Boer** provided locations of species of *Solenopsis* sensu stricto in the Netherlands, as derived from his inventories of the Dutch ant fauna.

2.4 CONSULTED COLLECTION MATERIAL

- We checked the Dutch *Solenopsis invicta* specimens in the collection of the Plant Protection Service, Wageningen (by Bert Vierbergen and Jinze Noordijk), the Zoological Museum Amsterdam (by Peter Boer), the collection of the KAD, Wageningen (by Peter Boer, Bert Vierbergen and Jinze Noordijk) and the National Museum of Natural History Naturalis in Leiden (by Peter Boer).
- We checked the Dutch *Solenopsis geminata* specimens in the collections of the Plant Protection Service, Wageningen (by Bert Vierbergen and Jinze Noordijk) and the collection of the KAD, Wageningen (by Peter Boer, Bert Vierbergen and Jinze Noordijk).
- An old specimen from 1966 that was identified by Chris van de Bund as *Solenopsis gayi* (Spinola, 1851) in the collection of the Plant Protection Service, Wageningen was checked (by Bert Vierbergen and Jinze Noordijk).
- An old specimen from 1957, that was identified as *Solenopsis xyloni* McCook, 1879 in the collection of the Zoological Museum Amsterdam was checked (by Peter Boer).

3 INTRODUCED FIRE ANT SPECIES IN THE NETHERLANDS

This chapter gives an overview of introductions and interceptions of fire ants in the Netherlands. The information on the introductions is followed by some notes on the species biology, ecology and native range.

3.1 THE RED IMPORTED FIRE ANT *SOLENOPSIS INVICTA*

Solenopsis invicta in the Netherlands

In the Netherlands, three records of introduced workers and one record of an introduced nest of RIFA are known (Table 1, and see Aukema & Vierbergen 2002).

Table 1. Recorded imports of *Solenopsis invicta* in the Netherlands. ZMA = Zoological Museum Amsterdam; PPS = Plant Protection Service, Wageningen.

date	location	individuals	product, mode of arrival	origin	collection
?	Rotterdam	6 minor workers	Goods, on ship	Mexico?	ZMA
1957	Rotterdam	2 major workers, 23 minor worker	Tabacco, on ship	?	ZMA
21.viii.2002	De Kwakel	1 intercepted nest	*Ficus*, unknown	USA	PPS
19.xii.2008	?	1 major worker, 2 minor workers	?	?	PPS

Introduction to the species

The Red imported fire ant *Solenopsis invicta* (or RIFA) is native to the tropical areas of Central and Southern America, comprising Argentina, Bolivia, Brazil, Paraguay, Peru and Uruguay (Pitts 2002, in Tschinkel 2006). Here it can be found in rainforest soils, even at sites subject to inundation (Ross & Trager 1990, Tschinkel 2006). Sufficient rainfall or the presence of permanent water is necessary for *S. invicta* (Korzukhin *et al.* 2001, Tschinkel 2006). RIFA was accidentally imported in the 1930s in the southern states of the USA, probably via goods that arrived by boat in a seaport in Alabama, after which it became a notorious pest species. The species invades anthropogenic habitats, like agricultural fields, parks, urban meadows and gardens. When they colonise agricultural fields or meadows, they may damage crops, disturb cultivation or harm lifestock (see Chapter 5 for an overview of the possible impacts of RIFA). RIFA has in the last decade colonised several new countries including new continents: Australia, China, Malaysia, New Zealand (where it was eradicated successfully), Philipines, Taiwan and many Caribbean Islands.

The exact habitat requirements and preferences in their native range are not very well documented. However, several reasons can be given that might explain the success of RIFA in colonizing new regions, as becomes clear from many studies on ecology and biology of RIFA in introduced areas. Below, dispersal capabilities are discussed, followed by colony growth, life-history forms, diet and competition potential. After this, the records of RIFA imports in the Netherlands are presented.

Dispersal capabilities

RIFA is an opportunistic species that adapts to local circumstances and has a strong dispersal capicity. RIFA has the capability to perform nuptial flights *typically* throughout the year as could be shown in Guangdong province, China (Xu *et al.* 2009). Also in the USA, nuptial flights have been recorded every month of the year (Morrill 1974, Bass & Hays 1979). Most ant species have a restricted or strictly defined nuptial flight period, indicating that *Solenopsis invicta* has a higher potential to adapt to new circumstances. In countries with distinct seasons, alates of *Solenopsis invicta* (figure 2) are produced in spring, and they perform nuptial flights after rainfall and temperatures exceeding 24°C (Tschinkel 2006). Virgin females can also stay in the nest waiting for better reproduction possibilities in the next year. The males meet the gynes in the air at an altitude of more than 100 m. After mating, the inseminated females fly off to find suitable nesting sites (Goodisman et al. 2000a, 2000b). Most inseminated queens do not fly far from the colony of origin; others might fly several hundreds of meters or even several kilometers (reviewed by Tschinkel 2006 and Dhami & Booth 2008).

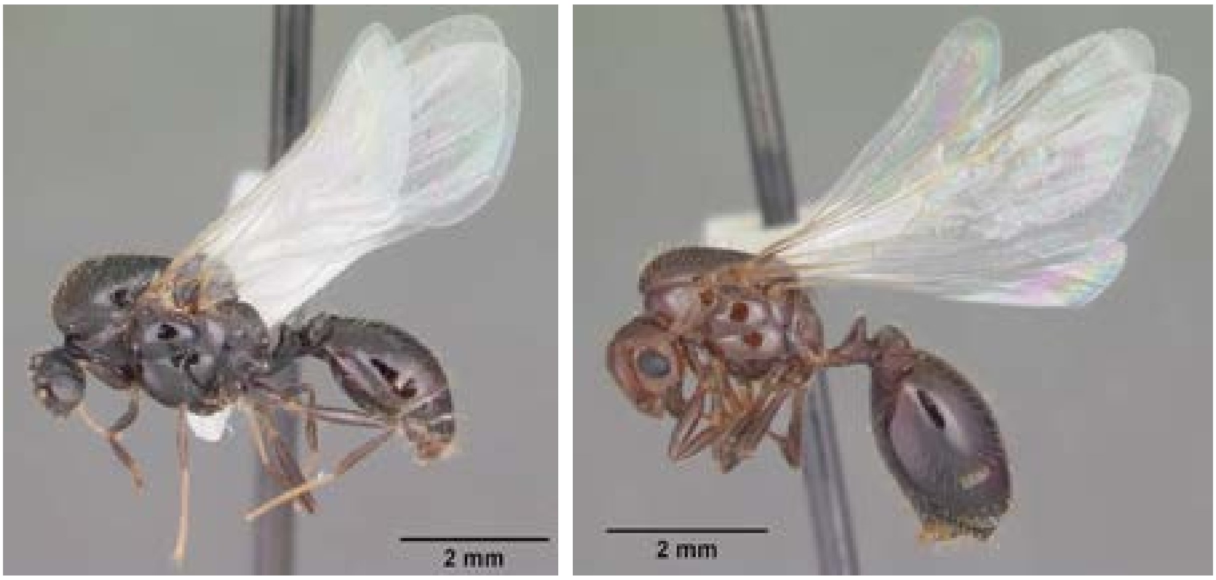

Figure 2. A male and female of *Solenopsis invicta* (photos: April Nobile / www.antweb.org).

In addition to the sexuals, also entire colonies of RIFA have the capability to disperse. Colonies can survive for a long period without food and withstand periods of stress. This is clearly illustrated by its potential to float on water (after flooding of its habitat) for weeks and installing a new nest when reaching a suitable habitat. The species has also the capability to easily establish nests in goods or in plant pots and to survive here for many weeks until new areas are reached (Tschinkel 2006). This characteristic strongly contributed to RIFA's success as a tramp species.

Colony growth & foraging

Markin *et al.* (1972 & 1973) have done research on colony growth of RIFA. Immediately following insemination during the nuptial flight, one or several queens start to construct one nest in the soil. The first eggs are laid within two or three days, and females may lay up to 200 eggs per hour (Tschinkel 1998). After 20-24 days the first workers appear from the pupae. A few days later they can be seen foraging in the surroundings (Markin *et al.* 1972). Within one year, the colony may grow to approximately 7000 workers (Markin *et al.* 1973). In the second year the nest might contain approximately 25,000 workers. When three years old, the nest may have increased to approximately 50,000 workers (Markin *et al.* 1973) or up to 230,000 workers (Tschinkel 1988). This last figure seems to be the maximum of a full-sized colony. RIFA nests show a very rapid growth, while most other ant species take much longer to reach full colony size. During this development, the nest mound grows exponentially, and may sometimes (in colder habitats) resemble nest mounds of wood ants *Formica* sensu stricto from Europe. Markin *et al.* (1973) described this as follows: "from a single vertical burrow of several cm's deep and 1.5 cc in volume, to an inmense mound 60 cm in diameter, 30 cm high, extending 2 meters below the ground, and containing up to 40 liters of galleries, tunnels and rooms". Tschinkel (2006) mentions a maximum colony volume of 100 liters.

Colony growth is also stimulated by their opportunistic ways of foraging. RIFA might consume any food item that is available in the surroundings, and can therefore easily adapt to local circumstances (e.g., Hays & Hays 1959, Morril 1977, Tschinkel 2006). In suitable habitats, fire ants are dominant over many other ant species, and therefore have a high success in obtaining a lot of food.

In addition, the absence of natural enemies – like fungi, nematodes, protozoans, *Wolbachia* bacteria, phorid flies, chalcid wasps and straw itch mites and a social parasitic ant – may allow *S. invicta* to reach densities that are much higher than normally occur in their native habitats.

Different life history traits

Both monogynous colonies (containing a single queen) and polygynous colonies (containing multiple queens within a colony) occur in RIFA (Shoemaker *et al.* 2006, Tschinkel 2006). These two types of social organisation have a genetic base: an allelic heterogeneity at the Gp9-locus (Goodisman *et al.* 2000b, DeHeer 2002). Both social forms have distinct differences in reproductive strategies.

- Alates from monogynous populations perform nuptial flights, thus mate in the air and might travel large distances in search of suitable habitat to found a new colony (Goodisman *et al.* 2000b, Tschinkel 1998, 2006). The queens raise the first generation of workers alone; i.e., independent colony founding (Tschinkel 1998).
- Alates from polygynous populations have other reproductive techniques *in addition* to nuptial flights. They frequently mate in the nest and disperse only short distances from the colony of origin (Goodisman *et al.* 2000b, Tschinkel 1998). Apparantly, these queens rarely accumulate sufficient body reserves to independently found a new colony. Instead they take workers with them to start a new colony, a process known as dependent colony founding or 'budding' (Tschinkel 1998, 2006).

New females of monogynous colonies have a higher chance of reaching unoccupied habitats, while new queens of polygynous colonies have a higher survival rate, because the start of a new colony is made easier by the workers that accompany her. Next to these two basic reproduction strategies, numerous variations exist as reviewed by Tschinkel (1998). For example, when the densities of fertilized alates from monogynous nests are high, several of them might group together and rear the first brood together. Additionally, initial colony growth involves a high degree of brood raiding from other nests; so that the strongest nest will pertain. Is has been observed that the remaining workers of a raided nest and even the queen follow the raiding workers to their nest. Especially the polygynous form of RIFA is highly succesful in quickly invading new habitat, and therefore of greater concern once established.

Solenopsis invicta has been found to hybridise with *S. richteri* in its introduced range in parts of the USA (but scarcely so in their native ranges, Ross & Trager 1990), resulting in an even more invasive hybrid (Tschinkel 2006). The release from endosymbionts in the introduced range may be responsible for the increased incidence of hybridisation and introgression outside the native range (Feldhaar et al. 2008).

3.1 THE TROPICAL FIRE ANT *SOLENOPSIS GEMINATA*

Solenopsis geminata in the Netherlands

There are 21 records of *Solenopsis geminata* in the Netherlands and the species was recorded in seven of the last ten years (Table 2). It is likely that many of the introductions go unnoticed and that some nests have not officially been reported by pest control organisations but have simply been eradicated on the spot. One established nest was found in a house in Amsterdam in 1992-1993; the nest was eradicated using chloredecone and no ants could be found in June 1993 (HIMH/BD 1994). The origin of this nest remains unknown (pers. comm. Mike Brooks). At Westerhoven some workers were found in a plant box at a tropical swimming pool in 1989. It is not unlikely that a nest was present but this could not be found. In addition to these (presumed) established nests, several records of introduced workers have been reported by the Plant Protection Service, Wageningen (Table 2). These imports mainly originate from Thailand, a country were *S. geminata* occurs as an exotic species.

Table 2. Recorded imports and establishments (in bold and red) and possible establishments (in red) of *Solenopsis geminata* in the Netherlands. PPS = Plant Protection Service, Wageningen; KAD = Kennis- en Adviescentrum Dierplagen, Wageningen. Records in red concern established nests.

date	location	individuals	Product, mode of arrival	origin	Collection
iv.1984	Zaltbommel	3 minor workers, 3 major workers	*Schefflera*, unknown	Honduras	PPS
12.xii.1989	Westerhoven (tropical swimming pool)	1 minor worker, 2 major workers, established?	pot plant, unknown	?	PPS
17.xii.1990	Amsterdam	1 minor worker		Thailand	PPS
15.vii.1992 21.vii.1992 & 19.i.1993	**Amsterdam, flat building**	**established nest(s)**	**?**	**?**	**KAD**
18.iv.2002	Aalsmeer, glass house	workers foraging on ground	?	?	PPS
??.??.2002	?	?	*Mangifera*, unknown	Thailand	PPS
9.vii.2003	Aalsmeer	1 minor worker, 1 major worker	*Phoenix* pot plant, unknown	Taiwan	PPS
23.iii.2004	Aalsmeer	5 minor workers, 4 major workers	*Bismarckia* pot plant, unknown	Thailand	PPS
18.viii.2004	Nijmegen	2 minor workers	?	Thailand	PPS
21.vii.2004	De Kwakel	8 minor workers, 1 major worker	*Milletia* pot plant, unknown	Thailand	PPS
30.viii.2004	De Kwakel	10 minor workers	*Ficus religiosa*, unknown	Thailand	PPS
8.vi.2005	Schiphol	1 minor worker	Vegetables / fruits in postal packet, by airplane	Suriname	PPS
11.iv.2007	Schiphol	1 minor worker	*Cestrum*, by airplane	Suriname	PPS
14.vi.2007	Pijnacker	?	*Phoenix* pot plant, unknown	Costa Rica	PPS
26.ix.2007	Schiphol	1 minor worker	*Brassica*, by airplane	Suriname	PPS
1.iv.2009	Honselersdijk	8 minor workers	*Bougainville* pot plant, unknown	Thailand	PPS
26.viii.2009	Honselersdijk	10 minor workers, 3 major workers	*Swieteni*, unknown	Thailand	PPS
14.i.2010	Honselersdijk	several minor workers, few major workers	*Ficus*, unknown	Thailand	PPS
16.iii.2010	Naaldwijk	5 minor workers	*Areca*, unknown	Thailand	PPS

Introduction to the species

The Tropical fire ant *Solenopsis geminata* (figure 3) is apparently native in an area from southern USA to the Guianas, western Amazonia and coastal Peru (Longino without year). Populations in the Antilles, Galapagos and possibly south-eastern USA are probably introduced, but these populations have been present for several centuries and some doubts about there origin remain (Trager 1991, Holway *et al.* 2002). *Solenopsis geminata* is currently a widely distributed species which is found in a large number of coastal areas and islands in tropical, subtropical and arid regions (Figure 6). Here, *Solenopsis geminata* is most abundant in open sunny areas like agricultural areas, natural areas with low vegetation and around human settlements (Longino without year). In its native range it mainly occurs in disturbed sites in moist tropical lowlands were it is the dominant species, eventually being increasingly replaced by other ant species when vegetation is recovering (Risch & Carroll 1982). In forested areas it is found in open micro-habitats, avoiding shaded areas (Harris without year), indicating their preference for warm conditions even in tropical areas.

Biology

Solenopsis geminata has a similar biology as RIFA and therefore this species is only shortly discussed. *Solenopsis geminata* colonies are large, with tens to hundreds of thousands of workers (both minor and major workers) (Way *et al.* 1998). Nests are in the upper part of the soil, usually in the form of a large exposed soil mound and often under the shelter of a stone, plant roots or dead wood (Harris without year). Like in *Solenopsis invicta*, both monogynous and polygynous colonies occur (Ross *et al.* 2003). Individual colonies have extensive nuptial flights, which may occur at any time of the year. Workers are generalized scavengers that may forage on anything edible and they recruit rapidly to resources. Other animals are part of the diet and are stung. When large food items are found, the workers often rapidly cover them with soil. *Solenopsis geminata* is a fierce competitor with other ants; its workers are aggressive and can reach great numbers (Torres 1984, Morrison 1996). In countries were it is introduced, the absence of natural enemies and lack of strong competition from native ant communities likely allows *S. geminata* to reach densities that are much higher than normally occur in their native habitats.

Figure 3. Major worker of *Solenopsis geminata*; the second photo shows the characteristic median furrow on the head (photo April Nobile / www.antweb.org).

3.1 OTHER *SOLENOPSIS* SPECIES

Twenty species of *Solenopsis* sensu stricto have been described (Trager 1991), and additionally several hybrids and undescribed species exist. In table 3 these ants are listed, including their native range and whether there exists any proof of the species becoming establisched after introduction outside their native range (Trager 1991). *Solenopsis invicta*, *S. geminata* and *S. richteri* are known invasive species and especially the former two have reached many regions of the world. Thus far there are no indications that other species of fire ant are likely to become an invasive species.

Other Solenopsis species in the Netherlands

There is one record of *Solenopsis gayi* for the Netherlands (Collection Plant Protection Service Wageningen, and see Aukema & Vierbergen 2002, Boer & Vierbergen 2008); ten major workers were reported as import with 'kinabast' from Peru on 2.viii.1966 in the harbour of Rotterdam (figure 4). Trager (1991) reports this species as a possible introduced ant in Colombia. Information on possible invasiveness or potential harm to humans or ecosystems could not be found in the literature or on the internet. Furthermore, no other interceptions of this species are reported since, and therefore it is not further considered here.

One specimen in the Zoological Museum Amsterdam was labelled as *Solenopsis xyloni* but re-identification showed it to be *Solenopsis invicta* (already incorporated in table 1).

Table 3. List of fire ant species with information on their native range and recorded introductions and establishments outside their native range (all according to Trager 1991). Species in red are considered notorious invasive ants.

Fire ant species	**Native range**	**Introduced and established**
S. virulens (F. Smith, 1858)	Amazon forest in northern South America	
S. substituta Santschi, 1925	Disturbed Cerrado vegetation in Brazil	
S. tridens Forel, 1911	Known from one site in Brazil	
S. geminata **(Fabricius, 1804)**	**Native in South America**	**Large parts of subtropical and tropical regions**
S. xyloni McCook, 1879	southern USA	
S. amblychila Wheeler, 1915	mountain areas in south western USA	
S. aurea Wheeler, 1906	Deserts and dry grasslands in south western USA and Mexico	
S. gayi (Spinola, 1851)	Chili and southern Peru	(Maybe in neighbouring country Colombia)
S. bruesi Creighton, 1930	Sand deserts, canyons and urban areas in near Lima, Peru	
S. invicta Buren, 1972	**(Sub-)Tropical forests in South America**	**Subtropical, tropical and arid regions in USA, Asia, Oceania**
S. interrupta Santschi, 1916	South America from Argentina to Bolivia	
S. macdonaghi Santschi, 1916	Floodplains in western Uruguay and eastern Argentina	(Maybe in neighbouring country Bolivia)
S. megergates Trager, 1991	southeastern Brazil	
S. pythia Santschi, 1934	Argentina	
S. quinquecuspis Forel, 1913	Southern Brazil, Uruguay and Argenitina.	
S. richteri **Forel, 1909**	**south eastern Brazil, Uruguay and Argentina**	**Southern USA**
S. saevissima (F. Smith, 1855)	Amazonian basin	
S. weyrauchi Trager, 1991	Peruvean Andes	
S. electra Forel, 1914	Argentina and Bolivia	Maybe in Paraguay
S. pusillignis Trager, 1991	Cerrado vegetation in Brazil	

Figure 4. One of the workers of *Solenopsis gayi* that was intercepted in the harbour of Rotterdam in 1966 (photo Bert Vierbergen).

4 RISK ASSESSMENT

4.1 PROBABILITY OF ENTRY

It is likely that fire ant species can be introduced into the Netherlands; both *S. invicta* and *S. geminata* have proved to be easily transported throughout the world and (nests of) both species have already ended up in the Netherlands. In addition, there exists an intensive potted plant trade in the Netherlands, leading to a high risk of fire ant introductions.

Due to the preference of both species to disturbed (open and sun lit) soils in warm areas, it is possible to list likely introduction pathways (see also Harris without year). The following materials from areas with *Solenopsis* species have especially a high risk of being contaminated with fire ants:

- Horticultural material; Fire ants establish themselves easily in pot plants that are in contact with the ground or plant material. This is clearly illustrated by the goods in which the fire ants arrived in the Netherlands as given in table 1 and 2.
- Agricultural goods; Plants, crops, soil and equipment from infested agricultural areas might harbour fire ants.
- Aquacultural material; Fire ants are found near areas of permanent water, such as dams, rivers, ponds and aquaculture containers. Because of this they may be spread by the associated trade industries.
- Forestry material; Deforested areas are prone to fire ant colonisation and the translocation of machinery, soil or plant material from such sites are under risk of contamination.

4.2 PROBABILITY OF ESTABLISHMENT

Solenopsis invicta

Solenopsis invicta is a 'hot climate specialist' and mainly inhabits hot arid regions (CLIMEX 2001, Morrison *et al.* 2004, Tschinkel 1993, 2006, IUCN/SSC Invasive Species Specialist Group 2009). Temperate and cold climates are largely unsuitable for successful establishment outdoors. While queens successfully produced first workers at temperatures between 24 and 35°C, optimum temperature was found to be between 27.5 and 32°C (Markin *et al.* 1972). At soil temperatures below 24°C queens fail to rear adult workers and colony founding stops (Markin *et al.* 1972, Tschinkel 2006). The present distribution also indicates the preference for warm arid areas; RIFA is currently found in:

- its native range in (sub-)tropical forests in South America (Tschinkel 2006),
- southern states of the USA: Alabama, Arkansas, Arizona, California, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and the entire island of Puerto Rico (Tschinkel 2006),
- many Caribbean Islands (Davis *et al.* 2001, Wetterer & Snelling 2006, Wetterer & Davis 2010),
- Taiwan since 2005 (Chen *et al.* 2006),
- Southern China since several years, but officially reported in 2005 (Zhang *et al.* 2007),
- the Philippines since 2004-2005 (www.wikipedia.com),
- Malaysia (Julie & Lee 2001),
- Australia since 2001 (Nattrass & Vanderwoude 2001),
- New Zealand, were established nests were eradicated (Gunawardana 2006).

The present range gives a good indication of the potential range of RIFA. The species is still spreading rapidly and especially in the last decade this spread seems to speed up. Morrison *et al.* (2004) used a model of Korzukhin *et al.* (2001) to produce a map of the world, indicating where *S. invicta* could reproduce after it becomes introduced (for the full map see:

http://www.ars.usda.gov/Research/docs.htm?docid=9168&page=2 and the original article). This model uses colony growth to predict the potential global range expansion. Colony growth was made dependent on minimum and maximum daily temperatures and precipitation data were superimposed upon temperature-based predictions. In figure 5, the potential range of RIFA in Europe is shown. Large parts of the Mediteranean region fall in the area prone to RIFA esthablisment but the Netherlands falls outside the area were establishment of the species is likely. Tschinkel (2006) holds these predictions as 'the most realistic to date', but remarks that at range margins the competition with local ant species that are better adapted to the cold circumstances might impede RIFA establishment and/or reproduction even further. Because of the existence of this scientific modelling study, the need to perform an additional GIS analyses in this risk assessment has become redundant. With the presently increasing temperatures the potential area of distribution of *S. invicta* will shift to the north.

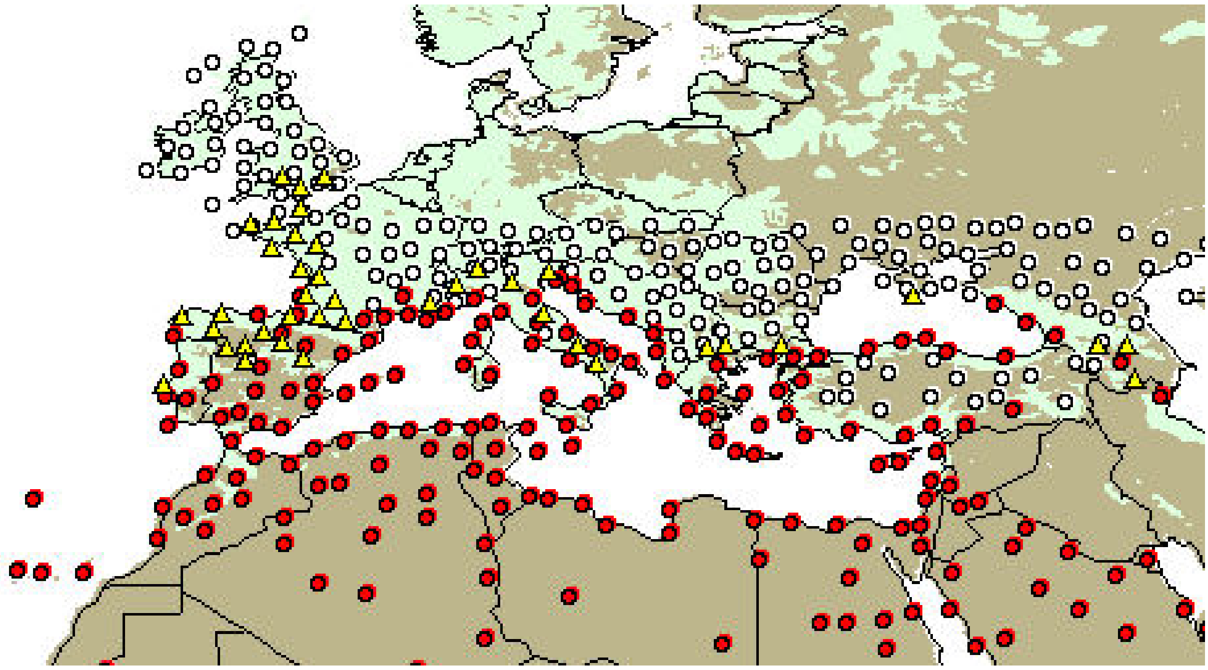

Figure 5. Potential range of *Solenopsis invicta* in Europe, the Middle East, and northern Africa from Morrison *et al.* (2004), available at: www.ars.usda.gov/Research/docs.htm?docid=9168&page=2, see text for the assumptions of the model. ●: potential colony reproduction is certain, ▲: potential colony reproduction is possible, ○: potential colony reproduction is unlikely.

Although it seems unlikely that RIFA becomes established outdoors, it may survive under warm conditions in buildings or greenhouses. RIFA has shown incidental temporary indoor establishments, at least the survival of a colony, also in the Netherlands (Table 1, Morril 1977, Tschinkel 2006). Reproduction and spread to outdoor circumstances after such an establishment in the Netherlands seem unlikely, due to unsuitable temperatures. Sometimes RIFA can spread within urban environments, but this has only been reported from cities in (sub)tropical areas, like Buenos Aires, Argentina (Folgarait *et al.* 2008) and Penang, Malaysia (Julie & Lee 2001).

Solenopsis geminata

Solenopsis geminata has an even more pronounced preference for warm temperatures than RIFA (Harris withour year), hence its vernacular name 'tropical fire ant'. Its present distribution range clearly shows this preference by the concentration between both tropics and in the southern USA (Figure 6). Based on its habitat preferences and current global distribution, it seems very unlikely that *S. geminata* can establish outdoors in the Netherlands.

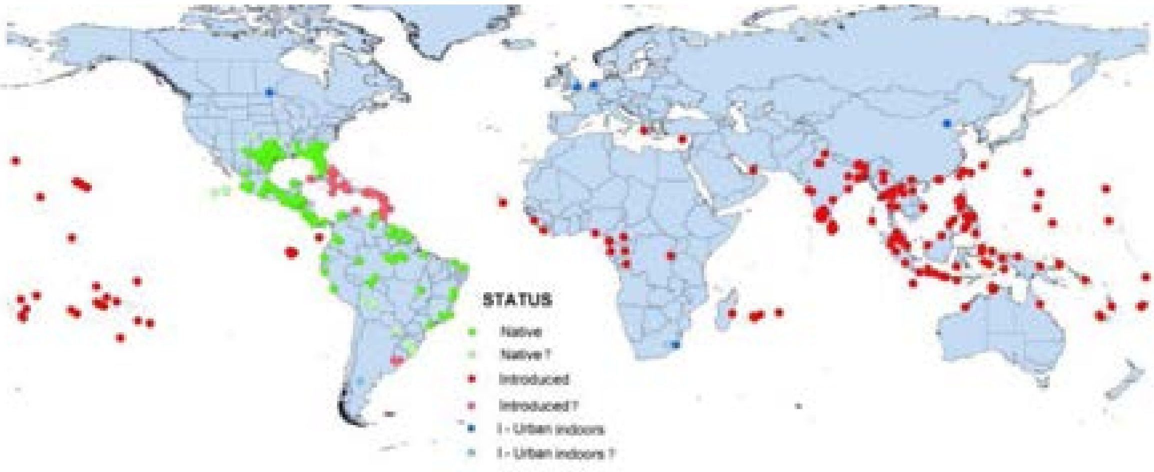

Figure 6. Locations of tropical fire ant *Solenopsis geminata* in the world (source: Harris withour year, the blue dot in the Netherlands is added according to HIMH/BD 1993).

On the other hand, indoor establishments in temperate regions are possible and are there are at least six records of this – see (pale) blue dots in Figure 6:

- Maquinchao, Argentina (latitude 41°15'S; Donisthorpe 1933 in Harris without year),
- Beijing, China (latitude 39°56'N; Wheeler 1927 in Harris without year),
- Kew Gardens, London (latitude 51°28'N; Donisthorpe 1943 in Harris without year),
- Winnipeg, Canada (latitude 49°50'N; Ayre 1977 in Harris without year),
- Durban, South Africa (latitude 29°52' S; Prins *et al.* 1990 in Harris without year).
- Amsterdam, the Netherlands (latitude 52°25'N; HIMH/BD 1993)

However, at none of these locations there were any subsequent records that indicated permanent establishments or reproduction (Harris without year, HIMH/BD 1993).

4.3 Probability of spread

Both *S. invicta* and *S. geminate* can either spread by independent founding or by dependent founding. In the first case a queen performs nuptial flight after which she independently starts a new colony while in the second case a new queens mates in the nest after which she take workers with her to found a new nest. In countries with distinct seasons nuptial flights take place after rainfall with temperatures exceeding 24°C (Tschinkel 2006). Soil temperature needs to be 24°C as well for successful colony founding. Nuptial flight conditions for *S. geminata* occur at similar circumstances, but exact temperatures are unknown (Harris without year). Both *S. invicta* and *S. geminata* can most probably not reproduce outdoors in the Netherlands, due to the low yearly average temperatures, during which no alates are produced. Also for indoor nests, it seems unlikely that nuptial flights occur, due to the lack of nuptial flight triggers (rainfall and changes in air humidity) and possibilities to mate high in the air. Nuptial flights may, however, take place when fire ant nests are situated indoors, provided that they can easily protrude outdoors, where nuptial flights are possible.

Both species also have polygynous populations. Although both the monogynous and polygynous form can be introduced, the polygynous form can spread faster in new introduction areas. They can increase the number of nests by independent founding; new queens mate in the nest and take workers with them to found a new nest. This presents possibilities for easy reproduction. Very likely *S. geminata* reproduction took place in the flat compartments at Amsterdam in 1992, but the exact circumstances and whether this population was mono- or polygynous are unknown (pers. comm. G. Vierbergen).

Spread after (indoor) establishment can take place by the movement of goods, soils or equipment from one indoor location to another. Internal pathways for the Netherlands are similar to those mentioned under '5.1 Probability of entry', and thus include the movement of agricultural equipment or associated plants and planting material, or soil or plant material, particularly garden or potted plants (Morrison *et al.* 2004, Harris without year).

4.4 ENDANGERED AREAS

In the Netherlands, only greenhouses and other heated buildings with permanent high temperatures (e.g., swimming pools, spas, zoos, botanical gardens) are currently under risk of establishment by fire ants. This makes buildings where potted pants or other goods mentioned under paragraph 5.1 are imported susceptible for introductions. Private homes are susceptible for establishments when the residents import high quantities of plants or food products to their houses after holidays in infested areas.

Future changes in the climate in the Netherlands might ask for a re-evaluation.

5 POTENTIAL IMPACT OF THE RED IMPORTED FIRE ANT

Fire ants are aggressive generalist foragers, which breed, spread and relocate fast. The ants will not only sting to subdue prey, but also when they are disturbed; this sting is painful for both humans and animals. Nests can harbour tens of thousands of workers and can, due to these high numbers, have a high impact on food resources and other animals. Below, a literature review is presented on recorded impacts of *Solenopsis invicta* and *S. geminata*. Of course, these examples concern regions where these species occur in high abundances; given the reasons in the preceeding chapter, it is unlikely that similar impacts can occur in the Netherlands, with the exception of indoor situations.

5.1 ECOLOGICAL IMPACT

In tropical and sub-tropical climate zones fire ants (*S. invicta* and *S. geminata*) may become dominant species in open, sunny and disturbed ecosystems. Because of their aggressive nature and high densities, they might affect naturally occurring species assemblages. Some doubt on the exact effects of this species remains however as the fire ants seem to occupy open niches in highly disturbed situations were the species assemblages is already unnatural (Tschinkel 2006).

In particular RIFA has been described as having the potential to devastate native ant populations (McGlynn 1999). It is competitively dominant to most other invasive ant species in suitable habitats. In its introduced range in the southern states of the USA it has displaced its congeneric species *S. xyloni* that is native to this region (Tschinkel 2006). In addition RIFA has had a strong negative impact on *S. richteri* and *S. geminata* in the southern USA where both species had been introduced before (Tschinkel 2006). RIFA has also displaced the Argentine ant (*Linepithema humile*) in areas in the USA where the latter has been introduced (Holway *et al.* 2002). In a detailed study in one small area, an invasion of polygynous RIFA caused a large decrease in ants and other arthropods (Porter & Savignano 1990). However, after 12 years the native ant assemblage (richness and abundance) had recovered completely (Morrison 2002). *Solenopsis geminata* also bears competitive advantages through worker aggression and by recruiting to food in higher numbers than other ants, thus reducing the access of other ants to food (Morrison 1996, Harris without year). However, Tschinkel (2006, and see also King & Tschinkel 2006) provides a very sound overview of studies on ant assemblages and RIFA and concludes that in most studies it is impossible to distinguish between the effects of disturbance and the effects of RIFA on other ants. In other words; it seems often impossible to conclude whether (i) disturbance reduces native ant species and promotes RIFA or whether (ii) RIFA reduces the ant fauna. The same seems to be the case in *S. geminate* and in studies by Risch & Carroll (1982, 1986) it was concluded that disturbance of habitats results in the impoverment of ant communities and the establishment of *S. geminata* and not competition between species.

Fire ants may reduce biodiversity among other invertebrates because of their ferocious hunting. Especially, invasions of polgynous RIFA colonies might have a large effect on arthropods (Porter & Savignano 1990). High abundance of invasive species directly after establishment is often followed by a period in which the exotic species is present in lower abundances. Recovery of the native community is than a possibility (as described above), but is probably highly dependent on source areas in the neighbourhood. In agricultural systems, *Solenopsis invicta* may sometimes be benefical to the crop because it reduces pest species, as could be shown in sugarcane and cotton fields (Tschinkel 2006). Fire ants are natural predators for pests such as weevils, bugs, earwigs, aphids, etc. However, in other systems, RIFA might stimulate the pest species, e.g. by protecting aphids from natural predators, and they also kill beneficial pollinators such as ground-nesting bee species (Tschinkel 2006).

RIFA also prey on vertebrates or may sting them when they disturb the nest. They have been reported to kill a number of species (reviewed by Tschinkel 2006) such as toadlets, the eggs, youngsters and adults of lizards and turtles, alligator hatchlings, young rabbits and other mammals. They have also been observed killing young rats and may kill young mongooses in their burrows (Pimentel 1955). Holway *et al.* (2002) argue that in the USA RIFA negatively impacts at least fourteen bird species, thirteen reptile species, one fish species and two small mammal species (through predation, competition and/or stinging). Also *Solenopsis geminata* can kill vertebrates (reviewed by Tschinkel 2006): quail and swallow chicks are mentioned. Effects on population levels remain largely unknown, but high densitiy polygynous colonies of RIFA can affect white-tailed deer populations, and have effects on pygmy mice (Tschinkel 2006). Such effects of monogyne populations are not known.

Solenopsis invicta may enhance or decrease plant survival, depending on the species and other biotic variables. They may benefit a plant by reducing pest insect species. On the other hand, they may reduce beneficial insects, such as mutualists, pollinators, seed dispersers or pest antagonists. There is doubt whether *S. invicta* inhibits the dispersal of ant-dispersed plant seeds. In some cases, it may interrupt seed dispersal by native ants or it may eat whole seeds.

5.2 Social impact

Fire ants have a painful sting, which may cause injuries to humans and animals. Especially the stings of RIFA are powerful and cause pain, red swellings and pustulea. Many stings or over-sensitivity of the victim may even cause an anaphylactic shock (More *et al.* 2008). Other *Solenopsis* species, like *S. geminata* and *S. richteri* might cause similar reactions in humans (Hoffman 1997). Workers of *S. geminata* also have powerful stings and are equally unwanted as RIFA in places that people frequent, like gardens, parks or agricultural areas (Lakshmikantha *et al.* 1996, Harris without year).

In addition to stinging, fire ant foragers are attracted to electric fields (MacKay *et al.* 1992) and can cause chewing damage to PVC coatings of electrical wiring potentially causing electrical shortcuts and resultant fires (Harris without year). In urban areas or in glasshouses or buildings, they may also bite holes in fabrics, plastics, rubber, and eat household foods (Harris without year) – similar to the nuisance caused by many other pest ants (Klotz *et al.* 2008, Van Loon 2009, Lach et al. 2010).

5.2 Economic impact

Fire ants are opportunistic omnivores and can therefore be both a pest and a beneficial predator in agricultural areas (see Tschinkel 2006, Harris without year). They may tend Homoptera species and therefore reduce crop viability through increased herbivory and diseases transmitted by these insects. However, *Solenopsis* species might also predate on pest insects, favouring the crops. Damage to various crops by *S. invicta* and *S. geminata* has been reported, as can be illustrated by several examples. (i) Wilson (2005) hypothesises that *Solenopsis geminata* invasions caused serious harm to sugar cane plantations already in the beginning of the 16th century, probably by stimulating populations of sap-sucking Homoptera species. (ii) In an area in India, *S. geminata* had eaten on 11% of potatoe and tomatoe plant individuals (Lakshmikantha *et al.* 1996). (iii) Foragers have also been recorded feeding on the seeds and seedlings of sorghum, corn, citrus, avocados, coffee, cocoa and tobacco (Harris without year).

Red imported fire ants also cause damage to agricultural equipment, like roads and electrical equipment due to size and location of nest mounds. *Solenopsis geminata* may cause damage to irrigation dripping systems. RIFA may attack horses, cows and sheep, and farmers or growers. Attacks on domestic animals and workers in the fields by *S. geminata* have occasionally also been recorded; like on poultry in India, coffee farmers in Mexico, tobacco farmers in Asia and *Heliconia* flower pickers in Australia (Harris withour year).

The current economic impact of *S. invicta* on humans, agriculture, and wildlife in the United States is estimated to amount to at least half a billion, if not several billion, dollars per year (Pimental *et al.* 2000, Morrison *et al.* 2004). In Texas at least 580 million US $ was spent in 2000 to control this pest (www.wikipedia.com). The Australian Bureau of Agriculture Resources Economics has estimated the losses procured in rural industries to amount to more than 6.7 billion AU $ over 30 years (www.wikipedia.com). Gutrich *et al.* (2007) undertook a study to estimate the potential economic costs to Hawaii, in case of the widespread establishment of the red imported fire ant. The authors of the study conclude that the estimated impact on various economic sectors in Hawaii would be around 211 million US $/year.

Apart from direct economic damage, 'indirect' effects caused by probable import restrictions if fire ants become established indoors in the Netherlands might also be a serious problem. Many countries, including the countries in the Mediterranean region, are susceptible for RIFA establishments (Figure 5).

These countries will have strict regulations on imports of certain goods from infested countries. If the Netherlands harbours fire ants, this will have serious consequences on our plant (material) export trade.

6 RISK MANAGEMENT

6.1 PREVENTION

Of course, prevention should be the main management tool to make sure that fire ants do not establish themselves indoors in the Netherlands. This involves early detection in and active surveillance of imported goods. In harbours and airports, there should be active checks on ant nests in goods. Imported goods that deserve special attention are plant, soil, wood and food material (see also paragraph 5.1) from infested areas (see paragraph 5.2). Specialists can identify the species, but basically all imported ant nests (i.e., the goods where it is in) should be destroyed, as other ant species might also become a nuisance (see also Van Loon (2009) for introduction pathways of *Lasius neglectus* in the Netherlands). It remains important to collect voucher specimens from introduction in order to keep track of the potential risk of establishment of the various species.

6.2 ELIMINATION

Single nest
The manual elimination of a single nest is often not too difficult. If the nest with the queen(s) is gone, the problem is over. If a single nest of a *Solenopsis* species can not be removed and exterminated manually, the ants might be killed by localy applying a pesticide. The use of Maxforce Quantum Gel is very often a good way to eradicate a single nest. The nest(s) of *S. geminata* in a flat building Amsterdam was eradicated by using baits of liver with 0,25% chlore-decone (HIMH/BD 1993). Many other pesticides can be used (see Harris without year): Amdro® (hydramethylnon), Distance® (pyriproxyfen) and/or Engage® (methoprene). The latter two are insect growth regulators that have no toxic effects, but they interfere with the reproductive capacity of the queen.

Populations
It is presently unlikely that outdoor populations can establish in the Netherlands. Elimination of *Solenopsis* populations outdoors is difficult, especially when polygynous *S. invicta* colonies are present with many nests and many queens per nest. When nests can not be removed and exterminated manually, pesticides can be used. In the USA several pesticides were used, but none seemed to be able to wipe out outdoor colonies. One should take care when using pesticides outdoors; in the USA the pesticide Mirex has been used often, leading to the disappearance of many ant species. Subsequently, *Solenopsis invicta* profited from the absence of ant species and because of its enourmous dispersal ability conquered the entire area. Baits with the above-mentioned insect growth regulators have all recently entered the market and new products continue to be developed and formulated. Currently, baits containing fipronil are showing promising results and have recently been registered by the US EPA.

10.3 CONTROL

When outdoor populations have become established and show to be impossible to remove, two control measures can be applied. The first one is to make its preferred habitat scarcer. This means that disturbed areas should be allowed to regenerate after which the vegetation succession will make the site less suitable for fire ants. In some areas, like agricultural areas, this is impossible to realise. The second control measure is the application of biological control agents. Tschinkel (2006) reviews these potential species, including three infectious groups of organisms (fungi, nematodes and protozoans), *Wolbachia* bacteria that causes a skewed sex ratio in offspring, phorid flies that lay eggs in workers, chalcid wasps and straw itch mites that are ectoparasites on the ants or their brood, and the social parasite *Solenopsis daquerri*. These biological control agents are still subjected to scientific study and their effectivity against fire ants is as yet insufficiently described.

7 CONCLUSIONS AND RECOMMENDATIONS

Of the twenty described species of *Solenopsis* senso strict only *Solenopsis invicta* and *S. geminata* have shown to be invasive and to become notorious tramp species. Both species are causing ecological, social and economic damage in areas where they become established. Nests of both species have been found in the Netherlands, of the former only during import inspection, but of the latter also one or two indoor establishment(s). There are reasons for being cautious about these species; (i) they are keen on anthropogenic and disturbed habitats, (ii) they are increaslingly being transported all around the world, (iii) after establishment they have a tremendous colonizing ability and (iv) they can have significant economical impact, including import restrictions to Mediterranean, subtropical and tropical countries.

However, considering the current distribution of the species and the current climate in the Netherlands it is not very likely that these species can establish outdoors. This is based on the information that is available from other countries. It is however possible that species can adapt to their behaviour or undergo genetical changes, resulting in unpredictable changes in their occurrence. Heated conditions indoors do seem to provide sufficient conditions for nests to pertain, although there is no evidence for reproduction indoors in temperate countries (maybe because nuptial flights do not occur here, due to lack of weather triggers). This does not mean that individual nests might not be a nuisance for persons that may come in contact with the stinging workers and especially in houses the ants can be a true pest.

This risk assessment concludes with the following recommendations:

- Imported ant nests should always be exterminated;
- Establishments of fire ants in heated buildings are to be expected, and after discovery should be exterminated;
- In future, when climate warming continues in Western Europe, a reanalysis of the risk of fire ant establishment (especially for *S. invicta*) becomes necessary.

LITERATURE

Aukema, B. & G. Vierbergen 2002. Nota – *Solenopsis invicta*: een gevaarlijke en potentiële 'invasive alien'. Plantenziektekundige Dienst, Wageningen.
Bass, J.A. & S.B. Hays 1979. Nuptial flights of the imported fire ant in South Carolina. Journal of the Georgia Entomological Society 14: 158-161.
Boer, P. & G. Vierbergen 2008. Exotic ants in The Netherlands (Hymenoptera: Formicidae). Entomologische Berichten, Amsterdam 68: 121-129.
Bolton, B., G. Alpert, P.S. Ward & P. Naskrecki 1995. Bolton's catalogue of ants of the world 1758–2005. Harvard University Press, Cumberland.
Chen, J.S.C., C.-H. Shen & H.-J. Lee 2006. Monogynous and polygynous Red imported fire ants, *Solenopsis invicta* Buren (Hymenoptera: Formicidae), in Taiwan. Environmental Entomology 35: 167-172.
CLIMEX 2001. The suitability of the climate of New Zealand for establishment of the red imported fire ant *Solenopsis invicta*. CSIRO Entomology.
Davis, L.R., R.K. Vander Meer & S.D. Porter 2001. Red imported fire ants expand their range accross the West Indies. Florida Entomologist 84: 735-736.
DeHeer, C.J. 2002. A comparison of the colony-founding potential of queens from single- and multiple-queen colonies of the fire ant *Solenopsis invicta*. Animal Behavior 64: 655-661.
Dhami, M.K. & K. Booth 2008. Review of dispersal distances and landing site behaviour of *Solenopsis invicta* Buren, Red Imported Fire Ant (RIFA). Centre for Biodiversity and Biosecurity, New Zealand.
Feldhaar, H., S. Foitzik & J. Heinze 2008. Lifelong commitment to the wrong partner: hybridization in ants. Philosophical Transactions of the Royal Society B-Biological Sciences 363: 2891-2899.
Folgarait, P.J., R.J.W. Patrock, G. Albioni-Montenegro, L. Saldua & L.E. Gilbert 2008. *Solenopsis invicta*: evidence for recent internal immigration across provinces in Argentina. Florida Entomologist 81: 131-132.
Goodisman, M.A.D., C.J. DeHeer & K.G. Ross 2000a. Unusual behavior of polygyne fire ant queens on nuptial flights. Journal of Insect Behavior 13: 455-468.
Goodisman, M.A.D., Ross, K.G. & Asmussen, M.A. 2000b. A formal assessment of the effects of gene flow and selection in the fire ant Solenopsis invicta. Evolution 54:606-616.
Gunawardana, D. 2006. Determination of nest age of *Solenopsis invicta* (Red imported fire ant) colony foind at Whirinaki, Napier. MAFBNZ, Investigation & Diagnostic Centre, Auckland, New Zealand.
Gutrich J.J., E. VanGelder & L. Loope 2007. Potential economic impact of introduction and spread of the red imported fire ant, *Solenopsis invicta*, in Hawaii. Environmental science & policy 10: 685-696.
Harris, R., without year. Invasive ant risk assessment – *Solenopsis geminata*. Biosecurity New Zealand. Available at: http://www.biosecurity.govt.nz/files/pests/invasive-ants/tropical-fire-ants/tropical-fire-ant-risk-assessment.pdf.
Hays, S.B. & K.L. Hays 1959. Food habits of *Solenopsis saevissima richteri* Forel. Journal of Economic Entomology 52: 455-457.
HIMH/BD 1994. Afdeling bestrijding van dierplagen, jaarverslag 1993. Hoofdinspectie Milieuhygiëne, Staatstoezicht op de Volksgezondheid, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Wageningen.
Hoffman, D.R. 1997. Reactions to less common species of fire ants. Journal of Allergy and Clinical Immunology 100: 679-683.
Holway, D.A., L. Lach, A.V. Suarez, N.D. Tsutsui & T.J. Case 2002. The causes and consequences of ant invasions. Annual Review of Ecology and Systematics 33: 181-233.
IUCN/SSC Invasive Species Specialist Group 2009. Solenopsis invicta. Global Invasive Species Database. Available at: http://www.issg.org/database/species/ecology.asp?si=77. [Accessed 14.vi.2010.]
Julie, P.S. & C.Y. Lee 2001. Identification key to common urban pest ants in Malaysia. Tropical Biometrics 18: 1-17.
King, J. R., & W. R. Tschinkel 2006. Experimental evidence that the introduced fire ant, *Solenopsis invicta*, does not competitively suppress co-occurring ants in a disturbed habitat. Journal of Animal Ecology 75: 1370-1378.

Klotz, J., L. Hansen, R. Pospischil & M. Rust 2008. Urban ants of North America and Europe - Identification, biology, and management. Cornell University Press Ithaca.

Korzhukin, M.D., S.D. Porter, L.C. Thomas & S. Wiley 2001. Modeling temperature-dependent range limits for the red imported fire ant (Hymenoptera: Formicidae: *Solenopsis invicta*) in the United States. Environmental Entomology 30: 645-655.

Lakshmikantha, B.P., N.G. Lakshminarayan, T.M. Musthak Ali & G.K. Veeresh 1996. Fire-ant damage to potato in Bangalore. Journal of the Indian Potato Association 23: 75-76.

Lach, L., C. Parr & K.L. Abbott 2010. Ant ecology. Oxford University Press, Oxford.

Longino, J.T., without year. Species: *Solenopsis geminata*. Available at: http://www.antweb.org/description.do?rank=species&name=geminata&genus=solenopsis&project= [Accessed on 14.vi.2010.]

Loon, A.J. van 2004. Mieren – Formicidae. In: T.M.J Peeters, C. van Achterberg, W.R.B. Heitmans, W.Klein, V. Lefeber, A.J. van Loon, A.A. Mabelis, H. Nieuwenhuijsen, M. Reemer, J. de Rond, J. Smit, & H.H.W. Velthuis, *De wespen en mieren van Nederland (Hymenoptera Aculeata)*. Nederlandse Fauna 6. Nationaal Natuurhistorisch Museum, KNNV-Uitgeverij & European Invertebrate Survey-Nederland, Leiden.

Loon, A.J. van 2009. Risicoanalyse van de plaagmier *Lasius neglectus*. EIS-Nederland, Leiden.

Markin, G.P., H.L. Collins & J.H. Dillier 1973a. Colony founding by queens of the Red imported fire ant, *Solenopsis invicta*. Annals of the Entomological Society of America 65: 1053-1058.

Markin, G.P., J.H. Dillier & H.L. Collins 1973b. Growth and development of colonies of the Red imported fire ant, *Solenopsis invicta*. Annals of the Entomological Society of America 66: 803-808.

McGlynn, T.P. 1999. The worldwide transfer of ants: geographical distribution and ecological invasions. Journal of Biogeography 26: 535-548.

MacKay, W.P., S. Majdi, J. Irving, S.B. Vinson & C. Messer 1992. Attraction of ants (Hymenoptera, Formicidae) to electric fields. Journal of the Kansas Entomological Society 65: 39-43.

More D.R., R.E. Kohlmeier, D.R. Hoffman 2008. Fatal anaphylaxis to indoor native fire ant stings in an infant. American Journal of Forenssic Medicine and Pathology 29: 62-63.

Morrill, W.L. 1974. Production and flight of alate red imported fire ants. Environmental Entomology 3: 265-271.

Morril, W.L. 1977. Red imported fire ant foraging in a greenhouse. Environmental Entomology 6: 416-418.

Morrison, L.W. 1996. Community organization in a recently assembled fauna: the case of Polynesian ants. Oecologia 107: 243-256.

Morrison, L.W. 2002. Long-term impacts of the invasion of an arthropod community by the imported fire ant, *Solenopsis invicta*. Ecology 83: 2337-2345.

Morrison, L.W., S.D. Porter, E. Daniels & M.D. Korzukhin 2004. Potential global range expansion of the invasive fire ant, *Solenopsis invicta*. Biological Invasions 6: 183-191.

Nattrass, R. & C. Vanderwoude 2001. A preliminary investigation of the ecological effects of Red Imported Fire Ants (*Solenopsis invicta*) in Brisbane. Ecological Management and Restoration 2: 220-223.

Pimentel, D. 1955. Relationships of ants to fly control in Puerto Rico. Economic Entomology 48: 28-30.

Pimentel, D., L. Lach, R. Zuniga & D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50: 53-64.

Pitts, J.P., J.V. McHugh & K.G. Ross 2005. Cladistic analysis of the fire ants of the *Solenopsis saevissima* species-group (Hymenoptera: Formicidae). Zoologica Scripta 34: 493-505.

Porter, S.D. & D.A. Savignano 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. Ecology 71: 2095-2106.

Risch, S.J. & C.R. Carroll 1982. Effects of a keystone predacious ant, *Solenopsis geminata*, on arthropods in a tropical agroecosystem. Ecology 63: 1979-1983.

Risch, S.J. & C.R. Carroll 1986. Effects of seed predation by a tropical ant on competition among weeds. Ecology 67: 1319-1327.

Ross, K.G. & J.C. Trager 1990. Systematics and population genetics of fire ants (*Solenopsis saevissima* complex) from Argentina. Evolution 44: 2113-2134.

Ross, K.G., M.J.B.Krieger & D.D. Shoemaker 2003. Alternative genetic foundations for a key social polymorphism in fire ants. Genetics 165: 1853-1867.

Shoemaker, D.D., C.J. Deheer, M.J.B. Krieger & K.G. Ross 2006. Population genetics of the invasive Fire ant *Solenopsis invicta* (Hymenoptera: Formicidae) in the United States. Annals of the Entomological Society of America 99: 1213-1233.

Seifert, B. 2007. Die Ameisen Mittel- und Nordeuropas. Lutra Verlags- und Betriebsgesellschaft, Görlitz.

Torres, J.A. 1984: Niches and coexistence of ant communities in Puerto Rico: repeated patterns. Biotropica 16: 284-295.

Trager, J.C. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae, Myrmicinae). Journal of the New York Entomological Society 99: 141-197.

Tschinkel, W.R. 1993. Resource allocation, brood production and cannibalism during colony founding in the fire ant *Solenopsis invicta*. Behavioral Ecology and Sociobiology 33: 209-223.

Tschinkel, W.R. 1998. The reproductive biology of fire ant societies. BioScience 48: 593-605.

Tschinkel, W.R. 2006. The Fire Ants. Belknap/Harvard University Press, Cambridge.

Way, M.J., Z. Islam, K.L. Heong & R.C. Joshi 1998. Ants in tropical irrigated rice: distribution and abundance, especially of *Solenopsis geminata* (Hymenoptera: Formicidae). Bulletin of Entomological Research 88: 467-476.

Wetterer, J.K. & R.R. Snelling 2006. The red imported fire ant, *Solenopsis invicta*, in the Virgin Islands (Hymenoptera: Formicidae). Florida Entomologist 89: 431-434.

Wetterer, J.K. & L.R. Davis Jr. 2010. *Solenopsis invicta* (Hymenoptera: Formicidae) in the Lesser Antilles. Florida Entomologist 93: 128-129.

Wilson, E.O. 2005. Early ant plagues in the New World. Nature 433: 32.

Xu, Y.-J., H. Jun, Y.-Y. Lu,, Z. Ling & G.-W. Liang 2009. Observation of nuptial flights of the Red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae) in Mainland China. Sociobiology 54: 831-840.

Zhang, R., Y. Li, N. Liu & S.D. Porter 2007. An overview of the Red imported fire ant (Hymenoptera: Formicidae) in mainland China. Florida Entomologist 90: 723-731.