Report of a Pest Risk Analysis

Helicoverpa armigera (Hübner, 1808)

Photo: Paolo Mazzei, www.insectimages.org

Pest: ***Helicoverpa armigera (Hübner, 1808)***

PRA area: European Union

Assessors: J.W. Lammers
(Plant Protection Service, The Netherlands)
A. MacLeod
(Central Science Laboratory, United Kingdom)

Date: August 2007

STAGE 1: PRA INITIATION

1.1 What is the reason for the PRA?

Helicoverpa (=Heliothis) armigera is currently placed on Annex I A II of Council Directive 2000/29/EC, indicating that it is considered to be relevant for the entire EU and that phytosanitary measures are required when it is found on any plants or plant products. EU Member states, in particular The Netherlands and United Kingdom, frequently intercept *H. armigera* on imported produce (especially *Dianthus* and Rosa cut flowers, *Phaseolus*, *Pisum* and *Zea mays*) and some ornamental cuttings. These imports often originate from Third Countries. However, *H. armigera* is already widely present in some EC members such as Greece, Portugal and Spain and present though less widespread in many more such as Austria, Czech Republic, France, Germany, Hungary, Italy and Lithuania. Furthermore, *H. armigera* is capable of migrating over long distances during late summer, leading to transient findings all over Europe. Therefore the current EU import regulations require modification to better take into account the current status of *H. armigera* in Europe and pathways for its introduction and spread. For all of these reasons the justification for classifying *H. armigera* as a I A II pest should be re-examined.

1.2 Taxonomic position of pest

Name: *Helicoverpa armigera (Hübner, 1808)*

Synonyms: *Heliothis armigera* (Hübner), *Chloridea armigera* (Hübner) *Heliothis obsoleta* Auctorum, *Chloridea obsoleta*, *Helicoverpa obsoleta* Auctorum, *Heliothis fusca* Cockerell, *Heliothis rama* Bhattacherjee & Gupta, *Noctua armigera* Hübner.

Common names: Old World (African) bollworm, corn earworm, cotton bollworm.

Taxonomic position:

- *Insecta*
  - *Lepidoptera*
    - *Noctuidae*
      - *Heliothinae*
        - *Helicoverpa*
          - *Helicoverpa armigera*

STAGE 2: PEST RISK ASSESSMENT

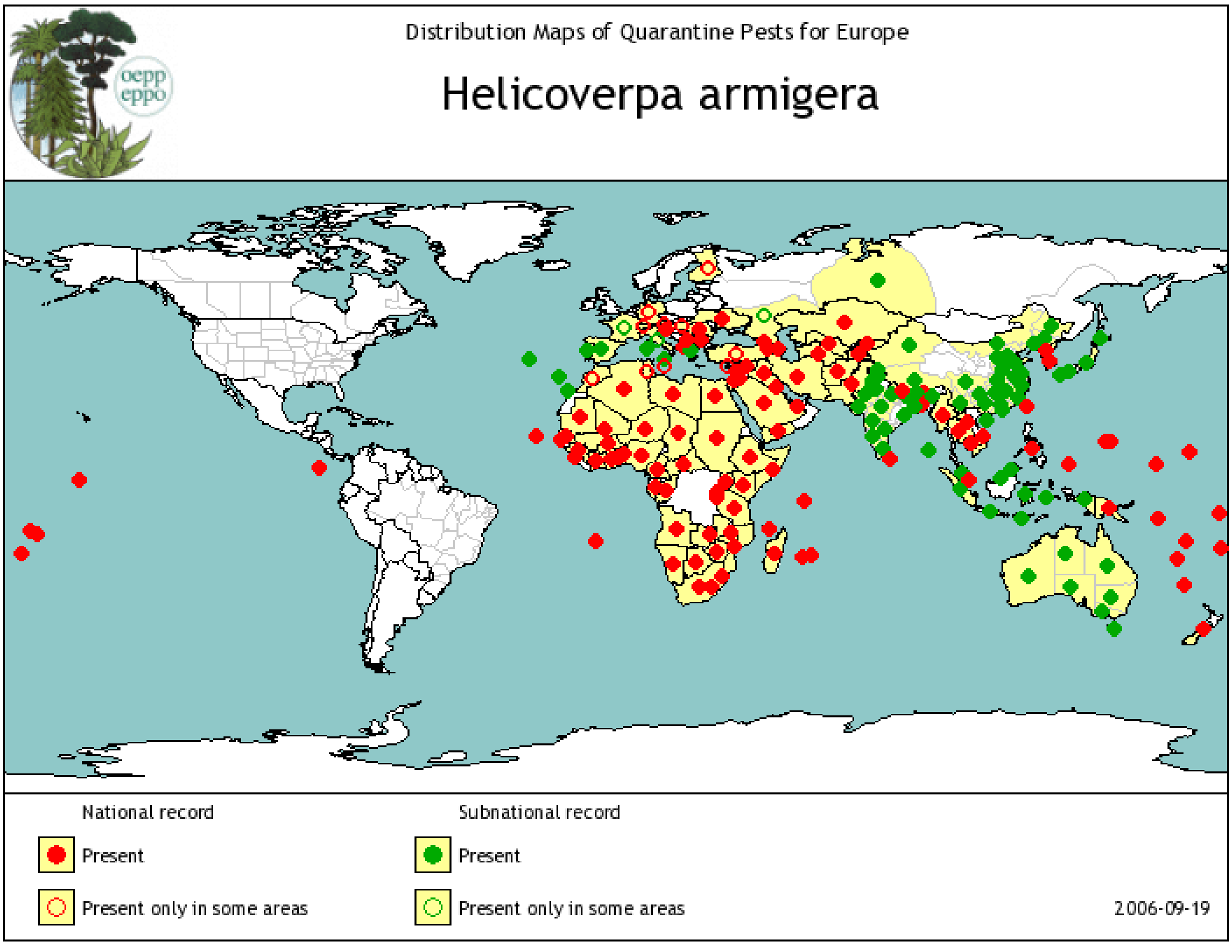
2.1 Probability of introduction

2.1.1 Entry

Geographical distribution

The global distribution of *Helicoverpa armigera* is shown in Figure 1. The pest is present and widespread in Asia, Africa and Oceania (EPPO, 2006). Given the current pest status in Europe (table 1, PRA), *H. armigera* is established in the following EU Member States: Bulgaria, Greece, Portugal, Romania, Spain (widespread) and Cyprus, France, Hungary and Italy (restricted distribution).

Figure 1. Distribution map of *Helicoverpa armigera* (EPPO, 2006).



Major host plants or habitats

H. armigera is a highly polyphagous species. The most important crop hosts of which *H. armigera* is a major pest are tomato, cotton, pigeon pea, chickpea, sorghum and cowpea. Other hosts include dianthus, rosa, pelargonium, chrysanthemum, groundnut, okra, peas, field beans, soybeans, lucerne, *Phaseolus* spp., other Leguminosae, tobacco, potatoes, maize, flax, a number of fruits (Prunus, Citrus), forest trees and a range of vegetable crops (CAB, 2006; Multani and Sohi, 2002; Chandra and Rai, 1974; Gahukar, 2002; Kakimoto *et al*, 2003).

Pathway(s) for entry

Five pathways were assessed in the PRA:

Pathway 1. Cut flowers

Although many infested consignments (mainly *Dianthus* and Rosa) are intercepted annually (EUROPHYT, 2007) and large quantities of cut flowers are imported into the EU from Third Countries where *H. armigera* is present, the likelihood that *H. armigera* will enter the EU is low. The reason for this is that the pest is unlikely to transfer from the cut flower pathway to a suitable host. In order to be able to complete their life cycle, larvae must pupate in the soil (Attique *et al.*, 2000; Tripatis & Sharma, 1984; Chen *et al.*, 2002). Soil is absent in consignments of cut flowers and the majority of larvae are therefore not likely to develop to mature adults. If larvae on cut flowers are picked off and released into gardens, or placed on compost heaps when flowers are disposed of, larvae may then be able to move to a suitable place for pupation. If pupation is successful, adults will then have to undertake maturation feeding and find a mate before females can oviposit on hosts to complete the life cycle. The successive and successful completion of all of these events is unlikely to occur.

Probability of entry - Low

Pathway 2. Vegetables

The high number of EU interceptions in pods and beans (EUROPHYT, 2007) is a clear indication that *H. armigera* is very likely to be associated with the pathway *vegetables*. The volume of commodities carried along the pathway is high (table 3). However, like cut flowers, the overall likelihood of entry via this pathway is low for the same reasons as mentioned before for pathway 1 'cut flowers import'. Moreover, beans, peas and sweetcorn are prepared and cooked which is very likely to result in the removal or death of larvae, if present i.e. the risks are mitigated via processing and consumption.

Probability of entry - Low

Pathway 3. Cuttings

H. armigera has been intercepted several times in consignments of *Pelargonium, Dianthus* and *Chrysanthemum* cuttings (EUROPHYT, 2007). Several outbreaks in EU glasshouses are known to be the result of imported, infested cuttings (mainly *Pelargonium*) (archives of CSL and the Netherlands Plant Protection Service; EPPO, 1997), although the entry risk seems to be moderate. Given the number of interceptions and the volume of the pathway, the risk of *H. armigera* being associated with the pathway cuttings is lower compared to pathway 1 and 2. However, if imported cuttings are infested, the pest can relatively easy transfer to a suitable host and be able to find suitable pupation conditions.

Probability of entry - Moderate

Pathway 4. Natural spread

Given the evidence for long-distance migration (Wu Kong Ming *et al.*, 2006; Fengh *et al.*, 2005; Graham, 2000; Vaishampayan and Singh, 1996; Zhou *et al.*, 2000a and 2000b; Nibouche *et al.*, 1998; Pedgley, 1985 and 1986; Buleza, 1989; Rezbanyai Reser, 1984; Gomboc, 1999; Kaabers, 1984; Hansen, 1989; Palmqvist, 1996, 1997, 1998, 1999, 2000, 2001 and 2002; De Vos, 2000 and 2003; European Commission, 2006; WVF, 2007 personal communication), it is very likely that adult *H. armigera* moths are entering the EU from the south (north Africa) and east, across the EU border (Poland, Slovakia, Hungary and Romania). In this way, the pest can easily find a suitable host in the EU. Consequently, some of the EU territory in these eastern areas is already infested, notably Hungary and Romania.

Probability of entry - High

Pathway 5. Passenger luggage

Hand luggage is not checked routinely in the EU for phytosanitary purposes. Nevertheless, it is likely that passengers entering the EU also carry luggage infested with *H. armigera* from time to time, as is the case in the USA (Venette *et al.*, 2003). When carried in luggage, *H. armigera* larvae are likely to be feeding on fruit, vegetable or cut flower commodities. As with pathways 1 and 2, the likelihood that *H. armigera* will spread and establish as a result of it being carried in luggage is low given the likely end uses of the commodities being transported. Moreover, the volume of this pathway is very low.

Probability of entry – Very low

2.1.2 Establishment

Plants or habitats at risk in the PRA area

The pest can attack many species that are of economic importance in the PRA area, such as tomato, maize, beans and ornamental plants such as *Chrysanthemum* and *Pelargonium*.

Climatic similarity of present distribution with PRA area (or parts thereof)

According to Farrow & Daly (1987) *H. armigera* is established and overwinters up to about 40°N in Europe. However, given the current pest status in Europe (table 1), this limit has since the 1980's moved north up to approximately 45°N (interpretation of data; Figure 2), and now includes the following EU Member States: Greece, Portugal, Romania, Spain (widespread) and Cyprus, France, Hungary and Italy (restricted distribution) (CAB, 2006; European Commission, 2006). This means that the climate in these EU-regions is suitable for establishment. *H. armigera* has probably reached the limits of its natural distribution in the EU, not taking possible climate changes into account.

Probability of outdoor establishment in southern parts of the EU – up to 40-45°N: very high

There are numerous reports every year of *H. armigera* being caught in light traps during the summer in northern EU countries, such as Sweden, the UK and The Netherlands (Franzen, 2004; Vos, 2003 and 2000; Pedgley, 1985; Waring 2006 and others). During the summer, the range of *H. armigera* in Europe may extend as far as 59°N in the northern hemisphere (Farrow and Daly, 1987). In northern European countries, gravid female moths could establish a small population outside during favourable weather in the summer and autumn (Waring, 2006) and, with climate change, such events are likely to occur more often. However, to survive winter the females will have to find a suitable glasshouse within which to complete development. To date, *H. armigera* has not been observed to overwinter outdoors in northern parts of the EU.

Probability of outdoor establishment in northern parts of the EU: very low

Several outbreaks of *H. armigera* have occurred in glasshouses and have been reported in the literature (Marek & Navratilova, 1994; Bues *et al.*, 1988; Hachler *et al.,* 1998; Stigter *et al.*, 2004; Sannino *et al.*, 2004). In the UK, there have been eight outbreaks of *H. armigera* at ornamental glasshouse nurseries since 1997 (CSL archives), in The Netherlands 16 since 1996 (archives of the Netherlands Plant Protection Service), in Finland 11 since 1997 (EPPO, 1997). Based on developmental thresholds and thermal constants of 10.5°C and 51 degree-days for eggs; 11.3°C and 215.1 degree-days for larvae, and 13.8°C and 151.8 degree-days for pupae (Jallow & Matsumura, 2001) it is likely that *H. armigera* is able to overwinter in heated glasshouses, especially when a suitable soil or growth media for pupation is available.

Probability of establishment in glasshouses: high

Aspects of the pest's biology that would favour establishment

A female may lay up to about 3,000 eggs (more than 400 in 24 h), mainly at night. Depending on the climatic conditions, 2 to 11 generations annually have been reported (EPPO, 2007; Shanower and Romeis, 1999). The wide geographic distribution over the world (table 1) shows that *H. armigera* can establish in regions with (seasonal changes from) tropical climates (i.e. Africa, tropical Asia) to regions with a cooler temperate climate (i.e. Mediterranean area of the EU). In regions with a cooler, temperate climate, *H. armigera* overwinters in a diapause stage (Kurban *et al.*, 2005). Feng *et al.* (2005) state that gene flow is high because of large-scale migration of populations.
Furthermore, *H. armigera* has developed resistance against insecticides. Field failures resulting from pyrethroid resistance have been reported from Australia, Thailand, Turkey, India, Indonesia and Pakistan (CAB International, 2006).

2.1.3 Spread

Spread by human assistance

H. armigera can be moved very rapidly with plants and plant products through trade from infested EU-areas to non infested areas. Since 1998 EU countries notified the Commission 33 times about the presence of the pest in EU consignments, mainly in products from Spain (Europhyt). However, the geographic distribution of *H. armigera* has not rapidly increased.

Spread by natural means

H. armigera can move very easily due to natural migration. Pedgley (1985) showed that *H. armigera* migrates up to 1,000 km to reach Britain and other parts of Europe from sources in southern Europe and northern Africa. Migrant individuals have been observed in Denmark (Kaabers, 1984), Norway (Hansen, 1989), Sweden (Palmqvist, 1996, 1997, 1998, 1999, 2000, 2001 and 2002), Estonia, Latvia, Slovenia, Czech Republic and Poland (European Commission, 2006) and the Netherlands (de Vos, 2000 and 2003). In Sweden, these observations followed weather with high-pressure periods with warm southeast winds in late summer (August and September) or occasionally in the autumn (October and November). However, despite continually re-entering regions of the EU where it is not established, either via traded commodities or natural migration, the geographic distribution of *H. armigera* has not rapidly increased. For example *H. armigera* was first reported from Hungary in 1951 but did not establish in neighbouring Austria until 2003 (CAB International, 2006). It is presumed that spread is primarily limited by the poor over-wintering capabilities of *H. armigera* and it will remain a transient pest in Northern Europe. In one case, *H. armigera* was observed in a Dutch tomato glasshouse and the introduction source could not be traced. Natural migration might have been the cause of this outbreak. Figure 2 illustrates the current situation. Although in the past natural spread has been slow, it may speed up in future as the climate of Europe changes.

Probability of (rapid) spread: low

Which part of the PRA area is the endangered area?

The endangered area is the many outdoor host crops in the south and southeast of the EU, although these areas are largely infested already. Other endangered areas are greenhouses in the northern part of the EU where host plants are grown. In the past, most infestations were observed in greenhouses where imported *Pelargonium* and *Chrysanthemum* cuttings were cultivated.

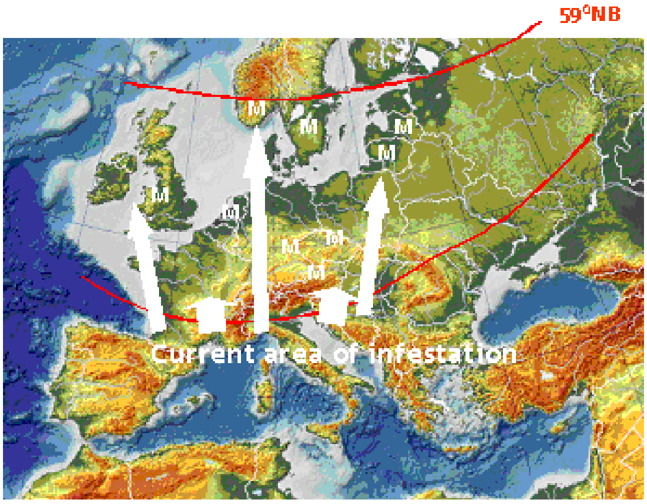


Figure 2. An illustration of the current infested area (approximation) and countries where long-distance migration of *H. armigera* moths has been reported (M).

2.2 Potential economic consequences

Worldwide the annual control costs and production losses amount to $5 billion (www.genomealliance.org.au/projects/Bollworm/Bollworm.htm).

Economic impact of the pest outside the EU

Outside the EU, *H. armigera* is an important pest of cotton and many other crops in many countries (Gujar *et al.*, 2000). 50% of all insecticides used in India and China are used to control this pest. Farmers spend up to 40% of their annual income to buy chemicals to curb *H. armigera* (www.fightthemoth.org/mozilla/global/global.html). In India, losses were estimated to exceed $US 500 million in the late 1980s with an additional $US 127 million spent on insecticides annually (KN Mehrotra, Indian Agricultural Research Institute, New Delhi, unpublished data, 1987/88 in CAB, 2006).

(Potential) economic impact in the EU

In the EU area of establishment, *H. armigera* is of economic importance in Portugal and Spain and of lesser importance in other countries where it is also established (EPPO, 2007). Arno *et al.* (1999) state that *H. armigera* is one of the most important pests of tomatoes intended for processing, in Spain.

From time to time, (very) serious damage by *H. armigera* is reported elsewhere in Europe, especially in warm years (see below). The reason for this is that the rate of development is temperature dependent. A full cycle takes at least 20 days at 30°C and 62 days at 20°C (Sharma & Chaudhary 1988). More generations will develop if it is a warm year, consequently resulting in higher population levels and greater potential for economic damage. 2003 was such a warm year:

Sekulic *et al.* (2004) reported damage, mainly on maize, sunflower, soybean, tomato, pepper and beans, in the Voivodina Province of Serbia and Montenegro in the very warm summer of 2003. 93.7% of maize plants were infested, in sunflower crops 80-100% of the plants were damaged and 85.3% of the soybean pods were injured in August. Horvath *et al.* (2004) reported the occurrence of very high numbers of *H. armigera* in sunflower fields in Kecskemet and Bacsalmas, Hungary, in the same warm year (2003). 64.4% of the sunflower heads were infested with, on average, more than five *H. armigera* larvae per head. Again in 2003, unusually serious damage was observed in Italy in many field and glasshouse crops. Sannino *et al.* (2004a) state that the unusually warm summer weather caused population levels to increase above average levels. In the spring of 2003, *H. armigera* was a serious problem on pepper crops in the Metaponto region in Italy. 30% of the pepper fruits and 70-80% of the pepper plants were damaged. The larvae fed on leaves, flowers and fruits, with fruits recording the most serious damage (Sannino *et al.,* 2004b).

In the summer of 1996, high infestation levels were observed on field-cultivated tomatoes in Sicily, Italy, resulting in economic losses (Pinto *et al.,* 1997). In 1995, *H. armigera* attacked vineyards (grapevines) in the county of Tolna, Hungary. Young larvae made minute holes in the vines, more developed larvae gnawed deep holes in the vines, which became soiled by excrement (EPPO, 1996). Serious damage caused by *H. armigera* larvae was observed in a young elderberry at Inarcs, Hungary, in August, 2002. Larvae damaged the leaf and carved the stem. Damaged stems were then broken by wind (Domotor, 2003).

There are only a limited number of reports on outbreaks of *H. armigera* in glasshouses; most of the reports only mention the presence and eradication of the pest, while only a few articles mention some damage. Marek and Navratilova (1995) report that *H. armigera* larvae infested carnation flowers and tomatoes in glasshouses in southern Moravia, Czech Republic. In the carnation flowers, damage levels were not significant, in tomato crops the highest damage level was 5%. Sannino *et al.* (2004a) report 'serious damage in many field and glasshouse crops in Italy'.

In the UK, *H. armigera* larvae are typically detected amongst crops of rooted Pelargonium cuttings or on growing Chrysanthemums. The extent of the damage can vary, but it is typically minor and may be isolated to one or a small number of plants. As well as insecticide applications, treatment typically involves the regular removal of larvae plus the removal of all plugs and plants with signs of damage. So extensive damage is usually avoided although "noticeable area of damage" have occurred occasionally in Chrysanthemum crops prior to detection.

In summary, *H. armigera* is a serious pest on outdoor crops in Portugal and Spain, predominantly on tomato crops. Occasionally, serious damage is reported from other southern and south-eastern European countries, especially in years with warm summers. The pest can cause damage in glasshouse crops as well. However, the glasshouse crops most at risk are those that are situated in or near the current area of distribution where high population levels are present. High numbers of adult moths can enter glasshouses in these areas, resulting in direct economic impact. The natural migration of *H. armigera* to northern parts of the EU occurs from August onwards. Given this late arrival and the relatively low number of arriving adults (compared to the numbers in the infested areas), the likelihood of entry into glasshouses and the likelihood of rapid build-up of population levels capable of causing an economic impact are low. Pest numbers would not be expected to exceed economic injury levels in field crops in northern parts of the EU.

H. armigera has probably reached the limits of its natural distribution in the EPPO region (EPPO, 2007), not taking possible climate changes into account. This suggests that *H. armigera* is currently on the limit of its economic consequences in the EU as well, although factors like resistance development against insecticides might worsen the current situation in the future. An overview of resistance problems is presented here:

The development of resistance to insecticides has been documented most extensively for the synthetic pyrethroids, but (in some areas) *H. armigera* has also developed resistance to other insecticides i.e. endosulfan, the carbamates and organophosphates (Armes, 1993 and 1995; Armes *et al.,* 1992, 1994 and 1996; Forrester *et al.*, 1993; Kranthi *et al.*, 2001; Martin *et al.*, 2000 and 2003; Torres Villa *et al.*, 2002a). Also, in the EU, insecticide resistant populations are present in Spain (Torres Villa *et al.*, 2002a and 2002b) and France (Martin *et al.*, 2005; Bues *et al.,* 2005). *H. armigera*'s migratory movements could explain the spread of resistance, recently reported in Spain, to southern France (Bues *et al.*, 2005).

Torres Villa *et al.* (2002b) investigated the pyrethroid resistance status of *H. armigera* in Spain during a 5 years period (1995-1999). Toxicological bioassays were completed in the laboratory on F1 offspring of 35 field-derived strains collected from a range of crops and other host plants or from light traps. Seven pyrethroids, cypermethrin, bifenthrin, cyfluthrin, lambda-cyhalothrin, deltamethrin, permethrin and fenvalerate were tested. A substantial inter-strain variation in pyrethroid resistance was evident. No, low or moderate insecticide resistance were prevalent for most insecticide-strain combinations. But in four cases high resistance to cypermethrin and deltamethrin and very high resistance to lambda-cyhalothrin and deltamethrin were recorded, some of which were associated with field control failures. The authors concluded that such resistance levels to pyrethroids in European populations of *H. armigera* had not been previously reported by using experimental bioassay procedures. Overall, pyrethroid resistance in *H. armigera* in Spain was not as high or widespread compared with situations found in other areas of the world.

In 1995-1998, Torres *et al.* (2000) carried out similar research in Extremadura and Murcia (Spain). In Extremadura, moderate resistance to endosulfan, methamidophos, trichlorfon, monocrotophos and fenvalerate; high resistance to carbaryl, fenitrothion, azinphos-methyl, cypermethrin, cyfluthrin and lambda -cyhalothrin and very high resistance to lindane and deltamethrin were detected. In Murcia, moderate resistance to chlorpyrifos, fenitrothion, trichlorfon, monocrotophos, bifenthrin, cyfluthrin, permethrin and fenvalerate; high resistance to endosulfan and lambda -cyahalothrin; and very high resistance to lindane, carbaryl, azinphos-methyl, cypermethrin and deltamethrin were recorded. The authors conclude that the results indicate that *H. armigera* has resistance to an array of insecticides that could determine field control failures.

Bues and Boudinhon (2003) report on the resistance mechanisms of the species to pyrethroids. They state that their research results might explain the failure with chemical control methods reported by farmers. They conclude that it is important to carefully choose insecticides and alternate insecticides and emphasize the risk of gene dispersion conferring resistance to insecticides as a result of the migratory behaviour of this species.

CONCLUSIONS OF PEST RISK ASSESSMENT

Southern and southeastern part of the EU
Helicoverpa armigera has probably reached the limits of its natural distribution in the EU, not taking possible climate changes into account. *H. armigera* is a serious pest of field crops in Portugal and Spain. In other countries in the southern and central part of Europe, the pest causes serious damage from time to time, especially in warm years. Spread of insecticide resistant populations, already reported in Spain and France, might make it a more serious pest in the future in the EU.

H. armigera is currently regulated within Council Directive 2000/29/EC (Annex IAII; harmful organism which introduction into, and spread within, all member states shall be banned; harmful organism known to occur in the Community and relevant for the entire Community) with specific requirements for plants of *Dendranthema, Dianthus* and *Pelargonium* (Annex IVAI; 27.1). Despite the fact that *H. armigera* is a serious pest, the current phytosanitary (import) measures no longer provide protection to the southern and central European countries of the EU, because:

- *H. armigera* is established, widespread and common in southern Europe and some central European countries and has probably reached the limits of its natural distribution in the EU.
- Insecticide resistant *H. armigera* populations are already present in the EU.

Northern part of the EU
H. armigera moths are known to migrate over long distances from infested areas in the south to the northern part of the EU. During the summer, the range of *H. armigera* in Europe may extend as far as 59°N in the northern hemisphere. In northern European countries, gravid female moths could establish a small population outside during favourable weather in the summer and autumn and, with climate change, such events are likely to occur more often. However, to survive winter the females will have to find a suitable glasshouse within which to complete development. Consequently, transient populations occasionally develop in outdoor areas of the EU, which are expected to die out without eradication measures. It is thus similar to several migrant moths, e.g. *Autographa gamma*, that never overwinter but can damage crops in some years during the summer and autumn.

Given the above, only glasshouses in northern EU-areas are currently potentially benefiting from EU wide phytosanitary legislation. But for these, the level of risk is rather low. In the last decade, several *H. armigera* outbreaks have occurred in EU greenhouses in northern EU countries (Finland, United Kingdom, The Netherlands). In almost all cases, the most likely sources of infestation were imported cuttings (mainly *Pelargonium* and *Chrysanthemum*). One outbreak in a Dutch tomato glasshouse could not be traced back to import related pathways. Natural migration may have been the cause of this outbreak. Such outbreaks in glasshouses have not been prolonged or were not very difficult to eradicate, although the latter may become more difficult due to ongoing insecticide resistance development.

Many imported consignments of cut flowers (mainly *Dianthus* and *Rosa*) and pods of *Pisum* and *Phaseolus* infested with *H. armigera* are being rejected by EU Member States annually. However, with the current knowledge, import of infested cut flowers or vegetable commodities has not led to introductions in greenhouses. It can be stated that, even without the rejection of the many infested consignments, a significant increase of introductions and the area of infestation would not occur as a result of this.

Conclusion of Pest Risk Assessment

The current phytosanitary (import) measures no longer provide protection to the southern and central European countries of the EU. Only glasshouses in northern EU-areas are currently potentially benefiting from EU wide phytosanitary legislation. The most important pathways in relation to glasshouses are the 'Import of cuttings of mainly *Pelargonium* and *Chrysanthemum*', and, to a lesser extent, 'Natural spread / migration'.

Stage 3. Pest Risk Management

Pathway 1. Import of cuttings of mainly *Pelargonium* and *Chrysanthemum*
There are specific EU requirements in place both for import and for EU internal movement for this pathway, as follows (EU Council Directive 2000/29/EC, Annex IVAI):

27.1. Plants of Dendranthema (DC.) Des Moul., Dianthus L. and Pelargonium l'Hérit. ex Ait., intended for planting, other than seeds	*Official statement that:* *(a) no signs of Heliothis armigera Hübner, or Spodoptera littoralis (Boisd.) have been observed at the place of production since the beginning of the last complete cycle of vegetation* *or* *(b) the plants have undergone appropriate treatment to protect them from the said organisms.*

The entry risk of this pathway is rated 'moderate'. Furthermore, when found in glasshouses, populations of *H. armigera* have been eradicated relatively easily in the past. Therefore, the abovementioned EU requirements (IVAI – 27.1) give sufficient protection.

Pathway 2. Natural spread / migration
H. armigera is established in large parts of the EU, is a polyphagous species and can migrate over long distances, sometimes in large numbers. Climatic conditions are considered the key factor that limit the distribution of *H. armigera*. If the (climatic) conditions become suitable in areas outside the current area of distribution, natural migration or simply spread will result in the (temporary) establishment of the pest. Therefore, measures aimed at containment or exclusion are not a viable option. The only plausible *containment* measure is to make sure that EU trade of propagation material (especially *Pelargonium* and *Chrysanthemum*) is free from the pest, in order to protect glasshouse crops outside the current area of distribution.

OVERALL CONCLUSION
Helicoverpa armigera should be removed from Annex IAII as the prospects and efficacy of measures for continued exclusion are limited. The only plausible measure to protect glasshouses in northern EU countries is to make sure that EU trade of propagation material (especially *Pelargonium* and *Chrysanthemum* cuttings) is free from the pest. The current EU requirements provide sufficient protection.

Recommendation for possible measures:

27.1. Plants of Dendranthema (DC.) Des Moul., Dianthus L. and Pelargonium l'Hérit. ex Ait., intended for planting, other than seeds	*Official statement that:* *(a) no signs of Heliothis armigera Hübner, or Spodoptera littoralis (Boisd.) have been observed at the place of production since the beginning of the last complete cycle of vegetation* *or* *(b) the plants have undergone appropriate treatment to protect them from the said organisms.*

Literature citations

Armes, N. J., 1993. Pyrethroid and endosulfan resistance in *Helicoverpa armigera* in India. *Resistant Pest Management* 5 (1): 34-39.

Armes, N. J., 1995. Pyrethroid resistance in *Helicoverpa armigera* in Nepal. *Resistant Pest Management* 7 (1): 11.

Armes, N. J., Jadhav, D. R., King, A. B. S., 1992. Pyrethroid resistance in the pod borer, *Helicoverpa armigera*, in southern India. *Proceedings, Brighton Crop Protection Conference, Pests and Diseases,* 1992 Brighton, November 23-26, 1992: 239-244.

Armes, N. J., Banerjee, S. K., DeSouza, K. R., Jadhav, D. R., King, A. B. S., Kranthi, K. R., Regupathy, A., Surulivelu, T. and Venugopal Rao, N., 1994. Insecticide resistance in *Helicoverpa armigera* in India: recent developments. *Proceedings Brighton Crop Protection Conference, Pests and Diseases,* 1994, vol 1: 437-442.

Armes, N. J., Jadhav, D. R., DeSouza, K. R., 1996. A survey of insecticide resistance in *Helicoverpa armigera* in the Indian subcontinent. *Bulletin of Entomological Research* 86 (5): 499-514.

Arnó, J., Gabarra, R., Roig, J. and Fosch, T. 1999. Integrated pest management for processing tomatoes in the Ebro Delta (Spain). ISHS Acta Horticulturae 487: 207-212 On-line available at www.actahort.org/books/487/487_28.htm

Attique, M.R., Abdul-Ghaffar, Mohyuddin, A.I. and Ahmad, Z., 2000. Pupation and diapausing behaviour of Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) in the Punjab. Pakistan Journal of Zoology, 32:1, pp 61-64 (abstract).

Brevault, T. and Achaleke, J., 2005. Status of pyrethroid resistance in the cotton bollworm, *Helicoverpa armigera*, in Cameroon. Resistant-Pest-Management-Newsletter.15(1): 4-7 (abstract).

Bues, R., J.F. Toubon, H.S. Poitout and Boudindhon, L., 1988. Dynamique des populations et lutte microbiologique contre la noctuelle de la tomate (Heliothis armigera) sous serres dans le sud de la France. [Dynamics of populations and microbiological control of the tomato moth (Heliothis armigera) in greenhouses in the south of France]. PHM Revue Horticole 285: 43-48 (abstract).

Bues, R. and Boudinhon, L., 2003. Resistance of Helicoverpa armigera (Lepidoptera: Noctuidae) to insecticides in the South of France. Cahiers Agricultures; 12(3): 167-173 (abstract).

Bues, R., Bouvier, J. C., Boudinhon, L., 2005. Insecticide resistance and mechanisms of resistance to selected strains of *Helicoverpa armigera* (Lepidoptera : Noctuidae) in the south of France. Crop Protection 24(9): 814-820 (abstract).

CAB International, 2006. Crop Protection Compendium. Wallingford, UK: CAB International.

Cameron, P.J. and Walker, G.P., 2004. *Helicoverpa armigera* resistance management strategy. New Zealand Plant Protection Society (Inc). On-line available at www.hortnet.co.nz/publications/nzpps/resistance/helicoverpa.htm

Camprag, D., R. Sekulic, T. Kereši, and F. Baca., 2004. [Corn earworm (*Helicoverpa armigera* Hübner) and measures of integrated pest management.] Faculty of Agriculture, Novi Sad, YU, 183 pp.

Chandra, B.K.N. and Rai, P.S., 1974. Two new ornamental host plants of *Heliothis armigera* Huebner in India. Indian Journal of Horticulture, 31(2): 198.

Chen-FaJun, Zhai-BaoPing, Zhang-XiaoXi, Chen, F.J., Zhai, B.P. and Zhang, X.X., 2002. Biological habits of tunnelling and pupation of cotton bollworm. Plant Protection, 28:1, pp 20. (abstract).

Devi, N. S., Singh, O. H., Devjani, P. and Singh, T. K., 2002. Natural enemies of Helicoverpa armigera Hubner on chickpea. Annals of Plant Protection Sciences, 10(2): 179-183 (abstract).

Domotor, I., 2003. A new pest of elderberry (*Sambucus nigra* L. 1753): the cotton bollworm (*Helicoverpa armigera* Hubner 1808). Novenyvedelem-. 2003; 39(8): 391-393 (abstract).

EPPO, 1996. EPPO Reporting Service (6) – 141.

EPPO, 1997. EPPO Reporting Service (9) – 181.
EPPO, 2004a. EPPO Reporting Service (01) – 12.
EPPO, 2004b. EPPO Reporting Service (01) – 13.
EPPO, 2006. Distribution maps of Quarantine Pests. *Helicoverpa armigera*. On-line available at www.eppo.org/QUARANTINE/insects/Helicoverpa_armigera/HELIAR_map.htm
EPPO, 2006b. EPPO Reporting Service (08) – 162.
EPPO, 2007. Datasheets on quarantine pests – *Helicoverpa armigera*. (Downloaded on 15 March 2007)
European Commission, 2006. Information on Regulated Non-Quarantine Pests. HA/svi D(2006), Brussels, 17 February 2006.
EUROPHYT, 2007. European database on plant health information.
Farrow, R.A. and Daly, J.C., 1987. Long-range movements as an strategy in the genus *Heliothis* (Lepidoptera: Noctuidae); A review of its occurrence and detection in four pest species. Australian Journal of Zoology 35 (1): 1-24.
Farrow, R.A. and Smith, J.M.B., 1999. Long distance migration of insects to a subantarctic Island. Journal of Biogeography 26 (6): 1161-1167 (abstract).
Feng, H.Q., Wu, K.M., Cheng, D.F. and Guo, Y.Y., 2004. Northward migration of Helicoverpa armigera (Lepidoptera: Noctuidae) and other moths in early summer observed with radar in Northern China. Journal of Economic Entomology. 97(6): 1874-1883.
Feng, H.Q., Wu, K.M., Ni, Y.X., Cheng, D.F. and Guo, Y.Y., 2005. Return migration of Helicoverpa armigera (Lepidoptera: Noctuidae) during autumn in northern China. Bulletin of Entomological Research. 95(4): 361-370.
Forrester, N. W., Cahill, M., Bird, L. J., Layland, J. K., 1993. Management of pyrethroid and endosulfan resistance in Helicoverpa armigera (Lepidoptera: Noctuidae) in Australia. Bulletin of Entomological Research: Supplement Series (Supplement 1): 132 pp.
Franzen, M., 2004. Interesting Macrolepidoptera finds in Sweden 2003. Entomologisk-Tidskrift. 125(1/2): 27-42 (abstract)
Gahukar, R.T., 2002. Population dynamics of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on rose flowers in central India. Journal of Entomological Research, 26(4): 265-276 (abstract).
Gomboc, S., 1999. *Helicoverpa armigera* HBN. (Lep., Noctuidae) - a quarantine pest which has a rather long history in Slovenia. Zbornik predavanj in referatov 4 Slovenskega Posvetovanja o Varstvu Rastlin v Portorozu od 3 do 4 Marca 1999. 1999; 247-253. (abstract).
Graham, G., 2000. New method provides accurate tracking of *Heliothis* populations. Australian Cottongrower, 21 (1): 8-9 (abstract).
Gujar, G. T., Kumari, A., Kalia, V and Chandrashekar, K., 2000. Spatial and temporal variation in susceptibility of the American bollworm, *Helicoverpa armigera*, (Hubner) to *Bacillus thuringiensis* var. *kurstaki* in India. Current Science, 78 (8): 995 – 1000.
Hachler, M., Jermini, M. and Brunetti, R, 1998. Two new harmful noctuids on tomatoes in glasshouse in South and Western Switzerland. Revue Suisse de Viticulture, d'Arboriculture et d'Horticulture, 30(5): 281-285 (abstract).
Hansen, L.O., 1989. Species of Lepidoptera new to Norway. Fauna Norvegica Series B 36 (2): 119-124.
Hardwick, D.F., 1965. The corn earworm complex. Memoirs of the Entomological Society of Canada 40, 1-247
Henry, A. and Kumar, D., 2005. Influence of abiotic factors against jassid and pod borer of mungbean (Vigna radiata L.) in arid regions of Rajasthan. Journal of Arid Legumes. 2(1): 181-182 (abstract).
Horvath, Z., Boros, J. and Skoric, F.D., 2004. Damage of sunflower caused by the cotton bollworm (*Helicoverpa armigera*, Hubner) in the region of Kecskemet and Bacsalmas in 2003. Helia 27(41): 173-179 (abstract).
Jallow, MFA., Matsumura, M. 2001. Influence of temperature on the rate of development of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) *Applied Entomology and Zoology,* 36 (4), 427-430

Jiang Mingxing, Xie Liqun and Zhang Xiaoxi, 1999. Characteristics of diapause induction of cotton bollworm. Yingyong Shengtai Xuebao 10 (1): 60-62 (abstract).

Kaabers, S., 1984. Danish migrating butterflies from 1983 find of migrating and flucuating pyralids and large butterflies. Flora og Fauna 90 (3-4): 107-113.

Kakimoto, T., Fujisaki, K. and Miyatake, T. Egg laying preference, larval dispersion, and cannibalism in *Helicoverpa armigera* (Lepidoptera: Noctuidae). Annals of the Entomological Society of America, 96(6): 793-798 (abstract).

Kranthi, K.R., Deepak Jadhav, Ravindra Wanjari, Sandhya Kranthi and Russell, D., 2001. Pyrethroid resistance and mechanisms of resistance in field strains of *Helicoverpa armigera* (Lepidoptera: Noctuidae). Journal of Economic Entomology, 94(1): 253-263.

Kurban, A., Yoshida, A., Izumi, Y., Sonoda, S. and Tsumuki, H., 2005. Pupal diapause of Helicoverpa armigera: sensitive stage for photoperiodic induction. Appl. Entomol. Zool. 40 (3): 457–460.

Marek, J. and Navratilova, M., 1995. Novy sklenikovy skudce, Helicoverpa armigera (Noctuidae, Lepidoptera). [A new glasshouse pest, Helicoverpa armigera (Noctuidae, Lepidoptera) in the Czech Republic.] Ochrana Rostlin UZPI 31 (2): 143-147 (abstract).

Martin, T., Ochou, G. O., Hala N' Klo, F., Vassal, J. M. and Vaissayre, M., 2000. Pyrethroid resistance in the cotton bollworm, Helicoverpa armigera (Hubner), in West Africa. Pest Management Science 56 (6): 549-554.

Martin, T., Ochou, O. G., Vaissayre, M. and Fournier, D., 2003. Organophosphorus insecticides synergize pyrethroids in the resistant strain of cotton bollworm, Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) from West Africa. Journal of Economic Entomology 96 (2): 468-474.

Martin, T., Ochou, G. O., Djihinto, A., Traore, D., Togola, M., Vassal, J. M., Vaissayre, M. and Fournier, D., 2005. Controlling an insecticide-resistant bollworm in West Africa. Agriculture Ecosystems and Environment 107 (4): 409-411.

Multani, J.S. and Sohi, A.S., 2002. *Helicoverpa armigera* (Hubner) on carnation, Dianthus caryophyllus Linn. in Punjab. Insect-Environment, 8(2): 82 (Abstract).

Netherlands Plant Protection Service, 2006. Pest report - Helicoverpa armigera Hübner on Phaseolus vulgaris, www.minlnv.nl/pd

Nibouche, S., Bues, R., Toubon, J. F. and Poitout, S., 1998. Allozyme polymorphism in the cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae): comparison of African and European populations. Heredity, 80: 438 – 445.

Palmqvist, G., 1996. Remarkable records of Macrolepidoptera in Sweden 1995. Entomologisk Tidskrift 117 (1-2) 35-48.

Palmqvist, G., 1997. Remarkable records of Macrolepidoptera in Sweden 1996. Entomologisk Tidskrift 118 (1) 11-27.

Palmqvist, G., 1998. Remarkable records of Macrolepidoptera in Sweden 1997. Entomologisk Tidskrift 119 (1) 13-27.

Palmqvist, G., 1999. Remarkable records of Macrolepidoptera in Sweden 1998. Entomologisk Tidskrift 120 (1-2): 59-74.

Palmqvist, G., 2000. Remarkable records of Macrolepidoptera in Sweden 1999. Entomologisk Tidskrift 121 (1-2): 31-45.

Palmqvist, G., 2001. Intressanta fynd av storfjarilar (Macrolepidoptera) i Sverige 2000. [Remarkable records of Macrolepidoptera in Sweden 2000.] Entomologisk Tidskrift 122 (1-2): 41-55.

Palmqvist, G., 2002. Intressanta fynd av storfjarilar (Macrolepidoptera) i Sverige 2001. [Remarkable records of Macrolepidoptera in Sweden 2001.] Entomologisk Tidskrift 123 (1-2): 53-63.

Palmqvist, G., 2003. Intressanta fynd av storfjarilar (Macrolepidoptera) i Sverige 2002. [Remarkable records of Macrolepidoptera in Sweden 2001.] Entomologisk Tidskrift 124 (1-2): 47-58.

Pandey, R.K., Singh, G. R. and Akhilesh-Tripathi, 2005. Role of natural enemies on larval population of *Helicoverpa armigera* on chickpea sown on different dates. Shashpa, 12(1): 35-37 (abstract).

Pedgley, D.E., 1985. Windborne migration of Heliothis armigera (Hubner) (Lepidoptera: Noctuidae) to the British Isles. Entomologist'-s-Gazette. 36(1): 15-20.

Pedgley, D.E., 1986. Windborne migration in the Middle East by the moth *Heliothis armigera* (Lepidoptera: Noctuidae). Ecological Entomology, 11 (4): 467-470.

Pinto, M. lo., Agro, A., Salerno, G. and Peri, E., 1997. Serious attacks of the tomato moth *Helicoverpa armigera* (Hubner). Informatore Agrario, 53(9): 67-69 (abstract).

Rao, G.M.V.P., Rao, N.H. and Raju, K., 2005 Insecticide resistance in field population of American bollworm, *Helicoverpa armigera* Hub. (Lepidoptera: Noctuidae). Resistant-Pest-Management-Newsletter. 15(1): 15-17 (abstract).

Reddy, N. A. and Kumar, C. T. A., 2004. A study on correlation between abiotic factors and incidence of tomato fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). Mysore Journal of Agricultural Sciences. 38(3): 417-421 (abstract).

Rezbanyai Reser, L., 1984. On *Heliothis armigera* Hbn., its migration flight year 1983, and data on its occurrence in Switzerland in earlier years (Lepidoptera: Noctuidae). Mitteilungen der Entomologischen Gesellschaft Basel, 34 (3): 71-91 (abstract).

Sannino, L., Espinosa, B., Caponero, A. and Manucci, F., 2004a. Unusual Lepidoptera infestations of crops in the year 2003. Informatore Fitopatologico, 54(12): 35-38 (abstract).

Sannino, L., Espinosa, B. and Caponero, A., 2004. *Helicoverpa armigera* (Hubner) harmful to pepper crops in Italy. Informatore Fitopatologico, 54(1): 23-25 (abstract).

Scott, K.D., Lawrence, N., Lange, C.L., Scott, L.J., Wilkinson, K.S., Merritt, M.A., Miles, M., Murray,.D. and Graham, G.C.,2005. Assessing moth migration and population structuring in Helicoverpa armigera (Lepidoptera: Noctuidae) at the regional scale: example from the Darling Downs, Australia. Journal of Economic Entomology. 98(6): 2210-2219.

Sekulic, R., Tatjana, K., Masirevic, S., Vajgand, D., Gordana, F. and Radojcic, S., 2004. Incidence and damage of cotton bollworm (Helicoverpa armigera Hbn.) in Vojvodina Province in 2003. Biljni Lekar Plant Doctor, 32(2): 113-124 (Abstract).

Shanower, T. G. and Romeis, J., 1999. Insect pests of pigionpea and their management. Annual Review of Entomology, 44: 77-96.

Stigter, H., 2004. Helicoverpa armigera (Hübner) in a Dutch tomato greenhouse (Lepidoptera: Noctuidae). XXII International Congress of Entomology, Brisbane Australia.

The State of Queensland, Department of Primary Industries and Fisheries, 2007. Parasitoids: Natural enemies of Helicoverpa. www2.dpi.qld.gov.au/fieldcrops/17694.html (website visited at 13-06-2007).

Torres Vila, L. M., Rodriguez Molina, M. C., Palo, E., Bielza, P. and Lacasa, A., 2000a. The resistance to insecticides of *Helicoverpa armigera* Hubner in Spain: available data. Boletin de Sanidad Vegetal, 26(4): 493-501 (abstract).

Torres Vila, L. M., Rodriguez Molina, M. C., Palo, E., Estal, P. del and Lacasa, A. 2000b. The larval parasitoid complex of *Helicoverpa armigera* on tomato in the Vegas del Guadiana (Extremadura). Boletin de Sanidad Vegetal; 26(3): 323-333 (abstract).

Torres Vila, L. M., Rodriguez Molina, M. C., Lacasa Plasencia, A., Bielza Lino, P., 2002a. Insecticide resistance of *Helicoverpa armigera* to endosulfan, carbamates and organophosphates: the Spanish case. Crop Protection 21 (10): 1003-1013 (abstract)

Torres Vila, L. M., Rodriguez Molina, M. C., Lacasa Plasencia, A., Bielza Lino, P., Rodriguez del Rincon, A., 2002b. Pyrethroid resistance of Helicoverpa armigera in Spain: current status and agroecological perspective. Agriculture Ecosystems and Environment 93: 55-66 (abstract).

Tripathis, S.R. and Sharma, S.K., 1984. Biology of Heliothis armigera (Hubner) in the Terai Belt of eastern Uttar Pradesh, India (Lepidoptera, Noctuidae). Giornale Italiano di Entomologia, 2:8, pp. 215-222 (abstract).

Undirwade, D.B. and Nimbalkar, S.A., 2005. Effect of host plants on development of insecticide resistance in *Helicoverpa armigera* (Hubner) Journal of Soils and Crops. 15(1): 115-117 (abstract).

Vaishampayan, S, Jr and Singh, H.N., 1996. Evidences on the migratory nature of *Heliothis armigera* (Hubner) adults collected on light trap at Varanasi. Indian Journal of Entomology, 57 (3): 224-232 (abstract).

Venette, R.C., Davis, E.E., Zaspel, J., Heisler, H. and Larso, M., 2003. Mini Risk Assessment. Old World bollworm, Helicoverpa armigera Hübner [Lepidoptera: Noctuidae]. Department of Entomology, University of Minnesota. 36 pp.

Vos, R. de, 2000. Trekvlinders in 1999 (zestigste jaarverslag) (Lepidoptera).[Migrating lepidoptera in 1999 (sixtieth report).] Entomologische Berichten 60 (12): 217-230.

Vos, R. de, 2003. Migrating Lepidoptera in 2000 and recent adventive records. Sixtyfirst report. Entomologische Berichten 63 (1): 14-20.

Waring, P. 2006. Moth report. British Wildlife. December 2006.

Wilson, A.G.L., T. Lewis and Cunningham, R.B., 1979. Overwintering and spring emergence of Heliothis armigera (Lepidoptera: Noctuidae) in the Naomi Valley, New-South-Wales, Australia. Bulletin of Entomological Research 69 (1): 97-110.

Wu KongMing, Zhai BaoPing, Feng HongQiang, Cheng DengFa and Guo YuYuan, 2006. Radar observations on the migratory behavior of the second generation cotton bollworm moths in the north part of northern China. Acta Phytophylacica Sinica. 33(2): 163-167

WVF, 2007. Werkgroep Vlinderfaunistiek, Amsterdam.

Zhao, X.C., Dong, J.F., Tang, Q.B., Yan, Y.H., Gelbic, I., Van Loon, J.J.A. and Wang, C.Z. Hybridization between *Helicoverpa armigera* and *Helicoverpa assulta* (Lepidoptera: Noctuidae): development and morphological characterization of F1 hybrids.: Bulletin of Entomological Research, 95(5): 409-416.

Zhou, X., Faktor, O., Applebaum, S.W., Coll, M., 2000a. Population structure of the pestiferous moth Helicoverpa armigera in the Eastern Mediterranean using RAPD analysis. Heredity 85 (3): 251–256.

Zhou, X., Applebaum, S.W., Coll, M., 2000b. Overwintering and Sping Migration in the Bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Israel. Environmental Entomology 29 (6): 1289-1294.

Name of NL Pest Risk Analyst: Wiebe Lammers

Editorial comments and advice: Antoon Loomans and Marja van der Straten.

Address: Plant Protection Service
Geertjesweg 15, 6706 EA Wageningen

Name of UK Pest Risk Analyst: Alan MacLeod

Editorial comments and advice: Ray Cannon, Dominic Eyre and Richard Baker.

Address: Central Science Laboratory,
Sand Hutton, York, YO41 1LZ UK.

Date: August 2007