

EPPO Datasheet: *Helicoverpa armigera*

Last updated: 2020-10-23

IDENTITY

Preferred name: *Helicoverpa armigera*

Authority: (Hübner)

Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta:
Lepidoptera: Noctuidae

Other scientific names: *Chloridea armigera* (Hübner), *Chloridea obsoleta* auctorum, *Heliothis armigera* (Hübner), *Heliothis obsoleta* auctorum

Common names: African cotton bollworm, Old World bollworm, corn earworm, cotton bollworm, tobacco budworm, tomato grub

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EPPO Categorization: A2 list

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EPPO Code: HELIAR



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Notes on taxonomy and nomenclature

The genus *Helicoverpa* (Lepidoptera: Noctuidae) contains several polyphagous moths that cause severe negative impacts on agricultural crops worldwide during their larval development. *H. armigera* (Old World cotton bollworm) is the most widely distributed of these pests and causes the most severe economic damage. *H. armigera* is closely related to *H. zea* (New World corn earworm), sharing external morphology, overlapping bioclimatic niche use, and host range and cannot be distinguished with the naked eye (Mitchell & Gopurenko, 2016). The phenology of the species is poorly understood. Hardwick (1965) referred 17 species (including 11 new species) to the *Helicoverpa* species complex on the basis of differences in both male and female genitalia. *H. armigera* is considered a global pest with an ever-expanding distribution, possessing outstanding dispersal abilities and a broad feeding range. *H. armigera* is one of the most polyphagous species in the subfamily Heliothinae (Rajapakse & Walter 2007). Given the difficulty of distinguishing *Helicoverpa*/*Heliothis* species in the Heliothinae subfamily (with 381 species described), based on morphological characters (dissection of genitalia is required for identification), molecular markers are the best option for accurate detection of species in the *Helicoverpa* genus. In addition, *H. armigera* and *H. zea* can hybridize and produce fertile offspring (Nagoshi *et al.*, 2016, Cordeiro *et al.*, 2020), hence, *H. armigera* x *H. zea* hybrids might exist in the field, with unknown biological traits (e.g. resistance genes), and/or impacts in relevant crops. It is possible that *H. armigera* x *H. zea* hybrids could cryptically spread and avoid detection.

HOSTS

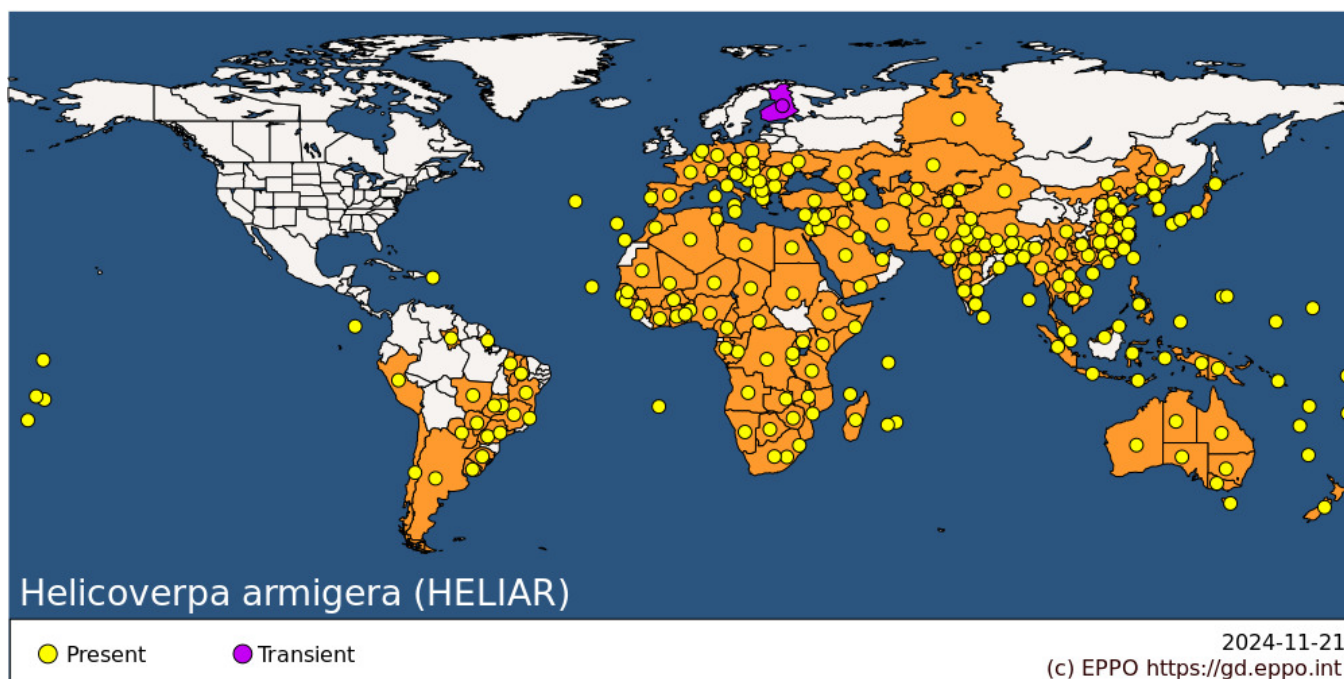
H. armigera is a highly polyphagous species, feeding primarily on ornamental plants and flowers. Asteraceae (N= 50 genera), Fabaceae (N=42 genera), and Poaceae (N=14 genera) are ranked as the top preference (Cunningham & Zalucki, 2014). It has a preference for nitrogen-rich, harvestable fruiting parts of valuable crops. Among the numerous economically important hosts are: cotton, tobacco, tomatoes, potatoes, maize, flax, soybean, sorghum, lucerne, *Phaseolus*, chickpeas, other Leguminosae, and a number of fruits (*Prunus*, *Citrus*) and forest trees.

Host list: *Abelmoschus esculentus*, *Aeschynomene indica*, *Allium cepa*, *Amaranthus* sp., *Antirrhinum majus*, *Arachis hypogaea*, *Asparagus officinalis*, *Avena sativa*, *Beta vulgaris*, *Brassica oleracea*, *Cajanus cajan*, *Cannabis sativa*, *Capsicum annuum*, *Carthamus tinctorius*, *Chamelaucium* sp., *Chrysanthemum x morifolium*, *Cicer arietinum*, *Citrullus lanatus*, *Citrus x limon*, *Coffea arabica*, *Cucumis sativus*, *Cucurbita maxima*, *Delphinium* sp., *Dianthus caryophyllus*, *Eucalyptus camaldulensis*, *Fragaria* sp., *Gladiolus* sp., *Glycine max*, *Gossypium hirsutum*, *Guizotia abyssinica*, *Helianthus annuus*, *Ipomoea batatas*, *Lablab purpureus*, *Lathyrus odoratus*, *Liatris* sp., *Limonium* sp., *Linum usitatissimum*, *Mangifera indica*, *Medicago sativa*, *Mentha spicata*, *Nicotiana tabacum*, *Ocimum* sp., *Oryza sativa*, *Phaseolus vulgaris*, *Pinus radiata*, *Pisum sativum*, *Ricinus communis*, *Sesamum indicum*, *Solanum lycopersicum*, *Solanum melongena*, *Solanum tuberosum*, *Sonchus oleraceus*, *Sorghum bicolor*, *Sphaeranthus indicus*

, *Spinacia oleracea*, *Triticum aestivum*, *Vigna radiata*, *Vigna unguiculata*, *Zea mays*

GEOGRAPHICAL DISTRIBUTION

Commonly reported in the Old World (Europe, Africa, Asia) and Australasia, the migratory *H. armigera* has recently become established in Central and South America (Paraguay and Brazil, 2013; Argentina, Uruguay and Puerto Rico, 2014; Peru, 2016). In 2015, several specimens were trapped in Florida (US), but subsequent surveys confirmed that the pest did not establish (El-Lissy, 2015, Hayden & Brambila, 2015; NAPPO, 2016). Larvae intercepted at US and European ports suggest that the pest may be present in more countries in the Americas (Gilligan *et al.*, 2015, 2019). In the EPPO region, *H. armigera* is established only in the southern part where it can overwinter. In the northern part, only transient populations are found outdoors. Indoors, most of the pest findings are linked to imports of infested plant material and are subject to eradication measures.



EPPO Region: Albania, Algeria, Armenia, Austria, Azerbaijan, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Finland, France (mainland), Georgia, Germany, Greece (mainland), Hungary, Israel, Italy (mainland, Sardegna, Sicilia), Jordan, Kazakhstan, Kyrgyzstan, Malta, Moldova, Morocco, Netherlands, North Macedonia, Poland, Portugal (mainland, Azores, Madeira), Romania, Russia (Southern Russia, Western Siberia), Serbia, Slovakia, Slovenia, Spain (mainland, Islas Canarias), Switzerland, Tunisia, Türkiye, Ukraine, Uzbekistan

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Congo, Democratic republic of the, Cote d'Ivoire, Egypt, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Saint Helena, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

Asia: Afghanistan, Bangladesh, Bhutan, Cambodia, China (Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Neimenggu, Shandong, Shanxi, Sichuan, Xianggang (Hong Kong), Xinjiang, Xizhang, Yunnan, Zhejiang), Cocos Islands, India (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Nagaland, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal), Indonesia (Irian Jaya, Java, Maluku, Nusa Tenggara, Sulawesi, Sumatra), Iran, Iraq, Israel, Japan (Hokkaido, Honshu, Kyushu, Shikoku), Jordan, Kazakhstan, Korea Dem. People's Republic, Korea, Republic, Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia (Sabah, Sarawak, West), Myanmar, Nepal, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam, Yemen

Central America and Caribbean:

Puerto Rico

South America: Argentina, Brazil (Amapa, Bahia, Distrito Federal, Espirito Santo, Goias, Maranhao, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Parana, Piaui, Rio Grande do Sul, Roraima, Sao Paulo), Chile, Paraguay, Peru, Uruguay

Oceania: American Samoa, Australia (New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia), Fiji, Guam, Kiribati, Marshall Islands, Micronesia, New Caledonia, New Zealand, Norfolk Island, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu

BIOLOGY

H. armigera possesses outstanding dispersal abilities. When ovipositing, females can move 5-10 km. They can also migrate over long distances (>100 Km) and aided by wind up to 2000 Km (Behere *et al.*, 2013). In addition, they have high fecundity (approximately 3000 eggs are laid per female over 10 days to 3 weeks). Eggs can hatch after 3 days if temperature is favorable (27-28°C). Adult emergence occurs from May to June, depending on latitude and can be seen up to October depending on suitable weather conditions. The broad host range of the species enables multiple choices for refugia during unfavorable conditions and allows persistence and geographic expansion. *H. armigera* has a short generation time, approximately 30 days in the field, and up to 12 generations per year with optimal temperate and tropical conditions (average 3-5 in Mediterranean and subtropical regions). The duration of the different life stages decreases as temperature rise, with an optimal of 32.5°C. Facultative diapause (genotypically variable) allows for the persistence of populations in the presence of harsh conditions.

H. armigera presents a broad preadaptation and resistance to synthetic pesticides and transgenic crops producing *Bacillus thuringiensis* toxins (*Bt* crops) (Downes *et al.*, 2010; Pearce *et al.*, 2017). *H. armigera* has a mutualistic symbiont virus (HaDNV-1) that enhances its resistance to baculoviruses and *Bt* toxin (Xu *et al.*, 2014). Insecticide resistance is more evident in 4th and 5th instar larvae. Insecticide resistance has been extensively reported for synthetic pyrethroids (Tossou *et al.*, 2019). Resistance to other insecticides, e.g. endosulfan, carbamates and organophosphates has also been reported (Torres-Villa *et al.* 2002).

The life history and fecundity of *H. armigera* has been described in different main hosts plants. The development time (egg to adult emergence) was estimated at 15 days in chickpea, 12 in navy bean and cowpea and 11 in maize and soybean. The duration of the larval period is approximately 3 days in cowpea, chickpea and soybean, whereas in maize it is approximately 4 days. The motionless larval pre-pupal stage spans 13-14 days depending on the host plant, reaching 14.4 days on soybean. The pupal period is highest in maize (42.7 days) and lowest in chickpeas (35.2 days). Adult moths can live up to 52 days in maize and approximately 49 days in cowpea, soybean and chickpeas. Fecundity was recorded as highest in cowpea with 93 eggs/day and an overall 778 eggs gross fecundity; and lowest in maize, with 56 eggs/day and 417 gross fecundity (Fathipour *et al.*, 2020). Larvae reared on an artificial diet show a distinct host preference decreasing from tobacco to cotton, followed by tomato and chili pepper. Adult females prefer tobacco for oviposition (Hu *et al.*, 2018). Host preference is variable within the same host plant species. Different varieties of soybean influence the feeding preference and behaviour of larvae. Naseri *et al.* (2009) tested the feeding behavior, development time and mortality of *H. armigera* larvae in thirteen varieties of soybean finding differences in the duration of the development time (34 to 42 days); the larval period (17-23 days), the longevity of males (8.8 to 12.7 days) and females (8.4 to 10.9 days). Larvae mortality was very different depending on soybean variety, ranging from 8.3% to 29.6%.

DETECTION AND IDENTIFICATION

Symptoms

On cotton

Bore holes are visible at the base of flower buds, the latter being hollowed out. Bracteoles are spread out and curled downwards. Leaves and shoots may also be consumed by larvae.

On tomatoes

Young fruits are invaded and fall. Secondary infections by other organisms lead to rotting.

On maize

Cobs are invaded and developing grain is consumed. Secondary bacterial infections are common.

Morphology

Eggs

Yellowish-white and glistening at first, changing to dark-brown before hatching; pomegranate-shaped, 0.4-0.6 mm in diameter; the apical area surrounding the micropyle is smooth, the rest of the surface sculptured in the form of approximately 24 longitudinal ribs, alternate ones being slightly shorter, with numerous finer transverse ridges between them; laid on plants which are flowering, or are about to produce flowers.

Larva

The first and second larval instars are generally yellowish-white to reddish-brown, without prominent markings; head, prothoracic shield, supra-anal shield and prothoracic legs are very dark-brown to black, as are also the spiracles and tuberculate bases to the setae, which give the larva a spotted appearance; prolegs (5 pairs) are present on the third to sixth, and tenth, abdominal segments. A characteristic pattern develops in subsequent instars. Fully-grown larvae are about 30-40 mm long; the head is brown and mottled; the prothoracic and supra-anal plates and legs are pale-brown, only claws and spiracles remaining black; the skin surface consists of close-set, minute tubercles. Crochets on the prolegs are arranged in an arc. The final body segment is elongated. Colour pattern: a narrow, dark, median dorsal band; on each side, first a broad pale band, then a broad dark band; on the lateral line, a broad, very light band on which the row of spiracles shows up clearly. The underside is uniformly rather pale. On the basic dorsal pattern, numerous very narrow, somewhat wavy or wrinkled longitudinal stripes are superimposed. Colour is extremely variable depending on diet, and the pattern described may be formed from shades of green, straw-yellow, and pinkish- to reddish-brown or even black.

Pupa

Mahogany-brown, 14-18 mm long, with smooth surface, rounded both anteriorly and posteriorly, with two tapering parallel spines at posterior tip.

Adult

Stout-bodied moth of typical noctuid appearance, with 3.5-4 cm wing-span; broad across the thorax and then tapering, 14-18 mm long; colour variable, but male usually greenish-grey and female orange-brown. Forewings have a line of seven to eight blackish spots on the margin and a broad, irregular, transverse brown band. Hindwings are pale-straw colour with a broad dark-brown border that contains a paler patch; they have yellowish margins and strongly marked veins and a dark, comma-shaped marking in the middle. Antennae are covered with fine hairs.

For more information, see Dominguez Garcia-Tejero (1957), Hardwick (1965), Cayrol (1972), Delatte (1973).

Detection and inspection methods

The feeding larvae can be seen on the surface of plants, but they are often hidden within plant organs (flowers, fruits etc.). Bore holes may be visible, but otherwise it is necessary to cut open the plant organs to detect the pest in its larval stage. Larvae show a feeding preference for the reproductive parts of the host plant, and the lower surface of the leaves is a common preferred oviposition site.

Sex-pheromone traps (species, or genus specific traps) have replaced light traps (non-specific species traps) as the former provide a more effective tool to monitor adult moths. These traps facilitate identification and counting and disrupt mating. Pheromone traps can also detect early spring emergence of adult moths thus assisting with control measures and distribution assessments (Reddy & Manjunatha, 2000; Baker *et al.*, 2011). Bucket traps with a

pheromone bait have been reported as the most efficient traps to catch *Helicoverpa* moths, e.g. bucket trap (Guerrero *et al.*, 2014). For adult mass trapping, an average of 30-50 pheromone traps per hectare led to approximately 9000 adults/trap in infested tomato plantations (Shah *et al.*, 2017). Trap crops can attract, divert, intercept and retain *H. armigera*. Spring trap crops can attract *H. armigera* as they emerge from overwintering pupae and reduce the early season buildup of populations, as well as allowing early detection of the pest. Traps should be placed at 1.5 to 1.8 m above the ground (Aheer *et al.*, 2009).

Identification of all stages in the EPPO region will be difficult in the field should the very similar American (*H. zea*) or Australian (*H. punctigera*) species be introduced and become established. Separation of the adult from similar species is most reliably done by reference to the male genitalia (Hardwick, 1965; Pogue, 2004) or using molecular tests. Protocols for DNA barcoding based on COI are described in Appendix 1 of PM 7/129 and can be used to support the identification of *H. armigera* and *H. zea* specimens (EPPO, 2021). A multiplex real-time PCR test was also developed to distinguish *H. armigera* and *H. zea* (Gilligan *et al.* 2015). Given the known economic impact of the species worldwide, accurate identification is key to avoiding costly impacts in valuable economic crops.

The EPPO Diagnostic Protocol PM 7/19 provides recommendations on how to detect and identify *H. armigera* (EPPO, 2003). Possible confusions with other species including *H. zea* are also covered.

PATHWAYS FOR MOVEMENT

The moths are facultative migrants. When conditions become unfavorable, adults can migrate over long distances, borne by wind, for example from southern Europe to the UK (Pedgley, 1985). In high-latitude regions without breeding populations, moths appear in late summer after days of southerly winds and air temperature above an 11°C threshold for larval development. In international trade, eggs and larvae of *H. armigera* can be transported with plants for planting, cut flowers and vegetables (EFSA, 2014). *H. armigera* is regularly intercepted on consignments of cuttings and cut flowers (e.g. chrysanthemums, *Dianthus*, roses), fruit and vegetables (e.g. capsicum, strawberries, maize cobs, mangoes, peas).

PEST SIGNIFICANCE

Economic impact

H. armigera has been reported causing serious losses throughout its range, in particular to cotton, tomatoes and maize. Estimated loss in crop productivity (e.g. maize, soybeans, tomatoes and cotton) in Asia, Europe, Africa and Australasia is greater than 2 Billion USD annually (Tay *et al.*, 2013). In India losses to pigeon pea and chickpea production surpassed 300 Million USD (Reed & Pawar, 1981). In Brazil, one year after detection, economic impact was estimated at 1 Billion USD (Mastrangelo *et al.*, 2014). Damage on soybeans in Brazil reached 100% in non-*Bt* soybeans.

For example, on cotton, two to three larvae on a plant can destroy all the bolls within 15 days; on maize, they consume grains; on tomatoes, they invade fruits, preventing development and causing fruit fall. An outbreak of this noctuid occurred on young *Pinus radiata* in New Zealand in 1969 and 1970, when the larvae consumed more than 50% foliage of about 60% trees. Damage has been reported in India on potatoes, sunflowers, *Guizotia abyssinica*, pigeon peas and cotton. Damage in cotton from *H. armigera* can be up to 100% in unmitigated fields.

In the EPPO region, *H. armigera* is of significant economic importance in Israel, Morocco, Portugal, Russia and Spain and of lesser importance in the other countries where it is established.

Control

H. armigera is a difficult pest to control since it is highly polyphagous, its larvae live inside their host plants and it has developed resistance to numerous pesticides. Efforts are being made in many countries to control *H. armigera*, using both biological and chemical means. A combined Integrated Pest Management approach encompassing multiple strategies in parallel, e.g. predators and parasitoids, as well as pathogens as biocontrol agents and crop management strategies (e.g. intercropping crops to sustain predators and parasitoids, trap crops), and the use of

resistant plant cultivars is recommended and proven effective (Duraimurugan & Regupathy, 2005).

Natural enemies have been found, including egg, larval, and pupal parasitoids and predators. These include Braconidae, Ichneumonidae, Trichogrammatidae, Scelionidae, and Tachinidae. Predators include Chrysopidae, Nabidae, Anthoridae (*Orius* spp. and *Geocoris* spp.), Miridae, Coleoptera, and Araneae. Success has been achieved on specific crops with augmentative releases of natural enemies, and complex biocontrol systems incorporating several predators/parasitoids. In China, *Trichogramma chilonis* has been shown to be the main egg parasitoid of *H. armigera* in cotton (Liu *et al.*, 2016). Fathipour and Sederatian (2013) suggest that natural enemies provide considerable benefit in soybean, but cannot control *H. armigera* populations alone, especially in areas prone to migratory invasions. Moore *et al.* (2004) tested the potential of nuclear polyhedrosis virus (NPV) for the biocontrol of the pest in citrus tree, while Jeyarani *et al.* (2010) showed the same pattern for biocontrol in cotton and chickpeas. *B. thuringiensis* has been shown to considerably reduce European populations of *H. armigera* (Avilla *et al.*, 2005). Recently (Chen *et al.*, 2020) a new virus with potential for biocontrol of *H. armigera* has been identified, *Heliothis virescens ascovirus 3i* (HvAV-3i).

The use of resistant crop plants, e.g. chickpea cultivars (*Cicer arietinum*) in combination with *B. thuringiensis* has also been an effective biocontrol strategy for larvae of *H. armigera* (Devi, 2011) although resistance to *Bt* transgenic cotton has also been reported (Gunning *et al.*, 2005). Overwintering pupae can be controlled by ploughing in the fall and winter, in late maturing crops, exposing the pupae to heat and predation (Duffield, 2004).

Many crop management strategies commonly used to improve health of crops also apply to the control of *H. armigera*. Proper tillage, irrigation, destruction of crop residues and crop rotation can substantially help keep populations under an economical threshold level. Summer trap crops can divert *H. armigera* from an economically important crop. These trap crops have also been utilized to enhance populations of natural enemies. A sorghum trap crop, used to manage *H. armigera*, increased rates of parasitism by *Trichogramma chilonis* in the pest population (Virk *et al.*, 2004). These trap crops must be destroyed prior to the pupation of *H. armigera* larvae to halt the progression of the pest.

Phytosanitary risk

H. armigera is a polyphagous pest which can attack many crops of economic importance in the EPPO region (e.g. maize, tomato and several vegetable crops, ornamentals). Although it is certainly a serious outdoor pest in Mediterranean countries, quarantine status mainly arises from the risk of introduction into glasshouse crops in northern Europe, however current global climate trends could shift and/or expand the distribution of the species. Reports 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, 2000, 2003; Pedgley, 1985; Waring, 2006) attests that the species can move to higher latitudes. Facultative diapause present in this species could facilitate adaptation to more extreme seasonal temperatures. CLIMEX (bioclimatic niche model) has been used to estimate the climatic suitability for *H. armigera* globally and corroborates these statements (Kriticos *et al.*, 2015). The suitable areas for expansion based on the existence of suitable crops, irrigation patterns, cold stress mechanisms, and heat stress accumulation rates using CLIMEX predicts a broader distribution of the pest ranging from South America to North America (up to the border with Canada), Southern Africa to Northern Europe and Southern Russia, Eastern Asia and Australia.

PHYTOSANITARY MEASURES

Imported plants for planting should derive from an area where *H. armigera* does not occur or from a place of production where *H. armigera* has not been detected during the previous 3 months.

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