EPPO Datasheet: *Leptinotarsa decemlineata*

Last updated: 2021-06-17

IDENTITY

Preferred name: *Leptinotarsa decemlineata*
Authority: (Say)
Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta: Coleoptera: Chrysomelidae
Other scientific names: *Chrysomela decemlineata* (Say), *Doryphora decemlineata* Say, *Polygramma decemlineata* (Say)
Common names: Colorado beetle (GB), Colorado potato beetle (US), ten-lined potato beetle, ten-striped spearman
view more common names online...
EPPO Categorization: A2 list
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EU Categorization: PZ Quarantine pest (Annex III)
EPPO Code: LPTNDE

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HOSTS

The Colorado beetle, *Leptinotarsa decemlineata* attacks potatoes and various other cultivated and wild solanaceous plants. It prefers to feed on and has a faster growth rate on *Solanum tuberosum* than on other *Solanaceae* (Bongers, 1970). Geographically isolated populations of *L. decemlineata* may differ in their preference for new host plants and on wild *Solanaceae* they may have a slower development rate, a higher mortality and have emerging adults weighing less than those that fed on *S. tuberosum* (Hiiesaar *et al.*, 2020). Among the wild *Solanaceae*, *S. berthaultii* is not a preferred host due to the presence of glandular trichomes that hinder the activity of the beetle (Groden & Casagrande, 1986). Resistance exists, to varying degrees, among *Solanum* spp., for example, *S. chacoense*, and *S. pinnatisectum* are highly resistant (Carter, 1987, Casagrande, 1982).

Throughout Eurasia, the Colorado beetle causes damage to potatoes, aubergines, tomatoes and feeds on various wild nightshades, such as *S. elaeagnifolium* and *S. rostratum* (Wang *et al.*, 2017). Wild solanaceous species (e.g. *S. dulcamara* and *S. nigrum*) occur widely and can act as a reservoir for infestation (Hiiesaar *et al.*, 2020).

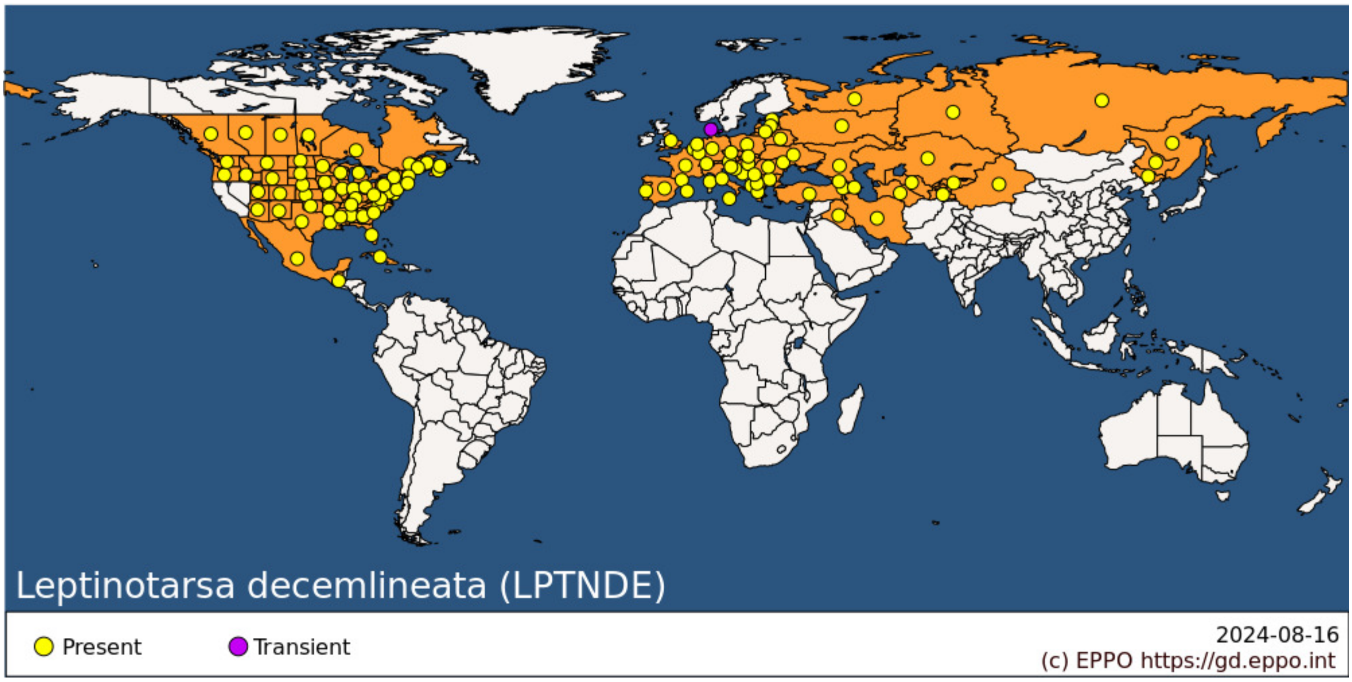
Host list: *Hyoscyamus niger*, *Solanum dulcamara*, *Solanum elaeagnifolium*, *Solanum lycopersicum*, *Solanum melongena*, *Solanum rostratum*, *Solanum sarrachoides*, *Solanum tuberosum*

GEOGRAPHICAL DISTRIBUTION

L. decemlineata is native to North America and rapidly spread to potato crops across America from native *Solanum* hosts. This mode of expansion may have contributed to the significant genetic diversity of contemporary populations, possibly contributing to the rapid evolution of climate tolerance, host range, and insecticide resistance (Izzo *et al.,* 2018). Despite the ban on importing American potatoes to avoid infestation of *L. decemlineata* since 1875 in several western European countries, including Germany, Belgium, France and Switzerland, the insect was officially found in 1922 in France in the Bordeaux area. In the following years the Colorado beetle spread naturally to the neighbouring countries despite the attempts to contain and control it. Immediately after the Second World War, the Colorado beetle continued its expansion towards the east, colonizing much of the European continent and spreading to the European part of the former Soviet Union.

In the following years, *L. decemlineata* expanded eastwards, to Iran, Kazakhstan, Kyrgyzstan, Turkmenistan, Armenia and Uzbekistan, although precise data about the steps of this progressive expansion in the area are not available (Jolivet, 1991). *L. decemlineata* was reported for the first time in China in 1993 in Xinjiang region (Cong *et al.*, 2020). Since 2013 it is also present in the northeast of China in the Jilin and Heilongjiang provinces, probably spreading from Russia (Guo *et al.*, 2010; Liu *et al.*, 2012).

Currently *L. decemlineata* is distributed between latitudes 15 ° and 60 ° N while it is not generally present in tropical countries, nor in most of eastern Asia. It is absent in the Korean peninsula, Japan, India, Africa and in the temperate southern hemisphere (Vlasova, 1978, Worner, 1988, and Jolivet, 1991). In Europe the species is widely spread, with the exception of Denmark, Finland, Norway, Sweden and the United Kingdom, including the islands of Guernsey and Jersey (Thomas & Wood, 1980). In these islands there are frequent interceptions but the species is not established.



EPPO Region: Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France (mainland, Corse), Georgia, Germany, Greece (mainland), Hungary, Italy (mainland, Sicilia), Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Moldova, Netherlands, North Macedonia, Poland, Portugal (mainland), Romania, Russia (Central Russia, Eastern Siberia, Far East, Northern Russia, Southern Russia, Western Siberia), Serbia, Slovakia, Slovenia, Spain (mainland, Islas Baleares), Switzerland, Türkiye, Ukraine, United Kingdom (England), Uzbekistan
Asia: China (Heilongjiang, Jilin, Xinjiang), Iran, Iraq, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
North America: Canada (Alberta, British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Québec, Saskatchewan), Mexico, United States of America (Alabama, Arizona, Arkansas, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, Wyoming)
Central America and Caribbean: Cuba, Guatemala

BIOLOGY

The yearly cycle of *L. decemlineata* starts in spring or early summer, depending on climate and physiological state, with the emergence from the ground of overwintering adult beetles over a period of several weeks (Hare, 1990). The beetles overwinter as diapausing adults in the soil, typically at depths of 7.6 to 12.7 cm (Lashomb & Ng, 1984). Following emergence overwintered adults disperse to find suitable host plants by walking and flying. Unfed beetles display greater flight activity than those that locate a suitable host and begin feeding soon after emergence (Ferro *et al.*

, 1999). There is a tendency for mass emergence during the course of one or two days. The beetles make a (usually) short flight, or walk, to the nearest potato field. Locating potato plants appears to be largely by chance, although the odour of potato plants has been shown to be attractive (Jermy *et al.*, 1988). However, under laboratory conditions the smell of potato plants is attractive to beetles, and plants damaged by feeding activity are more attractive than healthy potato plants (Bolter *et al.*, 1997; Landolt *et al.*, 1999). Food intake is zero at 10°C and a maximum at 25°C. After feeding, the beetles mate. Oviposition follows within a day or two, females laying their eggs (from 15 to 30°C), 10-30 at a time, in several orderly rows on the lower leaf surface. Egg-laying usually continues over a period of several weeks, until midsummer, with each female laying up to 2000 eggs. The eggs hatch in 4-12 days (provided temperatures are above 12°C) and the emerging larvae start to feed immediately. The larvae hatch using egg bursters or oviruptors situated on the meso and metathorax and abdominal segment 1 (Cox, 1988). They seldom stop feeding, except to shed their skins. Moulting occurs four times during the course of 2-3 weeks (with an optimum temperature of 30°C). Larvae are hardy and resistant to unfavourable weather, though heavy rain and strong winds may lead to high mortality, especially in the earlier instars. The larvae in the wandering phase leave the plant to pupate in the ground and change their behaviour from photophylous during the feeding period, to photophobic (Meng *et al.*, 2019). Egg cannibalism by adults accounts for an average of 19% of the eggs being lost (Schrod *et al.*, 1996) but can also be higher during the first stage. It is particularly common at high temperatures with low humidity. Cannibalism becomes negligible under normal conditions and when suitable foliage is present.

Larvae from the same egg mass hatch synchronously and tend to remain grouped on the lower leaf surface until the first moult, after which they migrate to immature foliage on the plant. Larvae are voracious foliage feeders (CABI, 2021). Although total consumption depends on host plant, first instars consume approximately 3% of the total foliage consumed during development and second, third and fourth instars consume approximately 5, 15 and 77% of the total (Ferro *et al.*, 1985). By the 4th instar, the larvae attack the petioles and stems. Mortality during overwintering in Ukraine averaged 30%, but could be as high as 83%, due mainly to fungal and bacterial infections (Koval, 1984). A significant portion of pre-diapause adults migrate to field margins near tree lines before burrowing into the soil, although large numbers of beetles also enter the soil and overwinter within potato fields (Weber & Ferro, 1993; Weber *et al.*, 1994). The important factors in inducing overwintering are photoperiod and temperature, whereas it is primarily temperature which determines the length of diapause and emergence from the soil; in spring the first adults emerge at 68 day-degrees C above 10.5°C (Mailloux *et al.*, 1988; Lefevere *et al*., 1989). The development rate of *L. decemlineata* increases with increasing temperature from 15 ° C to 31 ° C. The survival rate decreases in the order of 27° C > 23° C > 19° C > 31° C > 15° C, suggesting that an excessively high or low temperature is unfavourable for survival (Zhou, 2010). In warmer areas, the fecundity of the succeeding generations is lower than for the first generation, and the number of eggs laid by females also decreases by roughly 25% a month during the summer. The removal of host plants seems to be a primary factor in the induction of diapause in some southern populations (CABI, 2021). For some potato beetle populations in North Carolina, potato harvest, which occurs during late June when daylengths are at their longest, causes the beetles to burrow into the soil where they remain in a state of diapause until the following spring. The survival of these beetles until the following spring is positively related to the amount of time that they have access to host foliage before entering the soil (Nault & Kennedy, 1999).

The number of generations is largely a function of temperature, varying between about four in the hottest areas of its habitat (cycle completed in 30 days) to one full and one partial generation near the colder extremes. There are some cold areas with only one partial generation: the beetle cannot establish itself permanently in such areas. In general, sunny weather with a mean daily air temperature of 17-20°C results in mass spread and development but, if the temperature does not exceed 11-14°C and humidity is high, this does not occur, and the population may decrease (Svikle, 1976). A detailed account of the bioenergetics of larval development in the laboratory in relation to temperature is given by Chlodny (1975). For other details of biology see also Riley (1877), Johnson & Ballinger (1916), Grison (1963), Le Berre & Louveaux (1981), Louveaux & Piganeau (1980), Sokolov (1981), Bartlett (1985), Tauber *et al.* (1988a; 1988b).

DETECTION AND IDENTIFICATION

Symptoms

Both adults and larvae eat the potato foliage (?ndreou, 2015), eventually stripping all leaves from the haulm; exceptionally, the tubers are also eaten. Characteristic, black and rather sticky excrement is left on the stem and leaves by all stages. On aubergine, the main damage is caused by the larvae devouring leaves, flowers, growing fruits, buds and even the stem leaving the skeletal plants and compromising the crop yield (Pollini *et al.*, 2000). *L. decemlineata* adults prefer to colonize potato plants in monoculture rather than those surrounded by non-host vegetation, while the effects of potato plant density on dispersion have not been evaluated. In general, adult beetles show a tendency to constantly remain on the plants they originally colonized (Bach, 1982).

The response of solanaceous crops to defoliation by *L. decemlineata* varies considerably with the phenological stage of the plant (CABI, 2021). For example, tomato seedlings cannot recover from extensive feeding by *L. decemlineata* adults, but as the plant canopy increases, the level of defoliation that can be tolerated also increases (Schalk & Stoner, 1979). Potato has been shown to be least susceptible to yield loss when defoliated very early or late in the season (Hare, 1990; Ferro *et al.*, 1983). Hare (1990) and Zehnder & Evanylo (1989) demonstrated that potato could withstand high levels of defoliation within a few weeks before harvest. Many studies have shown that potato plants are least tolerant of defoliation during the bloom stage (Cranshaw & Radcliffe, 1980; Hare, 1990; Wellik *et al.*, 1981; Ferro *et al.*, 1983; Shields & Wyman, 1984; Dripps & Smilowitz, 1989; Senanayake & Holliday, 1990; Nault & Kennedy, 1996). The only exceptions were reported by Zehnder & Evanylo (1989) and Zehnder *et al.* (1995) who showed that potato was most sensitive to yield loss when defoliated during pre-bloom.

Morphology

Eggs

Yellow or light-orange, long-oval, about 1.2 mm long, and found in rows on the underside of potato leaves.

Larva

Has a large abdomen and arched body; 1st instar is cherry-red with glistening black head and feet; later instars become progressively carrot-red, then pale-orange, with a line of several small black dots on each side of the body marking the spiracles.

Pupa

Yellowish in colour, similar in appearance to that of the larva. Immobile, it settles in an earthy cell at a depth of 5-15 cm where the definitive metamorphosis will take place. For more details, see Cox (1996).

Adult

A stout, oval, strongly convex and hard-backed beetle, about 1 x 0.6 cm; yellowish-brown except for five narrow black stripes on each of the two creamy-yellow wing covers; about a dozen small black spots on the top of the head and thorax; the tips of the legs are dark-brown or black.

Detection and inspection methods

Because of their size and distinctive colouration, adults and larvae are not difficult to observe by visual inspection. *L. decemlineata* has a tendency to release its hold on plants that are shaken, and this characteristic can be used to detect insects hidden among foliage. Visual sampling of potato fields was found to be as efficient for estimating population density as the whole-plant bag-sampling method, and more efficient than sweep netting (Senanayake & Holliday, 1990). For area surveys, soil sampling at harvest for buried beetles in diapause gives reliable results (Glez, 1983). A sequential sampling plan has been reported for estimating populations of Colorado potato beetle egg masses and of adults and larvae (Hamilton *et al.*, 1997a).

PATHWAYS FOR MOVEMENT

The main means of natural spread of the beetle over large areas is by wind-borne migration, particularly of the spring generation. Adults can also be carried over long distances in sea water.

Adults and larvae can be easily transported on potato plants and tubers, and in all forms of packaging and transport.

Fresh vegetables grown on land harbouring overwintered beetles are common means of transport in international trade.

Colorado beetle may also spread as a hitchhiker on transport (e.g. lorries) by walking, or flying, on board. As a result, it will most likely be found on the outside of packages. However, there is no special association with the packing material, and the risk of inadvertent transport in packaging is considered low (Cosner, 2013).

PEST SIGNIFICANCE

Economic impact

The Colorado beetle is one of the most economically damaging insect pests of potato in the many countries where it now occurs (Hare, 1990). Both adults and larvae feed on this host, and often cause complete defoliation of the infested potato plants, with considerable yield losses (50% of the crop in some EPPO countries). *L. decemlineata* is also suspected of spreading several potato diseases, including *Ralstonia solanacearum* and *Clavibacter sepedonicus*.

Damage has also been reported on other crops; for example, tomato yield was reduced by 67% in a field test in Maryland, USA, when numbers of larvae increased from five to ten per plant (Schalk & Stoner, 1976). *L. decemlineata* is also considered to be a serious pest of aubergine in Europe and North America. In China, Colorado beetle severely damages potato, affects aubergine, and occasionally damages tomato (Liu *et al.*, 2012). In Xinjiang the damage caused by *L. decemlineata* ranges between 30% and 50% and in some cases it can reach 90% of the total yield (Guo *et al.*, 2010). Estimates indicate that the economic losses caused by Colorado beetle in China are 3.2 million USD dollars a year and it was suggested that this could go up to 235 million USD dollars once the species has spread more widely in China (Liu *et al.*, 2012).

Control

A large amount of research has concentrated on finding and developing means of control. However, the use of insecticides remains the most common means of controlling the pest and, in many EPPO countries, such control is obligatory by law. Throughout the EPPO region where *L. decemlineata* is present, the beetle is considered not to be as important a pest of potato as it was in the past. This is because effective plant protection products are available and the routine control of *L. decemlineata* has become incorporated into the established pattern of potato cultivation. To contain the development of the Colorado beetle populations, insecticides can be used against eggs, larvae or adults.

For a long time, the chitin inhibitor insecticide (e.g. triflumuron, teflubenzuron and novaluron) activity on eggs and 1st instar larvae was successfully applied at the first emergence of overwintered adults in spring (Guanda & Tassoni, 1992).

Since the mid-1980s, the neonicotinoids have been the most commonly used insecticides for the control of *L. decemlineata*, either applied on the canopy or, in the case of thiametoxam, directly on the seed tuber, reducing canopy applications during the growing season. At present in the European Union all neonicotinoids have been revoked with the exception of acetamiprid which is still used at the beginning of the infestation.

Currently, chemical control is generally carried out from the first appearance of overwintered adults by exploiting the contact and ingestion activity of some insecticides (broad spectrum actives such as pyrethroids or more specific insecticides such as chlorantraniliprole or metaflumizone). Colorado beetle infestations often remain confined to the edge of the field for most of the season. This allows targeted spraying leaving between 60 and 95% of the plot untreated.

The ability of this species to develop resistance to practically all the insecticides used to control it has led to repeated failures of the pest control strategies in many areas (Casagrande, 1987; Georghiou & Lagunes-Tejeda, 1991; Bishop & Grafius, 1996). Since the 1960s, *L. decemlineata* has developed resistance to 54 different insecticides including imidacloprid and eight other neonicotinoids (Whalon *et al.*, 2013). In the United States, in New York State, adults of *L. decemlineata* have been reported with up to 155-fold increased resistance to imidacloprid after three seasons of use (Zhao *et al.*, 2000). Moreover, clear cross resistance was proved between imidacloprid, thiamethoxam and clothianidin suggesting that rotation using neonicotinoids insecticides should be avoided (Mota-Sanchez *et al.*, 2006; Alyokhin *et al.*, 2007; 2008).

The resistance management for *L. decemlineata* is based on agronomic pest management techniques, such as the adoption of longer rotations, the adoption of techniques to delay the colonization of crops (by moving the sowing date or using mobile barriers), the experimentation with action thresholds and the alternation of insecticides with different modes of action (Kennedy & French, 1994; Grafius, 1997; Midgarden *et al.*, 1997; Dively *et al.*, 1998).

Crop rotation usually delays the colonization of the plots by overwintered adults and reduces the size of the population that subsequently develops within the field. Reductions of 90% or more of *L. decemlineata* population have been reported on potato under crop rotation compared to potato grown without rotation (Lashomb & Ng, 1984; Wright, 1984). The effect of crop rotation increases with increasing distance from the overwintering site of adults. Follett *et al.* (1996) suggested 0.5 km as the minimum distance needed to benefit from the effect of crop rotation in terms of reduction of pest population.

The choice of sowing date can also be used to reduce the population of second-generation larvae; early sowing of short cycle varieties allows harvesting before the second generation of larvae appears. In contrast, colonization of late-growing plantations grown under rotation occurs later in the season, causing most adults of the summer generation to emerge after the critical photoperiod for diapause induction has been reached. Consequently, these adults do not produce a second generation of larvae (Weber & Ferro, 1993).

The development of Colorado beetle resistant varieties may represent a strategy to contain the pest with a reduced number of insecticide applications (Maharijaya & Vosman, 2015). However, at present there is currently no clarity as to which pest control mechanisms of the plant may cause high insect mortality and lower defoliation (Crossley *et al.*, 2018). There are few studies in which the benefits of using economic thresholds for managing *L. decemlineata* have been reported (CABI, 2021). In several instances, however, potato tuber yield did not significantly differ between an economic-threshold-based management approach and the conventional management program. However, fewer insecticide applications were needed to manage *L. decemlineata* infestations when an action threshold was used (Wright *et al.*, 1987; Stewart & Dornan, 1990; Zehnder *et al.*, 1995). Genetically modified crops producing *Bacillus thuringiensis* (Bt) toxins present numerous advantages when compared to other agro-technical, mechanical, biological and chemical measures. However, pest resistance and public concerns in relation to genetically modified crops are major problems associated with this type of crops (Balaško *et al.*, 2020).

In organic farming, spinosad-based formulations, a fermented substance obtained from a mixture of two toxins produced by *Saccharopolyspora spinosa*, are used to control the pest. Over the past decade in the state of New York, potato beetles have developed resistance to this active substance, although the resistance has partially regressed when its use was stopped (Klein, 2019).

Foliar applications of *Bacillus thuringiensis* serovar *tenebrionis* formulations also provided good pest control. *B. thuringiensis* serovar *tenebrionis* acts upon ingestion so it is more effective against young larvae and has a limited residual activity. Correct application timing and careful wetting of the crop are essential for effective control (Zehnder & Gelernter, 1989; Ferro & Lyon, 1991; Zehnder *et al.*, 1992; Dubois & Jossi, 1993; Korol *et al.*, 1994).

In laboratory tests, adults and larvae treated with oil and extracts from the seeds of the neem tree (*Azadirachta indica*) showed a reduced feeding speed and a reduction in fertility and viability which were also confirmed in field tests carried out with AZT-extract and AZT-extract + neem oil (Kaethner, 1992).

The following arthropod predators and parasites of *L. decemlineata* are known: *Chrysomelobia labidomerae, Chrysoperla carnea, C. sinica, Edovum puttleri, Euthyrhynchus floridanus, Lebia grandis, Myiopharus doryphorae, Oplomus dichrous, Perillus bioculatus, Podisus maculiventris, Rhynocoris* sp. In addition, the nematodes *Heterorhabditis heliothidis, Hexamermis* sp., *Pristionchus uniformis, Steinernema feltiae, S. glaseri;* the fungi *Beauveria bassiana, B. tenella, Paecilomyces farinosus, Penicillium funiculosum*; the bacterium *Bacillus thuringiensis*; the protozoa *Nosema* spp.; and certain iridoviruses have been used against the beetle with varying degrees of success.

Phytosanitary risk

Because of its capacity for adaptation to different climatic conditions (Ushatinskaya & Ivanchik, 1982) and different host plants (Hsiao, 1984), the Colorado beetle continues to cross international borders and invade new areas. The beetle has obviously not reached the extent of its geographic range in the EPPO region but its spread has slowed considerably in recent years, almost entirely due to international collaborative action, especially between France and the Channel Islands, with EPPO support (Thomas & Wood, 1980).

In the European Union Colorado beetle is regulated by Regulation 2019/2072 (Annex III) with protected zones in force in Cyprus, Ireland, Malta, Northern Ireland, parts of the Spain (Ibiza and Minorca) and Portugal (Azores and Madeira), seven districts of Finland and five counties in Sweden. The spread within the protected areas could take place through the flight of adults and through the movement of plant material (EFSA, 2020). A cost-benefit analysis performed by Aitkenhead (1981) indicated that the cost of the measures used to exclude *L. decemlineata* from the United Kingdom would be less than the likely costs of control, if introduced. Even a moderate increase in temperature could modify the voltinism of *L. decemlineata* in Europe, increasing the chances of spreading the species in currently uninfested areas (Jönsson *et al.*, 2013). Climate change could lead to a higher pressure of Colorado beetle in most of the potato growing areas (Wójtowicz *et al.*, 2013, Pulatov *et al.*, 2016). Colorado beetle could increase the number of generations; an increase in temperature of 2° C above that recorded in recent years would allow the development in Poland of two entire generations of the beetle, and further increases in temperature could even allow the occurrence of three generations. Successful expansion of *L. decemlineata* to higher latitudes can be explained by the diapause synchronization with local photoperiod conditions but further northward expansion may be limited by inherent difficulties in initiating overwintering with very long photoperiods. (Lehmann *et al.*, 2012, 2015). Furthermore, the lack of knowledge on species-specific responses to temperature and light conditions creates uncertainty in assessments on the impact of climate change also because agricultural practice will have a great impact on the actual results of this process (Jönsson *et al.*, 2013). Potential distribution has been discussed by Jolivet (1991) for Asia and by Sutherst (1991) for the world. The maximum entropy models (MaxEnt) show that in the future the Colorado beetle range could expand and occupy the hot areas of North America, South Africa, Europe, China and Australia. Furthermore, future climatic conditions could promote its expansion also in the northern regions (Wang *et al.*, 2017). Many aspects of the insect's behaviour in China still need to be clarified (i.e. genetic variations, the ability to adapt the environment or the mechanisms that have caused a rapid development of resistance to pesticides) (Guo *et al.*, 2017).

PHYTOSANITARY MEASURES

Countries may require that consignments of any plants or plant products be found free from the pest after having been subjected to sorting and packaging techniques in suitable premises. In addition, they may require that potatoes and certain vegetable crops had been grown in a field which had been inspected during the growing season and found free from the pest and which was in an area where either the pest does not occur or is under intensive official control.

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