EPPO Datasheet: *Diabrotica virgifera zeae*

Last updated: 2022-06-02

IDENTITY

Preferred name: *Diabrotica virgifera zeae*
Authority: Krysan & Smith
Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta: Coleoptera: Chrysomelidae
Common names: Mexican corn rootworm
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EPPO Categorization: A1 list
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EU Categorization: A1 Quarantine pest (Annex II A)
EPPO Code: DIABVZ

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Notes on taxonomy and nomenclature

The subspecies *Diabrotica virgifera zeae* was distinguished from the nominate subspecies, *Diabrotica virgifera virgifera* LeConte by Krysan *et al.* in 1980 following various observations on the distribution, morphology and biology of 'Mexican populations' of *Diabrotica* which are adapted to a tropical climate. The many reports of *D. longicornis* from Eastern Texas or Mexico made before this date, are now considered to be of *D. virgifera zeae*. Krysan *et al*. (1980) observed that 'Mexican populations' are morphologically very similar to *D. virgifera*, including in respect of the male genitalia and this resulted in the new taxon being described as a subspecies of *Diabrotica virgifera*. *D. virgifera* is readily distinguished from *D. longicornis* using external morphological criteria as well as by comparison of the male genitalia. Attempts to distinguish the two subspecies *D. virgifera virgifera* and *D. virgifera zeae* with molecular tools have until now proved unsuccessful (Clark *et al.*, 2001). Except for the colour criteria (see paragraph on morphology), incidence of *Wolbachia* bacteria inducing reproductive incompatibility is reported as a characteristic that separates and supports the separation of these subspecies. Giordano *et al*. (1997) reported that *Wolbachia*-free *D. virgifera virgifera* individuals had no reproductive incompatibility with *D. virgifera zeae*.

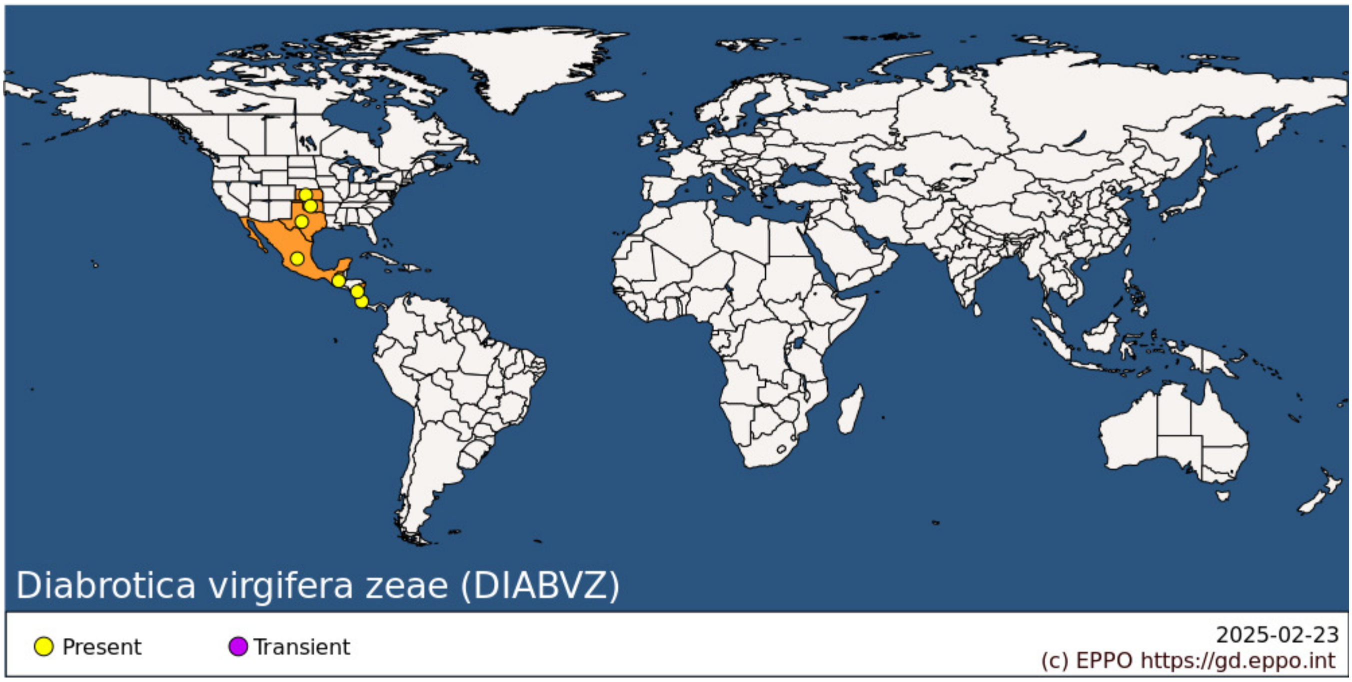
HOSTS

Adults of the Mexican corn rootworm feed on the leaves, silks, pollen and immature seeds of maize (*Zea mays*) (Poaceae). Larvae feed on roots, damaging the root tips and the prop roots. However, this subspecies is not only a pest of corn, it has also been reported in association with non-corn grass pollen and from a wide range of non-grass plant species. For example, Jones and Coppedge (2000) identified 45 plant families, 63 plant genera and 27 plant species from which pollen was used as foraging resource by adults captured in Texas.

Host list: *Amaranthus*, *Ambrosia*, *Amorpha*, *Ampelopsis arborea*, *Aster*, *Betula*, *Bidens*, *Brachiaria plantaginea*, *Callirhoe*, *Cannabis sativa*, *Carya illinoinensis*, *Castilleja*, *Catalpa speciosa*, *Ceanothus americanus*, *Celtis laevigata*, *Cephalanthus occidentalis*, *Chamaecrista*, *Cirsium*, *Commelina*, *Cucurbita foetidissima*, *Cucurbita pepo*, *Cyperus conglobatus*, *Cyperus odoratus*, *Digitaria ciliaris*, *Diospyros*, *Eleusine indica*, *Eragrostis mexicana*, *Euphorbia*, *Fraxinus pennsylvanica*, *Glycine max*, *Gossypium hirsutum*, *Helianthus annuus*, *Ilex*, *Iva*, *Juniperus*, *Magnolia*, *Medicago arabica*, *Medicago sativa*, *Menispermum canadense*, *Mimosa strigillosa*, *Morus microphylla*, *Neltuma glandulosa*, *Neptunia*, *Oenothera*, *Oxalis*, *Panicum hallii*, *Parthenium*, *Parthenocissus quinquefolia*, *Pinus*, *Proboscidea*, *Quercus*, *Rhus glabra*, *Rubus*, *Rumex*, *Sagittaria*, *Salix nigra*, *Senna*, *Sesbania*, *Sicyos*, *Sideroxylon*, *Solanum*, *Sorghum*, *Sphaeralcea*, *Tamarix*, *Thelesperma*, *Toxicodendron radicans*, *Trifolium*, *Typha angustifolia*, *Typha latifolia*, *Ulmus crassifolia*, *Urtica*, *Verbena*, *Viburnum*, *Vitis*, *Zanthoxylum clava-herculis*, *Zea diploperennis*, *Zea mays*

GEOGRAPHICAL DISTRIBUTION

D. virgifera zeae mainly occurs from Guatemala through Central Mexico to the coastline of Texas as well as in parts of southern Oklahoma (Krysan and Smith, 1987 cited by Giordano *et al*., 1997). Expanded maize production may have facilitated the movement of *D. virgifera zeae* northward from Mexico, resulting in a region of secondary contact with *D. virgifera virgifera* in northern Texas, where the subspecies hybridize.



North America: Mexico, United States of America (Kansas, Oklahoma, Texas)
Central America and Caribbean: Costa Rica, Guatemala, Nicaragua

BIOLOGY

Branson *et al*. (1982) has reported observations on the biology of the Mexican corn rootworm in the state of Jalisco, Mexico, a region where water availability rather than temperature affects cropping practices. This subspecies is univoltine but can be multivoltine (two or more generations per year) in tropical regions where continuous maize cultivation occurs. Oviposition starts around mid-August when eggs are deposited by females near the base of corn stalks. *D. virgifera zeae* overwinters as eggs (diapause) at a depth of 10 to 15 cm in sandy soils and down to 30 cm in clay soils; the eggs remain for 6-8 months throughout the winter. The duration of diapause is reported to last on average 253 days (Mitchell *et al*., 2010) but, according to Branson *et al*. (1982), this can vary greatly within the same population (i.e. from 50 to 300 days). Eggs that terminate diapause during the winter remain dormant, in chill quiescence, until soil temperatures exceed the threshold for post diapause development (11°C). They also remain in quiescence in case of moisture deficit (Krysan *et al*., 1977). Low precipitation and high temperatures are the main causes for egg mortality (Martinez *et al*., 2014). The larvae develop for approximately 36 days, going through three different stages. After the last larval stage, the insect pupates, remaining as a pupa for 8 or 9 days, after which the adult emerges from the soil and begins to feed, preferring pollen or maize silks. In Mexico, emergence patterns are variable, depending on the location: on the Paci?c coast, adults start to emerge at the end of July, with peak emergence in mid-August, while at high altitude in Central Mexico the ?rst adults are often observed as early as mid-June, although the peak emergence is in September. Adults mate and then the females enter a pre-oviposition stage lasting 23 days, at the end of which they oviposit around 1000 to 1100 eggs per female. The complete life cycle of *D. virgifera zeae* lasts 40 to 45 days and coincides with the reproductive phenology of maize.

The effect of temperature has been investigated by Woodson and Chandler (2000) in a controlled environment using eight different temperatures (from 15°C to 33°C +/- 0.5°C). Development from egg hatch to adult occurred only in the range of 15-30°C with the fastest development between 21 and 27°C. There is no significant difference between the sexes in terms of development speed. Mexican corn rootworm required on average 473 degree days (DD) (base 10.3°C), from hatching to adult emergence, whereas Western corn rootworms (*D. virgifera virgifera*) required less time - 434 DD - to complete its development. Eggs of Mexican corn rootworm survived better and lost water less readily in a desiccating environment suggesting a better adaptation to drier conditions (Krysan *et al.*, 1977).

DETECTION AND IDENTIFICATION

Symptoms

Damage to plants mainly results from the larvae feeding on the roots, with the rate of damage being directly correlated to the number of larvae per plant and to the percentage of clay in the soil (given that survival of larvae increased as the percentage of clay increased). Because of the damage to the roots, damaged plants show symptoms of lack of water even when there is good soil moisture, also the damage reduces the plant's ability to anchor and support itself, which can lead to the plant falling over or forming a ‘goose neck’. The older larvae burrow in the cortical parenchyma of the roots, and then dig channels in the central vascular tissue. Tunnels in maize roots are thus a characteristic symptom, though they may be due to other species. Adults have been reported in association with many different plant species, these associations involved floral parts rather than foliage according to Clark *et al*., 2004) but the literature does not mention any particular symptoms associated with this pollen feeding.

Morphology

Egg

Eggs are oval and are light yellow when freshly oviposited, turning brown before hatching; they measure 0.6 mm in length and 0.35 mm in width. It has been noted by Atyeo *et al*. (1964) that the surface of the egg of rootworm pests is covered with primary polygons and sometimes secondary ridges, useful indicators for identification using the scanning electron microscope. *D. virgifera virgifera* and *D. virgifera zeae* are readily distinguished from *D. longicornis* (the closest species) by the absence of secondary ridges inside angular polygons for the first two species; the pits inside polygons of *D. longicornis* are rounded, evenly spaced and there are about 6-12 per polygon. Chorion sculpturing of *D. virgifera virgifera* is indistinguishable from that of *D. virgifera zeae* (Krysan *et al*., 1980).

Larva

Newly hatched larvae are translucent and almost colourless while mature larvae are creamy white, with the head and end of the abdomen dark brown (Mitchell *et al*., 2010). Larvae are 2-3 mm long at emergence and have six very small legs, the last instar measures up to 12-19 mm and has no urogomphi (a paired outgrowth of the last body segment). The identification key of Mendoza and Peters (1964) can be used to differentiate mature larvae of *D. virgifera* from those of *D. undecimpunctata howardi* and *D. longicornis*. To our knowledge, it is not possible morphologically to distinguish the larvae of the two subspecies of *D. virgifera*.

Pupa

The pupa is about 7.5 mm long and 4.5 mm width, white, becoming yellow with age and looking like an adult with rudimentary antennae, legs and wings. The tip of the abdomen bears a pair of stout spines, and smaller spines are found dorsally on the other abdominal segments. There is a sexual dimorphism at the pupal stage, female pupae bearing a pair of distinctive papillae on the venter near the apex of the abdomen, whereas such papillae are lacking for males (Krysan and Miller, 1986). Pupae are found in earthen cells in the soil near plant roots.

Adult

Length 4.8-5.4 mm long. Elytra basic colour green, maculate, with two fuzzy-edged, sulphur yellow, round maculae on each elytra. Head basic coloration yellow with filiform antennae, pronotum green or pale olivine, subquadrate, deeply bifoveate, scutellum yellow or amber yellow. Tarsi yellow or yellow ochre. Tibia bicoloured, yellow, outer edge with piceous (i.e. glossy black or glossy brownish-black) or testaceous (i.e. brick-red or brownish-red) line, or almost entirely darkened. Femora bicoloured, yellow or green, outer edge chestnut to piceous. *D. virgifera zeae* is easily distinguished from the nominate subspecies, *D. virgifera virgifera*, by the green elytra lacking longitudinal vittae (lines). From the similar *D. longicornis* and *D. barberi* it can be separated by the femora of *D. virgifera zeae* that are bicoloured with dark, chestnut or piceous, outer edge, while in *D. longicornis* and *D. barberi* femora are unicolorous green or clear yellow. A full description of the adult is available in Derunkov *et al*. (2013).

Detection and inspection methods

The detection of *D. virgifera zeae* requires the collection of insect specimens for analysis. Visual examination of imported plant commodities and soil or washing the roots and sifting soil to recover hidden stages (i.e. larvae or pupae) is possible, but the effectiveness of these methods is quite uncertain, especially in cases of very low levels of infestation. Moreover, in case of interception of a larva, there is no morphological method to differentiate the two subspecies of *D. virgifera*; and while DNA sequences are available in some databases (NCBI or BOLD), they are not supported by validation data. Yellow sticky traps baited with chemical kairomone attractant and cucurbitacin-baited traps can be used for the monitoring of production sites (Jackson *et al*., 2005; Luna, 2006; Alston and Worwood, 2012). However, the effectiveness of these methods is quite uncertain, especially in cases of very low levels of infestation.

Adults of *D. virgifera zeae* can be identified using the diagnostic protocol for *D. virgifera virgifera* which includes a key to the adults of the main *Diabrotica* species which occur in US agriculture (EPPO, 2017). Microsatellites have been developed and are sufficiently polymorphic to be used for diagnostics and surveillance performed during pest management programmes (Waits and Stolz, 2008).

PATHWAYS FOR MOVEMENT

Little information is available in the literature on the movement capacities of this subspecies, but it is very likely that these are equivalent to the capabilities of *D. virgifera virgifera*. While the larvae move relatively little, the adults of *D. virgifera* are good fliers and can travel readily from field to field or migrate over longer distances, moving with weather features such as cold fronts (Grant and Seevers, 1989). However, their flight potential is not sufficient to spread from North or Central America to the EPPO region. Hitchhiking behaviour is a possibility, as observed with *D. virgifera virgifera* in Europe. The EFSA Panel on Plant Health performed a pest categorization of *D. virgifera zeae* which included a full investigation of potential pathways (EFSA PLH, 2019). While there is no obvious means of intercontinental dispersal in trade, since the insects would not normally be expected to be carried by consignments of seeds or grain, *D. virgifera zeae* may move in international trade as immature stages (eggs, larvae or pupae) in soil and growing media (with or without host plants) than as adults. Europhyt records of pest interceptions from 1995 to 2019 do not report any interceptions of this species in the EU (EFSA PLH, 2019) and survival of immature stages on roots of host plants, or in soil (either as a commodity on its own, or when accompanying plants for planting in international trade), is not known. Considering that the rearing of *Diabrotica* species in laboratory facilities requires experience and attentiveness of the operator and also a good knowledge of the ecological needs of the insect to promote the growth and development of the insect (Jackson, 1986), the survival rate is probably very low.

PEST SIGNIFICANCE

Economic impact

D. virgifera (including the two subspecies) has been considered as the ‘most serious insect pest of dent corn in the major corn-producing states of the north-central United States and Canada’ (Levine & Oloumi-Sadeghi, 1991). The cost of soil insecticide treatments to limit larval damage to roots and of aerial sprays to reduce adult damage to silks, when combined with crop losses, can approach 1000 million USD annually (Krysan and Miller, 1986). The subspecies *D. v. zeae* is considered as a serious pest of corn in several areas of Central and Southern Texas as well as in Mexico. For example, *D. virgifera zeae* was one of the most important pests of irrigated maize in the central part of the Mexican state of Jalisco and was considered to be an increasing problem (Salido, 1987). Depending on the state and the year, reported losses in maize grain yield in Mexico vary from a few kilograms to 1 tonne/ha (Amatitlán and Ameca states) to 1.6 tonnes/ha (Guanajuato state) or as much as 2.5 tonnes/ha in Ahualulco and Mixtlán states (different authors, cited by Alfilerillo (2019)). In Atlacomulco, yields reduced by more than 80% when insecticides were not used (Ayala, 2000 cited by Segura-Leon, 2004).

Control

In respect of *D. virgifera virgifera* management, Levine and Oloumi-Sadeghi (1991) refer to the following approaches in their detailed review of integrated pest management (IPM) options for this pest: crop rotation, tillage and soil environment, planting and harvesting dates, host-plant resistance, biological control, as well as control of adults and larvae with insecticides. Current IPM strategies rely on the monitoring of pest populations, use of economic thresholds and integration of the different control methods.

In Texas, control of the Mexican corn rootworm has been mainly based on soil insecticides even when a rotation with another crop was possible (Spurgeon *et al.*, 2004). Monitoring adults in one season gives a reasonably good forecast of damage in the following season for *D. virgifera virgifera* (Levine and Gray, 1994) but treatment thresholds for adult Mexican corn rootworms are largely empirical. For example, treatment thresholds of 0.5 adult beetle per plant or 100 beetles per trap are specified in literature. Many different types of traps are available for *D. virgifera virgifera* (Hesler and Sutter, 1993), whereas for *D. virgifera zeae*, more information is needed for interpretation of trap captures and implementation of trapping systems regarding seasonal patterns of capture, trap efficiency in relation to crop phenology etc. Preliminary results show, for example, that adult *D. virgifera zeae* populations estimated by plant visual examinations are highest during flowering, whereas captures on sticky and kairomone-baited traps are lowest during this period. Thus, peak beetle population estimates occurred later for both trap types than was found using visual examination of whole plants (Spurgeon *et al*., 2004).

Bacillus thuringiensis (Bt) corn technology is a management option used on the American continent and significantly reduces the amount of root pruning by the Mexican corn rootworm (Mays and Kerns, 2021). The role of parasites and predators on *D. virgifera zeae* is currently poorly documented and more research is needed about the possible natural enemies to be used for biological control.

Phytosanitary risk

Maize, the main host of *D. virgifera zeae*, is widely cultivated in the EPPO region and is of particular importance in areas such as the Danube basin, the Po valley of Italy or the southwest of France. The potential distribution of the Mexican corn rootworm in the EU has been approximated by the EFSA Panel on Plant Health (EFSA PLH, 2019) using the global Köppen–Geiger climate zone categories. They concluded that certain climatic zones (semi-arid steppe and warm temperate climate, fully humid, hot summer) occur both in the area of origin and in several European countries (mainly in the south). They considered that as *D. virgifera zeae* is a subtropical organism, cold temperatures and frost may limit its distribution, taking into account that it occurs primarily in regions with few frost days. Based on the map by Krysan and Miller (1986), the EFSA Panel concluded, on the basis of the number of frost days, that there are areas in central and southern North America which are similar to areas in the EU with few frost days. Therefore, they assume that climatic conditions in the EU do not limit the ability of *D. virgifera zeae* to establish, and that the introduction of *D. virgifera zeae* would most probably have an economic impact in the EU through the reduction of maize yields. This conclusion most probably applies to countries cultivating maize in other parts of the EPPO region.

PHYTOSANITARY MEASURES

Adults actively ?y and are unlikely to remain on the plants during harvesting or transatlantic trade. Entry into the EPPO region at the adult stage seems therefore unlikely, even though many potential host plant species are reported for adults (see Host section), including some ornamental species which may be imported from North America into the EPPO region. Nevertheless, EFSA PLH (2019) has considered that fresh maize cobs and forage/green maize are open pathways that could provide a route of entry for adults. Some control measures could be implemented to mitigate this risk at the place of production (such as chemical treatments), or on the commodity before export (such as treatment of plants by storage in modified atmosphere).

In contrast, eggs and larval stages are hidden in soil and thus could travel and remain undetected during import controls. However, larval host plants are limited to few species, the main one being maize which is not traded with soil. Moreover, as is the case in several EPPO countries (e.g. in the EU; EU, 2019), a prohibition on the import of soil or growing media from most third countries should prevent the entry of immature stages.

Even though current national regulations in the EPPO region may not cover the true host range of *D. virgifera zeae*, phytosanitary measures are widely applied to plants for planting and soil. The possible entry pathways can therefore be considered as already partially closed in several EPPO countries.

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ACKNOWLEDGEMENTS

This datasheet was extensively revised in 2022 by Philippe Reynaud. His valuable contribution is gratefully acknowledged.

How to cite this datasheet?

EPPO (2025) *Diabrotica virgifera zeae*. EPPO datasheets on pests recommended for regulation. Available online. https://gd.eppo.int

Datasheet history

This datasheet was first published in 1997 in the second edition of 'Quarantine Pests for Europe' (as *Diabrotica virgifera*) and revised in 2022. It is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', ‘Hosts’, and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

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Co-funded by the European Union