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Pest categorisation of *Diabrotica virgifera zeae*

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Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Diabrotica virgifera zeae* (Coleoptera: Chrysomelidae), the Mexican corn rootworm, for the EU. This is one of two subspecies of *D. virgifera* which occurs in Central America, Mexico and central southern parts of the USA (Texas, Oklahoma and New Mexico). The preferred larval host is maize (*Zea mays*) roots, although larvae can feed on the roots of sorghum and other grass species. Adults feed on the leaves, silks, immature seeds of maize, and pollen of up to 63 plant genera. Eggs are laid in the soil of maize fields in late summer/early autumn and hatch in late spring. Adults are found in and near maize fields from May until frosts appear later in the year. *D. virgifera zeae* is univoltine except where maize is grown continuously when there can be multiple overlapping generations each year. In the Americas, *D. virgifera zeae* is considered a key maize pest. *D. virgifera zeae* is regulated by Directive 2000/29/EC (Annex IAI). A general prohibition of soil from most third countries prevents the entry of immature stages of *D. virgifera zeae*. However, adults could be carried on sweetcorn or green maize. Maize is grown widely across the EU, but establishment may be limited to warmer parts of southern EU. Should it establish in the EU, impact on maize yields is anticipated. Phytosanitary measures are available to inhibit entry of this pest. *D. virgifera zeae* satisfies the criteria, which are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest. *D. virgifera zeae* does not meet the criteria of occurring in the EU, nor plants for planting being the principal means of spread, for it to be regarded as a potential Union regulated non-quarantine pest.

Keywords: Corn pest, Mexican corn rootworm, maize, pest risk, plant health, plant pest, quarantine

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

Council Directive 2000/29/EC[1] on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community establishes the present European Union plant health regime. The Directive lays down the phytosanitary provisions and the control checks to be carried out at the place of origin on plants and plant products destined for the Union or to be moved within the Union. In the Directive's 2000/29/EC annexes, the list of harmful organisms (pests) whose introduction into or spread within the Union is prohibited, is detailed together with specific requirements for import or internal movement.

Following the evaluation of the plant health regime, the new basic plant health law, Regulation (EU) 2016/2031[2] on protective measures against pests of plants, was adopted on 26 October 2016 and will apply from 14 December 2019 onwards, repealing Directive 2000/29/EC. In line with the principles of the above mentioned legislation and the follow-up work of the secondary legislation for the listing of EU regulated pests, EFSA is requested to provide pest categorisations of the harmful organisms included in the annexes of Directive 2000/29/EC, in the cases where recent pest risk assessment/ pest categorisation is not available.

1.1.2. Terms of reference

EFSA is requested, pursuant to Article 22(5.b) and Article 29(1) of Regulation (EC) No 178/2002[3], to provide scientific opinion in the field of plant health.

EFSA is requested to prepare and deliver a pest categorisation (step 1 analysis) for each of the regulated pests included in the appendices of the annex to this mandate. The methodology and template of pest categorisation have already been developed in past mandates for the organisms listed in Annex II Part A Section II of Directive 2000/29/EC. The same methodology and outcome is expected for this work as well.

The list of the harmful organisms included in the annex to this mandate comprises 133 harmful organisms or groups. A pest categorisation is expected for these 133 pests or groups and the delivery of the work would be stepwise at regular intervals through the year as detailed below. First priority covers the harmful organisms included in Appendix 1, comprising pests from Annex II Part A Section I and Annex II Part B of Directive 2000/29/EC. The delivery of all pest categorisations for the pests included in Appendix 1 is June 2018. The second priority is the pests included in Appendix 2, comprising the group of *Cicadellidae* (non-EU) known to be vector of Pierce's disease (caused by *Xylella fastidiosa*), the group of *Tephritidae* (non-EU), the group of potato viruses and virus-like organisms, the group of viruses and virus-like organisms of *Cydonia* Mill., *Fragaria* L., *Malus* Mill., *Prunus* L., *Pyrus* L., *Ribes* L., *Rubus* L. and *Vitis* L.. and the group of *Margarodes* (non-EU species). The delivery of all pest categorisations for the pests included in Appendix 2 is end 2019. The pests included in Appendix 3 cover pests of Annex I part A section I and all pests categorisations should be delivered by end 2020.

For the above mentioned groups, each covering a large number of pests, the pest categorisation will be performed for the group and not the individual harmful organisms listed under "such as" notation in the Annexes of the Directive 2000/29/EC. The criteria to be taken particularly under consideration for these cases, is the analysis of host pest combination, investigation of pathways, the damages occurring and the relevant impact.

Finally, as indicated in the text above, all references to 'non-European' should be avoided and replaced by 'non-EU' and refer to all territories with exception of the Union territories as defined in Article 1 point 3 of Regulation (EU) 2016/2031.

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[1] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. OJ L 169/1, 10.7.2000, p. 1–112.

[2] Regulation (EU) 2016/2031 of the European Parliament of the Council of 26 October 2016 on protective measures against pests of plants. OJ L 317, 23.11.2016, p. 4–104.

[3] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31/1, 1.2.2002, p. 1–24.

1.1.2.1. Terms of Reference: Appendix 1

List of harmful organisms for which pest categorisation is requested. The list below follows the annexes of Directive 2000/29/EC.

Annex IIAI

(a) Insects, mites and nematodes, at all stages of their development

Aleurocantus spp.
Anthonomus bisignifer (Schenkling)
Anthonomus signatus (Say)
Aschistonyx eppoi Inouye
Carposina niponensis Walsingham
Enarmonia packardi (Zeller)
Enarmonia prunivora Walsh
Grapholita inopinata Heinrich
Hishomonus phycitis
Leucaspis japonica Ckll.
Listronotus bonariensis (Kuschel)
Numonia pyrivorella (Matsumura)
Oligonychus perditus Pritchard and Baker
Pissodes spp. (non-EU)
Scirtothrips aurantii Faure
Scirtothrips citri (Moultex)
Scolytidae spp. (non-EU)
Scrobipalpopsis solanivora Povolny
Tachypterellus quadrigibbus Say
Toxoptera citricida Kirk.
Unaspis citri Comstock

(b) Bacteria

Citrus variegated chlorosis
Erwinia stewartii (Smith) Dye
Xanthomonas campestris pv. *oryzae* (Ishiyama) Dye and pv. *oryzicola* (Fang. et al.) Dye

(c) Fungi

Alternaria alternata (Fr.) Keissler (non-EU pathogenic isolates)
Anisogramma anomala (Peck) E. Müller
Apiosporina morbosa (Schwein.) v. Arx
Ceratocystis virescens (Davidson) Moreau
Cercoseptoria pini-densiflorae (Hori and Nambu) Deighton
Cercospora angolensis Carv. and Mendes
Elsinoe spp. Bitanc. and Jenk. Mendes
Fusarium oxysporum f. sp*. albedinis* (Kilian and Maire) Gordon
Guignardia piricola (Nosa) Yamamoto
Puccinia pittieriana Hennings
Stegophora ulmea (Schweinitz: Fries) Sydow & Sydow
Venturia nashicola Tanaka and Yamamoto

(d) Virus and virus-like organisms

Beet curly top virus (non-EU isolates)
Black raspberry latent virus
Blight and blight-like
Cadang-Cadang viroid
Citrus tristeza virus (non-EU isolates)
Leprosis
Little cherry pathogen (non- EU isolates)
Naturally spreading psorosis
Palm lethal yellowing mycoplasm
Satsuma dwarf virus
Tatter leaf virus
Witches' broom (MLO)

Annex IIB

(a) Insect mites and nematodes, at all stages of their development

Anthonomus grandis (Boh.)
Cephalcia lariciphila (Klug)
Dendroctonus micans Kugelan
Gilphinia hercyniae (Hartig)
Gonipterus scutellatus Gyll.
Ips amitinus Eichhof
Ips cembrae Heer
Ips duplicatus Sahlberg
Ips sexdentatus Börner
Ips typographus Heer
Sternochetus mangiferae Fabricius

(b) Bacteria

Curtobacterium flaccumfaciens pv. flaccumfaciens (Hedges) Collins and Jones

(c) Fungi

Glomerella gossypii Edgerton

Gremmeniella abietina (Lag.) Morelet

Hypoxylon mammatum (Wahl.) J. Miller

1.1.2.2. Terms of Reference: Appendix 2

List of harmful organisms for which pest categorisation is requested per group. The list below follows the categorisation included in the annexes of Directive 2000/29/EC.

Annex IAI

(a) Insects, mites and nematodes, at all stages of their development

Group of Cicadellidae (non-EU) known to be vector of Pierce's disease (caused by *Xylella fastidiosa*), such as:

1) *Carneocephala fulgida* Nottingham
2) *Draeculacephala minerva* Ball
3) *Graphocephala atropunctata* (Signoret)

Group of Tephritidae (non-EU) such as:

1) *Anastrepha fraterculus* (Wiedemann)
2) *Anastrepha ludens* (Loew)
3) *Anastrepha obliqua* Macquart
4) *Anastrepha suspensa* (Loew)
5) *Dacus ciliatus* Loew
6) *Dacus curcurbitae* Coquillet
7) *Dacus dorsalis* Hendel
8) *Dacus tryoni* (Froggatt)
9) *Dacus tsuneonis* Miyake
10) *Dacus zonatus* Saund.
11) *Epochra canadensis* (Loew)
12) *Pardalaspis cyanescens* Bezzi
13) *Pardalaspis quinaria* Bezzi
14) *Pterandrus rosa* (Karsch)
15) *Rhacochlaena japonica* Ito
16) *Rhagoletis completa* Cresson
17) *Rhagoletis fausta* (Osten-Sacken)
18) *Rhagoletis indifferens* Curran
19) *Rhagoletis mendax* Curran
20) *Rhagoletis pomonella* Walsh
21) *Rhagoletis suavis* (Loew)

(c) Viruses and virus-like organisms

Group of potato viruses and virus-like organisms such as:

1) Andean potato latent virus
2) Andean potato mottle virus
3) Arracacha virus B, oca strain
4) Potato black ringspot virus
5) Potato virus T
6) non-EU isolates of potato viruses A, M, S, V, X and Y (including Yo, Yn and Yc) and Potato leafroll virus

Group of viruses and virus-like organisms of *Cydonia* Mill., *Fragaria* L., *Malus* Mill., *Prunus* L., *Pyrus* L., *Ribes* L., *Rubus* L. and *Vitis* L., such as:

1) Blueberry leaf mottle virus
2) Cherry rasp leaf virus (American)
3) Peach mosaic virus (American)
4) Peach phony rickettsia
5) Peach rosette mosaic virus
6) Peach rosette mycoplasm
7) Peach X-disease mycoplasm
8) Peach yellows mycoplasm
9) Plum line pattern virus (American)
10) Raspberry leaf curl virus (American)
11) Strawberry witches' broom mycoplasma
12) Non-EU viruses and virus-like organisms of *Cydonia Mill., Fragaria L., Malus Mill., Prunus L., Pyrus L., Ribes L., Rubus L.* and *Vitis L.*

Annex IIAI

(a) Insects, mites and nematodes, at all stages of their development

Group of *Margarodes* (non-EU species) such as:

1) *Margarodes vitis* (Phillipi)
2) *Margarodes vredendalensis* de Klerk
3) *Margarodes prieskaensis* Jakubski

1.1.2.3. Terms of Reference: Appendix 3

List of harmful organisms for which pest categorisation is requested. The list below follows the annexes of Directive 2000/29/EC.

Annex IAI

(a) Insects, mites and nematodes, at all stages of their development

Acleris spp. (non-EU)
Amauromyza maculosa (Malloch)
Anomala orientalis Waterhouse
Arrhenodes minutus Drury
Choristoneura spp. (non-EU)
Conotrachelus nenuphar (Herbst)
Dendrolimus sibiricus Tschetverikov
Diabrotica barberi Smith and Lawrence
Diabrotica undecimpunctata howardi Barber
Diabrotica undecimpunctata undecimpunctata Mannerheim
Diabrotica virgifera zeae Krysan & Smith
Diaphorina citri Kuway
Heliothis zea (Boddie)
Hirschmanniella spp., other than *Hirschmanniella gracilis* (de Man) Luc and Goodey
Liriomyza sativae Blanchard
Longidorus diadecturus Eveleigh and Allen
Monochamus spp. (non-EU)
Myndus crudus Van Duzee
Nacobbus aberrans (Thorne) Thorne and Allen
Naupactus leucoloma Boheman
Premnotrypes spp. (non-EU)
Pseudopityophthorus minutissimus (Zimmermann)
Pseudopityophthorus pruinosus (Eichhoff)
Scaphoideus luteolus (Van Duzee)
Spodoptera eridania (Cramer)
Spodoptera frugiperda (Smith)
Spodoptera litura (Fabricus)
Thrips palmi Karny
Xiphinema americanum Cobb sensu lato (non-EU populations)
Xiphinema californicum Lamberti and Bleve-Zacheo

(b) Fungi

Ceratocystis fagacearum (Bretz) Hunt
Chrysomyxa arctostaphyli Dietel
Cronartium spp. (non-EU)
Endocronartium spp. (non-EU)
Guignardia laricina (Saw.) Yamamoto and Ito
Gymnosporangium spp. (non-EU)
Inonotus weirii (Murril) Kotlaba and Pouzar
Melampsora farlowii (Arthur) Davis
Mycosphaerella larici-leptolepis Ito et al.
Mycosphaerella populorum G. E. Thompson
Phoma andina Turkensteen
Phyllosticta solitaria Ell. and Ev.
Septoria lycopersici Speg. var. *malagutii* Ciccarone and Boerema
Thecaphora solani Barrus
Trechispora brinkmannii (Bresad.) Rogers

(c) Viruses and virus-like organisms

Tobacco ringspot virus
Tomato ringspot virus
Bean golden mosaic virus
Cowpea mild mottle virus
Lettuce infectious yellows virus
Pepper mild tigré virus
Squash leaf curl virus
Euphorbia mosaic virus
Florida tomato virus

(d) Parasitic plants

Arceuthobium spp. (non-EU)

Annex IAII

(a) Insects, mites and nematodes, at all stages of their development

Meloidogyne fallax Karssen
Popillia japonica Newman
Rhizoecus hibisci Kawai and Takagi

(b) Bacteria

Clavibacter michiganensis (Smith) Davis et al. ssp. *sepedonicus* (Spieckermann and Kotthoff) Davis et al.
Ralstonia solanacearum (Smith) Yabuuchi et al.

(c) Fungi

Melampsora medusae Thümen
Synchytrium endobioticum (Schilbersky) Percival

Annex I B

(a) Insects, mites and nematodes, at all stages of their development

Leptinotarsa decemlineata Say
Liriomyza bryoniae (Kaltenbach)

(b) Viruses and virus-like organisms

Beet necrotic yellow vein virus

1.2. Interpretation of the Terms of Reference

Diabrotica virgifera zeae is one of a number of pests listed in the Appendices to the Terms of Reference (ToR) to be subject to pest categorisation to determine whether it fulfils the criteria of a quarantine pest or those of a regulated non-quarantine pest for the area of the EU excluding Ceuta, Melilla and the outermost regions of Member States (MSs) referred to in Article 355(1) of the Treaty on the Functioning of the European Union (TFEU), other than Madeira and the Azores.

2. Data and methodologies

2.1. Data

2.1.1. Literature search

A literature search on *D. virgifera zeae* was conducted at the beginning of the categorisation in the ISI Web of Science bibliographic database, using the scientific name of the pest as search term. Relevant papers were reviewed, and further references and information were obtained from experts, as well as from citations within the references and grey literature.

2.1.2. Database search

Pest information, on host(s) and distribution, was retrieved from the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, 2019) and relevant publications.

Data about the import of commodity types that could potentially provide a pathway for the pest to enter the EU and about the area of hosts grown in the EU were obtained from EUROSTAT (Statistical Office of the European Communities).

The Europhyt database was consulted for pest-specific notifications on interceptions and outbreaks. Europhyt is a web-based network run by the Directorate General for Health and Food Safety (DG SANTÉ) of the European Commission, and is a subproject of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. The Europhyt database manages notifications of interceptions of plants or plant products that do not comply with EU legislation, as well as notifications of plant pests detected in the territory of the MS and the phytosanitary measures taken to eradicate or avoid their spread.

2.2. Methodologies

The Panel performed the pest categorisation for *D. virgifera zeae*, following guiding principles and steps presented in the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel et al., 2018) and in the International Standard for Phytosanitary Measures No 11 (FAO, 2013) and No 21 (FAO, 2004).

This work was initiated following an evaluation of the EU plant health regime. Therefore, to facilitate the decision-making process, in the conclusions of the pest categorisation, the Panel addresses explicitly each criterion for a Union quarantine pest and for a Union regulated non-quarantine pest in accordance with Regulation (EU) 2016/2031 on protective measures against pests of plants, and includes additional information required in accordance with the specific ToR received by the European Commission. In addition, for each conclusion, the Panel provides a short description of its associated uncertainty.

Table 1 presents the Regulation (EU) 2016/2031 pest categorisation criteria on which the Panel bases its conclusions. All relevant criteria have to be met for the pest to potentially qualify either as a quarantine pest or as a regulated non-quarantine pest. If one of the criteria is not met, the pest will not qualify. A pest that does not qualify as a quarantine pest may still qualify as a regulated non-quarantine pest that needs to be addressed in the opinion. For the pests regulated in the protected zones only, the scope of the categorisation is the territory of the protected zone; thus, the criteria refer to the protected zone instead of the EU territory.

It should be noted that the Panel's conclusions are formulated respecting its remit and particularly with regard to the principle of separation between risk assessment and risk management (EFSA founding regulation (EU) No 178/2002); therefore, instead of determining whether the pest is likely to have an unacceptable impact, the Panel will present a summary of the observed pest impacts. Economic impacts are expressed in terms of yield and quality losses and not in monetary terms, whereas addressing social impacts is outside the remit of the Panel.

Table 1: Pest categorisation criteria under evaluation, as defined in Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column)

Criterion of pest categorisation	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Criterion in Regulation (EU) 2016/2031 regarding protected zone quarantine pest (articles 32–35)	Criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest
Identity of the pest (Section 3.1)	Is the identity of the pest established, or has it been shown to produce consistent symptoms and to be transmissible?	Is the identity of the pest established, or has it been shown to produce consistent symptoms and to be transmissible?	Is the identity of the pest established, or has it been shown to produce consistent symptoms and to be transmissible?
Absence/ presence of the pest in the EU territory (Section 3.2)	Is the pest present in the EU territory? If present, is the pest widely distributed within the EU? Describe the pest distribution briefly!	Is the pest present in the EU territory? If not, it cannot be a protected zone quarantine organism	Is the pest present in the EU territory? If not, it cannot be a regulated non-quarantine pest. (A regulated non-quarantine pest must be present in the risk assessment area)
Regulatory status (Section 3.3)	If the pest is present in the EU but not widely distributed in the risk assessment area, it should be under official control or expected to be under official control in the near future	The protected zone system aligns with the pest-free area system under the International Plant Protection Convention (IPPC). The pest satisfies the IPPC definition of a quarantine pest that is not present in the risk assessment area (i.e. protected zone)	Is the pest regulated as a quarantine pest? If currently regulated as a quarantine pest, are there grounds to consider its status could be revoked?

Criterion of pest categorisation	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Criterion in Regulation (EU) 2016/2031 regarding protected zone quarantine pest (articles 32–35)	Criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	Is the pest able to enter into, become established in, and spread within, the EU territory? If yes, briefly list the pathways!	Is the pest able to enter into, become established in, and spread within, the protected zone areas? Is entry by natural spread from EU areas where the pest is present possible?	Is spread mainly via specific plants for planting, rather than via natural spread or via movement of plant products or other objects? Clearly state if plants for planting is the main pathway!
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?	Would the pests' introduction have an economic or environmental impact on the protected zone areas?	Does the presence of the pest on plants for planting have an economic impact, as regards the intended use of those plants for planting?
Available measures (Section 3.6)	Are there measures available to prevent the entry into, establishment within or spread of the pest within the EU such that the risk becomes mitigated?	Are there measures available to prevent the entry into, establishment within or spread of the pest within the protected zone areas such that the risk becomes mitigated? Is it possible to eradicate the pest in a restricted area within 24 months (or a period longer than 24 months where the biology of the organism so justifies) after the presence of the pest was confirmed in the protected zone?	Are there measures available to prevent pest presence on plants for planting such that the risk becomes mitigated?
Conclusion of pest categorisation (Section 4)	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential quarantine pest were met and (2) if not, which one(s) were not met	A statement as to whether (1) all criteria assessed by EFSA above for consideration as potential protected zone quarantine pest were met, and (2) if not, which one(s) were not met	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential regulated non-quarantine pest were met, and (2) if not, which one (s) were not met

The Panel will not indicate in its conclusions of the pest categorisation whether to continue the risk assessment process, but following the agreed two-step approach, will continue only if requested by the risk managers. However, during the categorisation process, experts may identify key elements and knowledge gaps that could contribute significant uncertainty to a future assessment of risk. It would be useful to identify and highlight such gaps so that potential future requests can specifically target the major elements of uncertainty, perhaps suggesting specific scenarios to examine.

3. Pest categorisation

3.1. Identity and biology of the pest

3.1.1. Identity and taxonomy

Is the identity of the pest established, or has it been shown to produce consistent symptoms and to be transmissible?

Yes, the identity of *D. virgifera zeae* is established and taxonomic keys are available for its identification to subspecies level.

The New World genus *Diabrotica* Chevrolat, 1836 (Coleoptera: Chrysomelidae: Galerucinae) is one of the largest leaf beetle genera, with about 354 described species (Derunkov et al., 2015). Ten species or subspecies within this genus are generally recognised as pests (Krysan 1986). The corn rootworm complex (*Diabrotica* spp.) is comprised of the northern corn rootworm (*Diabrotica barberi* Smith and Lawrence), the western corn rootworm (*Diabrotica virgifera virgifera* LeConte), both serious pests of maize in North America and the Mexican corn rootworm (*D. virgifera zeae* Krysan and Smith). The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, inhabits the south-eastern region of the USA and can cause economic damage but is a relatively minor pest of maize.

Two subspecies of *D. virgifera* have been described: *virgifera* LeConte and *zeae* Krysan & Smith (Krysan et al., 1980) (see Section 3.1.3 below).

In Mexico, *D. virgifera zeae* was often incorrectly identified as *Diabrotica longicornis* (Say) or simply *D. virgifera* before 1980 (Segura-Leon, 2004). Indeed until 1980, *D. virgifera*, as described by LeConte and known as a pest throughout northern central USA, was considered to be the only variant of the species. However, evidence based on mating compatibility (Krysan et al., 1977), egg diapause intensity (Krysan et al., 1977), behaviour and morphology (Krysan et al., 1980) confirmed that *D. virgifera* has two subspecies: *D. virgifera virgifera* and *D. virgifera zeae* (Krysan et al., 1980; Tallamy et al., 2005).

D. virgifera zeae is readily distinguished from the typical subspecies *D. virgifera virgifera* by the green elytra without maculae. Indeed, subspecies *virgifera* has elytra with dark dots, often expanding to cover most of elytra while subspecies *zeae* has entirely green elytra or with a narrow dark spot on the anterior part of them (Krysan et al., 1980).

Giordano et al. (1997) proved that the two subspecies are allopatric except for two known regions of sympatry in Texas and Mexico. No pheromonal or structural barriers to mating, as well as no ecological or temporal isolation between the two subspecies exist. However, when male *D. virgifera virgifera* from a South Dakota (U.S.) population have been mated with female *D. virgifera zeae* from Texas or central Mexico many eggs were laid but most did not hatch. The reciprocal cross always produced fertile eggs. The presence of the bacterium *Wolbachia*, which commonly causes cytoplasmic incompatibility between arthropod closely related taxa, in most US populations of *D. virgifera virgifera* is the cause of the unidirectional reproductive incompatibility between subspecies. *Wolbachia* could be functioning as an isolating mechanism between the subspecies in hybrid zones (Meinke, 2008). Indeed, Giordano et al. (1997) demonstrated that populations of *D. virgifera virgifera*, with the exception of two populations in southern Arizona, are infected with a strain of *Wolbachia*. Populations of *D. virgifera zeae* are not infected.

3.1.2. Biology of the pest

D. virgifera zeae is generally univoltine but adapted to multivoltinism in tropical regions where continuous cropping of maize is possible (Krysan, 1978; Branson et al., 1982).

Eggs are laid in the soil during September and October, at depths between 15 and 30 cm or more depending on the kind of soil and its moisture. In areas without continuous maize, the eggs overwinter and hatch in late spring (Branson et al., 1982). Krysan et al. (1977) demonstrated that the duration of diapause varied greatly in a population of eggs from central Mexico: when these eggs were held at 25°C, initial hatch occurred at 50 days and the last egg hatched after 300 days. Occasional winter rains, residual soil moisture in some soils throughout the dry season, and irrigation make the length of the enforced dormancy season for eggs in central Mexico variable (Branson et al., 1982). Krysan et al. (1977) hypothesised that egg dormancy is broken by the availability of soil moisture, not temperature. The minimum soil moisture necessary to terminate dormancy (dry quiescence) must be between 11.6 and 20.6%.

Where maize is grown continuously some eggs will hatch in November and December if moisture is available to develop a new population of *D. virgifera zeae* (Krysan, 1978). This adaptability, along with implied vagility, has led to the situation in central Mexico where, within 100 km, one can find all stages at the same time, depending upon differences in maize growing practices (e.g. continuous maize or not, irrigated or not) (Branson et al., 1982).

Low rainfall and high temperatures are one of the main causes of egg mortality and consequent population density decrease (Eben and Espinosa, 2004; Sivcev et al., 2009; Martínez-Jaime et al., 2014).

Once hatched, the larvae feed on the roots of maize, especially prop roots, removing the root tips and much of the root proper. Three larval instars are described for *D. virgifera* s.l. (Segura-Leon, 2004). The adults are seen in and near maize fields starting from May until frosts appear later in the year. Adults feed on the leaves, silks, pollen and immature seeds of maize. In Mexico, *D. virgifera zeae* adult emergence patterns are variable. For example, in Jalisco (a Mexican state on the Pacific coast), adults are observed at the end of July, with peak emergence in mid-August (Branson et al., 1982; Cocke et al., 1994); while in Toluca (above 2,500 m in central Mexico), the first adults are often observed earlier, e.g. in mid-June, although peak emergence is later e.g. in September (Segura-Leon, 2004).

3.1.3. Intraspecific diversity

D. virgifera zeae was described by Krysan & Smith (Krysan et al., 1980) as a subspecies of *D. virgifera* based on evidence of mating compatibility (Krysan et al., 1977), egg diapause intensity (Krysan et al., 1977, 1977), behaviour and morphology (Krysan et al., 1980).

Laboratory and field studies have shown that *D. virgifera virgifera* and *D. virgifera zeae* are sexually compatible and that their populations intergrade where their distributions overlap (Krysan et al., 1980).

Early studies using allozymes (McDonald et al., 1985; Krysan et al., 1989) and PCR–RFLP of the internal transcribed spacer region, ITS1 in the nuclear ribosomal DNA (Szalanski et al., 1999) found low levels of differentiation in geographically isolated populations of *D. virgifera virgifera* (western corn rootworm), *D. virgifera zeae* (Mexican corn rootworm) and *D. barberi* (northern corn rootworm), suggesting high dispersal ability and limited barriers to gene flow.

Moreover, in the same paper, Szalanski et al. (1999) performed a PCR–RFLP study of a DNA region representing 12 kb of the mitochondrial genome, proving that, there was no variation between subspecies, therefore suggesting a recent common evolutionary history. Because of the lack of variation at these mitochondrial regions, microsatellite markers have since been developed for all three species (Kim and Sappington, 2005; Kim et al., 2007; Waits and Stolz, 2008).

3.1.4. Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, detection and identification methods for *D. virgifera zeae* are available.

Detection

Symptoms:

Root feeding causes physiological stress which stunts plant growth and can lead to plant lodging. The first indication of rootworm injury to maize may be seen in late June or early July when plants fall over after strong winds or heavy rainfall. Root feeding can also result in the invasion of plant tissue by secondary pathogens, such as bacteria and fungi, which increase the incidence of root rots (Ward et al., 2005).

Pheromone trapping:

D. virgifera zeae is attracted by the sex pheromone 8R-methyl-2R-decyl propanoate (Guss et al., 1984). Non-pheromonal attractants have been tested; traps baited with a 1:1:1 mixture of 1,2,4-trimethoxybenzene, 1H-indole and E-cinnamaldehyde captured the greatest number of females but not significantly more than traps baited with a 1:1:1 mixture of veratrole, 1H-indole and 2-phenylacetaldehyde or with 1H-indole alone (Lance et al., 1992). Kairomone-based and sticky traps have been tested for their efficacy in monitoring adult populations of *D. virgifera zeae*. They should be placed < 10 m into the field and their efficacy depends on the plant stage and on the seasonal patterns of female beetle reproductive phenology (Spurgeon et al., 2004).

Identification:

Immature stages:

Identification of *Diabrotica* larvae to species level is difficult and for several species is impossible if only morphological approaches are used (Krysan, 1986).

Adult morphology:

Body length: 4.8–5.4 mm. Body width: 2.2–2.4 mm. Head basic coloration: yellow, clypeus black or chestnut. Male antennae are filiform, as long as body, bicoloured, with antennomere 1 uniformly yellow and antennomeres 2–11 uniformly olive ocher. The pronotum is green or pale olivine. The scutellum is yellow or amber yellow. Elytra are green, with two fuzzy-edged sulfur yellow, round maculae on each elytron. Elytral epipleura completely green. Elytra surface with four distinct sinuate sulci. Tarsi are yellow or yellow ocher. Tibiae are bicoloured, yellow, outer edge with piceous or testaceous line, or almost entirely darkened. Femora are also bicoloured, yellow or green, outer edge chestnut to piceous. The aedeagus has four internal sac sclerites (Derunkov et al., 2013). *D. virgifera zeae* is distinguished from *D. virgifera virgifera*, by the green elytra, with at most, a thin, weak, short anterior spot. From the similar *D. longicornis* and *D. barberi*, it can be separated by the same features as the nominate subspecies: femora of *D. virgifera zeae* are as a rule bicoloured with dark, chestnut or piceous, outer edge, while in *D. longicornis* and *D. barberi*, femora are entirely green or flavous. The shape of aedeagus and the internal sac sclerites differentiates all three species as well as other species similarly coloured (Derunkov et al., 2013).

Molecular methods:

Polymorphic microsatellite loci (high resolution molecular markers) were constructed using pooled *D. barberi* and *D. virgifera zeae* genomic DNA. This strategy produced microsatellites that are broadly polymorphic in *Diabrotica*, and can be used in population genetic studies, analyses of dispersal, investigation of insecticide resistance, diagnostics and in the surveillance of pest management programmes (Waits and Stolz, 2008). Other studies focused on using molecular markers to establish the phylogeny of the genus *Diabrotica* (e.g. Szalanski et al., 1999; Clark et al., 2001a,b). These could also be used for diagnostic purposes.

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

D. virgifera zeae is present in the Nearctic region only (Figure 1). It occurs in Central America, Mexico and central southern parts of the USA. It ranges from Panama northward to Costa Rica, Nicaragua, Guatemala, the Caribbean (no details are available on national distribution within the Caribbean), Mexico (excluding northwest Mexico), central Texas and Oklahoma (EPPO, 2019). In the United States, its westward distribution is limited by low rainfall, although irrigation has artificially extended its westward occurrence into New Mexico (Derunkov et al., 2013; EPPO, 2019; Mitchell et al., 2019).

There are six basic types of maize; dent, sweet, flint, pop, flour and pod (Brown et al., 1985). The distribution of *D. virgifera zeae* corresponds to the distribution of southern dent maize (Krysan et al., 1980).

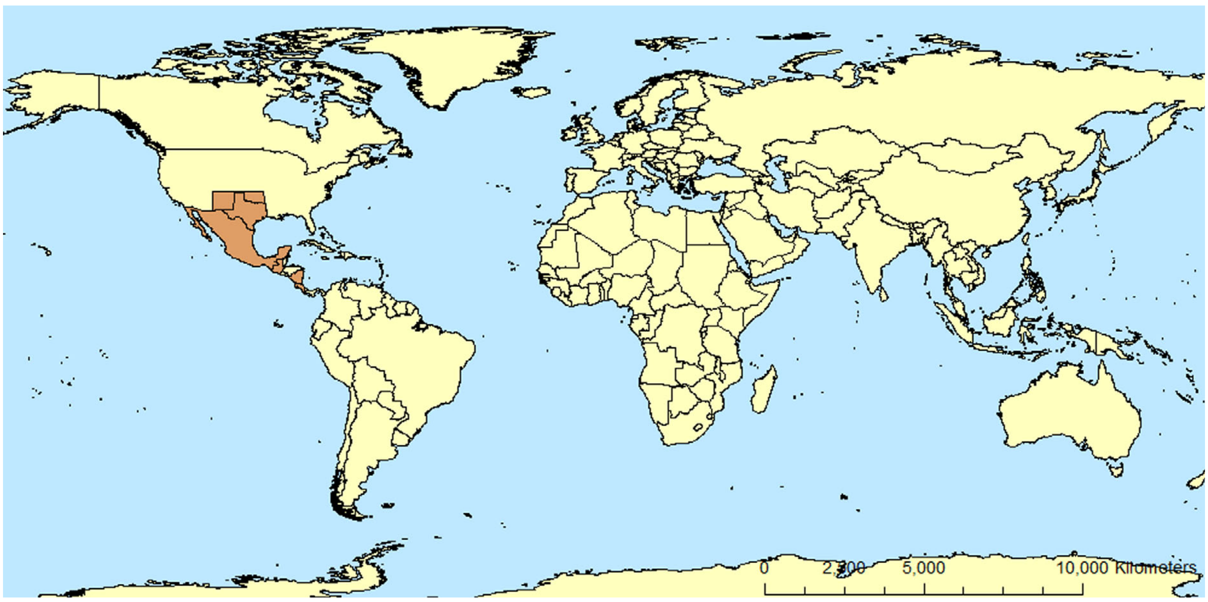

Figure 1: Global distribution map for *Diabrotica virgifera zeae*

3.2.2. Pest distribution in the EU

Is the pest present in the EU territory? If present, is the pest widely distributed within the EU?
No, *D. virgifera zeae* is not known to be present in the EU.

D. virgifera zeae is not known to be present in the EU.

3.3. Regulatory status

3.3.1. Council Directive 2000/29/EC

D. virgifera zeae is listed in Council Directive 2000/29/EC in Annex IAI. Details are presented in Tables 2 and 3.

Annexes I and II of the EU Directive 2000/29 list the quarantine pests for the EU. They were modified in 2009. Up to that moment *D. virgifera* was amongst pests listed. However, following the introduction of *D. virgifera virgifera* into the EU via at least five distinct events (Ciosi et al., 2008) and its spread into the EU after establishing in the Balkans in the 1990s (Carrasco et al., 2010), the listing in Annex I/AI was split into *D. virgifera zeae* which does not occur in Europe and *D. virgifera virgifera*, which does. *D. virgifera virgifera* was removed from the European Commission plant health directive in 2014 (Anon, 2014).

Table 2: *Diabrotica virgifera zeae* in Council Directive 2000/29/EC

Annex I Part A	**Harmful organisms whose introduction into, and spread within, all member states shall be banned**
Section I	Harmful organisms not known to occur in any part of the community and relevant for the entire community
(a)	Insects, mites and nematodes, at all stages of their development
	Species
10.1	*Diabrotica virgifera zeae* Krysan & Smith

3.3.2. Legislation addressing the hosts of *Diabrotica virgifera zeae*

Table 3: Regulated hosts and commodities that may involve *Diabrotica virgifera zea* in Annexes III, IV and V of Council Directive 2000/29/EC

Annex III Part A	**Plants, plant products and other objects the introduction of which shall be prohibited in all member states**	
	Description	**Country of origin**
14	Soil and growing medium as such, which consists in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark, other than that composed entirely of peat	Turkey, Belarus, [...] Moldavia, Russia, Ukraine and third countries not belonging to continental Europe, other than the following: [...] Egypt, Israel, Libya, Morocco, Tunisia
Annex IV Part A	**Special requirements which must be laid down by all member states for the introduction and movement of plants, plant products and other objects into and within all member states**	
Section I	**Plants, plant products and other objects originating outside the community**	
	Plants, plant products and other objects	Special requirements
	Seeds of *Zea mays* L.	Official statement that: (a) the seeds originate in areas known to be free from *Erwinia stewartii* (Smith) Dye; or (b) a representative sample of the seeds has been tested and found free from *Erwinia stewartii* (Smith) Dye in this test.

Annex V	Plants, plant products and other objects which must be subject to a plant health inspection (...) in the country of origin or the consignor country, if originating outside the community before being permitted to enter the community
Part A	Plants, plant products and other objects originating in the community
	–
Part B	Plants, plant products and other objects originating in territories, other than those territories referred to in part A
Section I	Plants, plant products and other objects which are potential carriers of harmful organisms of relevance for the entire Community
1	Plants, intended for planting, other than seeds but including seeds of [...] *Zea mays* L.

3.4. Entry, establishment and spread in the EU

3.4.1. Host range

A distinction between breeding and adult feeding hosts has to be made. Larvae are oligophagous and mostly feed on maize roots. Adults are polyphagous and can feed on maize flowers and leaves and also on different hosts belonging to different botanical families (Clark et al., 2004). Jones and Coppedge (2000) list 63 genera whose pollen was found in the gut of adults collected in Texan fields. Although maize is the only crop regularly attacked by *D. virgifera zeae*, it has been observed also infesting sorghum (Stewart et al., 1995) and feeding on the roots of several grass species (Mitchell et al., 2019). Indeed, eggs can be also laid in the soil of herbaceous weed hosts other than maize (Branson et al., 1982).

- Breeding hosts: maize (main host), sorghum, rusty flat sedge.
- Adult feeding hosts: *Solanum* spp. L., Asteraceae, Cucurbitaceae, Fabaceae and Poaceae (including maize).

Grass and herbaceous weeds appear to play an important role in the food habits of both the larvae and adults of *D. virgifera zeae* of central Mexico. Since this probably is the place of origin of *D. virgifera*, it is possible that some of these weeds were larval hosts before maize, and that *D. virgifera zeae* switched from grasses to specialise on maize in prehistorical times (Branson et al., 1982).

The breeding host (maize) is regulated (Table 4). Soil or growing media, such as from fields of maize where immature stages of *D. virgifera zeae* could be found, are also regulated.

3.4.2. Entry

Is the pest able to enter into the EU territory?

Yes, soil/growing media; forage / green maize and maize cobs could provide potential pathways

• soil/growing media	Closed due to legislation (2000/29 EC, Annex III, A 14.).
• fresh maize cobs	Open pathway
• forage/green maize	Open pathway

No records of interception of *D. virgifera zeae* have been found in the Europhyt Database between 1994 and 16 July 2019. However, the following commodities could constitute a pathway into the EU when imported from an infested area:

1) fresh maize cobs (sweetcorn) and forage/green maize
2) soil from maize fields.

Adults, could be carried by consignments of maize cobs or of forage/green maize (Smith et al., 1997). Other hosts on which adults are reported to feed on pollen could provide potential pathways but since the majority of them are not identified to species it is not possible to know whether they are regulated and if regulated whether the pathways are controlled or prohibited. Many of them are weeds.

The soil pathway can be considered as closed, as soil from *D. virgifera zeae* infested countries is banned from entering into the EU (Annex IIIA 14). The other pathway is not specifically regulated although as an Annex I/AI pest the entry of *D. virgifera zeae* into the EU is prohibited regardless of the commodity where it is found.

There are no data in Eurostat for the import of fresh or chilled sweetcorn (CN 0709 9060) prior to 2000 or after 2011. Figure 2 shows the amount of fresh or chilled sweetcorn imported from USA between 2000 and 2011. Eurostat reports imports of sweetcorn from Canada in 2000 (20 tonnes) and in 2008 (4 tonnes). However, 99.95% of sweetcorn imports from either USA or Canada were from USA between 2000 and 2011. No data are available for Central American countries.

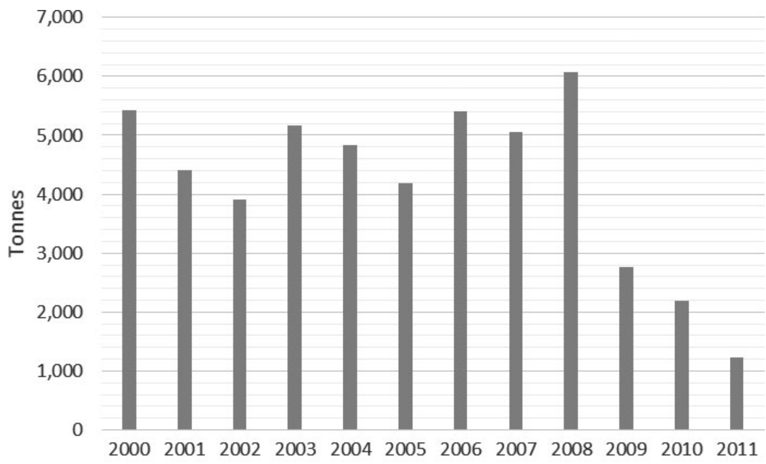

Figure 2: EU 28 annual import of fresh or chilled sweetcorn (CN 0709 9060) 2000–2011

Import code CN 2308 0090 is described as 'Maize stalks, maize leaves, fruit peel and other vegetable materials, waste, residues and by-products for animal feeding, whether or not in the form of pellets, n.e.s. (excl. acorns, horse-chestnuts and pomace or marc of fruit)'. It is unknown whether maize stalk and leaves with the potential to convey adult *D. virgifera zeae* would form a proportion of this category. Nevertheless, import volumes are shown in Table 4.

Table 4: EU 28 annual import of CN 2308 0090 (Maize stalks, maize leaves, fruit peel and other vegetable materials, waste, residues and by-products for animal feeding) from Costa Rica, Nicaragua, Guatemala, Mexico and USA, 2013–2018 (Thousand tonnes)

	2013	2014	2015	2016	2017	2018
Costa Rica	487	1,155	116	579	6,208	2,158
Nicaragua	–	–	–	–	–	–
Guatemala	88	–	–	–	0	0
Mexico	67	78	169	230	8,583	2,744
USA	440,892	152,576	167,277	72,890	264,971	556,789

3.4.3. Establishment

Is the pest able to become established in the EU territory

Yes, biotic and abiotic conditions are conducive for establishment of *D. virgifera zeae* in small areas of the EU such as south eastern Spain and parts of the east coast of Italy, where maize is cultivated.

The distribution and abundance of an organism that cannot control or regulate its body temperature are largely determined by host distribution and climate. Taking account of host distribution and comparing climates from the known distribution of an organism with climates in the risk assessment area can inform judgements regarding the potential distribution and abundance of an organism in the risk assessment area (Sutherst and Maywald, 1985; Ehrlén and Morris, 2015). The global Köppen–Geiger climate zone categories, and subsequent modifications made by Trewartha, describe terrestrial climate in terms of factors such as average minimum winter temperatures and summer maxima, amount of precipitation and seasonality (rainfall pattern) (Trewartha and Horn, 1980; Kottek et al., 2006) and can inform judgements of aspects of establishment during pest categorisation (MacLeod and Korycinska, 2019).

3.4.3.1. EU distribution of main host plants

The main host of *D. virgifera zeae*, maize (*Z. mays*), occurs in large parts of the EU. Maize is grown as grain or sweetcorn and as green maize (forage) across the EU in many MSs (Appendices A and B, Figure B.2). Table 5 shows the EU maize area 2014–2018.

Table 5: EU 28 area of grain and green maize (cultivation/harvested/production 1,000 ha) (EUROSTAT, accessed 29 June 2019)

	2014	2015	2016	2017	2018
Grain maize and corn-cob-mix (Eurostat code C1500)	9,610.16	9,255.56	8,563.21	8,271.64	8,286.69
Green maize (Eurostat code G3000)	6,147.80	6,267.95	6,256.88	6,183.30	6,363.05
Sum	15,757.96	15,523.51	14,820.09	14,454.94	14,649.74

D. virgifera zeae occurs over a range of Köppen–Geiger climate zones in Mexico, southern states of the USA and Central America (Krysan, 1986; Appendix B, Figure B.1a). Two of the Köppen–Geiger climate zones within which *D. virgifera zeae* occurs in America also occur in the EU (Appendix B, Figure B.1b), specifically BSk (cold, semi-arid steppe) which occurs in the EU in Spain, Italy and Greece, and Cfa (warm temperate climate, fully humid, hot summer) which occurs in the EU in Bulgaria, Romania, southern France, Spain and Italy (MacLeod and Korycinska, 2019).

Soil moisture, especially in winter and spring, is a feature likely to affect the distribution of *D. virgifera zeae*. Simple visual examination of global maps produced by the EU project WATCH (Water and Global Change e.g. http://www.waterandclimatechange.eu/land/global-land-maps-december) showing mean monthly % soil moisture, suggests that soil moistures in areas where *D. virgifera zeae* occurs can also be found in southern Europe. However, precise comparisons of monthly soil moisture between the Americas and EU are considered beyond the scope of a basic pest categorisation.

As a subtropical organism, cold temperatures and frost may limit the distribution of *D. virgifera zeae*. Appendix 2, Figure c shows the mean number of frost days each year in Central and southern North America overlaid with records of *D. virgifera zeae* as mapped by Krysan (1986). Frost day data for the 30-year period 1988–2017 was sourced from the Climatic Research Unit high resolution gridded data set CRU TS v. 4.03 at 0.5° resolution (https://crudata.uea.ac.uk/cru/data/hrg/). It is noteworthy that *D. virgifera zeae* occurs primarily in regions with few frost days. Appendix 2, Figure d shows the mean number of frost days each year across Europe. A simple visual comparison of the maps in Figures b and d suggests that there are areas where climate types BSk or Cfa coincide with areas in the EU with few frost days. Maize growing regions within these areas could provide conditions suitable for *D. virgifera zeae* establishment (Appendix B, Figure B.2). Therefore, we assume that climatic conditions in the EU do not limit the ability of *D. virgifera zeae* to establish.

3.4.4. Spread

Is the pest able to spread within the EU territory following establishment?

Yes, adults can fly and typically abandon maize fields to feed on other plant species and return to oviposit. This could be the major means of spread.

RNQPs: Is spread mainly via specific plants for planting, rather than via natural spread or via movement of plant products or other objects?

No, spread is mainly natural

While larvae of *D. virgifera zeae* move relatively little, adults typically abandon maize fields to feed on other plant species, and eggs can be deposited in the soil of other crops. Moreover, adults of the genus *Diabrotica* can migrate over longer distances, moving with weather features such as cold fronts (Smith et al., 1997). Early studies using allozymes (Krysan et al., 1989) and PCR–RFLP (based on the nuDNA ITS1 region; Szalanski et al., 1999) found low levels of differentiation in geographically isolated populations of *D. virgifera zeae*, suggesting high dispersal ability and limited barriers to gene flow.

3.5. Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory?

Yes, the introduction of *D. virgifera zeae* would most probably have an economic impact in the EU through the reduction of maize yields.

RNQPs: Does the presence of the pest on plants for planting have an economic impact, as regards the intended use of those plants for planting?[4]

Maize plants for planting are not anticipated to be a pathway for spread. Nevertheless, should *D. virgifera zeae* be present on other host plants for planting, an economic impact on the intended use of the plants would be expected.

D. virgifera zeae root damage weakens maize plants by reducing their ability to absorb water and nutrients. When roots are severely damaged, the maize plant can no longer support itself and falls over (lodges). Lodging may reduce corn yields and sometimes corn quality (Spike and Tollefson, 1991; Godfrey et al. 1993).

Yield losses resulting from rootworm feeding have been estimated to range from 0 to 15% but have been reported as high as 50% (Ward et al., 2005). In Mexico, losses in production range from 57% to 90% (in Jalisco), in Atlacomulco yield has been reduced by more than 80% when insecticide is not used (Segura-Leon, 2004). In the state of Guanajuato, Mexico, yield losses of 1,650 kg/ha have been estimated (Martínez-Jaime et al., 2014).

Larval injury is usually limited to the 3rd to 6th nodes of the maize roots because the development of these roots coincides with egg hatch and larval development. Initially, injured root tips will be discoloured or have brown lesions. Over time, primary and secondary roots can be completely pruned. Larvae often injure the succulent meristematic tissue near the root tip as the roots enter the soil. This stops root elongation giving these roots the appearance of being pruned. Larvae may tunnel into larger roots and occasionally into the plant stem. Damaged maize roots are more likely to be infected with root and stalk fungal diseases (Mitchell et al., 2019).

3.6. Availability and limits of mitigation measures

Are there measures available to prevent the entry into, establishment within or spread of the pest within the EU such that the risk becomes mitigated?

Yes, the existing measures (see Section 3.3) can mitigate the risks of entry, within the EU. Fresh maize cobs (sweetcorn) and foliage/green maize remain an open pathway and additional measures are available (see Section 3.6.1). Plants other than maize on which adults feed on pollen could provide potential pathways if transported when in flower. However, pollen hosts are generally wild plants and weeds and are not judged to provide a realistic pathway.

RNQPs: Are there measures available to prevent pest presence on plants for planting such that the risk becomes mitigated?

Yes, sourcing plants and plant parts including sweetcorn and green maize from PFA would mitigate the risk.

3.6.1. Identification of additional measures

3.6.1.1. Additional control measures

Potential additional control measures are listed in Table 6.

[4] See Section 2.1 on what falls outside EFSA's remit.

Table 6: Selected control measures (a full list is available in EFSA PLH Panel, 2018) for pest entry/establishment/spread/impact in relation to currently unregulated hosts and pathways. Control measures are measures that have a direct effect on pest abundance

Information sheet title (with hyperlink to information sheet if available)	Control measure summary	Risk component (entry/establishment/spread/impact)
Chemical treatments on consignments or during processing	Use of chemical compounds that may be applied to plants or to plant products (i.e. maize combs, green maize) after harvest, during process or packaging operations and storage (i.e. spraying/dipping pesticides)	Entry
Controlled atmosphere	Treatment of plants by storage in a modified atmosphere (including modified humidity, O_2, CO_2, temperature, pressure)	Entry
Crop rotation, assoc iations and density, weed/volunteer control	Cropping practices can affect *D. virgifera zeae* biology: • Historically, the most effective method for *D. virgifera zeae* management has been to rotate corn with soybean, sorghum; or forage grasses such as Johnson grass or wheat (Jones and Coppedge, 2000). However, in some cases damage occurred on corn roots in fields where sorghum was planted the previous year (Stewart et al., 1995). Large number of soybean pollen grains found on *D. virgifera zeae* adults (Jones and Coppedge, 2000)	Establishment & Spread
Chemical treatments on crops including reproductive material	Soil/seed-applied systemic insecticides have been applied to protect maize crops from rootworm larvae. Adult control is occasionally needed to protect maize silks and ear tips from injury (Capinera, 2001; French et al., 2014) Poor efficacy of various insecticides used to control rootworms in corn fields has been reported; however, this reduction in efficacy is primarily related to management and insecticide application issues more than insect resistance (Segura-Leon, 2004)	Establishment & spread
Use of resistant and tolerant plant species/varieties	• Some maize hybrids are tolerant to *D. virgifera zeae* damage (Pérez Domínguez et al., 2006) • Cultivars expressing *Bacillus thuringiensis* toxin genes were proved effective in controlling *D. virgifera zeae* (Siebert et al., 2012)	Establishment & spread
Biological control and behavioural manipulation	Predaceous larvae of a soldier beetle, *Chauliognathus* sp. (Coleoptera: Cantharidae) were frequently found feeding on rootworm larvae in Mexico (Branson et al., 1982). Diseases and predators appear to play a more important role in the population dynamics of *D. virgifera zeae* in Mexico compared with the *D. virgifera virgifera* of the corn belt (USA). Although a revision performed in 2009 found 290 publications on natural enemy–subtribe Diabroticina associations in the New World (Toepfer et al., 2009), research is still needed to properly exploit these natural enemies for biological control of *D. virgifera zeae* The availability of non-pheromonal attractants for *D. virgifera zeae* may prove useful to programmes for managing this pest species (Lance et al., 1992)	Establishment & spread

3.6.1.2. Additional supporting measures

Potential additional supporting measures are listed in Table 7.

Table 7: Selected supporting measures (a full list is available in EFSA PLH Panel et al., 2018) in relation to currently unregulated hosts and pathways. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk reduction options that do not directly affect pest abundance

Information sheet title (with hyperlink to information sheet if available)	Supporting measure summary	Risk component (entry/establishment/spread/impact)
Inspection and trapping	Imported host plants (i.e. green maize, maize combs) could be inspected for compliance from freedom of *D. virgifera zeae*	Entry
Laboratory testing	Examination, other than visual, to determine if pests are present using official diagnostic protocols	Entry
Certified and approved premises	Mandatory/voluntary certification/approval of premises is a process including a set of procedures and of actions implemented by producers, conditioners and traders contributing to ensure the phytosanitary compliance of consignments. It can be a part of a larger system maintained by a National Plant Protection Organization in order to guarantee the fulfilment of plant health requirements of plants and plant products intended for trade	Entry, establishment and spread
Delimitation of Buffer zones	Sourcing plants from a pest-free place of production, site or area, surrounded by a buffer zone, would minimise the probability of spread into the pest-free zone	Entry
Sampling	According to ISPM 31, it is usually not feasible to inspect entire consignments, so phytosanitary inspection is performed mainly on samples obtained from a consignment	Entry
Phytosanitary certificate and plant passport	An official paper document or its official electronic equivalent, consistent with the model certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (ISPM 5)	Entry
Certification of reproductive material (voluntary/official)	Mandatory/voluntary certification/approval of premises is a process including a set of procedures and of actions implemented by producers, conditioners and traders contributing to ensure the phytosanitary compliance of consignments. It can be a part of a larger system maintained by a National Plant Protection Organization in order to guarantee the fulfilment of plant health requirements of plants and plant products intended for trade	Entry, establishment and spread
Surveillance	ISPM 5 defines surveillance as an official process which collects and records data on pest occurrence or absence by survey, monitoring or other procedures	Establishment, spread

3.6.1.3. Biological or technical factors limiting the effectiveness of measures to prevent the entry, establishment and spread of the pest

No major issues with the present regulations in place.

3.6.1.4. Biological or technical factors limiting the ability to prevent the presence of the pest on plants for planting

No major issues with the present regulations in place.

3.7. Uncertainty

By its very nature of being a rapid process, uncertainty is high in a categorisation. However, the uncertainties in this case are insufficient to affect the conclusions of the categorisation.

4. Conclusions

D. virgifera zeae satisfies the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest. *D. virgifera zeae* does not meet the criteria of occurring in the EU, and plants for planting being the principal means of spread for it to be regarded as a potential Union regulated non-quarantine pest. Justification for such conclusions are summarised in Table 8

Table 8: The Panel's conclusions on the pest categorisation criteria defined in Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column)

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest	Key uncertainties
Identity of the pests (Section 3.1)	The identity of *D. virgifera zeae* is established and taxonomic keys are available for its identification to subspecies level	The identity of *D. virgifera zeae* is established and taxonomic keys are available for its identification to subspecies level	
Absence/presence of the pest in the EU territory (Section 3.2)	*D. virgifera zeae* is not known to be present in the EU	*D. virgifera zeae* is not known to be present in the EU. Therefore, it does not fulfil this criterion to be regulated as a regulated non-quarantine pest (RNQP)	
Regulatory status (Section 3.3)	The pest is currently listed in Annex IAI of 2000/29 EC	There are no grounds to consider its status of quarantine pest to be revoked	
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	The pest able to enter into, become established in, and spread within, the EU territory. The main pathways are: • Soil • Maize combs (sweetcorn) • Green maize • Plants for planting excluding seeds (hosts on which adults feed on pollen) imported from infested areas	Adults can fly and typically abandon maize fields to feed on other plant species and return to maize to oviposit. This could be the major means of spread	
Potential for consequences in the EU territory (Section 3.5)	The pests' introduction would most probably have an economic impact in the EU	Should *D. virgifera zeae* be present on plants for planting (although maize is not planted but seeded), an economic impact on its intended use would be expected	

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest	Key uncertainties
Available measures (Section 3.6)	There are measures available to prevent the entry into, establishment within or spread of the pest within the EU (i.e. sourcing plants from PFA)	There are measures available to prevent pest presence on plants for planting (i.e. sourcing plants from PFA, PFPP). However, maize is not planted but seeded	
Conclusion on pest categorisation (Section 4)	All criteria assessed by EFSA above for consideration as a potential quarantine pest are met with no uncertainties	The criteria of the pest being present in the EU territory and plants for planting being the principal means of spread are not met for it to be regarded as a potential Union regulated non-quarantine pest.The criterion of plants for planting being the main means of spread is also not met	
Aspects of assessment to focus on/scenarios to address in future if appropriate	Establishment, taking soil moisture, temperature and host distribution into account in more detail to identify the endangered area		

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Glossary

Containment (of a pest)	Application of phytosanitary measures in and around an infested area to prevent spread of a pest (FAO, 1995, 2017)
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 1995, 2017)

Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2017)
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2017)
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2017)
Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2017)
Measures	Control (of a pest) is defined in ISPM 5 (FAO 2017) as 'Suppression, containment or eradication of a pest population' (FAO, 1995). Control measures are measures that have a direct effect on pest abundance. Supporting measures are organisational measures or procedures supporting the choice of appropriate Risk Reduction Options that do not directly affect pest abundance.
Pathway	Any means that allows the entry or spread of a pest (FAO, 2017)
Phytosanitary measures	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2017)
Protected zones (PZ)	A protected zone is an area recognised at EU level to be free from a harmful organism, which is established in one or more other parts of the Union.
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2017)
Regulated non-quarantine pest	A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (FAO, 2017)
Risk reduction option (RRO)	A measure acting on pest introduction and/or pest spread and/or the magnitude of the biological impact of the pest should the pest be present. A RRO may become a phytosanitary measure, action or procedure according to the decision of the risk manager
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO, 2017)

Abbreviations

EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization
IPPC	International Plant Protection Convention
ISPM	International Standards for Phytosanitary Measures
MS	Member State
PLH	EFSA Panel on Plant Health
PZ	Protected Zone
RNQP	Regulated non-quarantine pest
TFEU	Treaty on the Functioning of the European Union
ToR	Terms of Reference

Appendix A – Detailed area of maize in EU Member States

Area of grain maize and corn-cob-mix cultivation/harvested/production (Eurostat code C1500) in EU Member States 2014–2018 (1000 ha) (Source: Eurostat).

	2014	2015	2016	2017	2018	5-year mean	% of 5-year mean
EU 28	9,610.16	9,255.56	8,563.21	8,271.64	8,286.69	8797.452	100.0
Romania	2,513.56	2,608.06	2,584.22	2,405.24	2,415.25	2505.266	28.5
France	1,848.07	1,639.49	1,458.32	1,435.70	1,423.92	1561.1	17.7
Hungary	1,191.42	1,146.13	1,011.56	988.82	943.98	1056.382	12.0
Italy	869.95	727.37	660.73	645.74	614.31	703.62	8.0
Poland	678.25	670.30	593.50	562.11	645.41	629.914	7.2
Germany	481.30	455.50	416.30	432.00	410.90	439.2	5.0
Bulgaria	408.40	498.64	406.94	398.15	444.50	431.326	4.9
Spain	418.55	398.26	359.28	333.63	326.60	367.264	4.2
Croatia	252.57	263.97	252.07	247.12	235.00	250.146	2.8
Austria	216.32	188.73	195.25	209.48	209.90	203.936	2.3
Slovakia	216.19	191.44	184.81	187.81	178.56	191.762	2.2
Greece	159.78	152.05	139.48	132.49	133.37	143.434	1.6
Portugal	107.64	97.91	88.61	86.52	90.46	94.228	1.1
Czech Republic	98.75	79.97	86.41	86.00	81.85	86.596	1.0
Belgium	62.83	58.40	52.10	49.00	53.99	55.264	0.6
Slovenia	38.33	37.74	36.39	38.29	36.75	37.5	0.4
Netherlands	18.00	15.80	12.27	12.25	13.77	14.418	0.2
Lithuania	19.00	11.71	12.43	9.93	13.39	13.292	0.2
Denmark	10.10	9.00	5.70	5.10	6.30	7.24	0.1
UK	0.00	4.00	5.00	5.00	7.20	4.24	0.0
Sweden	0.95	1.33	1.71	1.19	1.17	1.27	0.0
Luxembourg	0.22	0.14	0.13	0.08	0.09	0.132	0.0

Area of green maize (forage maize) cultivation/harvested/production (Eurostat code G3000) in EU Member States 2014–2018 (1000 ha) (Source: Eurostat).

	2014	2015	2016	2017	2018	5-year mean	% of 5-year mean
EU 28	6,147.80	6,267.95	6,256.88	6,183.30	6,363.05	6243.796	100.0
Germany	2,092.60	2,100.40	2,137.60	2,095.90	2,195.90	2124.48	34.0
France	1,411.80	1,475.23	1,433.16	1,406.01	1,422.20	1429.68	22.9
Poland	541.21	555.20	597.00	596.01	601.58	578.2	9.3
Italy	342.74	336.93	325.04	342.10	355.33	340.428	5.5
Czech Republic	237.24	244.96	234.40	223.21	224.11	232.784	3.7
Netherlands	226.00	223.86	203.81	203.51	203.25	212.086	3.4
UK	171.00	179.00	186.00	197.40	224.00	191.48	3.1
Denmark	178.20	182.40	182.40	166.70	179.60	177.86	2.8
Belgium	178.12	173.34	168.74	171.28	179.74	174.244	2.8
Greece	82.84	90.18	118.69	125.55	125.83	108.618	1.7
Spain	112.97	107.92	106.24	107.36	107.42	108.382	1.7
Austria	83.46	91.99	84.64	82.19	83.35	85.126	1.4
Slovakia	85.79	89.52	78.05	81.44	73.11	81.582	1.3
Portugal	85.39	80.78	80.26	78.43	79.03	80.778	1.3
Hungary	85.08	89.98	76.41	69.05	64.22	76.948	1.2
Romania	48.27	46.34	51.42	50.10	47.06	48.638	0.8
Slovenia	29.49	28.73	28.69	29.19	29.82	29.184	0.5
Croatia	28.79	32.60	30.98	28.29	25.00	29.132	0.5

	2014	2015	2016	2017	2018	5-year mean	% of 5-year mean
Bulgaria	25.13	26.56	31.10	29.93	27.24	27.992	0.4
Lithuania	28.50	29.25	26.59	24.34	28.25	27.386	0.4
Latvia	21.20	25.40	25.90	22.10	25.50	24.02	0.4
Sweden	15.67	15.65	15.74	16.80	17.17	16.206	0.3
Luxembourg	14.75	14.45	14.94	15.19	15.87	15.04	0.2
Ireland	13.87	12.85	10.92	11.88	17.76	13.456	0.2
Estonia	7.40	8.50	7.96	9.18	10.55	8.718	0.1
Cyprus	0.31	0.30	0.20	0.17	0.16	0.228	0.0

Appendix B – Maps of climate types, frost days and EU maize area

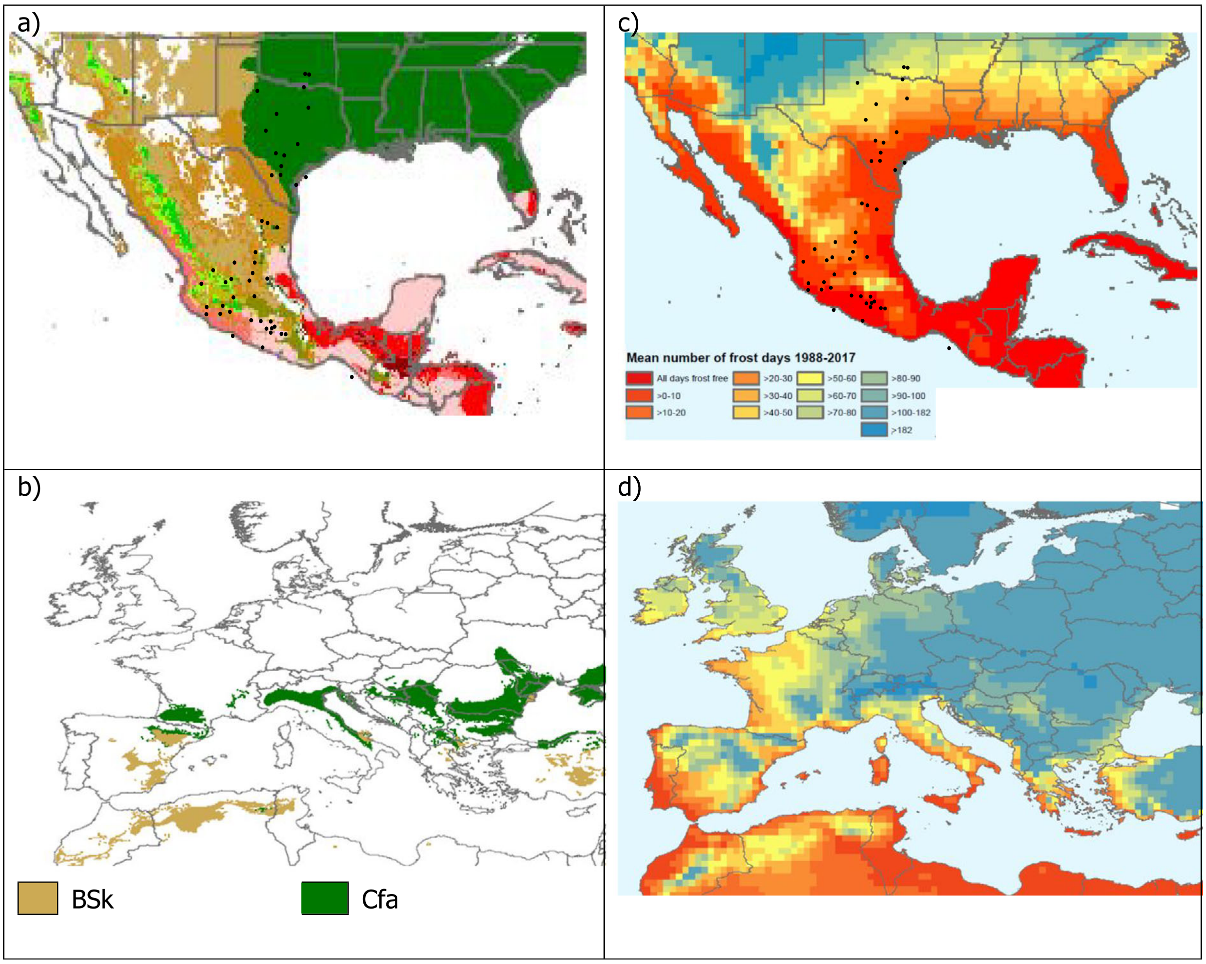

Figure B.1: Koppen–Geiger climate types and mean number of frost days in North and Central America which were visually compared to Europe (see Section 3.4.3 for detail). Black dots in (a) and (c) indicate occurrence of *D. virgifera zeae* (from Krysan et al., 1980)

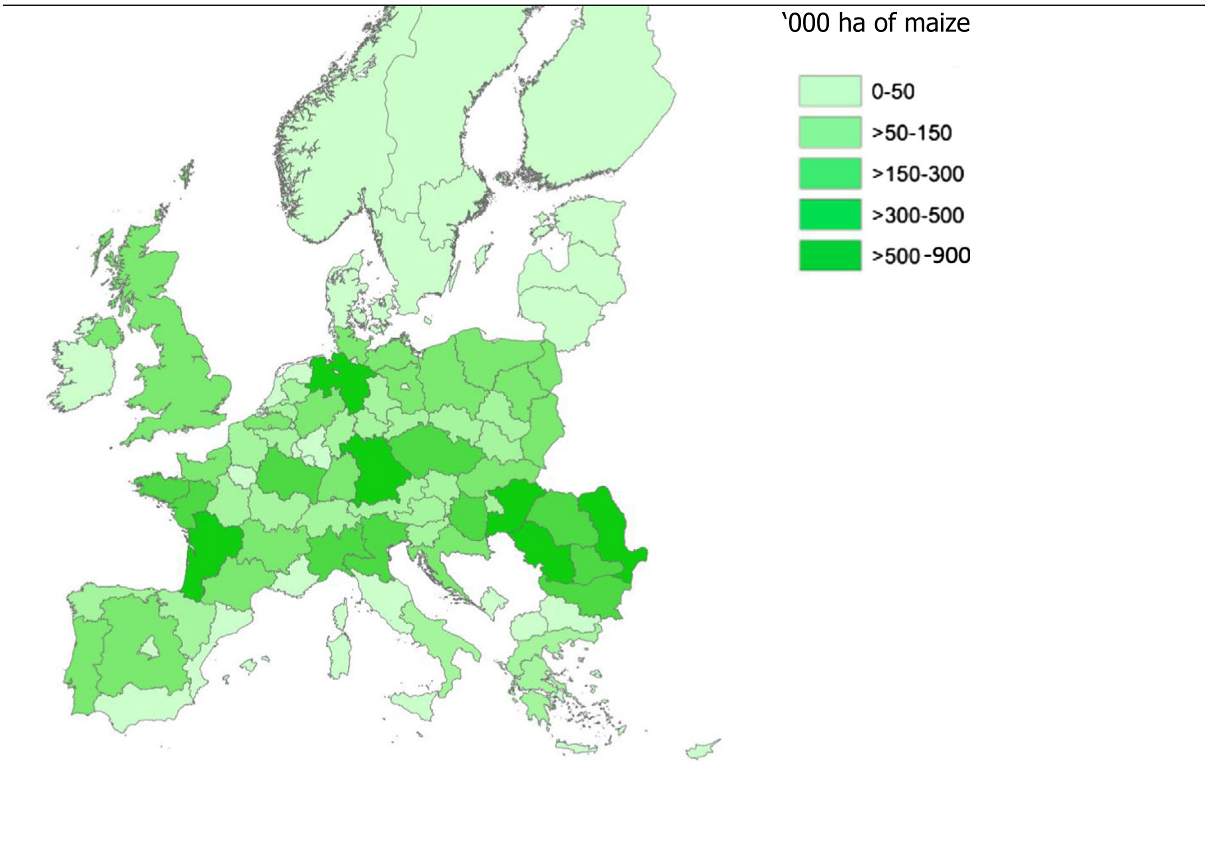

Figure B.2: EU area of maize production, NUTS 1 (1,000 ha of grain, corn-cob-mix and green maize) Source: http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do Data for 2017 or 2016