



EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA
PROTECTION DES PLANTES

Pest Risk Analysis for

Clavibacter nebraskensis (Actinobacteria: Microbacteriaceae)

Goss's bacterial wilt and leaf blight



Goss's systemic wilt. Courtesy: T. Jackson-Ziems, Nebraska-Lincoln University, USA

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The risk assessment follows EPPO standard PM 5/5(1) *Decision-Support Scheme for an Express Pest Risk Analysis* (available at https://eppo.int/RESOURCES/eppo_standards/pm5_pra), as recommended by the Panel on Phytosanitary Measures. Pest risk management (detailed in **Erreur ! Source du renvoi introuvable.**) was conducted according to the EPPO Decision-support scheme for quarantine pests PM 5/3(5). The risk assessment uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at <https://www.ippc.int/index.php>).

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Based on this PRA, *Clavibacter nebraskensis* was added to the EPPO A1 List of pests recommended for regulation as quarantine pests in 2026. Measures for seeds and grain of *Zea mays* are recommended.

**Pest Risk Analysis for
Clavibacter nebraskensis (Actinobacteria: Microbacteriaceae);
Goss's bacterial wilt and leaf blight**

PRA area: EPPO region in December 2025

Prepared by: Expert Working Group (EWG) on *Clavibacter nebraskensis*

Date: 1-4 December 2025. Further reviewed and amended by EPPO core members and Panel on Phytosanitary Measures (2026-03).

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Before the EWG meeting, the draft PRA was commented upon by H. Anderson and D. Eyre (DEFRA, UK), and A. Robertson (Iowa State University, USA). Euroseeds (organisation for the European seed sector) provided input from its member on issues related to maize seed production.

All personal communications in this PRA were obtained from July 2025 to January 2026 from: H. Anderson (DEFRA, UK), R. d'Andrimont (European Commission, DG Agri), N. Avendaño Garcia (EWG – TRAGSATEC, Spain), M. Delos (EWG – DRAAF Occitanie, France), F. Gaffuri & M. Ciampitti (Regione Lombardia, Servizio Fitosanitario, Italy), B. Ghassemi (BOKU University, Austria), R. Glenz (EWG - Julius Kühn-Institut, Germany), T. Jackson-Ziems (EWG – Nebraska-Lincoln University, USA), T. Levi (NPPO, Israel), N. Mahfoudhi, NPPO, Tunisia), A. Robertson (reviewer – Iowa State University, USA). Elements provided by Euroseeds are also recorded as pers. comm.

The first draft of the PRA was prepared by the EPPO Secretariat, as well as J. Tuomola (climatic suitability, maize in the EPPO region) and M. Frem (economic impact assessment).

Ratings of likelihoods and levels of uncertainties were made during the meeting. These ratings are based on evidence provided in the PRA and on discussions in the group. Each EWG member provided a rating and a level of uncertainty anonymously and proposals were then discussed together in order to reach a final decision. Such a procedure is known as the Delphi technique (Schrader *et al.*, 2010).

Following the EWG, the PRA was further reviewed by the following core members: H. Anderson, A. Korycinska, JM Guitian Castrillon, T. Levi, N. Üstün, D.J. van der Gaag; as well as by the EPPO Secretariat (J. Martinez, D. Musolin).

The PRA, in particular the section on risk management, was reviewed and amended by the EPPO Panel on Phytosanitary Measures on 2026-03. EPPO Working Party on Phytosanitary Regulation and Council agreed that *C. nebraskensis* is added to the A1 List of pests recommended for regulation as quarantine pests.

Summary of the Pest Risk Analysis for <i>Clavibacter nebraskensis</i>
PRA area: EPPO region at December 2025 (Albania, Algeria, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guernsey, Hungary, Ireland, Israel, Italy, Jersey, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Montenegro, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Türkiye, Ukraine, United Kingdom, Uzbekistan).
Describe the endangered area: Potentially, all areas where maize is grown in the EPPO region are at risk of establishment and impact, although some uncertainty remains. Köppen Geiger climate types under which <i>C. nebraskensis</i> has had an impact in its current distribution (see Fig. 9 in section 9.1) occur over large areas where maize is grown in the EPPO region, and impact under other climatic conditions cannot be excluded. However, the exact extent of the endangered area cannot be determined because establishment and impact depend not only on the presence of maize, but also on other factors including the growing of susceptible maize types and local agricultural practices (such as continuous maize production and reduced tillage). The true extent of the endangered area would therefore depend on where these practices are used., with it being unclear whether there would be economic impacts seen in areas not using these practices or where other agricultural practices that do not favour the pest are implemented (e.g. crop rotation and tillage).
Main conclusions: <i>Clavibacter nebraskensis</i> is a seed-transmitted bacterium occurring in North America and South Africa whose main host is maize (<i>Zea mays</i>). Other natural hosts are <i>Setaria viridis</i> and shattercane (<i>Sorghum bicolor</i>) and many experimental hosts have been found through inoculation, but the role of these as alternative hosts is not clear. The primary phytosanitary risk of <i>C. nebraskensis</i> is associated with maize. The main source of inoculum where the pathogen is present are infested crop debris, although maize seeds may play a role in introducing the disease into new areas. No completely resistant maize cultivars exist, and susceptibility amongst cultivars varies. Some maize types (such as popcorn or sweet corn) appear to be more susceptible, possibly because selection of resistant cultivars is less likely due to a narrower genetic pool. Seeds (for planting) of <i>Zea mays</i> was identified as the most likely entry pathway, with a moderate likelihood and moderate uncertainty. The EWG noted in particular that some commercial seeds (for sale to growers) are imported into the EPPO region from countries where the pest occurs. Successful entry with grain of <i>Zea mays</i> (kernels for processing or consumption, but not for planting) requires a chain of unlikely events for transfer to a host to occur, although the risk of transfer is higher when associated with husks or maize plant debris. The likelihood of entry on grain was rated as low with a moderate uncertainty. The likelihood of establishment was rated as very likely with a moderate uncertainty. Maize is widely cultivated in many EPPO countries and in its current distribution, <i>C. nebraskensis</i> occurs under a wide range of climatic conditions. Subsequently, climate was generally not considered to be a limiting factor for establishment in areas of the EPPO region where maize is cultivated. The pathogen is known to occur under certain Köppen Geiger climate types that also occur in the EPPO region (<i>BSk</i>, <i>Cfa</i>, <i>Dfa</i>, <i>Dfb</i> – see section 9.1). These areas of the EPPO region were considered to be suitable for establishment with a higher degree of certainty than areas of the EPPO region which cultivate maize under climate types from which the pest has not been reported. The EWG considered that the extent of maize cultivation and agricultural practices in maize cultivation may have a greater effect on establishment than climate. Establishment is most likely to occur if the pathogen enters an area where there is a high density of maize cultivation and where agricultural practices such as continuous maize production (without crop rotation) and/or reduced or no-tillage are common. Although it is not possible to precisely delimit where favourable agricultural practices are widely used, they are known to occur in some areas, which would increase the establishment potential. The magnitude of spread was rated as moderate with a moderate uncertainty. Spread would occur naturally and through human-assisted means (such as infected seed or grain, green forage, silage, debris, contamination of machinery). It is noted that extreme weather events (strong winds, hail, and storms) move

infested crop debris and damage plants promoting disease development, which have an important role in the U.S. Midwest, may not happen at a comparable scale and frequency in the EPPO region, although their frequency is likely to increase as a result of climate change. In the EPPO region, like in South Africa, *C. nebraskensis* may not be detected immediately, allowing for significant spread and multiple outbreaks before detection.

Overall, impact in the current area of distribution was rated as moderate with a moderate uncertainty. In the past in the USA, initial outbreaks and reemergence events have had a high impact in terms of crop losses. Currently, direct economic losses are relatively low in the USA, where management practices are in place, although there is higher impact on a local scale in certain areas due to the cultivation of certain maize types that are more susceptible, or to the occurrence of severe weather events. In South Africa where the pathogen was first found in 2024, the disease has to date affected trade and can disrupt production.

For the potential economic impacts, two scenarios, optimistic and pessimistic¹, were assessed. Under the pessimistic scenario, the magnitude of impact in the area of potential establishment was rated as high with a moderate uncertainty. Under this scenario impacts were expected to be similar to US 'outbreak' years or specific severe cases. Under the optimistic scenario, the magnitude of potential impact was rated as moderate with a moderate uncertainty. Under this scenario yield losses exceeding normal variation were expected and some targeted measures would likely be necessary.

Phytosanitary risk for the <u>endangered area</u> No key uncertainty was identified that could affect this conclusion. Other main uncertainties are detailed in section 17.	High ☐	Moderate X	Low ☐
Level of uncertainty of assessment	High ☐	Moderate X	Low ☐
Other recommendations: EPPO Diagnostic protocol, production of awareness raising materials, engagement with industry. See section 18.			

¹ (from ANNEX 14, Step 1)

Optimistic scenario: the pathogen is detected early. Resistant maize cultivars rapidly become widely available and are adopted quickly over large areas. Major maize-producing regions have low monoculture rates or can implement effective crop rotation in most of their territory. Tillage is possible in many areas. Impact is similar to the current overall US situation.

Pessimistic scenario: the pathogen remains undetected for several years (which is realistic), allowing significant build-up and spread, introduction in a region with high maize monoculture and no-till practices, the development of resistant cultivars is slow or not possible at a large scale, and extreme weather events exacerbate the problem before management is implemented

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Pest Risk Analysis for *Clavibacter nebraskensis* (Actinobacteria: Microbacteriaceae) Goss's bacterial wilt and leaf blight

Stage 1. Initiation

Reason for performing the PRA:

Clavibacter nebraskensis causes Goss's wilt and leaf blight of maize, which, since its description in 1969, had only been reported from North America. The disease was prevalent in the western Corn Belt in the 1970s until, through the introduction of resistant hybrids, it became a rarity. In the mid-2000s, *C. nebraskensis* reemerged and the disease was observed in many maize-producing states in the USA to be causing losses especially until the 2010s. Currently, it is a managed pest of maize in the USA. *Clavibacter nebraskensis* was first found in South Africa in 2024. Considering its potential impact on maize in the EPPO region, it was added to the EPPO Alert List (EPPO, 2025a). In April 2025, the Panel on Phytosanitary Measures (PPM) selected *C. nebraskensis* as a possible priority for PRA, and in June 2025 the Working Party on Phytosanitary Regulations selected it for PRA.

The risk assessment follows EPPO Standard PM 5/5 *Decision-Support Scheme for an Express Pest Risk Analysis* (available at https://eppo.int/RESOURCES/eppo_standards/pm5_pra), as recommended by the EPPO Panel on Phytosanitary Measures in 2016. Pest risk management (detailed in ANNEX 1) was conducted according to the EPPO Decision-support scheme for quarantine pests PM 5/3(5). The risk analysis uses the terminology defined in ISPM 5 Glossary of Phytosanitary Terms (version as of 28 July 2025; IPPC Secretariat, 2025).

PRA area: EPPO region in December 2025 (map at https://www.eppo.int/ABOUT_EPPO/eppo_members)

Stage 2. Pest risk assessment

1 Taxonomy

Taxonomic classification: Kingdom: Bacteria / Class: Actinobacteria / Order: Micrococcales / Family: Microbacteriaceae / Genus: *Clavibacter* / Species: *Clavibacter nebraskensis* (Vidaver & Mandel 1974) Li *et al.* 2018 (EPPO, 2025b; CABI, 2020).

Clavibacter nebraskensis was previously considered as a subspecies of *C. michiganensis* and was elevated to species by Li *et al.* (2018). Previous names, especially *C. michiganensis* subsp. *nebraskensis*, are widely used in the literature.

Other scientific names: (EPPO, 2025b; CABI, 2020)

Clavibacter michiganensis subsp. *nebraskensis* (Vidaver & Mandel 1974) Davis *et al.* 1984

Corynebacterium michiganense pv. *nebraskense* (Vidaver & Mandel 1974) Dye & Kemp 1977

Corynebacterium michiganense subsp. *nebraskense* (Vidaver & Mandel 1974) Carlson & Vidaver 1982

Corynebacterium nebraskense Vidaver & Mandel 1974

Common names in English: Goss's bacterial wilt and leaf blight, leaf freckles and wilt, Nebraska leaf freckles and wilt (Schuster, 1975).

EPPO code: CORBNE

Recent studies showed that the genetic diversity of *C. nebraskensis* has increased (Agarkova *et al.*, 2011; Veregge *et al.*, 2025). In a survey of 41 strains, recently sampled strains tended to have higher virulence than strains sampled before 2010 (Veregge *et al.*, 2025)². Several studies identified isolates of *C. nebraskensis* that are not pathogenic on maize (5 out of 131 strains in one study [Agarkova *et al.*, 2011] and 4 out of 37 isolates in another study [Ahmad *et al.*, 2015]).

² The EWG noted, however, that this result might be an artefact of storage conditions of older strains because phytopathogenic bacteria tend to drop virulence when stored under laboratory conditions for a long time.

Notes on the terminology used in this PRA:

This PRA uses ‘maize’ to refer to *Zea mays*, and ‘corn’ where it refers to specific maize types³ or commodity names such as ‘sweet corn’, ‘flint corn’, ‘popcorn’, etc. All maize types belong to *Z. mays*, but they vary in their composition and intended use³. Susceptibility varies amongst cultivars and maize types, with some maize types being more susceptible to the disease overall (see section 2.6.1).

The morphology of maize plants is illustrated in Fig.1, with the terms used in this PRA.

The term ‘seed’ is used in the botanical sense when referring to biological concepts, but is sometimes replaced by ‘kernel’ when the intended use is for a purpose other than growth of a future crop. Otherwise, the terms ‘seed’ and ‘grain’ are used in relation to commodities/pathways in line with the definitions of ISPM 5 (IPPC Secretariat, 2025; see introduction to section 8).

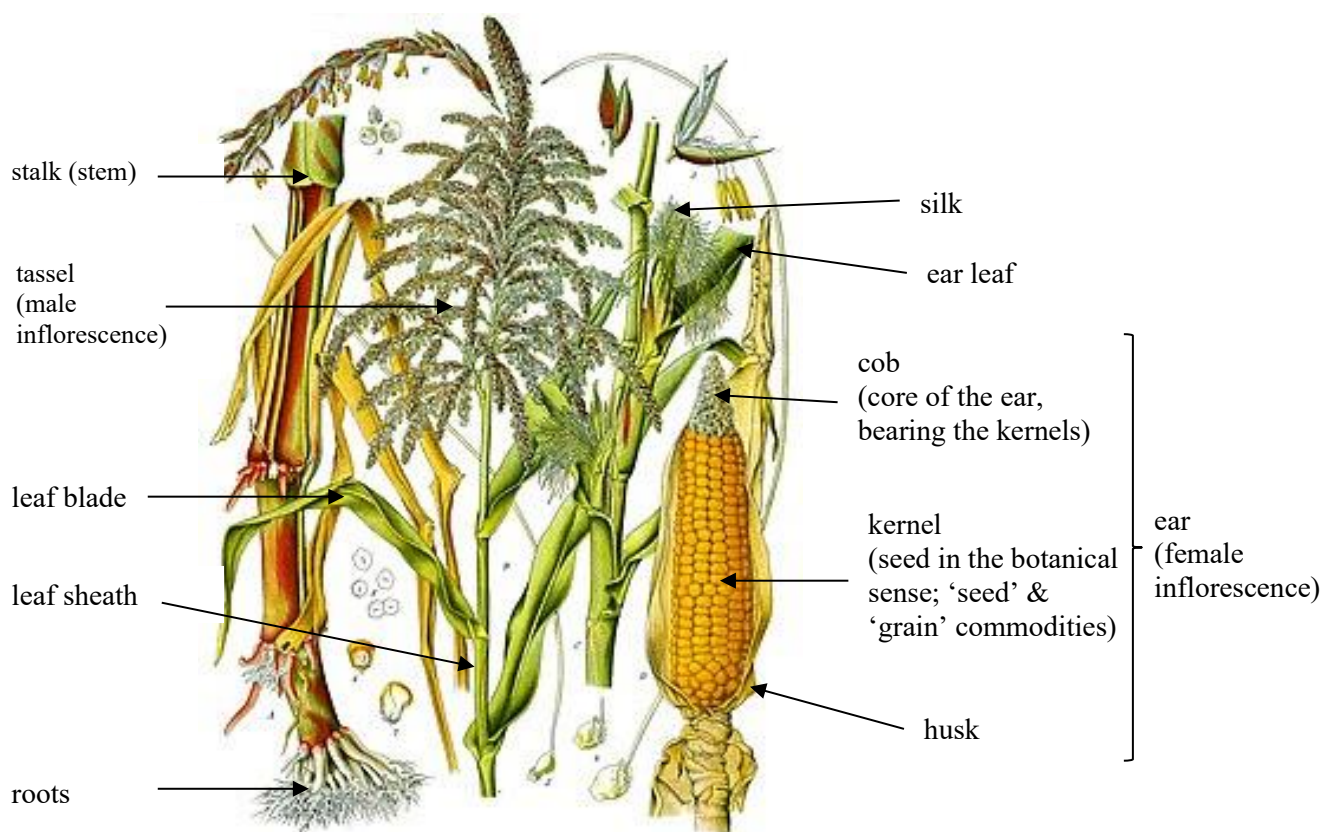


Fig. 1. Terms related to maize plants used in this PRA (Descriptions based on commonly used terms, illustration by FE Köhler, 1898, Köhler's Medizinal-Pflanzen - Köhler's Medizinal-Pflanzen in naturgetreuen Abbildungen mit kurz erläuterndem Texte, Vol. 3, Plate 78)

³ The taxonomy of *Zea mays* into subsp./var. varies according to sources. Below are examples of maize types and uses, with scientific names as in EPPO (2025b). The list below is not exhaustive.

Maize types	Comments
Dent corn / field corn - <i>Zea mays</i> subsp. <i>indentata</i>	99% of all corn in the USA. Food products (not eaten fresh – e.g. tortillas, flour, corn flakes etc.), animal feed (produced from grain, and silage), industrial (e.g. starch, syrup, biofuel, others), corn pipes
Flint corn - <i>Z. mays</i> subsp. <i>indurata</i>	Food products (not eaten fresh – e.g. corn flakes, flour), animal feed, ornamental and decoration, biofuel and various industrial uses
Flour corn <i>Z. mays</i> subsp. <i>amylacea</i>	Food products (as flour), animal feed, industrial uses
Popcorn – <i>Z. mays</i> subsp. <i>everta</i>	Food: popcorn
Sweet corn – <i>Z. mays</i> subsp. <i>saccharata</i>	Food: eaten fresh off the cob, or canned, or frozen
Waxy corn – <i>Z. mays</i> var. <i>ceratina</i>	Food industry, animal feed, industrial uses
Pod corn - <i>Z. mays</i> var. <i>tunica</i>	Ornamental, research

<https://www.naturetohomeagro.com>, <https://rohrerseeds.com/blogs/seeds/dent-flint-and-sweet-corn-whats-the-difference?srsltid=AfmBOoqHTblSksG2fcwDFq-7B7Cd52jm1P9391UadJXQfNobG4ltjYVY>;
<https://evolution.earthathome.org/grasses/andropogoneae/maize-types/>;

2 Pest overview

2.1 Morphology of *C. nebraskensis* and its colonies

Clavibacter nebraskensis is a gram-positive, non-flagellated, non-spore forming, aerobic coryneform bacterium (Schuster, 1975; Li *et al.*, 2018). In 40-h cultures, the size of cells ranges from 0.75-2.7 μm by 0.25-0.5 μm (Vidaver & Mandel, 1974).

On common laboratory growth media, colonies are usually round, convex, mucoid, viscid, glistening with entire margins, and have a diameter reaching 3-6 mm (Schuster, 1975 after 7 days; Vidaver & Mandel, 1974 after 5-7 days). Growth of *C. nebraskensis* is favoured by media containing yeast extract and is rather slow, with colonies rarely appearing before 3-4 days when cultured at an optimal temperature of between 24 and 28°C (Vidaver & Mandel, 1974). Colonies are yellow to orange on common laboratory growth media (Li *et al.*, 2018).

Clavibacter nebraskensis may either be present epiphytically on the plant or inside the plant, primarily in the xylem. In severely infected maize plants, *C. nebraskensis* might appear as an orange bacterial exudate leaking from cut vascular elements of the stem or as a colourless shiny sheen on both sides of the leaf (Schuster, 1975). Colonised vascular elements of the maize plant stalk become discolored tan to dark brown (T. Jackson-Ziems, A. Robertson, pers. comm.).

2.2 Life cycle

Clavibacter nebraskensis has been isolated from maize roots, stalks, leaf blades and sheaths, tassels, husks and silks, cobs and kernels; in kernels, it was isolated near the embryo and between the scutellum and the endosperm, i.e. inside kernels, as well as on the surface. It can be present on maize at any stage of development of the plant (Schuster, 1975, Block *et al.*, 2019; Biddle *et al.*, 1990). Photos are provided in ANNEX 2 and in EPPO Global Database.

Typically, the development of *C. nebraskensis* in the field is linked to infested maize debris (see section 2.3.1), on which *C. nebraskensis* overwinters. The bacterium on the infested maize debris can then provide an inoculum source to infect leaves of the new maize crop by water splash or be spread to new areas via windborne debris (Fig. 2 below; Eggenberger *et al.*, 2016; Malvick *et al.*, 2025).

Leaf lesions develop a few days following inoculation/infection (4-5 days in experiments on leaves; Mbofung *et al.*, 2016). This period may vary depending on variety, inoculum density, temperature, humidity, etc. Once inside the leaf, *C. nebraskensis* multiplies in the vascular tissue causing leaf blight or moves systemically through vascular bundles and causes wilt (see *Symptoms*; Schuster, 1975; Harding *et al.*, 2018). Systemic movement is passive, through the xylem. Once proliferated, exudate can ooze on leaf surfaces and spread locally to adjacent maize plants (see section 2.3.2).

Clavibacter nebraskensis can also live epiphytically on maize leaves (Smidt & Vidaver, 1986; Eggenberger *et al.*, 2016), and this inoculum can provide a source to infect other plants (see section 2.3.2).

Eggenberger *et al.* (2016) noted that sudden outbreaks of the disease or large-scale field infestations likely involve multiple infection cycles over more than one growing season, with initial infestations remaining unnoticed. Therefore, outbreaks may be the result of a gradual build-up of inoculum in new areas through epiphytic populations on asymptomatic plants, latent infections or low numbers of symptomatic plants, occurring individually or in small groups of a few plants throughout a crop, and thus going unnoticed.

The bacterium can enter plants through wounds (Malvick *et al.*, 2025) (see section 2.6.3) or natural openings. Mallowa *et al.* (2016) showed in a greenhouse study that the disease developed in the absence of severe wounding and hypothesised that *C. nebraskensis* may enter maize leaves through stomata and trichomes at the edge of leaves. Mullens & Jamann (2021) demonstrated that *C. nebraskensis* can enter in guttation droplets

via hydathodes⁴ in the absence of wounding (they did not obtain entry via stomata). Observations from fields in Iowa (USA) support these findings, with leaf lesions starting from the tip of the maize leaf at the top of the plants (A. Robertson, pers. comm. and photos in ANNEX 2).

Bacteria present on maize debris or as epiphytic populations are transferred from plant to plant by means of contact, as might occur by direct contact, plant debris, water, agricultural practices, etc. and can then enter the plant by natural openings or wounds occurring in normal plant growth. Lesions may develop on the plant, or the bacterium may remain epiphytic and asymptomatic.

C. nebraskensis is also seed-borne and seed-transmitted (see section 2.3.3).

Finally, other alternative hosts in the Poaceae may have a role in the life cycle (see section 2.3.4).

There is no evidence that root transmission occurs under field conditions, although Langemeier *et al.* (2017) noted that root-feeding insects may play a role in the epidemiology of the disease and Schuster (1975) was able to induce symptoms on leaves when roots of seedlings were infected by wounding in greenhouse experiments.

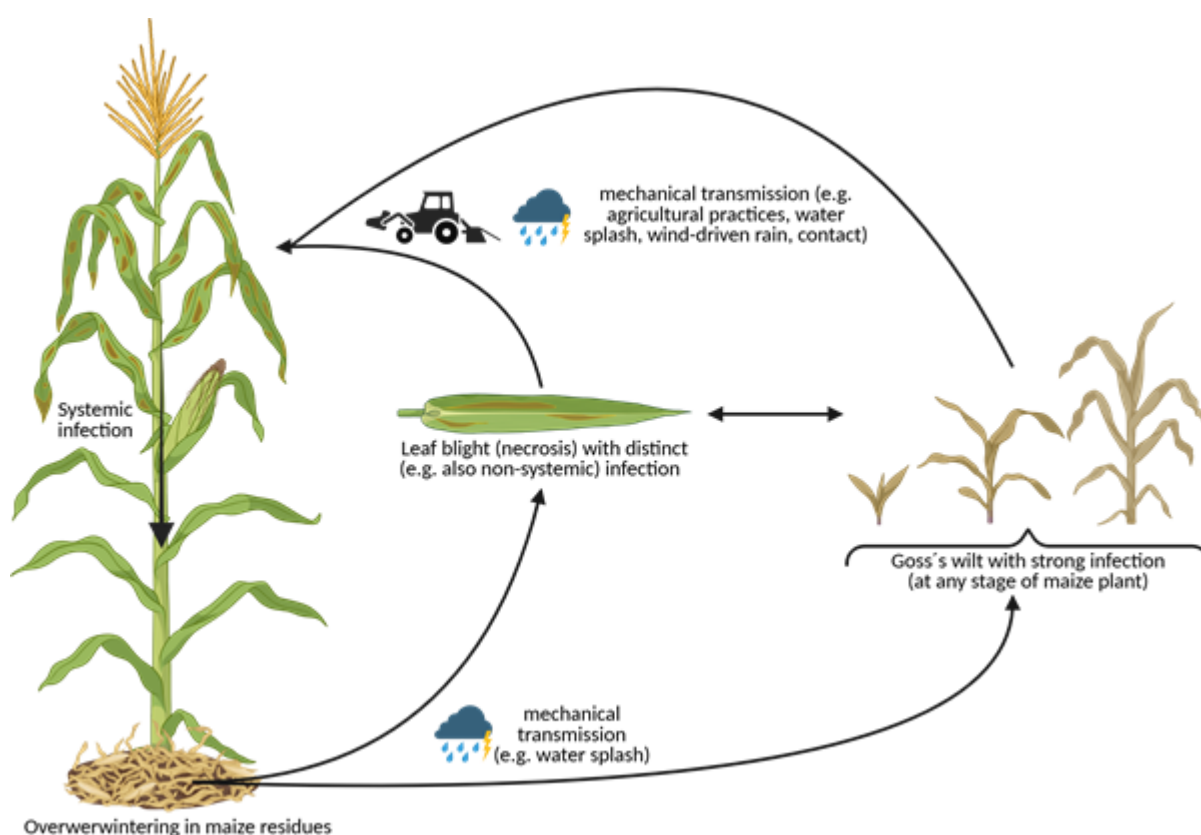


Fig. 2. Infection cycle of *Clavibacter nebraskensis* in an area of presence. Created in BioRender (R. Glenz, 2026; <https://BioRender.com/1qxf9q2>).

⁴ From Mullens & Jamann (2021, citing others): **stomata** are pores in the epidermis that facilitate gas exchange and can open and close. **Hydathodes** have distinctly different functions and structures. Their primary purpose is to exude excess water via guttation. Hydathodes are found at the tips and edges of leaves, have water pores that are always open, and have direct access to the ends of vascular bundles. When transpiration increases as a result of changes in lighting, temperature, and humidity, guttation droplets are drawn back into the plant, which draws in any pathogens that may have been splashed into the droplet. This entry route was shown for several bacteria, such as *C. michiganensis*, *Xanthomonas campestris* pv. *campestris*.

2.3 Known and potential sources of inoculum and survival of the bacterium

2.3.1 Infested maize debris

Infested maize crop debris (i.e. remaining in the field through winter and until the next maize crop) is the primary source of inoculum in the field (Schuster, 1975; Jackson *et al.*, 2007a, Eggenberger *et al.* 2016). The population of *C. nebraskensis* in debris is highest just after harvest and declines by four or five orders of magnitude over the winter and following summer (Smidt & Vidaver, 1986).

Survival. Many sources mention survival of inoculum for ‘at least 10 months’ on infested crop debris. This figure originates from Schuster (1975), who conducted experiments on various maize plant parts (leaf, stem, cob and ears) over a period of 10 months (survival checked by later inoculation to healthy seedlings) between autumn 1971 and June 1972 in Lincoln, Nebraska. Seedling infection reached 63-80% from infected leaf, stem, cob and ear tissues left on the soil surface for 10 months. Reduced rates of seedling infection were obtained when debris were buried in the soil over the same period (10 months): at 10-cm depth, infection only occurred with inoculations made from stem and cob tissues (respectively 30 and 5%), and at 20-cm depth, infection only occurred with inoculations made from stem tissue (40%) (Schuster, 1975).

Shorter survival is reported by Ikley (2019) in a field experiment in which maize, *Setaria faberi* (giant foxtail) and *Digitaria sanguinalis* (large crabgrass) (both experimental hosts – see section 7) were inoculated with *C. nebraskensis*, with symptomatic plants then left at the soil surface or buried at 15 cm-depth in the field in December 2013. Plant debris was sampled every 4 months for 2 years. *Clavibacter nebraskensis* was recovered (i.e. showing its ability to overwinter) and remained pathogenic for up to 4 months in debris of all inoculated hosts. No *C. nebraskensis* was recovered at or after 8 months. Leaves on the soil surface had fully decomposed after 16 months, and at 24 months some stalk tissue was present. The author concluded that in the environment and soil type at the experimental location in Indiana (USA), the bacterium could not survive in infested maize or alternative host debris as long as in Schuster’s experiments (Ikley, 2019).

Finally, in another experiment, survival of strains in air-dried leaves of greenhouse grown plants was less than 3 months (Vidaver, 1977).

The EWG assumed that, in favourable conditions, the bacterium may remain viable in the host debris on the soil surface until they are decomposed, which may take up to 16 months for leaves (Ikley *et al.*, 2019). The bacterium is not expected to survive in completely dry material over a longer period of time (i.e. several months).

2.3.2 Bacterium on maize plants

Exudate on the leaf surface (when the bacteria proliferates in the xylem and then leaks out to the surface) as well as epiphytic populations can spread locally to adjacent plants (see section 2.4). Eggenberger *et al.* (2016) demonstrated that epiphytic populations increased on asymptomatic plants throughout the growing season. Ikley (2019) hypothesised that epiphytic populations during the growing season may be more important than previously thought for the pathogen survival in Indiana, as the pathogen was still present in the area, despite their study not detecting pathogenic *C. nebraskensis* in infested host debris after 4 months. Botti-Marino (2017) reported no correlation between virulence and epiphytic or endophytic survival.

The EWG noted that maize volunteers growing in the crop following maize in a rotation may act as reservoirs for the bacterium to survive until the next maize crop is planted.

Survival. The bacterium survives on maize.

This PRA considers that *C. nebraskensis* can survive within maize plants, as well as externally such as in exudates on the leaf surface and as epiphytic populations on the leaf.

2.3.3 Maize seed

Clavibacter nebraskensis is both seed-borne (where it can be present on the surface or inside the kernel) and seed-transmitted (ISF, 2025; Block *et al.*, 2019; Biddle *et al.*, 1990). Seed-transmission (seed to seedling) has been demonstrated in several experiments (Block *et al.*, 2019; Schuster, 1975; Biddle *et al.*, 1990).

Block *et al.* (2019) provide the most comprehensive study on transmission from plant to seed and seed to seedling, due to the large number of seeds included in the trials and the fact that trials were conducted in the field. Previous studies used relatively small numbers of seeds (<12000), which may have led to overestimating the percentage of seed transmission (Block *et al.*, 2019). The text in this subsection refers mostly to Block *et al.* (2019), with further details on this study and others in ANNEX 3. The EWG noted that plant to seed

transmission and seed to seedling for *C. nebraskensis* cannot be quantitatively compared to that of *P. stewartii* subsp. *stewartii* (e.g. ISF, 2003; Block *et al.*, 1998) because experimental conditions differed.

Transmission from plant to seed. In Block *et al.* (2019), the percentage of seed infection for a susceptible hybrid was up to 21.4% of the seed sampled in inoculated plots, and 5.15% in non-inoculated plots (through contamination/spread of the bacterium from inoculated plants/plots to plants of non-inoculated plots). For a resistant hybrid (see section 2.6.1), these percentages were 2.5 % and 0.8% respectively. In other studies, the levels of infection of seed lots vary, from up to 21% (Schuster, 1975) or 29% (Shepherd, 1999) for naturally infected plants, or up to 31% from inoculated plants (Biddle *et al.*, 1990).

Against expectations of the study and unlike *P. stewartii* subsp. *stewartii*, Block *et al.* (2019) found low percentages (4 % and less) of infected seeds from resistant and moderately resistant plants with low disease severity (never reaching 5% leaf disease severity). Seed transmission is therefore not always linked to high leaf disease severity, nor to systemic infection. The EWG also noted that low levels of infection in the field may not be detected.

This PRA considers that *C. nebraskensis* can be transmitted from plant to seed even at low levels of infection. At very low infection levels, symptoms on plants may not be recognised as *C. nebraskensis*, resulting in undetected low levels of infected seeds.

Seed transmission (seed to seedling). Experiments described in Block *et al.* (2019) were conducted with seeds from one resistant, one susceptible, and two moderately resistant cultivars, both in field and greenhouse, undertaken at different times in 2013-2014. Across all the trials, the seed transmission rate was 12 events for 241,850 plants grown in the field or greenhouse (i.e. 0.005%), i.e. one seed transmission for every 20,000 plants, and the seed transmission rate adjusted to infected seed (seed transmission events divided by infected plants) was 0.04% overall. The seeds that led to disease transmission came from susceptible and moderately susceptible hybrids, with percentage of infection of seed lots ranging from 3.6 to 37%. Seed transmission was found only for seeds planted in one of the trial periods (June 2013 versus July 2013 or 2014), and the reasons for this are unknown.

Considering only the trial that led to seed transmission (i.e. with seeds from a susceptible hybrid and a moderately susceptible hybrid in one trial period with high disease severity), the seed transmission rate adjusted to infected seed (seed transmission events divided by potential infected plants) ranged from 0.065% to 0.084%.

This PRA considers that *C. nebraskensis* can be seed-transmitted (seed to seedling), at low rates (at most 0.084% in Block *et al.*, 2019). In North America, where the bacterium is well established, the main source of inoculum is host debris, and seed-transmission is not considered a major source of new infections. However, seed transmission may be important for introduction into areas where the bacterium is not present.

Survival. *C. nebraskensis* was readily isolated from 9 to 12 month old kernels, i.e. the bacteria were still viable and did not die before the next year's planting (Schuster, 1975). In an experiment on seed transmission, seed infection levels immediately before planting in spring were similar to those detected after harvest (and prior to storage during winter) (Biddle *et al.*, 1990). Neither harvest moisture nor drying treatment had any significant effect on internal populations of the pathogen nor the percentage of seeds infected (Biddle *et al.*, 1990).

In comparison, *P. stewartii* was detected from seed ranging between 5 months to 3 years old in various studies, with one study reporting that it survived in stored maize longer at low temperatures, but disappeared after 200-250 days in storage at 8-15°C (ISF, 2003 citing Pataky pers. comm., Rand & Cash, 1933 and Guo *et al.*, 1987).

This PRA considers that *C. nebraskensis* could survive in maize kernels for at least 1 year, with survival gradually decreasing over time.

2.3.4 Other plants

Natural infection in the field by *C. nebraskensis* was detected on two other Poaceae species (*Setaria viridis* and shattercane [*Sorghum bicolor*] – see Note in section 7). Many other Poaceae species are shown to be experimental hosts in inoculation trials (see section 7). Many authors note that these hosts may be a source of inoculum, acting as reservoir or overwintering hosts for the bacterium (e.g. Malvick *et al.*, 2025, Langemeier *et al.*, 2014, Schuster, 1975). However, their role in disease epidemics is not understood (Harding *et al.*, 2018). No experimental evidence has shown that these alternative hosts contribute to disease severity (Ikley, 2019). In this PRA, the term ‘alternative hosts’ is used to refer to all hosts other than maize (incl. experimental hosts – see section 7).

Osdaghi *et al.* (2023) states that neither systemic nor seed-borne infections were demonstrated in some tested alternative hosts. This seems to be based on limited experimental data on a few species:

- Shattercane (*Sorghum bicolor*) and Johnsongrass (*S. halepense*) (an experimental host) induced a hypersensitive response, restricting movement of the bacterium within the plant (Ikley *et al.*, 2015).
- No systemic infection on *Lolium multiflorum*, *Setaria faberi* and *S. halepense* (all are experimental hosts) was found in experiments. Symptomatic lesions did not exceed 65% on inoculated leaves. *Clavibacter nebraskensis* was not found in seeds of these hosts and was unable to colonize *S. halepense* rhizomes (Ikley, 2019).
- *Setaria faberi* (giant foxtail) had similar susceptibility to *C. nebraskensis* (leaf infection) as moderately tolerant maize hybrids (Campbell, 2017).
- Only leaf symptoms were observed on several inoculated *Setaria* species (Langemeier *et al.*, 2014).

Finally, Webster *et al.* (2019) found that some plants, including Poaceae and non-Poaceae, support epiphytic *C. nebraskensis* (see section 7), and may also play a role in the epidemiology of the disease. However, there is no confirmed evidence to support this.

Survival. The bacterium can survive on its hosts. Both *S. viridis* and *S. bicolor* have been found naturally infected in the field, but for experimental hosts, this has not been shown (see section 7).

Alternative hosts (see section 7) may be a potential reservoir and maintain populations of the bacterium. For the purpose of this PRA they are considered to be potential reservoirs of the bacterium, however, there are uncertainties on the host status of many of these species and their role in the epidemiology of the disease.

2.3.5 Elements not considered to be a source of inoculum

Based on the literature available, the following are not considered as potential sources of inoculum:

- **Soil without infested debris.** Pure colonies in experiments were found to survive less than two weeks in soil. In experiments over a period of 10 months, pure colonies did not survive on or in soil during that period (checked by inoculation to healthy seedlings) (Schuster, 1975).

This PRA concludes that the bacterium cannot survive in soil in the absence of plant debris, and soil on its own is therefore not a source of inoculum (but soil containing infested debris is – see above).

- **Contaminated water.** Being a bacterium, *C. nebraskensis* can survive in water according to Njom *et al.* (2025), however, there is no specific scientific data to support this for *C. nebraskensis*. In laboratory experiments, van der Wolf & van Beckhoven (2004) demonstrated that *C. sepedonicus* in water from various sources and at different temperatures survived between 0 to 35 days. They noted that *C. sepedonicus* may theoretically be transported at long-distance by flowing water, but irrigation water may present a risk only when there is a source that constantly releases high densities of the bacterium; otherwise, the pathogen will be strongly diluted in large volumes of water. Overhead irrigation is known to help disperse *C. nebraskensis*, but this is due to water mechanically dispersing the bacteria present on leaves via water splash, and not due to the bacterium being present in the irrigation water itself (see section 2.4).

Although irrigation water may act as a means of short-distance mechanical spread, there is no evidence that *C. nebraskensis* can survive for extended periods in water or that water bodies serve as sources of inoculum.

- **Maize silage.** Crop ensiling processes significantly reduce pathogen populations (as with composting or pasteurizing) (Harding *et al.*, 2018). The survival of related species such as *C. michiganensis* and *C. sepedonicus*, assessed from anaerobic digesters, composts and silage, showed that survival was significantly reduced (Harding *et al.*, 2018 citing Roozen & Vanvuurde, 1991; Kaemmerer, 2009; Ozdemir, 2009; Yogev *et al.*, 2009). No specific study was found on survival of *C. nebraskensis* exposed to ensiling processes. Proper ensiling is expected to kill most bacteria, while poor practices may allow survival around the edges of silage piles where temperatures did not reach the intended temperature level (T. Jackson-Ziems, pers. comm.). As there is no scientific evidence available on the efficacy of ensiling processes against *C. nebraskensis*, there is therefore uncertainty surrounding the role of silage or any resulting untreated manure as a source of inoculum. However, it is noted that silage production would remove most host debris from the field, i.e. reducing the inoculum in the field.

There is an uncertainty over whether silage could provide a source of inoculum.

2.4 Dispersal capacity

Clavibacter nebraskensis disperses passively. Within plants, it moves within vascular tissues. Between plants and fields, the bacteria present on living maize plants (as epiphytic populations or exudate) or on infested crop debris can disperse via contact between plants, water splash from rain, overhead irrigation, agricultural practices (e.g. machinery; Ikley, 2019; Harding *et al.*, 2018; Malvick *et al.*, 2025), wind-blown debris (Masiwa, 2025; Eggenberger *et al.*, 2016) or fauna (Eggenberger *et al.*, 2016). Dispersal from alternative hosts has not been demonstrated, but they are considered as potential reservoirs of the bacterium. Mechanisms of spread between fields and at longer distances are covered in section 11.

2.5 Environmental requirements

2.5.1 Temperature

Many sources present optimal temperatures for the disease development and the lethal temperatures for the pathogen, but all these appear to be based on only a few experimental studies.

Minimum temperature for survival or growth

- Schuster (1975) found that the bacterium retained pathogenicity up to 23 months (the longest period studied, not the maximum period of pathogenicity) in distilled water or mineral oil at 10°C.
- On growing medium in the laboratory (Vidaver & Mandel, 1974; Smidt & Vidaver, 1986), cultures grew at 10°C. On 10-14-day-old plants in growth chamber, retarded growth occurred at 12°C (Smidt & Vidaver, 1986).
- In the field, *C. nebraskensis* survives in plant debris in areas where winter temperatures are low. An analysis of (air) temperatures in a location in Nebraska where the bacterium was present (fig. 5 in Smidt & Vidaver, 1986) over several years shows minimum daily temperature reaching slightly below 0°C for a limited number of days in the year, and mean daily temperatures reaching slightly below 10°C. However, the pathogen is also found further north, where extreme temperatures are lower.

Low soil temperature in maize-growing areas in winter is not expected to kill the bacterium. In the USA and Canada, *C. nebraskensis* is reported from areas where minimum soil temperatures at 0-5 cm depth (°C) of the coldest month reach -10°C (see map in section 9.3.2).

The minimum temperature for survival and growth of *C. nebraskensis* is not known.

Occasional lower temperatures during the growing season are not considered to limit the survival.

The lethal temperature for the bacterium in winter in maize debris in the field is unknown. However, the bacterium remains viable in infested debris in locations where winter temperatures are clearly below 0°C.

Maximum temperature for survival and growth

On growing media in the laboratory, cultures did not grow at 37°C (both Vidaver & Mandel, 1974; Smidt & Vidaver, 1986). On 10-14-day-old inoculated plants in the growth chamber at 38°C, the pathogen died in about 1 day (Smidt & Vidaver, 1986). In experiments on growth, the pathogen did survive a day/night regime of 40/20°C (Smidt & Vidaver, 1986). *Clavibacter nebraskensis* can survive in areas where summer temperatures are high. An analysis of temperatures in a location of Nebraska where the bacterium was present (fig. 5 in Smidt & Vidaver, 1986) over several years shows maximum daily temperatures close to 40°C during a limited number of days, and mean daily temperatures reaching slightly above 30°C. The pathogen has been found further south, where extreme summer temperatures may be higher.

Exposure to 38°C for 1 day was lethal to *C. nebraskensis* in laboratory studies but it is expected that the pathogen could survive this temperature for short durations in the field. Such persistent high temperatures for 1 day or more are very unlikely to occur under field conditions. In most locations, daily fluctuations of temperatures would not kill the pathogen but would potentially slow its proliferation.

Optimal growth temperature

The optimal growth temperature of *C. nebraskensis* on growing medium is estimated to be around 26°C (Vidaver & Mandel, 1974; Smidt & Vidaver, 1986). In experiments on inoculated plants, shifting temperatures between a favourable day/night regime (32/25°C), and an unfavourable regime (40/20°C) and back, stopped and restarted bacterial growth (Smidt & Vidaver, 1986).

2.5.2 Relative humidity and rainfall

Several studies report that wet weather and high relative humidity favour proliferation and spread (e.g. Harding *et al.*, 2018). Mallowa *et al.* (2016) found that the disease incidence (symptoms on leaves) increased in higher artificial relative humidity (20-40% higher than ambient humidity) than in ambient humidity (of 10-30%, 12-25%, 40-60%). In contrast, Biddle *et al.* (1990) note that high relative humidity during seedling growth (85%, plastic-cover) had no detectable effect on transmission rate or symptom expression.

Hot, dry weather has been reported to slow disease development and makes symptoms difficult to distinguish from other disorders (Wise *et al.*, 2010). Nevertheless, Eggenberger *et al.* (2016) documented that disease incidence increased from infested debris in very dry growing seasons (with precipitation 40 to 80% lower than 30-year historical average), i.e. conditions that are usually unfavourable to disease development. The first detection of the bacterium in South Africa was during the 2023/2024 summer crop season, which was exceptionally hot and dry, leading farmers to report unknown symptoms; 4 out of 14 samples were confirmed with *C. nebraskensis* (Kgatlé, 2025).

Relative humidity and rainfall are not considered to affect survival of the bacterium, but are important for the development of the disease, spread and impact. However, information is lacking to take this into account in the PRA.

2.5.3 Extreme climatic events

Extreme weather events such as storms and hail can help the dispersal of *C. nebraskensis* and wound maize leaves (see section 2.6.3), providing entry points for the pathogen to infect plants (Harding *et al.*, 2018; Malvick *et al.*, 2025). Jackson *et al.* (2007a) found that wounds created by sandblasting⁵ during high winds often led to earlier infections and subsequently severe disease and yield losses, irrespective of the hybrid. However, they are not required for disease development.

2.5.4 Soil texture

Biddle *et al.* (1990) note that plant injury caused by sandblasting may be one of the factors explaining why the disease remains important in Nebraska because there ‘most of the corn is grown on sandy soils’. However, maize in Nebraska is also grown on other soils (T. Jackson-Ziems, pers. comm.).

Although sandy soil may be an aggravating factor when associated with extreme weather events, the disease also occurs in areas with other types of soil, therefore sandy soils are not a requirement for disease development.

2.6 Other factors favouring the pathogen

Other factors favouring the pathogen have been identified or hypothesised in the literature. The main factors are cultivar susceptibility and management practices that favour the persistence of infested crop debris.

2.6.1 Cultivar susceptibility

The susceptibility of maize genotypes to *C. nebraskensis* varies, and whilst there is no completely resistant maize hybrid (Calub *et al.*, 1974; Pataky, 1985 citing others; Malvick *et al.*, 2025), it is extremely rare to observe the disease on a resistant hybrid (A. Robertson, pers. comm.). **The term ‘resistant’ is used in this PRA in the same sense as in the literature, i.e. a good tolerance level but not complete resistance.**

In experiments, colonisation and development of leaf lesions were initially similar on a resistant and susceptible hybrid, but the resistant hybrid restricted the proliferation of *C. nebraskensis* and its movement within the xylem vessels (Mbofung *et al.*, 2016). Consequently, resistant cultivars are less likely to suffer from wilt, serious damage and death. No resistance breaking has been documented to date. Harding *et al.* (2018) noted that a risk of resistance-breaking strains remains because current genetic resistance is controlled by only a few loci.

⁵ The term ‘sandblasting’ describes any damage caused by wind-blown soil, and does not only refer to sandy soils.

Susceptibility affects disease incidence, disease severity and yield (Langemeier, 2017; Pataky, 1985; Jackson *et al.*, 2007a). In two adjacent fields with a similar yield history in Colorado, there was a difference of 63% in disease severity and yield between susceptible and resistant cultivars (ca. 12.2 vs. 4.5 t/ha⁶) (Jackson *et al.*, 2007a). Further data on yield and susceptibility are provided in section 12.

Cultivars in some maize types, such as popcorn and sweetcorn, appear to be more susceptible and are often mentioned as susceptible maize types (T. Jackson-Ziems, pers. comm.; Schuster *et al.*, 1975; Jackson *et al.*, 2007a; Wise *et al.*, 2010). This is consistent with the fact that selection of resistant cultivars is less likely for maize types like popcorn and sweet corn because the genetic pool is narrower (Jackson *et al.*, 2007a; Singh *et al.*, 2019).

Susceptibility also influences seed transmission (see section 2.3.3).

No information was found on the percentage of resistant versus susceptible maize grown in the USA.

Cultivar susceptibility is referred to throughout the assessment, but no data are available on the susceptibility/resistance level of cultivars that are imported or cropped in the EPPO region.

2.6.2 Agricultural practices favouring the persistence of infested crop debris

Continuous maize production (monoculture) and limited or no tillage practices allow the persistence of infested maize debris on the soil surface within fields, providing an inoculum reservoir for future infections (Wise *et al.*, 2010; Malvick *et al.*, 2025; Langemeier *et al.*, 2017).

Rotating out of maize production for one year allows the breakdown of debris and reduces *C. nebraskensis* levels in the field before the next maize crop is planted (Wise *et al.*, 2010). Bayer (2022) mention rotating two or more years without maize to be beneficial.

Tillage may maintain debris at or near the surface of the soil, while deep-ploughing buries debris greater than 10 cm (M. Delos, pers. comm.). In a study, the combination of no-tillage and leaving naturally infested debris on the ground resulted in 11.2% disease incidence, whilst burying debris via chisel plough (which loosens the soil) or moldboard plough (which inverts the soil) resulted in disease incidences of 1.1% and 0.04% respectively (Harding *et al.*, 2018 citing Mehl *et al.*, 2013). Deep-ploughing in the autumn reduces inoculum levels (Schuster, 1975). However shallow discing is more common, as deep tillage methods such as chisel or moldboard plough have negative effects on the soil (T. Jackson-Ziems, pers. comm.). Jackson *et al.* (2007a) recommend that debris is buried at least 60-90 days before planting. Lightly discing the residue in spring prior to planting also reduces inoculum levels (Jackson *et al.*, 2007a). Populations of the bacterium in debris will also naturally decline gradually over time (see section 2.3.1). The EWG noted that both tillage and deep-ploughing practices would be effective against the bacterium.

2.6.3 Wounding of maize plants

Although infection can occur in the absence of wounding (see section 2.2), infections were found to increase more rapidly through wound-inoculated maize stands than non-wounded stands (in both cases with infested maize debris as source of infection) (Eggenberger *et al.*, 2016). Wounds can be caused by extreme weather events (heavy rain, hail, strong winds transporting soil and crop debris) (Harding *et al.*, 2018; Malvick *et al.*, 2025; Rocheford *et al.* 1985) and insect feeding (Wise *et al.*, 2010). Wounds caused by sandblasting during high winds often leads to severe disease and yield loss, irrespective of the hybrid (Jackson *et al.*, 2007a).

2.6.4 Plant density in maize fields

Plant density influences disease occurrence, with the disease having been found in 75% of samples with a plant density above 67,500 seeds/ha (Langemeier *et al.*, 2017). Higher densities may lead to more contact between plants and create a favourable microclimate with higher humidity (Langemeier *et al.*, 2017). This factor is not mentioned in the management recommendations (see section 12.1).

⁶ Converted from '195 vs. 72 bu/acre'. For bushels, using the current USDA standard weight of a maize grain bushel, 56 pounds, i.e. 25.4 kg. 1 acre = 0.4047 ha. Figures obtained in kg were rounded to tonnes.

2.6.5 Irrigation

The disease may occur in fields regardless of irrigation practices, although irrigation may increase disease development (Malvick *et al.*, 2025). Splashes from overhead irrigation water can disperse the bacterium from infected to uninfected leaves, with extensive overhead irrigation in Nebraska suspected to have exacerbated the disease (Biddle *et al.*, 1990). In surveys, the bacterium was more often associated with samples from fields with centre pivot irrigation (Langemeier *et al.*, 2017), maybe due to creating a more humid environment and/or splash dispersal of the bacteria. In addition, agricultural practices connected to overhead irrigation might cause damage to the plants.

2.6.6 Presence of alternative hosts in maize fields

The role of alternative hosts in the disease epidemiology is unclear (see section 2.3.4) but removing them is part of recommended management methods (section 12.1). Theoretically, plants that support epiphytic populations in the field may also play a role in the epidemiology; however, epiphytic populations on plants other than maize has been shown only experimentally (see section 7).

2.7 Nature of the damage on maize plants

Damage to maize plants ranges from leaf blight to a systemic vascular wilt. Plants can be infected and show blight, wilt or die at any stage of development (Schuster, 1975).

Blight lesions can affect large areas of the leaf surface, leading to premature leaf death (Shepherd, 1999; Jackson *et al.*, 2007b). Leaf blight is more frequent than vascular wilt, but causes less yield losses than wilt (Langemeier, 2017; Wise *et al.*, 2010; Malvick *et al.*, 2025).

In the wilt phase, bacterial cells in the vascular bundles prevent water transportation (Langemeier *et al.*, 2017). Vascular wilt is often first observed in early vegetative growth stages of maize (V2-V6) (Malvick *et al.*, 2025), and can lead to stunting and progress to stalk rot and death (Jackson *et al.*, 2007a; Schuster, 1975). Infected young plants may die, while older plants may fail to reach normal size, form ears or tassels, and/or present reduced kernel fill (Harding *et al.*, 2018; Schuster, 1975).

Ears produced by infected plants can be smaller (Suparyono & Pataky, 1989b), resulting in effects on yield (see section 12). A study on grain quality showed significant reduction of the 1000-seed weight in plots with high disease severity (>5% leaf area affected) compared to low disease severity (0-5% leaf area affected), whilst there was no difference in test weight, protein content, moisture, starch or oil content (Robertson *et al.*, 2012; A. Robertson, pers. comm.). Whilst no study was found on how seed germination is affected, Schuster (1975) notes that severe seed infection may have a negative effect on germinability. As an indirect damage, lodging (i.e. bending of stems) can occur as systemically infected stems weaken (Malvick *et al.*, 2025). Also, symptomatic plants are predisposed to stalk rots caused by *Fusarium* spp., *Colletotrichum graminicola* and *Stenocarpella maydis* which themselves can also lead to increased lodging (A. Robertson, pers. comm.).

2.8 Signs and symptoms of infection

On maize plants, *C. nebraskensis* causes leaf blight and vascular wilt symptoms, but it can also be asymptomatic and survive epiphytically. Symptoms are illustrated in ANNEX 2.

Leaf blight on maize

Symptoms can include:

- Initial lesions as streaks of light green water-soaked tissue (Malvick *et al.*, 2025; Jackson *et al.*, 2007b).
- Progressing to large lesions, elongated, with irregular or wavy margins parallel to the veins (Schuster, 1975; Malvick *et al.*, 2025; Jackson *et al.*, 2007b; Langemeier *et al.*, 2017). The colour can vary: tan to greyish-brown (Malvick *et al.*, 2025; Jackson *et al.*, 2007b), grey to light yellow (Jackson *et al.*, 2007b), light greenish-yellow, occasionally reddish depending on hybrid or inbred (Schuster, 1975), grey and can have darker discoloured, water-soaked margins (Langemeier *et al.*, 2017). The margins of *C. nebraskensis* lesions are not always distinct, and the diseased tissue can “fade into” healthy tissue (A. Robertson, pers. comm.).

- At the leading edges of expanding lesions, dark green to black, discontinuous water-soaked spots (“freckles”) (Malvick *et al.*, 2025; Jackson *et al.*, 2007a; Schuster, 1975; Langemeier *et al.*, 2017), along the veins (Schuster, 1975). Freckles are around 1 mm² and cannot be rubbed off plant tissue (Wise *et al.*, 2010; Ahmad *et al.*, 2015). Saprophytic fungi growing on dead tissue are very often mistaken for freckles (see below). In recent observations on some cultivars in the USA, freckles were missing from lesions caused by *C. nebraskensis* (T. Jackson-Ziems, pers. comm.).
- On susceptible cultivars, lesions can coalesce and cover large parts of the leaf surface (Shepherd 1999).

Bacterial exudate can be present on leaves especially early in the morning when humidity is high. Exudate is described as sticky before drying (Kloppers, 2025a; Manitoba Agriculture, 2019). When dried, it is shiny (similar to dried varnish) (Malvick *et al.*, 2025; Jackson *et al.*, 2007b), especially when observing leaves in direct sunlight (Wise *et al.*, 2010; Langemeier *et al.*, 2017).

Leaf symptoms on other hosts and experimental hosts. In inoculation experiments, red vein discoloration and long red or small irregularly shaped lesions following the leaf veins were observed on shattercane, grain sorghum, sudangrass (all three *Sorghum bicolor* - see section 7) and sugarcane (*Saccharum officinarum*) (Schuster, 1975). Water-soaked freckled necrotic lesions and reddening of the leaf from the inoculation site were seen on *Digitaria sanguinalis* (large crabgrass), *Lolium multiflorum* (annual ryegrass), *Eriochloa villosa* (woolly cupgrass), *Andropogon gerardii* (big bluestem), *Schizachyrium scoparium* (little bluestem) and *Euchlaena mexicana* (teosinte) in experiments (Webster *et al.*, 2019). In a study on *L. multiflorum*, *Setaria faberi* and *Sorghum halepense*, lesions never exceeded 65% of inoculated leaves (Ikley, 2019).

Vascular wilt on maize

Symptoms can include:

- Leaves of infected seedlings may stick together due to bacterial exudate. In older plants, this may prevent emergence of tassels and cause the stalk to bend in the form of a loop (Schuster, 1975).
- Orange to brown discoloration of vascular/xylem tissues and water-soaked slimy stalk rot (Malvick *et al.*, 2025; Jackson *et al.*, 2007b; Wise *et al.*, 2010). The orange bacterial exudate can ooze when the stalk is cross-sectioned. In severe infections, exudate can form pockets of pure culture in the pith (Schuster, 1975).
- Discoloration of interior nodes and internodes, three or more above the adventitious roots, and general crown or basal rotting (Schuster, 1975).
- An orange colour can appear on the husks and kernels (Harding *et al.*, 2018). In heavily infected kernels, the orange bacterial colonies can be observed with the naked eye (Schuster, 1975).
- Wilted, stunted, lodged and dead plants (Malvick *et al.*, 2025; Jackson *et al.*, 2007b; Kloppers, 2025a) (which all may be caused by other diseases as well).

2.9 Detection methods and confusion with other causes

Visual inspection. Symptoms can be present on maize at any development stage (Schuster, 1975). Some symptoms may be misdiagnosed as other diseases (see *Confusion* below).

The symptom unique to *C. nebraskensis* is ‘freckles’ (see above) which appear translucent when the leaf is held up to the light (Bayer, 2022). Since freckles are the most distinguishing symptom, it is important not to confuse saprophytic fungal growth with freckles caused by this pathogen. When the leaf is backlit, freckles appear translucent; saprophytic fungi remain dark (A. Robertson, pers. comm.). Note that some, especially newer, hybrids may not develop obvious freckles requiring additional testing for disease diagnosis (T. Jackson-Ziems, pers. comm.).

Other symptoms/signs that are useful for diagnosis are:

- Bacterial streaming, easily seen from infected tissues under a microscope.
- In case of vascular wilt affected plants, cutting the stalk shows discoloration of the vascular elements and bacterial exudate that may ooze from the cut, especially when the stalk is under pressure.

Low levels of infection can remain undetected, as initial infection may begin in small clusters of infected plants or individual infected plants in a large field. There may also be asymptomatic infections (epiphytic populations) (Eggenberger *et al.*, 2016). The detection of ‘sudden outbreaks’ may be due to multiple infection

cycles over several growing seasons (Eggenberger *et al.*, 2016). Several authors mention that symptoms are more obvious near/after silking (R1 growth stage), and those symptoms are likely the result of infection during the vegetative grow stages. When visual detectable symptoms are present in the early development of the plant, there is a higher probability of a greater yield loss, because the disease progresses throughout the R stages (Harding *et al.*, 2018; Malvick *et al.*, 2025; A. Robertson, pers. comm.).

Symptoms on other hosts are not used to detect the disease. Webster *et al.* (2019) mention that monitoring of grasses for infection in field experiments is complicated due to factors such as infection by other pathogens and a lack of specific growing media.

Immunoreactions

An ELISA test kit (Neogen®) and Agdia ImmunoStrips® developed for *C. michiganensis* can detect *C. nebraskensis* but cannot discriminate consistently between this and other *Clavibacter* species (Korus, 2011). In addition, Agdia ImmunoStrip® also gives strong positive reactions with four isolates of *Ochrobactrum* sp. and *Microbacterium* sp. (Harding *et al.*, 2018). High sensitivity of the test can lead to false positive results in healthy plant samples that are surface-contaminated with *C. nebraskensis*. In Nebraska, positive reaction on the immunostrip in combination with microscopic confirmation of bacterial streaming from cut, symptomatic tissue, and visible symptoms are used to confirm the disease. Others are also combining those with the Gram staining test (T. Jackson-Ziems, pers. comm.). A microsphere immunoreaction was developed for the simultaneous detection of *C. nebraskensis* and *Pantoea stewartii* subsp. *stewartii* (Zhang *et al.*, 2013).

Molecular methods

For detection at import or low levels of incidence, molecular methods are available. Several PCR-based assays specific to *C. nebraskensis* exist (such as McNally *et al.*, 2016; Pastrik & Rainey, 1999; Yasuhara-Bell *et al.*, 2016; Waleron *et al.*, 2011; Larrea-Sarmiento *et al.*, 2019). Tambong *et al.* (2016) exploited genome data for the development of a multiplex TaqMan real-time PCR tool for rapid detection (Harding *et al.*, 2018).

Look alike diseases and disorders

- ***Exserohilum turcicum*** (northern corn leaf blight) lesions may be confused with *C. nebraskensis*, but they are cigar-shaped with more distinct margins between the healthy and infected tissue and lack freckles and bacterial exudate (Malvick *et al.*, 2025; A. Robertson, pers. comm.). Some photos are available in EPPO Global Database (EPPO, 2025b).
- ***Pantoea stewartii* subsp. *stewartii*** (Stewart's wilt) may cause leaf blight and similar water-soaked lesions with wavy or irregular margins (Schuster, 1975 citing others; Malvick *et al.*, 2025). However, *P. stewartii*'s lesions lack freckles (Malvick *et al.*, 2025). Streaks of *P. stewartii* are longer and might be clearer differentiated compared to the more oval lesions of *C. nebraskensis* (in leaf blight) (R. Glenz, pers. comm.). Wilting symptoms cannot be differentiated easily. Some photos are available in EPPO Global Database (EPPO, 2025b).
- **Drought/heat stress.** When leaf lesions caused by *C. nebraskensis* coalesce, damage can be confused with the effects of drought or hot drying winds (Jackson *et al.*, 2007b). The brown discoloration (leaf scorch and necrosis) caused by drought/heat stress tends to be more uniform in colour than that of *C. nebraskensis*, and the necrotic tissues do not present freckles, shiny bacterial exudate or bacterial streaming (Njom *et al.*, 2025). Plants that are systemically infected by *C. nebraskensis* may wilt and appear drought stressed (Harding *et al.*, 2018; Wise *et al.* 2010). In South Africa, when symptoms were reported, 14 symptomatic samples were submitted, of which only four tested positive; the negative samples were affected by severe heat and drought causing sunscald (Kgatle, 2025).
- **Other abiotic factors.** Wilt symptoms may be confused with leaf scorch from chemical burn, and leaf blight symptoms with nutrient deficiency or chemical injury (Wise *et al.*, 2010).

In the EPPO region, many pathogens cause leaf lesions on maize that may be confused with *C. nebraskensis*, including the bacteria *Dickeya zeae* (*Erwinia chrysanthemi* pv. *zeae*) and *Pantoea ananatis*, and the fungi *Bipolaris zeicola* (*Helminthosporium carbonum*), *Cochliobolus heterostrophus*, *Colletotrichum graminicola*, *Diplodia macrospora*, *Diplodia maydis* (*Stenocarpella maydis*), *Gibberella zeae* (a non-exhaustive list assembled by the EWG).

2.10 Identification

Identification can be performed using morphological and molecular methods. As for other bacteria, a combination of several methods is likely necessary for a confirmed diagnosis, and a pathogenicity test may be performed as final confirmation of infection and for assessment of the virulence of cultures (Flores-López *et al.*, 2024 citing Gross & Vidaver 1978; EPPO, 2016a & b; EPPO, 2021a, EPPO, 2022 – EPPO standards on diagnostics for *Pantoea stewartii* subsp. *stewartii*, *C. michiganensis*, *C. insidiosus* and *C. sepedonicus*). Isolation may be necessary for several identification methods such as morphological, biochemical, sequencing or pathogenicity tests. In South Africa, the bacterium was identified by morphological and molecular methods (PCR and high-throughput sequencing) and verification of Koch's postulates (Coertze *et al.*, 2025).

Noting that there were only 13 publicly available genomes of *C. nebraskensis* (9 complete and 4 draft) in NCBI (at the time), Flores-López *et al.* (2025a) added 16 complete and 2 draft genomes of *C. nebraskensis* strains, isolated from symptomatic maize leaves from Mexico (see section 6).

Genome information for *C. nebraskensis* is still increasing but reliable molecular detection/identification tests are already available. A seed testing procedure exists (Shepherd *et al.*, 2017). Testing procedures are being investigated in the EPPO region:

- In Lombardia (Italy), small-scale laboratory tests were carried out, on plants, to evaluate the effectiveness of the PCR method described by Larrea-Sarmiento *et al.* (2019) to detect *C. nebraskensis*. The test was performed on reference material (pure colonies) and on DNA extracted from artificially infected plants. To date, seed samples, intended for export, have been analysed using the method described by Shepherd *et al.* (2017) and no infected seeds were found. The crude extract is analysed by plate culture, while the colonies and DNA are analysed by the PCR method in Larrea-Sarmiento *et al.* (2019). The method described by Shepherd *et al.* (2017) is still under evaluation (F. Gaffuri and M. Ciampitti, personal communication).
- In Germany, initial lab tests have been performed on seed testing with high concentrations of *C. nebraskensis* and *Pantoea stewartii* subsp. *stewartii* (and both). The bacteria were reliably detected from artificially-contaminated washed and dried seeds by molecular tests (Tambong *et al.* 2016, McNally *et al.* 2016; Pastrik & Rainey 1999); and from the shoot basis of young seedlings grown from infected seeds, as well as from leaf extracts from artificially infected plants (R. Glenz, pers. comm.).

3 Is the pest a vector?

Yes ☐ No ☒

4 Is a vector needed for pest entry or spread?

Yes ☐ No ☒

Insects are not known to be involved in the transmission of *C. nebraskensis*, unlike in the case of *Pantoea stewartii*, which is transmitted by its vector the corn flea beetle *Chaetocnema pulicaria* (Shepherd, 1999; Wise *et al.*, 2010). Nevertheless, insects may play a role in spreading the bacterium mechanically (see section 2.4).

5 Regulatory status of the pest

In the EPPO region (at 2025-07), *C. nebraskensis* is a quarantine pest for Israel (Israel Ministry of Agriculture and Rural Development, 2009).

Information about the regulatory status of *C. nebraskensis* elsewhere in the world was sought (2025-12) from lists of regulated pests in EPPO Global Database (EPPO, 2025b), on the International Phytosanitary Portal (<https://www.ippc.int/fr/countries/all/regulatedpests/>, IPP, 2025) and from a general internet search. *Clavibacter nebraskensis* is regulated in many countries, at least: New Zealand (Biosecurity New Zealand, 2025), Mauritius (Mauritius Government, 2006); Botswana, Egypt, Ghana, Argentina, Bolivia, Brazil, Chile, Ecuador, Mexico, Paraguay, Peru, Venezuela, China, India, Indonesia, Korea Rep., Japan, Singapore (as *nebraskense*), Sri Lanka and Thailand (IPP, 2025). The information consulted is not exhaustive and *C. nebraskensis* may be regulated in more countries.

EPPO Global Database (EPPO, 2025b) indicates an 'A2' status for COSAVE and APPPC. However:

- for COSAVE, the labels 'A1' and 'A2' are used only to reflect the COSAVE categories I and II, respectively. Category I represents quarantine pests absent in all COSAVE countries whilst Category II represents quarantine pests in at least 4 countries. *C. nebraskensis* is a quarantine pest for Argentina, Bolivia, Brazil, Chile, Paraguay and Peru (COSAVE, 2024), and not for Uruguay (Uruguay, 2025).
- for APPPC, the A2 status is dated from 1993 and it was not possible to check it (see also section 6).

A pest alert was issued by the Pest Outbreak Alert and Response System (POARS) of the International Plant Protection Convention (IPPC, 2025).

6 Distribution

To date, *C. nebraskensis* has been reported in the USA, Canada and South Africa. A record from Mexico is discussed further down. The distribution of *C. nebraskensis* is illustrated in Fig. 3 and detailed in Table 1.

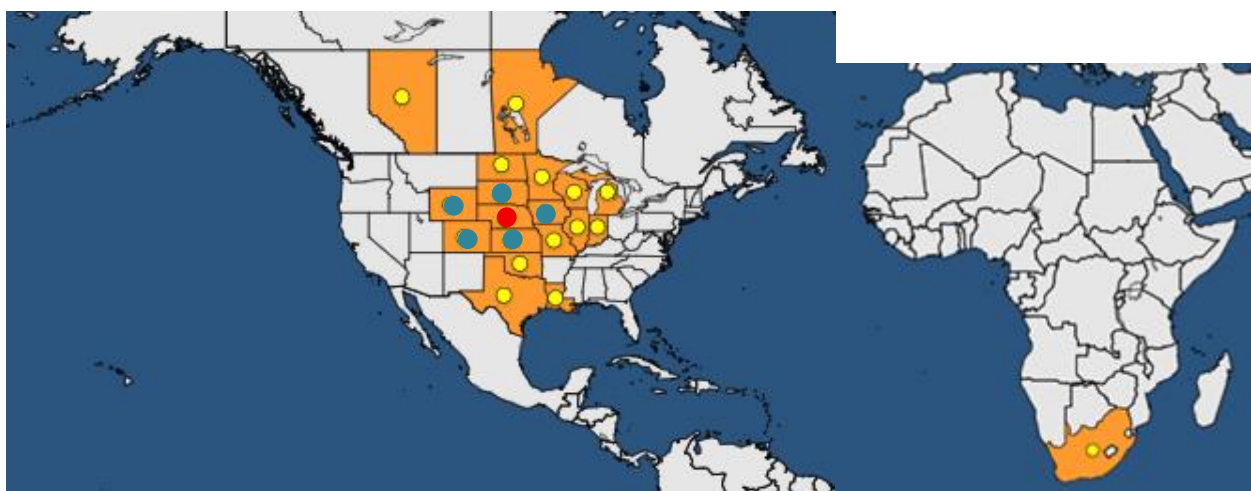


Fig. 3. Distribution of *Clavibacter nebraskensis* from EPPO Global Database (EPPO, 024b). **Red**: Nebraska (first report); **Blue**: 1970s: Colorado, Iowa, Kansas, South Dakota, Wyoming; **Yellow**: records from 2000s onwards.

Table 1. Distribution of *Clavibacter nebraskensis*.

Records of presence are from EPPO Global Database (EPPO, 2025b), which provides original references.

	Countries and states/provinces with reports of <i>Clavibacter nebraskensis</i>
Africa	South Africa (introduced): provinces of Eastern Cape, Free-State, Gauteng, North-West, Mpumalanga, Western Cape ⁷ , Northern Cape ⁷ , Limpopo ⁷ . <i>Uncertain records</i> : KwaZulu Natal.
North America	USA: Nebraska (first finding, 1969), Colorado, Iowa, Kansas, South Dakota, Wyoming (1970s), Illinois, Indiana, Louisiana, Michigan, Minnesota, Missouri, North Dakota, Oklahoma ⁸ , Texas, Wisconsin (from 2000s onwards). <i>Uncertain records</i> : Ohio and Montana are mentioned in the map of CISEH (2025). No published record was found. Absent from Ohio as of 2012 (https://ocj.com/2012/03/will-gosss-wilt-be-a-challenge-in-2012/). There are no reports/official confirmations from Ohio and Kentucky (A. Robertson, pers. comm.). Canada: Alberta (2013), Manitoba (2009) (Harding <i>et al.</i> , 2018).

⁷ Records for three provinces became available in April 2026 (South Africa Department of Agriculture, 2026): Western Cape and Northern Cape are new records and Limpopo was an uncertain record during the preparation of the PRA. These records are not fully taken into account in other sections. The assessment in the PRA was conducted with Eastern Cape, Free-State, Gauteng, North-West, Mpumalanga, and uncertain records Limpopo and KwaZulu Natal. It is noted that the Köppen Geiger climate types in the new records would not change the result of the climatic suitability assessment.

⁸ This record was found late during the preparation of the PRA, and is not mentioned in other sections. As climatic conditions are similar to adjacent states, it would not change the result of the assessment.

	Countries and states/provinces with reports of <i>Clavibacter nebraskensis</i>
	<i>Absent</i> : Ontario, Quebec. First observed in Ontario in 1999 based on symptoms (Zhu <i>et al.</i> , 2000) but positive identification was not made (Harding <i>et al.</i> , 2018). Extensive surveys in Ontario (2014 and 2015) and Quebec (2012), did not find <i>C. nebraskensis</i> (Harding <i>et al.</i> , 2018). No newer record was found.
	Mexico (uncertain records): Tlaxcala, Coahuila. See note below the table.

In South Africa, *C. nebraskensis* was first detected in 2024 from samples collected in maize farms in the provinces of Free State, North-West and Gauteng, and its presence was also reported in the Eastern Cape based on visual inspection of samples (IPPC, 2025, notification dated 14 March). Coertze *et al.* (2025) report isolates from the provinces of Gauteng and Mpumalanga. The records for Limpopo (Kgatle, 2025) and KwaZulu Natal (Kloppers, 2025b) are considered uncertain due to the nature of the publications.

Kloppers & Heuchlin (2024) mention that the disease may have been present undetected for several growing seasons. One farmer in Free State reported seeing symptoms in the season prior to identification of *C. nebraskensis*, but the cause was not identified at the time (van Rooyen, 2025). In 2025-11, Spandiel (2025, citing various sources) reported that the disease has remained contained locally ('partly due to low inoculum levels in the environment and weather conditions in recent seasons that were not favourable for its spread'). A national delimiting survey was conducted in the growing season 2025-2026, and confirmed the presence of *C. nebraskensis* in the provinces of Eastern Cape, Free-State, Gauteng, North-West, Mpumalanga, as well as in Eastern Cape, Northern Cape and Limpopo⁷, and no finding in KwaZulu Natal (South Africa Department of Agriculture, 2026).

In Mexico, Flores-López *et al.* (2024) identified strains from samples of several symptomatic maize crops in Tlaxcala in 2021 and from previous sampling in Coahuila in 2012. Flores-López *et al.* (2025a) provided 18 genomes from those strains. Further analyses showed a phylogeographic structure, with strains of Mexican origin forming a 'distinct yet closely related' cluster to those of the USA (Flores-López *et al.*, 2025b).

In 2025-05, the NPPO of Mexico informed the EPPO Secretariat that the results of Flores-López *et al.* (2024) cannot be used to indicate presence, in particular due to the lack of data on the origin of the seed used to grow infected crops, of precise location of infected crops, and the fact that the strains reported in the study belong to several clades. The NPPO of Mexico did not detect *C. nebraskensis* during targeted surveillance in 2024 in the localities mentioned. *Clavibacter nebraskensis* is included in regular surveillance because of its quarantine status, and further monitoring will be conducted in 2025 and 2026 (EPPO, 2025c).

Flores-López *et al.* (2024), referring to a Mexican bacteria collection database, also mention earlier occasional findings in several Mexican states (Sinaloa, 2011; Coahuila, 2012; Veracruz, 2013; Durango, Tlaxcala and Oaxaca, 2014).

Until more information is available, the PRA takes account of records in Tlaxcala and Coahuila in Mexico as a precautionary approach.

Although *C. nebraskensis* is listed as an A2 pest for the APPPC in EPPO Global Database (EPPO, 2025b) (see section 5), no evidence was found of its presence in Asia or the Pacific. This is not further considered in this PRA.

7 Host plants and their distribution in the PRA area

Natural infections of *C. nebraskensis* have been found on three Poaceae species: *Zea mays* (maize), *Setaria viridis* and *Sorghum bicolor* (see Table 2 and note below the table). All maize types can host the bacterium, although some are more susceptible (see section 2.6.1). Details on the presence of confirmed hosts in the EPPO region are given in section 9.1.

Many other Poaceae species were shown to be experimental hosts in inoculation trials (Table 3).

Experimental hosts are not detailed throughout the PRA (as normal in EPPO PRAs), but some elements are provided where relevant.

Table 2. Confirmed hosts of *Clavibacter nebraskensis* (Poaceae).

Confirmed hosts	Presence in PRA area	Reference
<i>Zea mays</i> , maize	Yes, widely cultivated	All references on <i>C. nebraskensis</i> , incl. Schuster, 1975
<i>Setaria viridis</i> , green foxtail	Yes, native to a large part of the region, introduced elsewhere (Euro+Med, 2025)	Schuster, 1975 (host in the field and experimental); Langemeier <i>et al.</i> , 2014 (experimental); Ikley <i>et al.</i> , 2015 (experimental)
<i>Sorghum bicolor</i> , shattercane See note below the table	Yes, at least in Europe	Schuster, 1975, as <i>S. bicolor</i> ; Ikley <i>et al.</i> , 2015 (experimental); See note below the table

Note: Taxonomic issue for *Sorghum bicolor*. Schuster (1975) reported natural infection of ‘shattercane’ (a weed), and experimental infection of shattercane, sudangrass and grain sorghum, respectively named in his article as *S. bicolor*, *S. vulgare sudanense* and *S. vulgare*. All three are currently classified as subspecies of *S. bicolor*. Grain sorghum is *S. bicolor* subsp. *bicolor*, while the taxonomic status of shattercane and sudangrass is unclear. Kanatas *et al.* (2021 citing others) consider shattercane and sudangrass as subsp. *drummondii*, while Mohler *et al.* (2021) consider shattercane subsp. *verticilliflorum*, noting that some authors use nothosubsp. *drummondii* for shattercane while others use subsp. *drummondii* for sudangrass. Publications from the USA on shattercane as weed often name it only *S. bicolor*⁹. In this PRA, shattercane is included among hosts and grain sorghum and sudangrass among experimental hosts, with the same scientific name, *S. bicolor*. Common names are used when there is a need to differentiate confirmed hosts from experimental hosts in the assessment.

Table 3. Experimental hosts of *Clavibacter nebraskensis* (all in the family Poaceae).

In relation to Webster *et al.* (2019), the EWG included as experimental hosts all plants on which inoculum >10⁶ CFU/leaf sample was found, with symptoms or as epiphytic populations. Details are provided in the table.

Experimental hosts	Presence in PRA area	Comments	Reference
<i>Andropogon gerardii</i> , big bluestem	Yes, available as an ornamental	Consistent expanding lesions and bacterial streaming, populations >10 ⁷ CFU/leaf sample 3 weeks post-inoculation	Webster <i>et al.</i> 2019
<i>Avena sativa</i> , oat*	Yes, widely cultivated	Detected 4 weeks after inoculation at 10 ⁶ -10 ⁷ CFU/leaf sample, without symptoms or bacterial streaming (epiphytic)	Webster <i>et al.</i> , 2019
<i>Digitaria sanguinalis</i> , large crabgrass	Yes, native in a wide area, introduced elsewhere, widespread (Euro+Med, 2025)	Consistent expanding lesions and bacterial streaming, populations >10 ⁷ CFU/leaf sample 3 weeks post-inoculation (Webster <i>et al.</i>)	Ikley, 2015; Webster <i>et al.</i> 2019
<i>Eriochloa villosa</i> , woolly cupgrass	Yes, native in Far-East Russia, introduced and invasive in other parts of EPPO (POWO, 2025; Lele <i>et al.</i> , 2025)	Consistent expanding lesions and bacterial streaming, populations >10 ⁷ CFU/leaf sample 3 weeks post-inoculation	Webster <i>et al.</i> 2019
<i>Euchlaena (Zea) mexicana</i> , teosinte	Yes, local presence as weed in France and Spain (M. Delos, pers. comm.)	Consistent expanding lesions and bacterial streaming, populations >10 ⁷ CFU/leaf sample 3 weeks post-inoculation	Schuster, 1975; Webster <i>et al.</i> 2019
<i>Hordeum vulgare</i> , barley*	Yes, widely cultivated	Detected 4 weeks after inoculation at 10 ⁶ -10 ⁷ CFU/leaf	Webster <i>et al.</i> , 2019

⁹ e.g. <https://ipm.ucanr.edu/PMG/WEEDS/shattercane.html>;
https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_sobi2.pdf

Experimental hosts	Presence in PRA area	Comments	Reference
		sample, without symptoms or bacterial streaming (epiphytic)	
<i>Lolium multiflorum</i> , annual ryegrass	Yes, native in a wide area, introduced elsewhere, widespread (Euro+Med, 2025)	Consistent expanding lesions and bacterial streaming, populations $>10^7$ CFU/leaf sample 3 weeks post-inoculation)	Ikley, 2015; Webster <i>et al.</i> 2019
<i>Panicum capillare</i> , witchgrass	Yes, native to a limited part of EPPO, introduced elsewhere, widespread (Euro+Med, 2025)	Inconsistent lesions and bacterial streaming 4 weeks after inoculation, populations of 10^6 - 10^7 CFU/leaf sample)	Webster <i>et al.</i> , 2019
<i>Panicum miliaceum</i> , Proso millet	Yes, native to a limited part of EPPO, introduced elsewhere, widespread (Euro+Med, 2025)	Inconsistent lesions and bacterial streaming 4 weeks after inoculation, populations of 10^6 - 10^7 CFU/leaf sample)	Webster <i>et al.</i> , 2019
<i>Saccharum officinarum</i> , sugarcane	Sugarcane no longer cultivated commercially in Andalucía, but some anecdotal plot may exist for touristic purposes https://motrilturismo.com/es/rutas/rutas-culturales/ruta-cana-azucar-y-ron		Schuster, 1975
<i>Schizachyrium scoparium</i> , little bluestem	Yes, available as an ornamental	Consistent expanding lesions and bacterial streaming, populations $>10^7$ CFU/leaf sample 3 weeks post-inoculation)	Webster <i>et al.</i> 2019
<i>Secale cereale</i> , rye*	Yes, widely cultivated	Detected 4 weeks after inoculation at 10^6 - 10^7 CFU/leaf sample, without symptoms or bacterial streaming (epiphytic)	Webster <i>et al.</i> , 2019 as winter ryegrass/ winter cereal rye
<i>Setaria faberi</i> , giant foxtail	Yes, native in W. Siberia, Russian Far East. Introduced to parts of EPPO (POWO, https://alienplantsbelgium.myspecies.info/content/setaria-faberi)		Langemeier <i>et al.</i> , 2014
<i>Setaria pumila</i> , yellow foxtail	Yes, native in a large part of EPPO, introduced elsewhere, widespread (Euro+Med, 2025)		Ikley <i>et al.</i> , 2015; Langemeier <i>et al.</i> , 2014
<i>Setaria verticillata</i> , bristly foxtail	Yes, native in a large part of EPPO, introduced elsewhere, widespread (Euro+Med, 2025)		Langemeier <i>et al.</i> , 2014
<i>Sorghum bicolor</i> as a- grain sorghum	a- at least France, Italy, Hungary, Romania, Bulgaria, Austria and Greece (ref)	See note below the table	Schuster, 1975 as <i>S. vulgare</i> and <i>S. vulgare sudanense</i> See note below the table

Experimental hosts	Presence in PRA area	Comments	Reference
b- sudangrass See note above this table	b- at least in Black Sea area, parts of E Europe, Russia (POWO, 2025)		
<i>Sorghum halepense</i> , Johnsongrass	Native in southern Mediterranean to Central Asia, and introduced in a large part. Wild and weed (Andújar <i>et al.</i> , 2013, POWO, 2025; Euro+Med, 2025)		Ikley, 2019, citing Ikley, 2015
<i>Tripsacum dactyloides</i> , eastern gamagrass	Yes, available as an ornamental.		Schuster, 1975
<i>Triticum aestivum</i> , wheat*	Yes, widely cultivated	Detected 4 weeks after inoculation at 10 ⁶ -10 ⁷ CFU/leaf sample, without symptoms or bacterial streaming (epiphytic)	Webster <i>et al.</i> , 2019 as spring wheat

* Regarding the experimental hosts wheat, barley, oat and rye, the EWG noted that *C. nebraskensis* has never been observed on at least wheat, rye and oat in the field in Nebraska, despite the fact that these cereals are grown in the same areas as maize (T. Jackson-Ziems, pers. comm.).

Uncertain hosts

***Echinochloa crus-galli*.** *C. nebraskensis* was isolated from this plant, but there is no evidence that this plant can be infected (Webster *et al.*, 2019 citing Schuster, 1972, Wysong *et al.*, 1981). No other host record was found (apart from citations of Wysong *et al.*, 1981 in other articles).

Other Poaceae. In experiments, Poaceae species differed in their capacity to host the pathogen (Ikley *et al.*, 2015) and not all Poaceae species are considered as hosts in this PRA. Studies on experimental hosts in the USA have focused on plants occurring in maize-growing areas, and other Poaceae species may be hosts or experimental hosts. In addition, the confirmed host *S. viridis* and various experimental hosts are not native from North America but from the EPPO region. The bacterium may be able to infect more Poaceae species than those listed above.

Non-Poaceae. In inoculation experiments, none of the non-Poaceae species tested were found to be hosts (Schuster, 1975; Webster *et al.*, 2019). Webster *et al.* (2019) note that *Helianthus annuus*, *Glycine max*, *Fagopyrum esculentum*, *Amaranthus tuberculatus* and *A. retroflexus* did not develop symptoms and bacterial streaming. They supported epiphytic populations <10⁶ CFU/sample one month after inoculation and may have a role in the epidemiology of the disease. However, it is not known how long *C. nebraskensis* can survive on these species, but it may be long enough to allow the pathogen to infect maize. Due to the low population level, these were considered as uncertain hosts.

No host records

***Saccharum spontaneum*.** Ikley (2019) cites Schuster (1975), but the latter only mentions *S. officinarum*.

8 Pathways for entry

The maize pathways in this section are divided according to the plant parts they include. The different intended uses influence transfer and are covered under individual pathways.

The terms ‘seed’ and ‘grain’ are used in line with definitions in ISPM 5 (IPPC Secretariat, 2025):

- *seeds (as a commodity)* – seeds (in the botanical sense) for planting,
- *grain (as a commodity)* – seeds (in the botanical sense) for processing or consumption, but not for planting.

It should be noted that the description of customs code in trade databases do not always use these words. Relevant customs codes were considered under the pathway and their names given as in the trade databases (italicised).

The following pathways for entry of *C. nebraskensis* are discussed in section Erreur ! Source du renvoi introuvable.:

- Seeds of *Zea mays* (section 8.1.1)
- Grain of *Zea mays* (kernels for processing or consumption, either separated or attached to the cobs (ears) including sweet corn with or without husks) (section 8.1.2)
- Other maize plant parts (section 8.1.3)
- Contamination by infested plant debris (of soil on its own, used machinery and vehicles, shipping containers, traveller's footwear) (section 8.1.4)

The following pathways are considered very unlikely and are discussed in section 8.2:

- Plants for planting of *Zea mays* (except seeds)
- Maize silage
- Maize decorations and objects
- Processed maize
- Seed of *Sorghum bicolor* and *Setaria viridis*
- Grain of *Sorghum bicolor*
- Contamination by plants for planting (except seeds) or debris of *Sorghum bicolor* and *Setaria viridis*.
- Natural spread

8.1 Pathways for entry

Note that in this section information on import prohibitions and phytosanitary measures is provided only for some countries of the PRA area (see individual pathways).

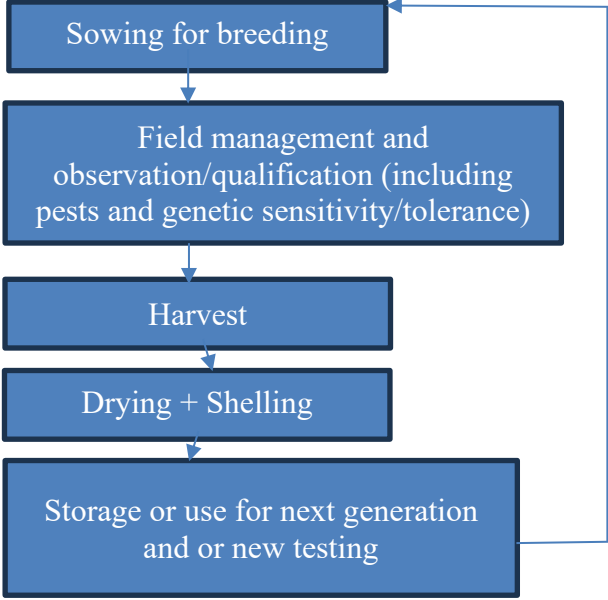
Trade data on imports into EPPO from countries where the pest occurs was extracted from UN Comtrade, FAOStat and Eurostat databases. The customs codes considered relevant for each pathway are detailed in each pathway. Understanding how maize commodities are covered in the common nomenclature was challenging and references are given to documents that describe the customs codes considered.

The EWG noted the following issues that create uncertainties on trade volumes for each pathway and for the PRA: inconsistencies in the data of UN Comtrade and Eurostat; known misallocation of maize consignments to unrelated codes; uncertainty on the intended use of some imports; insufficient information on trade flows in particular for maize seeds, including whether some consignments imported into EPPO countries are reexported.

8.1.1 Seeds of *Zea mays*

Pathway	Seeds of <i>Zea mays</i>
Coverage	Seeds intended for planting and traded for that purpose. Note that this may include seeds for all types of maize, including ornamental maize.
Plants concerned	<i>Zea mays</i> .
Pathway prohibited in the PRA area?	No information.
Pathway subject to a plant health inspection at import?	Yes, at least in part. In the EU Commission Implementing Regulation 2019/2072, specific requirements exist for <i>Zea mays</i> seeds in relation to <i>Pantoea stewartii</i> subsp. <i>stewartii</i> (pest-free area or testing) (for <i>hybrids of sweetcorn (Zea mays var.saccharata) for sowing</i> - CN code for 07129011, and maize seeds with CN codes 10051013, 10051015, 10051018, 10051090) (EU, 2025a). However, these requirements would not cover <i>C. nebraskensis</i>. Inspection is required for the same commodities, although these are unlikely to detect <i>C. nebraskensis</i> without testing. In addition, inspection is required for <i>sweetcorn for sowing</i> and <i>sweetcorn as parts of plants, other than fruits and seeds</i> both under the CN code 07099960 (EU, 2025b). The name corresponding to this code in the common nomenclature is ‘sweet corn’ and does not specify if it code covers seeds or grain. This category represents small trade volumes and is mentioned under both pathways (seed and grain). Where the pest is regulated in the EPPO region, sampling and testing may be performed. In Türkiye, requirements are made in relation to <i>Pantoea stewartii</i> subsp. <i>stewartii</i> (N. Üstün, pers. comm.). In Israel, maize seeds imported from the USA should be free from <i>C. nebraskensis</i>. The place of production should be officially inspected during the growing season and found free from the bacterium (T. Levi, pers. comm.).
Pest already intercepted?	No known interception on this pathway in the EPPO region. An interception was made in Mexico on USA seeds in a consignment which was also found to be infected with <i>P. stewartii</i> (Ayala Labarrios <i>et al.</i>, 2004). In South Africa, introduction on seeds is considered the most likely scenario by Masiwa (2025).
Most likely stages that may be associated	The bacterium can be present inside <i>Zea mays</i> seeds and externally on the surface.
Important factors for association with the pathway	Presence of the bacterium inside seeds caused by plant to seed transmission is more likely for susceptible cultivars than for moderately resistant or resistant ones (no detailed data on the type of cultivars that are used to produce seeds and/or traded into the EPPO region). On susceptible cultivars, percentages of transmission from plant to seed reached 20-30 % in various experiments (see section 2.3). Schuster (1975) found that heavily infected seeds may not germinate, but it is unlikely that such seeds will be in commercial consignments. No information was available on whether seed imported into the EPPO region are from resistant cultivars. Association with the pathway may be higher for some maize types which appeared to be more susceptible (such as popcorn and sweet corn; see section 2.6.1).

Pathway	Seeds of <i>Zea mays</i>
	Infection depends on conditions, i.e. it varies for different years and locations. In general, it is more likely from areas of central-north USA where the bacterium is prevalent. According to information obtained during the preparation of a pest risk analysis on <i>Pantoea stewartii</i>, between 2017 and 2019 (January-March), maize seed was exported from 30 states with the primary maize seed production area in the USA being the Midwest (Iowa, Nebraska, Illinois); most maize seed exported from the USA would have been produced in the USA (EFSA, 2019b). U.S. States with Corn Seed Exports into the European Union, 2017-2019  Figure is from EFSA, 2019b (exports from states in red). It is noted that in the USA, <i>C. nebraskensis</i> is present in the same areas as <i>Pantoea stewartii</i> subsp. <i>stewartii</i>, for which an association with seed is known. There may be infestation in seed production in areas where the disease also occurs in other maize production. In South Africa, introduction may have been linked to seeds (Masiwa, 2025). Respondents in EFSA (2019b) noted that maize seeds imported into the EU from the USA are used for breeding purposes, mainly for line development (hybrid seed production for the EU market would happen in the EU) (EFSA, 2019b). Additional information was provided by Euroseeds based on answers from their members, and are reported in this PRA as ‘Euroseeds, pers. comm.’ Euroseeds (pers. comm.) commented that seeds imported into the EU were mostly intended for research and breeding, and not as commercial seeds. One reason for this is the risk of GMO adventitious presence. For imports from South Africa, it was noted that these imports are very rare due to difference in the maturity period of most of South African cultivars being too long for the majority of continental Europe, unlike for the North African or South Eastern part of the EPPO region. The EWG noted that companies that do produce maize seeds in the EPPO region are likely to import seeds for breeding, while others may have part of their production in North America. It is also noted that South Africa is one of the places where hybrid lines are multiplied in order to accelerate the selection process (M. Delos, pers. comm.). Each maize seed lot represents a unique production location and crop year, but it is possible that seeds from different fields can be blended (Euroseeds, pers. comm.). The EWG noted that, as detailed under <i>Trade</i> below, import volumes into some EPPO countries seem very large if being imported purely for breeding purposes. The EWG therefore assumed that some commercial seed is imported into EPPO countries, recognizing that there may also be mistakes with the recording of maize grain under codes for maize seeds, and quantities that are re-exported to outside EPPO. There is import of a significant quantity

Pathway	Seeds of <i>Zea mays</i>
	of commercial seeds into sweet corn production into the EU (M. Delos, pers. comm.). Some quantities of commercial seeds are recorded as being imported by companies that are ‘seed distributors’ (in addition to seed breeders) (from analysis of the data in the EU Traces, R. Glenz, pers. comm.). Regarding the processes during seed breeding and production, a general outline was provided by Euroseeds (pers. comm.).  <pre> graph TD A[Sowing for breeding] --> B[Field management and observation/qualification (including pests and genetic sensitivity/tolerance)] B --> C[Harvest] C --> D[Drying + Shelling] D --> E[Storage or use for next generation and or new testing] E --> A </pre> Seeds from countries where the bacterium occurs are likely certified for their quality, which may/would include requirements for absence of pathogens. The following elements were provided (Euroseeds, pers. comm.): • In the USA, South Africa and Canada, the seed production process includes official field inspections by authorised parties (locally authorised or accredited individuals), as well as visual inspections of seed consignments to ensure no debris, soil or other material moves inadvertently. Measures implemented to eliminate plant debris from seed shipments reduces the likelihood of association with <i>C. nebraskensis</i>. In the USA, if the pathogen is suspected, infected leaves are sent by the inspector to an approved laboratory for confirmation. Detection of <i>C. nebraskensis</i> from field samples would prevent issuance of a USDA phytosanitary certificate that declares freedom from <i>C. nebraskensis</i>, prohibiting export to countries that regulate <i>C. nebraskensis</i>. • Best practices for managing the disease include surveillance, regular field scouting by trained personnel, informed field selections, effective weed control and thorough cleaning of field machinery and operations before and after processing seeds or crops. South African internal standards for field seed production are available (https://sagrainmag.co.za/2025/03/03/gosss-wilt-of-maize-what-producers-should-know/). In seed production,

Pathway	Seeds of <i>Zea mays</i>
	cleaning of equipment is a standard procedure for avoiding variety/seed mixture and maintaining the purity of seed lots. Field selection is guided by trend analyses that identify areas with low weed presence and favourable soil conditions to minimize disease risks. • Visual crop inspection is carried out to be able to distinguish abiotic plant stress from diseases with the appropriate investigative follow-ups. In case of doubt, analyses are carried out to distinguish from effects of drought damage, for example. Staff training is key. Inspectors for field disease inspections are well trained and know the symptoms of <i>C. nebraskensis</i>. Local lesions on the leaves are the most common symptoms seen and these do not result in seed transmission. Seed transmission only occurs if the maternal plants are systemically infected at a development stage prior to flowering; these systemic plants are very easy to identify and often are stunted and do not mature at the same time as healthy maternal plants. Therefore, they are easily rogued out during field inspections. Diseased plants are customarily rogued out of the field so that no systemically infected maternal plants could be harvested. Removing these potentially infected plants eliminates sources of inoculum and reduces the potential spread of the bacterium. However, the EWG noted that: external seed-borne <i>C. nebraskensis</i> may be present on the seed; low level of infection in the field may not be detected; and transmission from plant to seed has also been shown to occur in plants even with low levels of infection (see section 2.3.3). • Seeds typically must be field inspected or seed health tested using an NSHS-approved agar plating method (NSHS, 2001) for export to most international locations including the EU. Most US mainland seed production fields intended for export undergo default phytosanitary inspections for Goss's wilt because final destinations are often undetermined. Seed testing for <i>C. nebraskensis</i> is not readily conducted on seed exported to countries where it is not regulated or where other equivalent measures are accepted. The EWG noted that tests may therefore not be performed for export to countries where there are no requirements, as is currently the case for most EPPO countries. • The production process includes annual testing for specific pathogens, such as <i>C. nebraskensis</i>. In case of doubt seed health testing is commonly used especially in the USA. Seed testing for <i>C. nebraskensis</i> is performed on an <i>as needed</i> basis and varies annually. In general, companies have advocated for equivalent measures such as field inspection over seed testing because <i>C. nebraskensis</i> seed infection rate is very low, making detection by sampling less efficacious. The risk of seed transmission from asymptomatic fields is extremely low. Goss's wilt is recognizable in field by characteristic symptoms and can be screened by Immunostrips-- to be confirmed with validated laboratory diagnostic assays if needed. The EWG noted that the effectiveness of sampling and testing for <i>C. nebraskensis</i> depends on the sensitivity of the test and the number of seeds taken for testing. • The quality standards in seed production applied vary depending on seed destination. The seed sector uses a phytosanitary qualification for each seed production field (commercial and breeding). These quality standards apply to breeder and parent seed for seed production. Commodity grain does not have the same standards. The harvesting process is secured through cleaning and destruction steps, supported by internal standards and protocols. Currently, harvesting of breeding material is performed manually (at least in the respondents' companies) to ensure that the next generation remains free from contamination. • After seed harvesting, standard seed processing is carried out. It includes corn seed drying to 12-15% moisture with heated air, which devitalises both <i>P. stewartii</i> subsp. <i>stewartii</i> and <i>C. nebraskensis</i> (unpublished, industry knowledge). The EWG noted that some papers state that heat air treatment of seeds does not 'remove' (or has no influence on) bacteria in seeds, and was uncertain on whether such treatments would devitalize <i>C. nebraskensis</i> in the seeds. • Further, gravity and vacuum separation of kernels from chaff, debris, and off-target density kernels is performed. Some maize kernels are passed through colour sorters to remove kernels that are off-color, off-size and/or damaged. However, the EWG noted that this would only separate heavily-infected seeds.

Pathway	Seeds of <i>Zea mays</i>
	- Seed are harvested and dried on cobs, and after shelling, cobs are destroyed. When seed is imported, some sorting/treatment/testing is done after import. Seed then undergo 3 weeks of analysis (purity, quality, PCRs etc.). The EWG was uncertain on whether these quality assessment and analysis at destination always include <i>C. nebraskensis</i>. Pictures illustrating the industrial process of seed harvesting, drying, husking, shelling, cleaning, sorting and packaging are available at https://gd.eppo.int/taxon/ZEAMX/photos (and https://gd.eppo.int/taxon/HELAN/photos). The EWG noted that: – it is not known if the same standards are applied throughout the industry and in all countries; – initial observations of single plants of maize with symptoms of <i>Pantoea stewartii</i> have occurred in Italy before the bacterium was regulated in the EU (EFSA, 2019a). The likelihood of such events happening for <i>C. nebraskensis</i> does not seem different, although <i>C. nebraskensis</i> has not been found to date; – seeds for ornamental purposes or garden use includes direct sale on the Internet, which may be subject to lower levels of control and quality control (see links under ‘Ornamental purposes’ in the reference list). No information was found and Euroseeds did not have information.
Survival during transport and storage	<i>Clavibacter nebraskensis</i> can survive on and in kernels for at least 1 year, with survival gradually decreasing over time (see section 2.3.3). In storage, <i>C. nebraskensis</i> isolates can lose pathogenicity over time, but this was recorded to happen after about 2 years (see section 2.5.1). Maize seeds are typically stored at 10-12°C (M. Delos, pers. comm.), which is not expected to affect survival of the bacterium. Euroseeds (pers. comm.) mentioned that maize seeds are typically used within 6 months of production, but it is possible for maize seed to be more than one year old at the time of sale. For some parental lines, seeds may be held in inventory for a few years.
Trade	Trade data for maize seeds are covered under the following customs codes: - 100510 (and sub-codes 11, 13, 15, 18, 19, 90 et ‘xx’) <i>maize (corn), seed</i> [under categories for cereals, which defines that ‘grains’ (i.e. kernels in the case of maize) are present, but excluding sweet corn – EU, 2025b]; - 07129011 <i>dried sweetcorn, hybrid, for sowing</i> [under categories for dried vegetables]; - 07099960 <i>sweetcorn</i> [under categories for <i>edible vegetables</i> and <i>certain roots and tubers</i> – EU 2025b]. The common nomenclature does not specify if this cover seeds or grain or both. It is not known if ornamental maize seeds are recorded under the codes above, but they likely represent a minor part of maize seed trade. The trade flows are difficult to analyse as imports into one EPPO country may be reexported. Misallocation of maize seeds commodities under wrong customs codes are also expected, probably representing a small proportion of the maize seed trade. For example in Germany, individual consignments of maize seeds have occasionally been registered/imported under codes such as 12099180 <i>vegetable seeds for sowing (excl. salad beet or beetroot Beta vulgaris var. conditiva, 12093000 seeds of herbaceous plants cultivated mainly for flowers, for sowing, or 07129019 dried sweetcorn Zea mays var. saccharata, whether or not cut or sliced, but not further prepared (excl. hybrids for sowing)</i> (R. Glenz, pers. comm.). Similar cases exist from Spain (N. Avendaño Garcia, pers. comm.).

Pathway	Seeds of <i>Zea mays</i>
	100510 maize (corn), seed Data on import into EPPO countries were extracted for 2021-2024 from UN Comtrade and Eurostat (Table 1 and Table 2 in ANNEX 4). Due to inconsistencies in data for EU countries, the analysis uses UN Comtrade for non-EPPO countries and Eurostat for EU countries. 2023 data is mostly used here because 2024 data may not be complete (or else reflect a sharp fall from 2023 to 2024 for most countries). The data generally show large variations from year to year. In 2023, imports reached approximately 2372 t from the USA, 471 t from Mexico, 38 t from Canada and 31 t from South Africa. Most countries report small volumes that may be compatible with use for breeding and research (see above), but there is an uncertainty on whether this is the case for larger quantities. Considering quantities over 50 t (rounded figures), in 2023, there were imports: – from the USA into the UK (1180 t), Türkiye (401 t), the Netherlands (374 t), Kazakhstan (212 t) and Romania (85 t); – from Mexico into the Netherlands (196 t), France (142 t) and Serbia (62 t). Türkiye, the UK and Kazakhstan represented the majority of imports of this commodity from the USA. In 2024, quantities over 50 t (rounded) were reported from the USA into Türkiye (887 t), the UK (457 t), Austria (351 t), the Netherlands (264 t), and Hungary (73 t). Türkiye was the largest importer increasing from 148 t in 2021 to about 887 t in 2024, while imports to the UK decreased from 1811 t in 2021 to about 457 t in 2024 (as for the Netherlands, from 1420 t in 2021 to 264 t in 2024). The large imports into Austria in 2024 were not reported in previous years. 07129011 dried sweetcorn, hybrid, for sowing Data on import into the EU were extracted for 2021-2024 from Eurostat (Table 3 in ANNEX 4) [this is a HS8 code, data are not available in UN Comtrade (which otherwise covers all EPPO countries)]. In 2023, imports reached approximately 848 t from the USA, 99 t from South Africa, and minor quantities (less than 10 kg) from Canada and Mexico. Taken together, volumes are not high but represent large numbers of seeds. 07099960 sweetcorn Minor trade volumes are reported, and it is unclear if they relate to seed or grain (Table 5 in ANNEX 4). Quantities for several EU countries correspond to those in FAO Stat for <i>Green corn (maize)</i> defined as <i>Maize harvested green for food</i> (see details in section 8.1.2), but not for all countries. Trade data is analysed in section 8.1.2.
Transfer to a host	For transfer to occur, the infected seed should produce an infected seedling. The rate of transmission is low (see section 2.3.3). There is an uncertainty on whether some (unknown) factors that may affect the success of transfer.
Likelihood of entry and uncertainty	Moderate likelihood with a moderate uncertainty. • In the USA, <i>C. nebraskensis</i> is present in the same area as <i>Pantoea stewartii</i> subsp. <i>stewartii</i>, which has a known association with seed. • There are also imports of commercial seeds in addition to those imported for research and breeding.

Pathway	Seeds of <i>Zea mays</i>
	• There may be infestations in seed production in areas where the disease also occurs in other maize production. • Limiting the likelihood: processes applied to seed production mitigates the risk, low transmission from seed to seedling. <i>Uncertainty:</i> • Trade data and the part of commercial seeds. • Whether the processes described are used throughout the industry and effectiveness in reducing the risk of presence. • No data on ornamental seeds. • Prevalence of <i>C. nebraskensis</i> in fields used to produce maize seeds. • Origin of seeds within infested countries. • Presence in Mexico seed production. • Whether South Africa outbreaks are due to imported seeds.

8.1.2 Grain of *Zea mays* (kernels for processing or consumption, either separated or attached to the cobs (ears) including sweet corn with or without husks)

Pathway	Grain of <i>Zea mays</i> (kernels for processing or consumption, either separated or attached to the cobs (ears) including sweet corn with or without husks)
Coverage	All pathways that include kernels for consumption or other intended uses (but not for planting). • <i>Sweet corn, with or without husk.</i> In the UK, some sweet corn is known to be imported with husks, creating concerns (and mitigation) in relation to the fungus <i>Phyllachora maydis</i> (more details below, H. Anderson, pers. comm.). Maize ears are also popular food, with more diversity in North America, and may be brought back by passengers. • <i>Grain for human consumption.</i> This grain is likely to be imported for further packaging and/or processing. Sweet corn and grain for human consumption may also be food aid. • <i>Grain as animal feed.</i> • <i>Grain for ethanol production.</i> There is a major production of ethanol from maize grain in the EPPO region, at least in Europe. Over the period 2019-2023, maize represented each year about 50% of the feedstock used (others being wheat, other cereals, sugars, ligno-cellulosic) (ePure, 2019, 2020, 2021, 2022, 2023). Maize for ethanol is mostly grain (first generation ethanol). The various outputs of ethanol production fall in section 8.2. • <i>Grain for other industrial uses.</i> Maize grain is used to produce dextrin, starch etc. (https://www2.education.uiowa.edu/html/eportfolio/tep/07es102folder/miniweb/usesofcorn.htm).
Plants concerned	Maize.
Pathway prohibited in the PRA area?	Not known.
Pathway subject to a plant health inspection at import?	Yes, at least in some EPPO countries. In the EU (Commission Implementing Regulation 2019/2072 – EU, 2025a), the following commodities are inspected due to regulation of other quarantine organisms: in Part A of Annex XI: Sweet corn (07099960), maize (corn), other (10059000). Inspections are not likely to detect <i>C. nebraskensis</i> without testing. In the UK, the fungus <i>Phyllachora maydis</i> was detected in a sample of sweetcorn husks showing fungal symptoms, collected at a sweetcorn processor (UK NPPO, pers. comm.). Thus even if <i>C. nebraskensis</i> is not regulated, the bacterium may be intercepted during inspections based on symptoms on e.g. husks.
Pest already intercepted?	No known interception.
Most likely stages that may be associated	The bacterium may be present in the husks, cobs, kernels, or any associated maize debris contaminating consignments.

Important factors for association with the pathway	Transmission from the vegetative parts of the plant to kernel is limited, and association is more likely if husks, and cobs are present, or infested maize debris contaminate the consignment. As a precaution, the UK assessment for <i>Phyllachora maydis</i> assumed that all imported sweetcorn had the potential to be associated with husk and leaf material, and that processing and final packaging was being conducted in the UK (UK NPPO, pers. comm.). However, part of the imported sweet corn may not have husks, and processing and final packaging may occur at origin, which would limit association. Ears for personal consumption transported by passengers may come from gardens, with husks and with a lower quality and without controls. Fields for grain production are likely subject to less scrutiny than for seed production, while quality standards may be higher for grain for food versus grain for feed. In both cases, grain must be sorted from leaf debris, with the amount of debris remaining in consignments likely to be minimal. The Codex Alimentarius standard for food maize (of <i>Z. mays indentata</i> and <i>Z. mays indurata</i>) includes a tolerance of 1.5 % for all extraneous organic matter (FAO, 2019). Export specifications from some countries indicates maximum levels of 1-2% (https://www.internationalmongers.com/agriculture-products/). No information was found on whether there are special procedures to avoid infected grain in exported consignments (for all origins).
Survival during transport and storage	Overall, the bacterium can survive in all plant parts, surviving in kernels for at least 1 year, with survival gradually decreasing over time (see section 2.3.3). It is also expected to survive in drying material as it is noted to survive in crop debris in the field (see section 2.3.1), although it may not survive in completely dried material. Sweet corn is a perishable product whose shelf life does not exceed a week and needs to be stored/transported refrigerated (0-1°C in BMT, 2026a). At harvest, its water content is around 75% and would be conserved through storage because drying degrades the product (BMT, 2026a). <i>C. nebraskensis</i> would therefore survive in storage in/on the kernels, and any other plant material associated. No information was found on whether other maize grain can be transported with high water content. The Codex Alimentarius standard for maize as food (of <i>Z. mays indentata</i> and <i>Z. mays indurata</i>) indicates a 15.5 % maximum moisture content (FAO, 2019). Maize grain transported in bulk normally has a maximum water content of 11.5-14 % for shipping, above which cargo losses may occur (BMT, 2026; https://itemscatalogue.redcross.int/relief--4/food--5/cereals--18/maize-corn--FCERMAIZ.aspx). At such low water contents, associated leaf debris would be quite dry but possibly not completely dry. Survival of <i>C. nebraskensis</i> in leaf debris would decrease as the material further dries.
Trade	Trade data for maize grain are understood to be covered under three customs codes: - 100590 <i>maize (corn), other than seed</i>; [under categories for cereals, which defines that ‘grains’ (kernels in this case) are present, but excluding sweet corn – EU, 2025b]; - 07099960 <i>sweet corn, fresh or chilled</i>; [under categories for edible vegetables and certain roots and tubers – EU 2025b]. See note in 8.1.1; - 07129019 <i>dried sweetcorn Zea mays var. saccharata, whether or nor cut or sliced, but not further prepared (excl. hybrids for sowing)</i> [under categories for dried vegetables]. No information was found on the proportion of maize grain imported into the EPPO region as feed or food.

	100590 maize (corn), other than seed. Data from UN Comtrade show imports from all countries where the pest occurs to 43 EPPO countries in 2023, with 2.1 million t from Canada, 495 000 t from the USA, 204 000 t from South Africa and 262 t from Mexico (Table 4 in ANNEX 4). [Data were not extracted from Eurostat]. 07099960 sweet corn, fresh or chilled. Data from Eurostat show minor imports to 5 EU countries in 2021-2023, with in 2023 approximately 7 t from Mexico and 4.5 t from the USA (against 75 t in 2022), and less than 1 t from South Africa (Table 5 in ANNEX 40) [this is a HS8 code, data are not available in UN Comtrade (which otherwise covers all EPPO countries)]. Note that it is unclear if the quantities reported included seeds or grain. In FAOStat, the commodity <i>Green corn (maize)</i> is defined¹⁰ as ‘Maize harvested green for food. <i>Saccharata</i> variety is commonly known as sweet corn’. Data for 2021-2023 (Table 6 in ANNEX 40) is similar to 07099960 for France and Finland, but shows additional imports into the UK, with in 2023 about 440 t from the USA, 135 t from Mexico and 12 t from South Africa, as well as about 30 t to the Netherlands from South Africa (not in Eurostat data). 07129019 dried sweet corn. Data from Eurostat (<i>dried sweetcorn Zea mays var. saccharata, whether or nor cut or sliced, but not further prepared (excl. hybrids for sowing)</i>) shows minor imports from countries where the pest occurs to 9 EPPO countries in 2023, with 2.6 t from the USA mostly to the Netherlands and France, and quantities <0.25 t from other countries where <i>C. nebraskensis</i> occurs (Table 7 in ANNEX 4). While in 2021-2023 all feedstock used for ethanol in the EU was produced in Europe, in 2019 more than 99% (out of approximately 12 billion t) was grown in Europe and in 2020 more than 98% (out of approximately 13 billion t). This leaves under 120 million t (maize grain or other species used for ethanol production) imported in 2019 and under 260 million t imported in 2020. It is not known where this material is imported from, and whether it enters under the customs code for maize, other than seed. Regarding grain used for industrial purposes (dextrin, starch, oil etc.), it is likely that the final products are imported, not the grain itself. No information was sought.
Transfer to a host	Grain is further processed for human consumption (e.g. boiled) or eaten by cattle. Grain for ethanol production or other industrial purposes is heavily processed, eliminating the bacterium. Grain is unlikely to be planted (unintended use) at least commercially as it would not ensure acceptable production; although, this may happen in gardens on a small scale. Transfer would be possible only in case of spillage during unloading, handling, transport or storage, or if discarding fresh or drying waste carrying the pathogen close to or directly into production fields. For successful transfer to a living host, infected material would need to be spilled close to maize crops at a stage where it still carries viable bacterium, and the bacterium dispersed to nearby plants by wind or water. Transfer is more likely if the infected material is unloaded or discarded directly into a growing maize crop, than if debris are discarded into the field before a maize crop is planted. Theoretically the bacterium may also transfer to its other confirmed hosts, but evidence is lacking to consider this possibility. • <i>transfer at unloading.</i> Sweet corn with husks and leaves imported into the UK for commercial purposes were unloaded outdoors prior to being moved indoors for processing, and the NPPO assessed that there was a risk of dispersal by the wind of <i>P. maydis</i> on infected plant debris (H. Anderson, pers. comm.). Similarly for <i>C. nebraskensis</i>, maize debris may be carried by the wind or water to nearby maize fields.

¹⁰ <https://openknowledge.fao.org/server/api/core/bitstreams/133abe54-26f6-48a5-afeb-e512bcc37ebb/content>

	For infected grain, maize debris contaminating grain consignments, or cobs lost at unloading, may be carried by water or wind to nearby maize fields. However, imported grain (for all uses) is probably stored indoors to maintain its properties before consumption or processing, and the quantity escaping at unloading is likely to be small. Because maize grain is a major part of first-generation ethanol production, it is not unlikely that some ethanol-production plants are located in maize-producing areas of the EPPO region. Germination from grain escaping unloading into an infected seedling may happen. However, transfer is unlikely. ● <i>transfer with waste</i> may happen if plant parts that carry the pathogen (husks, cobs, debris) are discarded in the close vicinity of maize fields. This may happen for waste from packaging/processing of sweet corn or industrial processing, or for cobs sold to final consumers for which waste may be discarded in gardens or on compost piles. The bacterium may survive in waste for a while (as it is shown to survive in debris), but higher temperature in compost piles and burying below other waste may limit transfer. Transfer from waste is unlikely if not in close vicinity of maize fields.
Likelihood of entry and uncertainty	Low with a moderate uncertainty ● Large volumes. ● Less control than in seed production, and the grain may be collected from many places. ● Higher disease incidence is seen in production fields than for seeds, at least in the USA. ● Grain for animal feed in particular may be imported into areas where there is production. ● Transfer is only likely following spillage. Transfer is a limiting factor, and therefore entry requires a chain of unlikely events. <i>Uncertainty:</i> more uncertainty than for seeds, but still in the moderate range. ● Whether husks or debris are frequent in consignments, incl. whether cleaning procedures are applied. ● Whether debris in maize grain (other than sweet corn) would be completely dry or may allow survival of <i>C. nebraskensis</i> ● Whether kernels initially intended as seeds at origin may be exported as grain if infected. ● Awareness/scrutiny of the disease at entry is less than for seeds. ● How often such spilled material comes in contact with maize fields.

8.1.3 Other maize plant parts

Pathway	Other maize plant parts
Coverage	This pathway covers any maize fresh/not processed plant parts traded as forage or for other intended uses (except grain, dealt with in 8.1.2). <i>For forage:</i> according to EFSA (2018), forage maize is either grown for this purpose or is a by-product of grain production. The commodity may include stalks, leaves, cobs and husks, and in the second case, also grain, and is obtained by shredding of the aerial plant parts. It is not clear if this product may be raw (i.e. large pieces of plants), or is traded in other forms such as pellets or silage bale https://www.indiamart.com/proddetail/60-kg-silage-bales-available-in-banswara-rajasthan-22596869455.html. The ensiling process is not expected to allow survival of the bacterium (see section 2.3.5 and is covered in section 8.2). <i>For other intended uses.</i> Maize crop debris (ligno-cellulosic) or empty cobs can be used for ethanol production (Geletukha <i>et al.</i>, 2020; https://edenproductsLtd.co.uk/2024/12/20/the-journey-of-a-corn-cob-from-the-field-to-a-multipurpose-product). No other intended uses were found in preparing this PRA.
Plants concerned	Maize.
Pathway prohibited in the PRA area?	No prohibition in the EU. No information for other EPPO countries.
Pathway subject to a plant health inspection at import?	Not known. In the EU (Commission Implementing Regulation 2019/2072), in Part A of Annex XI: <i>vegetable products of maize (Zea mays), not elsewhere specified or included, fresh</i> (14049000). In the current common nomenclature (EU, 2025b), the code corresponds to <i>vegetable products, not elsewhere specified, other</i> i.e. presumably not only maize. This is understood to cover all fresh plant parts of maize except grain and seeds, but there is uncertainty on whether this code is correctly allocated to fresh plant parts of maize. The use of ‘vegetable’ in the common nomenclature creates potential misinterpretation on the allocation of this code.
Pest already intercepted?	Not known.
Most likely stages that may be associated	The bacterium may be associated with all maize plant parts.
Important factors for association with the pathway	Presumably, infection would not prevent the use of maize plants as forage nor for ethanol production, and quality standards are probably lower than for grain as food or feed or seed production.
Survival during transport and storage	Even if some material is fresh when harvested and packed, it will progressively dry. The bacterium is expected to survive because it may survive in maize leaves for 16 months.

Pathway	Other maize plant parts
Trade	Trade data was searched to identify commodities that might correspond to forage containing stems and leaves, or maize plant parts for forage, ethanol production or other industrial uses are imported into the EPPO region from countries where the bacterium occurs. No evidence was found. • It is not clear if the code 14049000 <i>vegetable products of maize (Zea mays), not elsewhere specified or included, fresh</i> only covers maize (see row further above in this table). No data was sought. • The commodity <i>forage and silage, maize</i> of FAOStat does not show import from countries where <i>C. nebraskensis</i> occurs into EPPO countries in 2021-2023. Enlarged to 1986-2023, the data search returned only one import: 15 t from the USA to Albania in 2010. It is not known if this forage was green or silage (entry with the latter is considered very unlikely – see section 8.2). • Under the code 121300 <i>cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets</i>, data in UN Comtrade (not presented in the PRA) show limited imports to 19 EPPO countries in the period 2021-2024, with in 2023, with about 1 t from Canada, 0.3t from Mexico, 0.5 t from South Africa and 10 t from the USA (with over 1 t only to Czech Republic, Germany, Sweden). The Netherlands was the largest yearly import with 16 t in 2024. However, the code covers all cereals and there is a high uncertainty on whether maize plant parts were traded. • Under the code 23080090 <i>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)</i>, data in Eurostat (not presented in the PRA) shows limited imports to all EU countries in 2021-2024, with in 2024 about 39000 t from the USA (mostly to Ireland, Germany and France), 350 t from Canada (mostly to Poland) and 9800 t from Mexico (mostly to Ireland and Germany) and minor quantities (< 1 t) from South Africa. However, there is a high uncertainty on the part of maize under this code, as well as whether the material is imported fresh or not, in pellets or not (most feed is likely imported as pellets, which has a lower volume). When this code was investigated for a previous draft EPPO PRA, in Spain and in Ireland, import notifications under this code related to soya pellets (TRAGSA in Spain and NPPO of Ireland, pers. comm. in 2022). Similarly, in Germany, there was no imports concerning maize in the recent time connected to plant health (R. Glenz, pers. comm.). It was not found under which codes maize for industrial purposes (e.g. ethanol production) is covered. In conclusion, no evidence was found of a trade of other maize plant parts into the EPPO region.
Transfer to a host	Forage is intended to be eaten. The only transfer possibility would be if infested material is transported by the wind or water to neighbouring plants, during unloading, storage or feeding in the vicinity of maize crops. Plant parts for ethanol production would be processed, and transfer would only be possible if there was spillage at unloading (as for grain).
Likelihood of entry and uncertainty	There is not enough information to rate this pathway. There is no evidence of trade, but the EWG considered that such products are unlikely to be imported from countries where the bacterium is currently present, especially due to the costs involved.

8.1.4 Contamination by infested plant debris (of soil on its own, used machinery and vehicles, shipping containers, traveller's footwear)

Infested plant debris of maize (or other hosts) may be present in soil or become associated with machinery and vehicles that drive in maize fields, the shoes of workers walking in maize fields or shipping containers that have transported infected maize commodities in bulk. It is noted that many EPPO countries prohibit the import of soil as a commodity. In all cases, transfer is unlikely unless these carriers are disposed of/used/cleaned in maize production areas/places/sites at destination.

In relation to used machinery, Euroseeds (pers. comm.) noted that maize seed production is highly specialised and machinery is typically not switched between different types of production. In addition, equipment cleanout is a major critical control point for preventing any unintended movement of debris and soil that maybe harbouring pests. In general, no shared equipment is moved internationally. Nevertheless, the South Africa Department of Agriculture (2026) appears to consider used farming equipment as a potential pathway.

There is a high uncertainty attached to debris of *Sorghum bicolor* and *Setaria viridis*, because the role of these species in the epidemiology of the disease is not confirmed and there is no evidence that the bacterium could transfer from these plants to maize.

For the EPPO region, contamination pathways are considered unlikely overall, but there may be specific circumstances of imports from infested areas into maize production areas/places/sites in EPPO countries, which may make transfer possible (in particular of maize-specific used machinery). Many uncertainties are associated with these pathways such as whether machinery used in maize fields is traded internationally. This pathway is not assessed in detail but general recommendations are made in section 16.

8.2 Pathways with a very low likelihood of entry

Plants for planting of *Zea mays* (except seeds). Maize is very unlikely to be traded as plants for planting with roots. There is no evidence of association of *C. nebraskensis* with tissue cultures or pollen of maize. Whilst tissue culture may be exchanged, they are very unlikely to be infected due to the rigorous production standards and are also not grown outdoors. Maize pollen is unlikely to be used or exchanged in international trade, and it is not a traded commodity due to its viability (N. Mahfoudhi, pers. comm.).

Uncertainty: low

Maize silage. Silage is a bulky, low value and perishable product generally unlikely to be traded over large distances. Data for 1986-2023 from FAOStat show that the only import of 'maize silage' into the EPPO region from countries where *C. nebraskensis* occurs was 15 t from the USA to Albania in 2010.

Uncertainty: low

Maize decorations and objects. Maize plants and ears are used for decoration in the USA. No information was found that such decorations are imported into the EPPO region (seeds for planting of ornamental maize products are covered in the seeds pathway). Similarly, maize cob pipes are sold in Europe, imported from the USA, but the bacterium is not expected to survive processing. Brooms made from maize are a commodity in Eurostat, with no trade recorded from North America. Even if these objects are traded and the bacterium is present, it is unlikely to transfer to a maize field.

Uncertainty: low.

Processed maize. Industrial processes that transform maize kernels are likely to eliminate the bacterium, and even if they do not, transfer to maize crops from processed maize is unlikely because the material is unlikely to come into contact with agricultural land. Example of processed products are:

- 'Bran, sharps and other residues; of maize (corn), whether or not in the form of pellets, derived from the sifting, milling or other workings thereof' (category from customs codes);
- co-products of ethanol production represent more than 50% of the production from biorefineries in Europe, before ethanol (ePure, 2019-2023). Such co-products may be animal feed (e.g. corn gluten feed and meal [Popp *et al.*, 2016]; dried distiller's grain with solubles (DDGS) [Jensen *et al.*, 2012]). They are highly processed (protein extraction) and would not carry the bacterium;
- maize cob granules can be produced for industrial uses and for packaging (Eden Products Ltd, 2024a). Empty cobs (by-product from the maize industry) are ground up and sifted into two fractions, and granules are produced from the heavier parts and flour from the lighter parts (Eden Products Ltd, 2024b). It is

uncertain whether the bacterium can survive grinding and sifting however, the material would be dried and most material is destined for further processing or indoor use. Some uses for this material, such as for packaging or as abrasives, would ultimately end up being discarded as waste;

- Maize grain is used to produce dextrose, dextrin, starch, syrup or oil, which are used for many industrial applications, but such products would not support the bacterium.

Uncertainty: low.

Seed of *Sorghum bicolor* and *Setaria viridis*. There is evidence that *C. nebraskensis* is not associated with the seeds of shattercane (*Sorghum bicolor*); in experiments *C. nebraskensis* did not systemically infect this species or any other experimental hosts tested (see section 2.3.4). Consequently, seed of *S. bicolor* is very unlikely to be infected and due to the results of the above experiments on other Poaceae, it is also considered unlikely for *S. viridis* (with a higher uncertainty). Theoretically, the bacterium could be present at the surface of seeds however, there is no evidence of this in the field. This may also apply to the seed of any other species grown in the vicinity of infected maize. Infected plant parts of shattercane and *S. viridis* may be transported as a contaminant of equipment or grain shipment (covered under these pathways). There is no evidence of trade for seeds of these species, for which there is also no evidence of commercial cultivation in the EPPO region (see section 9.1).

Uncertainty: moderate (host status, whether seed can carry the pathogen as a contaminant, whether there is a trade from infested areas).

Grain of *Sorghum bicolor*. Shattercane is a confirmed host, and is unlikely traded. *Clavibacter nebraskensis* would not be present inside kernels (the bacterium was not systemic on this hosts). ‘Grain sorghum’, which may be traded, is an experimental host (see section 7).

*Uncertainty: moderate (host status of grain sorghum, whether grain can be contaminated by *C. nebraskensis*, whether there is a trade from infested areas).*

Contamination by plants for planting or debris of *Sorghum bicolor* and *Setaria viridis*. *Clavibacter nebraskensis* can be present on leaves of these plants, which may be associated as contaminant to consignments of other plant products. However, there is no evidence that the bacterium could transfer to a growing maize crop, and more generally, there is uncertainty surrounding the role of these plants in the epidemiology of the disease.

*Uncertainty: moderate (contamination by *C. nebraskensis*, association of plants for planting or debris of *Sorghum bicolor* and *Setaria viridis* with commodities from infested areas).*

Natural spread. *Clavibacter nebraskensis* cannot reach the EPPO region through natural spread from its current distribution. Natural spread may become relevant as an entry pathway if the bacterium is introduced closer to the EPPO region (e.g. neighbouring countries in Africa, the Middle East or Asia), and it will also be relevant for spread within the EPPO region after first introduction.

Uncertainty: low.

8.3 Rating of the overall likelihood of entry

Rating of the overall likelihood of entry	Very low	Low	Moderate	High	Very high
	☐	☐	X	☐	☐
Rating of uncertainty			Low	Moderate	High
			☐	X	☐

9 Likelihood of establishment outdoors in the PRA area

For establishment to occur, a population should develop from the initially infected maize plants and persist over many years (‘the foreseeable future’, definition of establishment in ISPM 5; IPPC Secretariat, 2025). Persistence in an isolated maize cropping system for 2-3 years and disappearance when maize is rotated to another crop would therefore not qualify as establishment.

9.1 Host plants

Maize is widely cultivated throughout the EPPO region, for seeds, grain, sweet corn, forage or industrial purposes (e.g. oil, bioethanol). In relation to non-industrial purposes, grain and forage (for silage) dominate production, with less acreage utilised for the cultivation of sweet corn and seeds (CEPM, 2016). No unique source of comprehensive data on the statistics of maize production nor the spatial distribution of the maize fields for the whole EPPO region was found. This PRA uses data and maps from the European Crop Map Explorer (EU Crop Maps below; Ghassemi *et al.*, 2024), Tang *et al.* (2023 and 2024), FAOSTat (ANNEX 5), Eurostat (ANNEX 6) and various articles. The EU Crop Maps and Tang *et al.* (2023 and 2024) provide the spatial distribution of maize fields, while Eurostat, while Eurostat and FAOSTat record the statistics reported by countries. In all EPPO countries, maize may also be grown in gardens.

Illustrative maps. Figs 5 and 6 illustrate the area used to cultivate maize in the EPPO region. Fig. 5 is based on 10 x 10 m resolution data from the *European Land Use / Cover Area frame Survey (LUCAS) 2022*, recording maize-growing for the EU and Ukraine (Ghassemi *et al.*, 2024). Fig. 6 provides an illustration of the distribution and density of maize in the whole EPPO region (presumably grain and green maize) based on data by Tang *et al.* (2023 and 2024). Like for the area data (see below), there are discrepancies between the map and data, with Fig. 6 showing substantial maize cultivation in areas where it is known not to be grown (e.g. northern Finland).

Data in statistical databases. From FAOSTat and Eurostat (ANNEX 5 and ANNEX 6), the UK and Tunisia are the only EPPO countries not recording maize cultivation. Nevertheless, maize is also grown in these countries: in the UK, 241,200 ha in 2025 (of which 155,500 ha for fodder or grain maize, and 85,500 ha for anaerobic digestion – UK Government, 2025); and in Tunisia, mostly for animal feed with 1,240 ha in 2021 (Hammami *et al.*, 2025).

Countries with areas above 0.5 million ha maize in 2022 in FAOSTat and Eurostat were (rounded figures) (ANNEX 7): Ukraine (4.1), France (2.7), the Russian Federation (2.6), Germany (2.5), Romania (2.2), Poland (1.8), Türkiye (1.4), Serbia (1), Italy and Hungary (0.9 each) and Bulgaria (0.5). EU Crop Maps does not add countries to this list, although it reports larger maize production areas in these countries. Maize in France (2023) notes a general reduction of European maize cultivation in 2023 (due to falling prices, increased production costs and rising pressure on water resources) with the exception of Türkiye where maize was expected to increase to provide a replacement for cotton.

Note on maize data used and discrepancies. In sections 9 and 13, data on percentages of maize grown in different Köppen-Geiger climate types of individual countries were extracted by integrating the spatial distribution of maize fields (EU Crop Maps, ANNEX 9) with the Köppen-Geiger climate types (Beck *et al.*, 2023). For the year considered (2022), there are substantial differences in maize areas from EU Crop Maps, Eurostat and FAOSTat (ANNEX 7). Data from the various sources is used, but there is an uncertainty on the actual total maize-growing areas in EPPO countries.

Data between Eurostat and FAOSTat are overall consistent for *Grain maize and corn cob mix/maize (corn)*, but not for *green maize/green corn (maize)*.

Maize areas reported from EU Crop Maps are generally larger than in Eurostat, sometimes much larger. One possible explanation could be if maize categories in Eurostat do not reflect all maize produced, but this does not appear to be the case: Eurostat details *Grain maize and corn cob mix*¹¹ and *Green maize*¹², the latter also covering energy crops (EU, 2023). Sweet corn is covered under *Other vegetables cultivated for*

¹¹ Defined as ‘*Zea mays* L., harvested for grain, as seed or as corn-cob-mix’ (EU Implementing Directive 2023/1589 under *Cereals for the production of grain (including seed)*). Includes: grain maize harvested by hand, corn-picker, corn-sheller or combine harvester, regardless of the use, including grain for silage; grain harvested together with parts of the cob, but with humidity higher than 20% and used for silage (so called corn-cob-mix, CCM – humidity 30-35%) (EU, 2023).

¹² Defined as ‘*Zea mays* L. grown mainly for silage (whole cob, parts of or whole plant) and not harvested for grain’ (EU Implementing Directive 2023/1589 - under *Annual plants harvested green*). Includes green maize directly consumed by animals (without silage), whole cobs (grain, rachis, husk) harvested for feedstuff or silage, as well as whole cobs for renewable energy production (EU, 2023).

fruit, together with *Cucumis metuliferus* and *Physalis* (EU, 2023), but the limited areas (Table 2 in ANNEX 6) do not explain the differences with EU Crop Maps. Grain used for industrial purposes is presumably under the grain maize category. Differences between EU Crop Maps and Eurostat may also be affected by classification errors, the classification procedure and differences in reference data (B. Ghassemi, R. d'Andrimont, pers. comm.).

EU Crop Maps provides a valuable indication of where maize is grown in individual countries, while Eurostat (for the EU and some associated countries) and FAOSTat (for other EPPO countries), provide official statistics for maize grain (which includes seeds in their description) and green maize productions. Even if the percentages of maize per climate type are not precise, they are more accurate than considering that maize is equally distributed in all climate types of a country.

In individual sections, details are provided on the data and how it is used. EPPO countries that review this PRA to decide on the need for regulation may use detailed national statistics to refine the assessment.



Fig. 5. Maize in the EU and Ukraine in 2022. EU CropMap Explorer background Open Street Map EC (Ghassemi *et al.*, 2024) [CartoDB, dark matter]

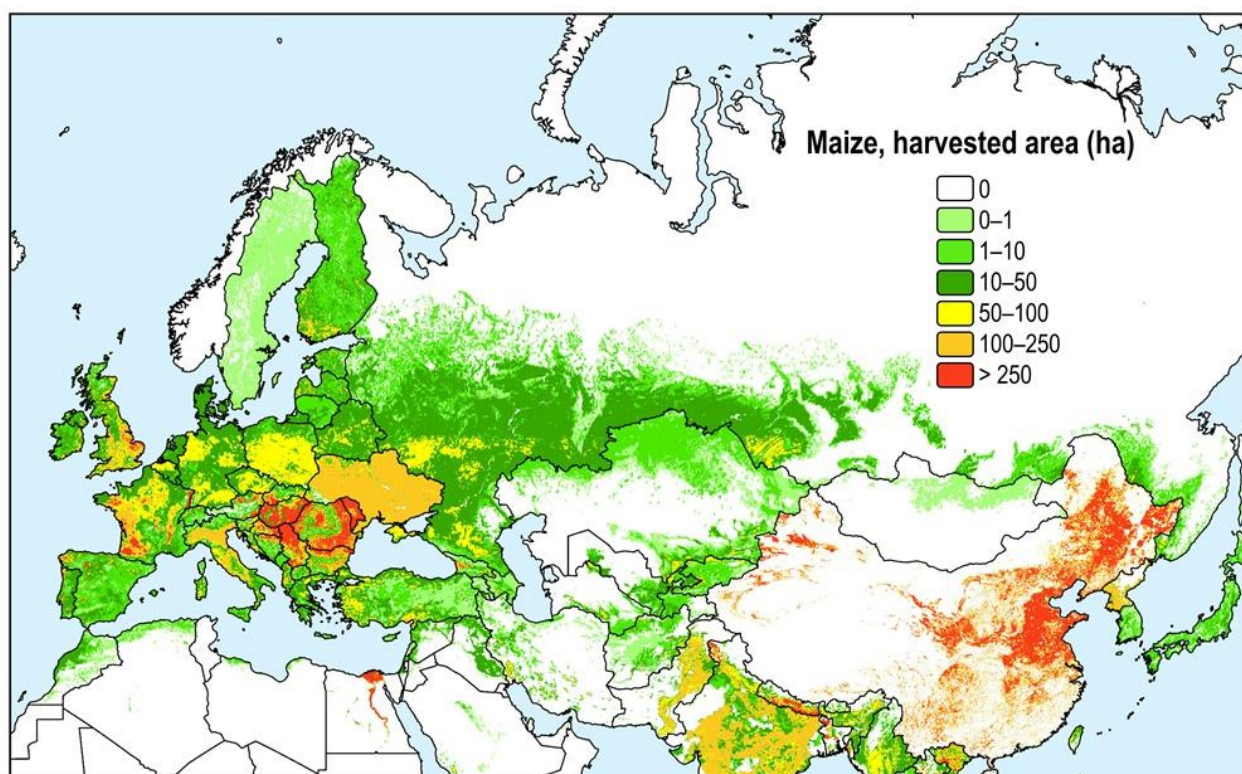


Fig 6. Maize harvested area (in ha). Map prepared by J. Tuomola, based on data for ‘maize’ (understood to be for grain) and ‘forage maize’ compiled by Tang et al. (2024) and retrieved from the dataset provided in Tang et al. (2023). At the spatial resolution of 0.05° used in Tang et al. (2023, 2024), a grid cell has a size of approximately 5.6 km × 5.6 km, corresponding to about 3000 ha. Consequently, where the map shows for example 0-1 ha, it corresponds to 0-1 ha maize per 3000 ha. Note that data is not provided for some areas where maize is grown (e.g. Tunisia) and indicates substantial areas where it is not likely grown (e.g. northern Finland). See Tang et al. (2023, 2024) for details about the quality of data.

Several aspects of maize cultivation would influence establishment:

- According to EFSA (2019b), maize seeds exported to the EU from the USA are used for breeding purposes, mainly for line development. Such crops are likely to be under strict scrutiny. However, from the information available, the EWG assumed that some commercial seed is imported into EPPO countries (see section 8.1.1). The bacterium could also spread within the growing season to other maize crops in the vicinity.
- If some maize cultivars already used in the EPPO region present some resistance, this may reduce the likelihood of establishment of the bacterium as it may not be able to build up sufficient inoculum for reinfection. However, it is unlikely that the majority of cultivars currently used in the EPPO region are resistant. Maize cultivars cultivated in the EPPO region are currently not selected for resistance or tolerance to *C. nebraskensis*, which might increase the likelihood of establishment. Landraces may also be used in some countries, as reported in Hammami *et al.* (2025) for Tunisia. Maize types such as sweet corn and popcorn, which are known to generally be more susceptible, represent respectively about 70,000 ha and 20,000 ha in the EU (M. Delos, pers. comm.).
- Crop rotation (cultivating different crops in consecutive years), especially where maize crop debris are buried, may suppress the small quantity of bacteria that has built up over one season, or decrease bacteria population. However, during the growing season of maize, the bacterium may be transferred to nearby fields which practice maize cropping in that and the following season. Continuously cropping maize year after year would favour establishment. In addition, volunteer maize may retain the bacteria population in the fields when maize is not cultivated. In some areas of the EPPO region, maize is still grown as a monoculture, such as in southwestern France (Alletto *et al.*, 2022), and in Tunisia, some farmers grow two maize crops a year before and after summer (Hammami *et al.*, 2025). Both of these situations are likely to favour establishment. In France, popcorn is always grown in rotation with other crops than maize (mainly winter crops as grain cereals) (M. Delos, pers. comm.).

- Environmental impacts of agricultural practices and water shortage have triggered interest in management practices such as no tillage or reduced tillage. The increased uptake of these practices would favour establishment (see section 13.1).
- Non-commercial maize (e.g. grown in gardens) may provide reservoirs of the pathogen, as non-hybrid maize may be grown in consecutive years from saved seeds from plants grown in the previous year, but this is not expected to play a major role in establishment.

How the bacterium enters the EPPO region would affect its establishment potential. If an infected plant grows from seed in a maize field, establishment is more likely than if infected maize grains are spilled during unloading of a consignment. This is because plants resulting from a grain spillage are likely to be fewer in number and are unlikely to develop into larger plants (due to the lack of cultivation) which could build up an inoculum reservoir and transfer to a maize crop.

The natural host shattercane (*S. bicolor*) is native to northern sub-Saharan Africa and has been introduced into the semi-arid areas of Asia and Europe of the EPPO region. Shattercane is the most competitive weed of grain sorghum, and its size favours competition with maize (Kanas *et al.*, 2021). No evidence of cultivation was found, and the EWG therefore assumed it is not cultivated commercially in the EPPO region.

Setaria viridis is native to Eurasia and is widespread throughout the EPPO region, present in the wild and as a weed (Plants of the World Online, 2025). CABI (2021) mentions that it is recorded throughout Europe except the Azores (Portugal), the UK, the Faroe Islands, Ireland, Iceland and northern Russia according to Clayton (1980) but that there are sporadic records in the UK. The recording site iNaturalist includes records throughout the EPPO region, except in the northern part (Fig. 8). No evidence of cultivation was found, and the EWG therefore assumed it is not cultivated commercially in the EPPO region.

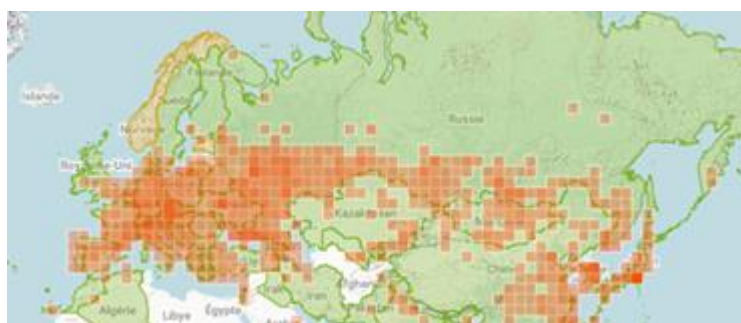


Fig. 8. *Setaria viridis* in the EPPO region, from iNaturalist (2025)

There is no information on the role of alternative hosts in the epidemiology of the disease and whether they may provide a reservoir for the pest.

9.2 Factors that favour establishment

The EWG considered that the following factors (see section 2.6) may be equally important or more important than climate for the establishment:

- continuous maize cropping,
- reduced or no tillage,
- cultivating maize at a high plant density,
- presence of volunteer maize plants during the crop rotation,
- growing susceptible maize cultivars, and
- the use of overhead irrigation.

However, there is limited knowledge on how these factors affects the establishment. In addition, these factors and their use are expected to vary throughout the EPPO region.

9.3 Climatic suitability

There is limited knowledge on the climatic conditions that are required for the establishment of *C. nebraskensis*. The pathogen is present in a wide range of climates in its current distribution. The EWG believed that the climate would have an influence on the likelihood of establishment, but it is not likely to be a limiting factor. The EWG concluded that the bacterium could potentially establish wherever maize is present if the applied cropping practices are not limiting the establishment. In the EPPO region, maize is grown within a range of temperatures that would allow for survival of the bacterium. Relative humidity varies, but irrigation is widely practiced in dry areas, and there is no evidence in the literature on how relative humidity affects establishment. Extreme weather events inducing wounds would be favourable for establishment.

A simple comparison of Köppen-Geiger (KG) climate types was carried out to identify the climatic conditions where the bacterium is known to occur, and to locate similar conditions within the EPPO region as they are likely favourable to the pest.

9.3.1 Köppen-Geiger climate matching and presence of maize in the EPPO region

Since specific occurrence data for *C. nebraskensis* were not available, climate matching was carried out at the level of subnational administrative areas from where the pest is reported. These administrative areas were divided into two groups: those with confirmed occurrence and those with uncertain occurrence (see section 6). For Mexico, where the pest status is unclear, the two specific locations reported by Flores-López (2024) were used in the analysis.

To identify KG climate types within the EPPO region that are likely to be suitable for *C. nebraskensis*, all climate types present in administrative areas where the pest currently occurs were extracted, including the proportions of each climate type within the areas (Table 1 in ANNEX 10; map in ANNEX 11). These data were further analysed to include only the climate types that are relevant to this assessment. In addition, the climate types present in the EPPO region where maize is presumably cultivated were considered. Details of this analysis are provided in ANNEX 8 (Table 1 for climate types that are relevant to the analysis, Table 2 for climate types that are not relevant).

In order to link climate types with maize-growing areas, the percentages of maize cultivation in every country under each climate type were extracted from EU Crop Maps Data, covering the EU and Ukraine (ANNEX 90 – see Note in section 9.1).

KG climate types were mapped for a recent climate period (1991–2020) and projected for the period 2041–2070 under Shared Socioeconomic Pathways SSP1-2.6 and SSP3-7.0.

The KG climate types were divided into two groups: ‘certain’ and ‘uncertain’ climate types.

Certain climate types

The KG climate types in which *C. nebraskensis* is likely present within its current distribution are as follows. Note that in this PRA, descriptions of KG climate types are from Beck *et al.* (2023; p. 2).

Certain KG climate types
<i>BSk</i> arid, steppe, cold
<i>Cfa</i> temperate, without dry season, hot summer
<i>Dfa</i> cold, without dry season, hot summer
<i>Dfb</i> cold, without dry season, warm summer

These all occur in the EPPO region (Fig. 9c and Table 2 in ANNEX 10).

Maize is widely present under these four climate types in the EPPO region (ANNEX 9), especially *Dfb* (40% of all maize areas – over 90% in many North European countries, and largely present in Ukraine and central Europe), while presence under *BSk*, *Cfa* and *Dfa* represent 8, 12 and 16% of maize areas respectively, with *BSk* dominating in Greece and Spain and *Cfa* – in Italy and Croatia.

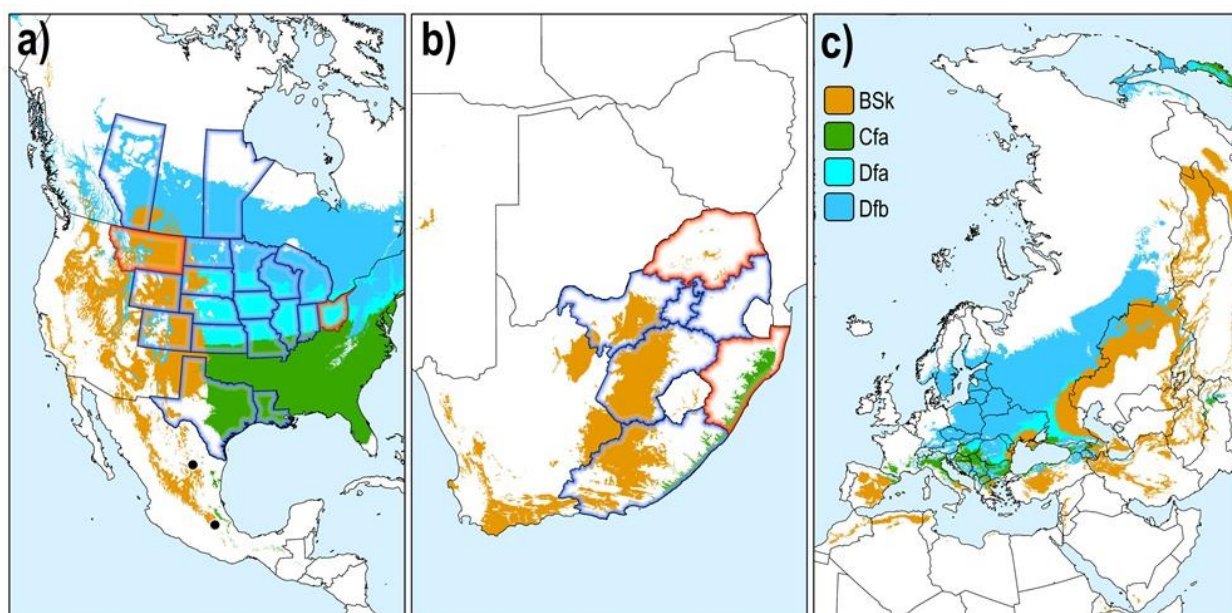


Fig. 9. ‘Certain’ Köppen-Geiger climate types with likely presence of *C. nebraskensis* in its current distribution, and their presence in the EPPO region.

(a) The four identified climate types where *C. nebraskensis* is likely to be present in administrative areas where the pest is recorded in North America (confirmed presence in blue, unconfirmed in red, black dots for two Mexican records). Descriptions of the climate types is provided in the text.

(b) Same climate types in administrative areas where the pest is recorded in South Africa.

(c) Area of the EPPO region where conditions likely favour establishment.

Distribution in the recent climate (1991–2020). Data for Köppen-Geiger types were sourced from Beck et al. (2023) at a resolution of 0.1° (about 11 km at the equator). The country borders on the map were sourced from GADM (2020). Map prepared by J. Tuomola (Ruokavirasto, Finland).

Uncertain climate types

Uncertain climate types are shown on Fig. 10 and listed in a table before Fig 10. They fall under two categories (analysis in ANNEX 8):

- Within administrative areas where *C. nebraskensis* is present, there are uncertainties on whether the bacterium is present under the climate types *Cfb*, *BSh*, *BWk*, *BWh* and *Dfc*. If *C. nebraskensis* further expands its range in South Africa in the coming years, it may show whether some of these climate types can be considered certainly suitable for establishment.

Maize is widely present in the EPPO region under the climate type *Cfb* (22% of maize areas), while *BSh*, *BWh* and *BWk* represent minor areas, in Spain (154 ha in total) and Cyprus (4 ha) (ANNEX 9, Table 2). However, these desert-type climates are prevalent in other parts of the EPPO region (North Africa, Middle East and Central Asia) for which data on the distribution of maize was not available. Some limited maize areas occur in the EPPO region under the climate type *Dfc* in Sweden and Finland (ANNEX 9, Table 2), and this climate type is also present in other parts of the region (e.g. Central Asia, Russian Federation) for which detailed data on the distribution of maize were not available.

- A number of climate types are present in the EPPO region where maize is or may be cultivated but do not occur in the current distribution of the pest. Among these, large areas of maize are cultivated under climate types *Csa* and *Csb* in Portugal and the Mediterranean, and some maize is cultivated under *Dsb* in Greece, according to EU Crop Maps data (ANNEX 9, Table 2). The climate types *Dsa*, *Dsc*, *Cfc*, *Dwb*, *Dwc*, *Dwd*, *Dfd* are present in non-EU EPPO countries and no detailed data on maize cultivation in these countries were found, but the data by Tang et al. (2023, 2024) indicate that some maize is cultivated under these types in the EPPO region, except for *Dwd* and *Dfd* (uncertainties explained in section 9.1). All these climate types are also relevant, because climate is not considered a limiting factor for *C. nebraskensis*, factors that are limiting the establishment are not known, and potentially the pest could establish wherever the maize is cultivated.

Uncertain KG climate types	
KG climate types with uncertain presence of <i>C. nebraskensis</i> in current distribution	KG climate types present in the EPPO region where maize is or may be cultivated but do not occur in the current distribution of the pest
<i>Cfb</i> temperate, without dry season, warm summer	<i>Csa</i> temperate, dry summer, hot summer
<i>BSh</i> arid, steppe, hot	<i>Csb</i> temperate, dry summer, warm summer
<i>BWk</i> arid, desert, cold	<i>Cfc</i> temperate, without dry season, cold summer
<i>BWh</i> arid, desert, hot	<i>Dsa</i> cold, dry summer, hot summer
<i>Dfc</i> cold, without dry season, cold summer	<i>Dsb</i> cold, dry summer, warm summer
	<i>Dsc</i> cold, dry summer, cold summer
	<i>Dwb</i> cold, dry winter, warm summer
	<i>Dwc</i> cold, dry winter, cold summer
	<i>Dwd</i> cold, dry winter, very cold winter
	<i>Dfd</i> cold, without dry season, very cold winter

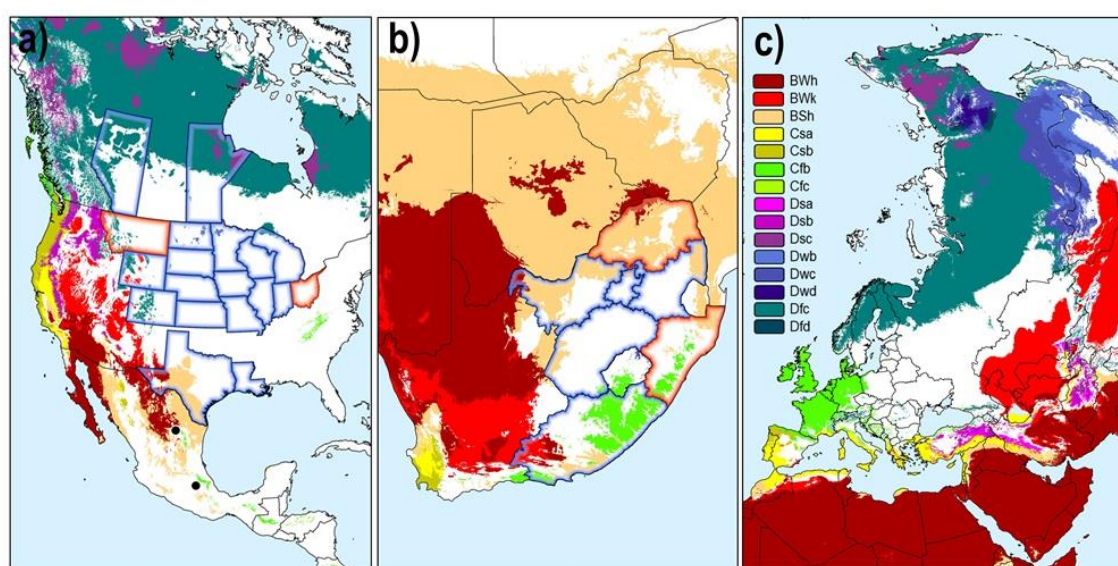


Fig 10. Uncertain climate types (uncertain presence of *C. nebraskensis* in its current distribution or climate type present only in the EPPO region).

(a) Climate types in administrative areas where the pest is recorded in North America (confirmed presence in blue, unconfirmed in red, dots for two Mexican records). Descriptions of the climate types is provided in the text.

(b) Same climate types in administrative areas where the pest is recorded in South Africa.

(c) Same climate types in the EPPO region.

Distribution in the recent climate (1991–2020). Data for Köppen-Geiger types were sourced from Beck et al. (2023) at a resolution of 0.1° (about 11 km at the equator). The country borders on the map were sourced from GADM (2020). Map prepared by J. Tuomola (Ruokavirasto, Finland).

An interactive map presents certain and uncertain climate types and can be downloaded at <https://upload.eppo.int/download/3136ode68b25dc>.

Climate change projections for 2041–2070 using two scenarios indicate that the area encompassing ‘certain’ climate types are likely to expand towards the north. In particular, climate types *BSk* and *Cfa* expand northwards, replacing *Cfb* in parts of Europe (ANNEX 12). ‘Certain’ and ‘uncertain’ climate types in climate change scenarios are also presented in the interactive map mentioned above. These changes may render some of these areas less suitable for maize cultivation (e.g. scarce water resources), subsequently reducing the likelihood of establishment.

9.3.2 Soil temperatures

The EWG noted that minimum soil temperatures in winter are not likely to be a limiting factor for establishment, as the minimum soil temperatures where maize is grown in the EPPO region are not below those in North America (Fig. 11).

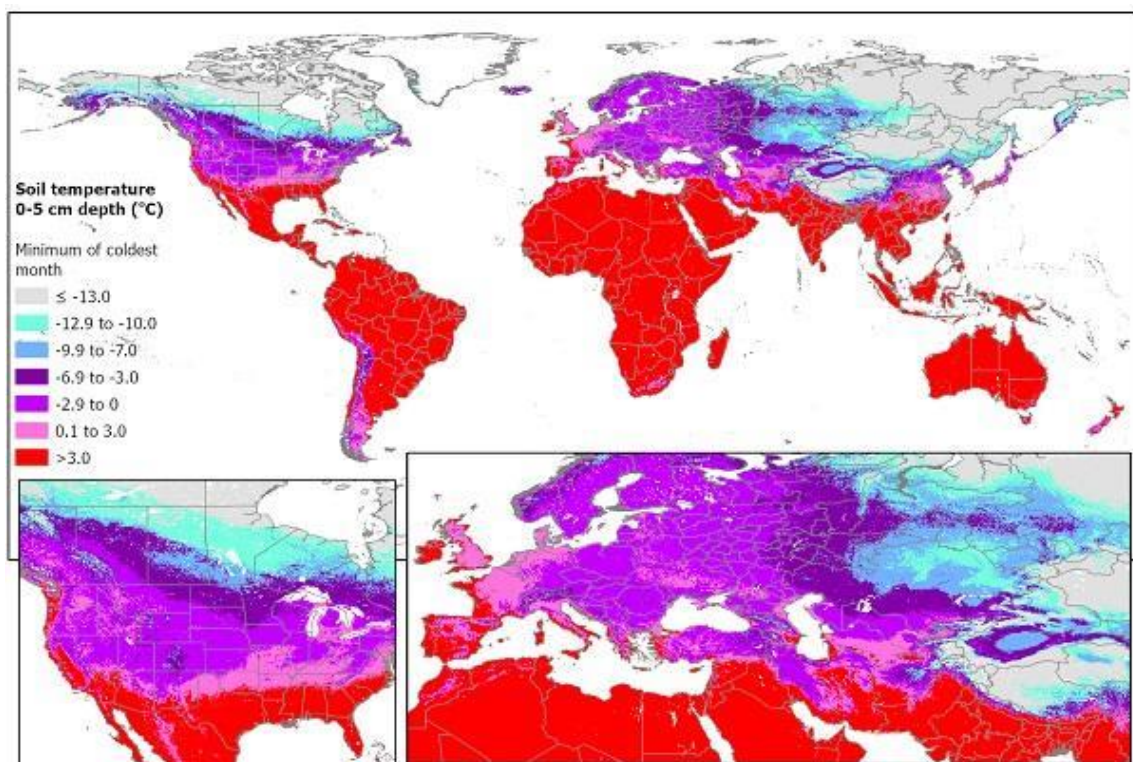


Fig. 11. Minimum soil temperature at 0-5 cm depth (°C) of the coldest month, map prepared by A. Korycinska (DEFRA, UK for the EPPO PRA on *Chloridea virescens*) from datasets of the Soil Temp project (Lembrechts *et al.*, 2022; van den Hoogen, 2022). The minimum soil temperature is understood to be the minimum of the monthly minimum temperatures (which are 5% percentile, not the extreme lowest value).

9.4 Conclusion

The EWG considered the likelihood of establishment as very likely with a moderate uncertainty. Maize is widely cultivated in many EPPO countries and in its current distribution, *C. nebraskensis* occurs under a wide range of climatic conditions. Subsequently, climate was generally not considered to be a limiting factor for establishment in areas of the EPPO region where maize is cultivated. The pathogen is known to occur under certain Köppen Geiger climate types that also occur in the EPPO region (*BSk*, *Cfa*, *Dfa*, *Dfb* – see section 9.1). These areas of the EPPO region were considered to be suitable for establishment with a higher degree of certainty than areas of the EPPO region which cultivate maize under climate types from which the pest has not been reported. The EWG considered that the extent of maize cultivation and agricultural practices in maize cultivation may have a greater effect on establishment than climate. Establishment is most likely to occur if the pathogen enters an area where there is a high density of maize cultivation and where agricultural practices such as continuous maize production (without crop rotation) and/or reduced or no-tillage are common. Although it is not possible to precisely delimit where favourable agricultural practices are widely used, they are known to occur in some areas, which would increase the establishment potential.

The likelihood of establishment in commercial production is considered higher than in seed breeding and seed production, because of more rigorous monitoring and management in the latter.

Uncertainty. Lack of knowledge of management practices that would lower the likelihood of establishment; which are the main limiting factors, and role of climate; role of alternative hosts as reservoir for the pathogen; survival duration of the pathogen in plant debris.

Rating of the likelihood of establishment outdoors	Very low	Low	Moderate	High	Very high x
	☐	☐	☐	☐	

Rating of uncertainty	Low ☐	Moderate x	High ☐
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10 Likelihood of establishment in protected conditions in the PRA area

Maize and other confirmed hosts are not grown in protected conditions. Although some experimental hosts may be grown in protected conditions, there is no evidence allowing the EWG to assess the likelihood of establishment in protected conditions in the PRA area.

11 Spread in the PRA area

Clavibacter nebraskensis is expected to spread slowly at the local scale (from plant to plant and field to field). Regarding distances of spread, in field experiments epiphytic *C. nebraskensis* was collected up to 2.5 m from inoculum sources around 15 days after establishing inoculation sources (infested debris). Maximum distances between previously and newly symptomatic plants reached 2.88 m for wound-inoculated source of inoculum, and 3.59 m for residue inoculated source. Symptomatic plants often form clusters near the source of inoculum (Eggenberger *et al.*, 2016).

In the EPPO region, like in South Africa, *C. nebraskensis* may not be detected immediately after introduction. In the worst case, detection may occur years after introduction, allowing for spread and multiple outbreaks before it is detected. Knowledge and experience of the pest in the EPPO region will be limited in the first phase.

At a local scale, *C. nebraskensis* may spread via contact between plants, mechanical means such as water splash from rain, overhead irrigation, agricultural practices, wind-blown debris or fauna (see section 2.4). In France, the risk of maize debris transported with wind is lower than in the USA due to differences in soil and climate, and this likely applies to other parts of the EPPO region (M. Delos, pers. comm.). Human-mediated spread is facilitated by the use of contaminated equipment (Kgatle, 2025). Forage and maize debris may also be important for spread at the local scale.

At long distance, the exchange of infected maize material either internally or as an external contaminant (e.g. seeds, grain, green forage or silage) and as a contaminant on machinery such as harvesters, footwear, equipment and shipping containers would allow further spread and could lead to new outbreaks. There may be movement of maize grain between EPPO countries for feed and industrial uses such as starch and ethanol production.

It is noted that maize seed certification for marketing in the EU includes requirements to ensure that the crop is ‘practically free from any pests which reduce the usefulness and quality of the seed’ (Directive 66/402 - annex I – part D (maize) – point 6).

Some pathways that are less likely for entry are more relevant for spread between/within EPPO countries. For instance, extreme weather events carrying infested crop debris may accelerate spread, although they may not happen at as a comparable scale and frequency in the EPPO region as in the U.S. Midwest, where they have an important role. Seed production is normally under official control with certification of seed lots, which would limit spread with seeds at least in the EU. It is not known if such schemes are widely used in non-EU EPPO countries.

Maize cultivars in the EPPO region are currently not selected for resistance or tolerance to *C. nebraskensis*, which might enhance the spread. The selection of resistant cultivars is also less likely for some maize types cultivated in the EPPO region as the genetic pool is narrower (e.g. popcorn, sweet corn) (M. Delos, pers. comm.).

There may also be more limitations for spread within the EPPO region than in North America due to maize cultivation being more disaggregated (see Fig. 5), the presence of natural obstacles (e.g. seas and mountains) and regulatory barriers between countries.

<i>Rating of the magnitude of spread</i>	<i>Very low</i> ☐	<i>Low</i> ☐	<i>Moderate</i> x	<i>High</i> ☐	<i>Very high</i> ☐
<i>Rating of uncertainty</i>			<i>Low</i> ☐	<i>Moderate</i> x	<i>High</i> ☐

Uncertainty: Whether long-distance spread would happen with the same risk as short-distance spread; which factors are more important for spread (extreme conditions, agricultural practices, etc.); frequency of extreme weather events in different parts of the EPPO region; mechanisms of spread in South Africa and timeframe; duration of the period before detection.

12 Impact in the current area of distribution

Canada. No evidence of economic damage was found in the literature. In Manitoba, *C. nebraskensis* was first found in 2009 (Harding *et al.*, 2018 citing Desjardins, 2010) and by 2011 it was found in 83% of 270 surveyed maize fields below the economic injury level (Harding *et al.*, 2018). In 2014-2015, the disease was detected in 38% of maize fields (64 of 169) in 15 of the 21 counties evaluated.

In Alberta, *C. nebraskensis* was first recorded in 2013 (Harding *et al.*, 2018 citing Howard *et al.*, 2015), and in 2013-2015 the disease was detected in 33% (32 of 97) of maize fields surveyed, spread across 6 of the 10 counties surveyed. The bacterium was found in new areas each year in geographically disparate locations, frequently associated with heavy rainfall and/or hail events in July-August. With favourable environmental conditions in the 2015 growing season, 50% of fields in Alberta and 45% of fields in Manitoba showed symptoms (Harding *et al.*, 2018).

South Africa. The disease was first found in 2024 in several provinces (IPPC, 2025). Research is needed on epidemiology in South African conditions and management options (Njom *et al.*, 2025). Limited information on losses is available however, Van Rooyen (2025) reports an infested field yielding 1.5 tonnes per ha lower than non-infested fields on a farm in Free State (Viljoenskroon). According to MG Kgatle cited in Spandiel (2025), South Africa has not experienced major yield losses, but the disease can disrupt production, affect trade, and pose challenges for national biosecurity if it spreads unchecked. This effect on trade is reported by Kloppers (2025a), noting that several countries suspended imports of maize commodities following the detection of the pathogen in South Africa. Current efforts focus on disease management (South Africa Department of Agriculture, 2026).

Mexico. The record for Mexico is considered unreliable by the NPPO of Mexico (see section 6). Infected maize plants were found in seven fields sampled in 2021 in the Panotla municipality (Tlaxcala). The plants showed signs of leaf blight and wilt symptoms, and at the R4 stage, symptom severity reached approximately 70-80% and disease incidence was 100% (Flores-López *et al.*, 2024).

USA. Currently (as of 2025), *C. nebraskensis* is not considered to be one of the most important pathogens of maize in the USA. However, whilst it is managed, it can still cause losses. The severity of the disease has varied over time, from its emergence and initial impact in the 1970s, to low importance from the mid-1980s to the early 2000s, and then re-emergence and spread of the disease from around 2006 (Langemeier *et al.*, 2017). Several factors may have led to the reemergence of *C. nebraskensis* in the USA in the mid-2000s, including continuous growing of maize (up to 50 years in some fields in extreme cases), widespread reduced or no-tillage production, loss of hybrids with high level of resistance, early season hail storms and strong winds favouring the development of systemic disease in the more susceptible young plants (Jackson *et al.*, 2007). Whilst in 2011, the disease was severe and widespread across the Corn Belt, in 2012-2013, it was less prevalent due to drought conditions, the increased use of less susceptible hybrids and rotation with nonhosts in the worst affected areas (Langemeier *et al.*, 2017). Since 2010, the disease has nevertheless had an economic impact in major producing states (Illinois, Indiana, Iowa, Minnesota and Nebraska) (Langemeier *et al.*, 2017 citing personal communications). However, since 2019, it has barely impacted production (A. Robertson, pers. comm. based on <https://loss.cropprotectionnetwork.org/crops/corn-diseases>).

Yield losses depend on the level of susceptibility or resistance of the cultivars grown and the timing of disease onset/growth stage at the time of inoculation (Malvick *et al.*, 2025; Suparyono & Pataky, 1989a & b). Disease severity also has an effect on losses. For example, when sampling fields in areas with high and

low disease severity (more or less than 5% leaf area affected) in Midwestern USA, plots with higher disease severity showed increased levels of stalk rot and the 1000-kernel-weight was significantly reduced (Robertson *et al.*, 2012).

The literature generally mentions that yield losses in the field can reach around 50% in epidemics on susceptible maize (e.g. Mallowa *et al.*, 2016 citing others; Jackson *et al.*, 2007b; see Table 1 in ANNEX 13). The incidence may be low overall in an area, but disease severity and yield losses can be high in the smaller areas affected. For example, in an outbreak in four parishes of northeast Louisiana, the incidence was estimated at less than 1% overall, while within affected circles in individual fields, disease severity reached 45-100%, and yield losses reached 50-100% (Singh *et al.*, 2015).

For the purpose of assessing potential losses in EPPO countries, data available on annual losses due to *C. nebraskensis* in the USA are used in section 13.2. A few data available from the USA are presented in ANNEX 13 (Crop Protection Network, 2016 to 2025) and Crop Protection Network Disease loss calculator (<https://loss.cropprotectionnetwork.org/>). It is noted that no data were found for years when reemergence is reported and damage might have been higher, such as 2006 or 2011.

Table 2 in ANNEX 13 shows a sharp decrease of losses after 2018. However, even for the period 2020-2024 where losses are lower than previously, year-to-year variation is over 8-fold between 2022 and 2024. Considering data from the Crop Protection Network Disease loss calculator, percentages of losses was highest in 2014. Estimated losses reached 1.3% for the 35 US states for which data is available (Table 3), 1.62% for the major maize producers Illinois, Nebraska and Iowa together (Table 4), and 2% for Nebraska (Table 5), while they were at a low level of 0.01% in Texas (Table 6). In 2024, the loss percentage was 0.01 % in all cases above, but 0.00 % for Texas.

12.1 Control methods

Control of the disease relies primarily on the combination of using less susceptible cultivars with methods to remove primary inoculum before the next maize crop is planted, i.e. rotation with nonhost crops and management measures to remove maize debris (Langemeier *et al.*, 2017). For instance, in seed production, planting less susceptible cultivars and employing tillage operations that bury debris are effective strategies for breaking the disease cycle and reducing the incidence of new infections. Additionally, rotating corn with other crops such as soybeans, dry beans, small grains, or alfalfa helps to diminish primary inoculum sources in corn residue (Euroseeds, pers. comm.).

Because of the ability of *C. nebraskensis* to survive epiphytically, this may help manage the disease from one maize growing season to the next, but may not completely eliminate the inoculum reservoir (Eggenberger *et al.*, 2016). There are no reliable in-season curative control measures and the best management of an existing infection is to assess it and plan for the next season (Bayer, 2022).

Key management measures available and effective against *C. nebraskensis* are as follows:

- **Use of resistant cultivars** (e.g. Langemeier *et al.*, 2017; Wise *et al.*, 2010; Bayer, 2022; Kloppers, 2025a; Njom *et al.*, 2025). See section 2.6.1.
- **Rotation with non-host crops** (Schuster, 1975; Langemeier *et al.*, 2017; Njom *et al.*, 2025; Claflin, 1999). See section 6.2.2.
- **Removing or incorporating crop debris** (Schuster, 1975; Jackson *et al.*, 2007a; Langemeier *et al.*, 2017). See section 6.2.2.
- **Other management-related methods in the literature**
 - Selection of seed from non-infested areas should decrease the chance of harvesting infected seed (Schuster, 1975).
 - Wise *et al.* (2010) mentions that *C. nebraskensis* is regulated in many countries and that certain countries require phytosanitary certificates for maize seed with tests or inspections required to determine that the seed lot or seed source is free from the pathogen.
 - Cleaning equipment thoroughly and the harvesting of infested fields last to minimise spread to uninfested fields is recommended (Kgatle, 2025; Kloppers, 2025a).
 - Weed management techniques to control grass weed species could reduce inoculum levels (e.g. Ikley, 2019; Wise *et al.*, 2010; Bayer, 2022; Kgatle, 2025; Kloppers, 2025a). Controlling weeds when they are small could potentially limit inoculum build-up in a field, and inhibit alternative hosts acting as a “bridge host” for *C. nebraskensis* in years when a field is rotated to a non-maize crop (Ikley, 2019).

There are no practical chemical control options (bactericides) against *C. nebraskensis*. This is due in particular to the need to repeat applications and difficulties to ensure proper coverage of the whole plant (T. Jackson-Ziems, pers. comm.). Copper products have been used to control bacterial diseases in other crops, but are not economically viable options for large, field-scale use in maize production (Wise *et al.*, 2010). Several studies did not find consistent benefits for reduction of disease severity¹³. However, certain components or inert ingredients in plant protection products and application adjuvants may have antimicrobial properties that could provide some element of curative action (T. Jackson-Ziems, pers. comm.).

The EWG rated the current situation in the distribution of the pest. Overall, impact in the current area of distribution was rated as moderate with a moderate uncertainty. In the past in the USA, initial outbreaks and reemergence events had high impact on losses. Currently, direct economic losses are relatively low in the USA, where management practices are in place, although there is higher impact locally on certain maize types or due to severe weather events. However, there have been significant impacts such as trade restrictions in South Africa and the implementation of control measures for farmers and authorities.

Rating of the magnitude of impact in the current area of distribution	Very low ☐	Low ☐	Moderate x	High ☐	Very high ☐
Rating of uncertainty			Low ☐	Moderate x	High ☐

Uncertainty. Social and economic impacts in South Africa; economic impact in Canada; situation in Mexico.

13 Potential impact in the PRA area

13.1 Factors influencing potential impacts on maize production:

Most impacts identified in this PRA are related to economic impacts. Environmental and social impacts were considered and a few are mentioned.

Early detection/management. Due to low seed transmission rates, introduction is most likely to occur as isolated events. There is a risk that, like in South Africa, the bacterium is identified only when the pest is already present in several areas, leading to local outbreaks before management practices are implemented.

Variety susceptibility. Susceptibility will influence yield losses, and economic impact may be high locally if susceptible cultivars are grown (similar to *P. stewartii*, ISF, 2003). Some American cultivars with a known level of resistance may already be used in the EPPO region. Otherwise, it may be possible to replace some susceptible cultivars, but as in North America, for specific intended uses resistant cultivars may not be available, and even if they are this could take time to implement. For instance, some maize types which are cultivated in the EPPO region are generally more susceptible (e.g. popcorn, sweet corn) (see section 9.1).

Resources would be needed to screen germplasm and breed maize for resistance (ISF, 2003 for *P. stewartii*). However, whilst development of resistant cultivars normally takes 5-10 years, because the traits are already used in the USA, it may take less time in the EPPO region (M. Delos, pers. comm.). Should *C. nebraskensis* be identified as a threat for the EPPO region, pre-emptive screening studies would be useful. In South Africa where the pest was detected in 2024, screening of cultivars was apparently initiated.

Triggers for screening and breeding of maize resistance are not known, and would presumably depend on demand, i.e. the need for breeding may be high in case of severe outbreaks and the necessity to change practices in various parts of the EPPO region. If *C. nebraskensis* impacts the market in EPPO countries, it would become a target for breeding for resistance (Euroseeds, pers. comm.). Selecting cultivars for

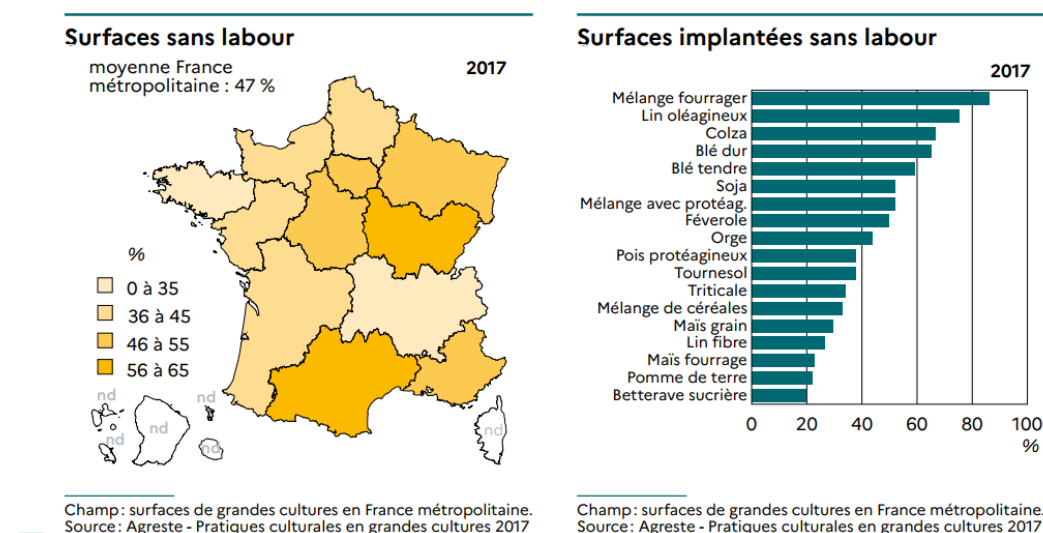
¹³ Copper hydroxide, several commercially available fungicides, and pesticide adjuvants in Schlund, 2015 cited in Wise *et al.*, 2010; copper hydroxide and citric acid at the 10th leaf stage of a susceptible hybrid planted into maize residues from the previous season in Mehl *et al.*, 2015 cited in Harding *et al.*, 2018.

resistance to the disease could have a negative impact on yield progression or other agronomic characteristics of the crop (M. Delos, pers. comm.).

For *P. stewartii*, it is noted that the cost of susceptible and resistant hybrids is similar (ISF, 2003). This is expected to be the same for *C. nebraskensis*.

Crop rotation and destroying maize debris would limit the disease, especially in combination with resistant cultivars, but this would require changes to agricultural practices in parts of the EPPO region. Reduced or no-tillage practices could increase impacts by *C. nebraskensis*, with the use of these practices having increased in recent years due to environmental concerns (Książak *et al.*, 2018). In dry areas, no tillage is used to save water and avoid soil degradation (Gerth-Niculescu, 2024; NWRM, 2025). Nevertheless, the use of these practices depends on local conditions and ploughing is still widely used (e.g. 6 ha out of 10 ha of maize grain production in Pays-de-la-Loire region, France in 2020-2021; DRAAF, 2025a).

No-tillage strategies are sometimes used for seed production and for commodity corn production (Euroseeds, pers. comm.). In France, tillage (mainly ploughing) is very common (in 2017, about 70% maize for grain production and silage production were ploughed before sowing [map below], in 2021, 25% had minimum tillage before sowing and only 5% with no-tillage; map below and DRAAF, 2025a & b.). The climate and irrigation allows for tillage across large areas, which may also be made mandatory more easily than in USA if *C. nebraskensis* is identified as a risk (M. Delos, pers. comm.). If ploughing is (re)introduced in some areas as a measure against *C. nebraskensis*, this may have subsequent environmental impacts (on soil and on energy/fuel consumption) and social impacts (mudslides and surface run-off).



Maize monoculture (continuous growing of maize for a number of years) is practiced in the EPPO region, although this may be declining due to the associated environmental impacts (e.g. erosion, nitrate leaching, pesticide transfer) and in some cases, reduced yields (Nevens & Reheul, 2001; Książak *et al.*, 2018; Ștefan *et al.*, 2018). In a questionnaire on the Integrated Pest Management (IPM) of maize (in the framework of the EU Horizon Europe project SUPPORT), 202 farmers (out of 203) did apply some IPM strategies, with 143 using site-specific crop rotation. Twenty-nine growers used no-till (among whom 12 also did not implement crop rotations) (Akter *et al.*, 2025). In France (as an example because no other comprehensive figures were found), monoculture (5 years continuous maize) represented less than 3 % of maize production in 2021, and share of monoculture of maize may vary according to the region, the main monocrop area for maize is in the plain around the city of Pau in southwestern France (M. Delos, pers. comm.).

Changes of practices may not be possible where ‘no-tillage’ strategies address issues such as water shortage, and crop rotation may also be difficult in part of the EPPO region; but cropping with an intermediate winter crop and associated practices (ploughing in) would reduce or eliminate the inoculum.

Irrigation. Overhead irrigation can lead to increased disease development and likely impact (see section 2.6.5). Overhead irrigation is utilised in the EPPO region which could exacerbate impacts, although the full extent of its use is not known.

Climatic conditions would influence impact, with higher impacts likely to be seen in areas with similar climates to regions of the USA where significant impacts have been seen, i.e. *Dfa* and *BSk* Köppen-Geiger climate types. In areas with *Cfa* or *Dfb* KG climate types, impacts may be lower, similar to what is observed in the USA. Impact is unlikely in areas similar to southern Canada, where levels of over 30% field infestation do not lead to economic impact (this includes large parts of Eastern Europe to Scandinavia and Russia eastwards). There is an uncertainty on impact for all other climate types that are present in the EPPO region, for example under *Cfb* KG climate type, which represents large areas of maize cultivation in the EPPO region.

Extreme weather events carrying infested crop debris may increase impacts, but these events may not happen at a comparable scale and frequency as in the US Midwest.

Climate change may change the level of impacts seen, because the area with climatic conditions most suitable for impact will change. Climate change may also lead to extreme weather events occurring more frequently and subsequently exacerbating spread. However, some of these areas may become less suitable for maize cultivation (e.g. scarce water resources).

Overall, there may be social impacts in the form of stress to affected farmers and traders.

13.2 Assessment of economic impact for the EPPO region

(Assessment prepared by M. Frem.)

13.2.1 Scope assessment

To understand the risks posed by *C. nebraskensis*, potential impacts are categorised into four key categories as follows: (i) direct economic losses, (ii) control costs, (iii) trade implications, and (iv) government response expenditures.

(i). Direct economic impact (Losses in tonnes and €): Partly quantitatively feasible.

This category would be reasonably estimated by transferring loss rates from US states to climate types, which can then be related to EPPO countries, although this is possible only for some climate types under which *C. nebraskensis* is present. Data are available for the price of grain per tonne.

(ii). Control costs (Increased or additional farm costs): Qualitatively feasible.

The control of *C. nebraskensis* would incur costs for farmers, linked to the adoption of less susceptible cultivars, higher quality seeds, rotation, tillage, cleaning of equipment etc. The critical unknown is the adoption rate of these practices by farmers in EPPO countries, and the availability of less susceptible cultivars, driven by the seed industry.

(iii). Trade impacts: Qualitatively feasible.

The decision to regulate the pest and the subsequent loss of specific export markets are policy-dependent. In addition, should the pest be introduced in the EPPO region, if PFAs are established and maintained, this would have costs.

(iv). Response costs (Government/NPPO costs): Qualitatively feasible.

The following costs may be incurred in relation to *C. nebraskensis*: surveillance including sampling and diagnostics, extension, research.

The detailed analysis in this PRA focused on the potential direct economic impact (i). To ensure a focused and meaningful analysis, detailed quantitative assessments were conducted (see ANNEX 14 and ANNEX 15) for a selected group of EPPO countries (selection analysis in 13.2.3) that meet two key criteria: (a) a high proportion of maize cultivation occurs in climate types at risk, and

(b) maize is predominantly grown for grain rather than forage or other uses according to data available in Eurostat.

In addition, the estimation of control, trade, and response costs has not been applied, as these categories are highly dependent on regional agricultural practices, policy decisions, and pest management strategies, which vary significantly across EPPO member countries.

13.2.2 Methodological overview of climate-risk driven loss assessment

Based on ANNEX 14, the direct economic impact of *C. nebraskensis* was calculated using a structured, five-step framework that integrates scenario planning, climate-risk zoning, and empirical loss data. As such, the assessment began by defining two impact scenarios (Step 1) to capture a range of plausible futures: an optimistic Scenario A with managed impact and a pessimistic Scenario B with significant impact. To geographically target the analysis, maize cultivation areas were stratified into analogous climatic risk zones (Step 2), identifying *BSk* and *Dfa* as Primary Risk zones and *Cfa* and *Dfb* as Secondary Risk zones. Empirical 10-year average yield loss rates from the US Goss's wilt belt were then extrapolated (Step 3) and applied to these KG climate types in EPPO countries, resulting in specific loss percentages for each scenario. Using 2022 Eurostat data, a national production baseline was established (Step 4). Finally (Step 5), the direct economic impact was quantified by calculating the reduction in tonnes and Euros for each country. This was achieved by applying the climate zone-specific loss rates to the stratified cultivation areas and valuing the lost production using national market prices, providing a spatially explicit and scenario-based estimate of potential losses.

Furthermore, tables provided in ANNEX 150 show the potential losses calculation. The calculation began with the baseline agricultural data (Table B1), establishing the production (in tonnes) and value (in Euros) for grain maize in each country without the pest in 2022. The total cultivated maize area for each country was then stratified into specific climate zones using 2022 data from EU Crop (Tables B2 & B3), and climatic zones were classified as either Primary or Secondary Risk based on their suitability for the bacterium's establishment and impact in the US in different states. For each of these risk categories, distinct yield loss rates based on US data were applied (Table B4) to create two impact scenarios: an optimistic (Scenario A) and a pessimistic (Scenario B). These loss rates were used to calculate new, reduced yields for every climate zone (Table B5). Finally, the impacted production in tonnes was determined by multiplying the climate zone-specific area by its corresponding impacted yield. The estimated future production value under two different scenarios A and B was then derived by multiplying this new production quantity by the country-specific market price (Tables B6, B7 and B8).

It is noted that the assessment was performed with figures for 2022 at a time where prices were abnormally high. Market prices are normally lower, around 180 €/tonne, against over 280 €/tonne in the assessment. Consequently, the financial loss is likely overestimated compared to normal years.

13.2.3 Country-based illustrations of direct economic losses in maize production

Because there is an uncertainty on whether the pest can establish under uncertain climate types and the damage it could cause, including *Cfb* which covers large maize production areas in the EPPO region, it is not possible to calculate a loss for these areas. Consequently, this method will not be used to calculate losses for all EPPO countries, but case studies are provided. However, EPPO countries can consider how to adjust them to their purposes.

Based on available data for the EPPO region, **Romania** and **Bulgaria** were particularly suitable for this purpose. In fact, 100% of their maize-growing areas fall within climate types considered at risk (see sections 9.1 and 9.2, and ANNEX 9). In addition, 98% and 95% of their maize is not green maize, indicating it is primarily grown for grain (ANNEX 6). Furthermore, **Hungary** also presented a viable case because 97% of maize area is in climates at risk and 91% of maize is not green maize. As such, Bulgaria, Hungary and Romania offered a robust basis for estimating direct economic losses in tonnes and Euros. The category for grain maize in Eurostat also covers maize seed, whose production is minor compared to grain in most countries, and the whole production was considered to be grain. Also, it is important to note that some maize may be used for silage/forage or ethanol production, which typically commands a lower market price than grain. Our estimates were limited to the grain maize in these countries. EPPO countries may adapt,

they provided illustrative case studies to their own contexts. In addition, countries with a major maize seed production (e.g. France) may consider how this affects the assessment for their country.

For Bulgaria, Hungary and Romania, the introduction of *C. nebraskensis* leads to significant economic and production losses to grain production in the pessimistic scenario B. Selected country-by-country analysis:

Case of Bulgaria: Summary of findings (Table 12 in this section & Table B6 in ANNEX 15).

Scenario A vs. Baseline (absence of *C. nebraskensis*): Shows a negligible loss of 1,218 tonnes (€0.35 million), representing a 0.05% decrease. This minor discrepancy is likely due to rounding differences in the yield calculations used for the climate zone breakdown in Table B6, confirming that Scenario A is effectively identical to the baseline.

Scenario B vs. Baseline (absence of *C. nebraskensis*): Demonstrates a significant impact, with a total loss of 32,986 tonnes of maize grain. In financial terms, this translates to a €9.54 million reduction in the value of production, representing a 1.29% loss nationally. This is the definitive measure of the economic impact of the yield reduction applied in Scenario B.

Table 12. Maize loss analysis 2022: Impact scenarios vs. Baseline (absence of *C. nebraskensis*) in Bulgaria. Price applied¹⁴: 289.20 €/tonne.

Item	Table B1 (Baseline)	Table B8 Scenario A	Loss (A vs. Baseline)	% Loss (A vs. Baseline)	Table B8 Scenario B	Loss (B vs. Baseline)	% Loss (B vs. Baseline)
Production (1000 t)	2,554.370	2,553.152	1.218	0.05%	2,521.384	32.986	1.29%
Production Value (1000 €)	738,723.804	738,371.723	352.081	0.05%	729,184.175	9,539.629	1.29%

Case of Hungary: Summary of findings (Table 13 in this section & Table B7 in ANNEX 15).

Scenario A vs. Baseline (absence of *C. nebraskensis*): Shows a negligible loss of 148 tonnes (€ 0.14 million), representing a 0.01% decrease. This minor discrepancy is likely due to rounding differences in the yield calculations used for the climate zone breakdown in Table B7, confirming that Scenario A is effectively identical to the baseline. 3% of the maize area is under *Cfb*, with no losses calculated in the assessment.

Scenario B vs. Baseline (absence of *C. nebraskensis*): Demonstrates a more pronounced impact, with a total loss of 38,228 tonnes of grain maize. In financial terms, this translates to a €11.01 million reduction in the value of production, representing a 1.38% loss against the national baseline. This is the definitive measure of the economic impact of the yield reduction applied in Scenario B.

Table 13. Maize loss analysis 2022: Impact scenarios vs. Baseline (absence of *C. nebraskensis*) in Hungary. Price applied: 290.50 €/tonne

Item	Table B1 (Baseline)	Table B8 Scenario A	Loss (A vs. Baseline)	% Loss (A vs. Baseline)	Table B8 Scenario B	Loss (B vs. Baseline)	% Loss (B vs. Baseline)
Production (1000 t)	2,765.60	2,765.452	0.148	0.01%	2,727.372	38.228	1.38%
Production Value (1000 €)	803,406.800	803,263.852	142.948	0.02%	792,301.811	11,104.989	1.38%

¹⁴ For the three countries, the price used is extracted from Eurostat 2022 figure for selling prices of crop products (absolute prices) - annual price (from 2000 onwards) [apri_ap_crpouta__custom_18271793]]

Case of Romania: Summary of findings (Table 14 in this section & Table B8 in ANNEX 15).

Scenario A vs. Baseline (absence of *C. nebraskensis*): Shows a negligible loss of 4,442 tonnes (€1.24 million), representing a 0.06% decrease. This minor discrepancy is due to rounding differences in the yield calculations used for the climate zone breakdown in Table B8, confirming that Scenario A is effectively identical to the national baseline.

Scenario B vs. Baseline (absence of *C. nebraskensis*): Demonstrates a significant impact, with a total loss of 128,693 tonnes of grain maize. In financial terms, this translates to a €36.01 million reduction in the value of production, representing a 1.60% loss nationally. This is the definitive measure of the economic impact of the yield reduction applied in Scenario B.

Table 14. Maize loss analysis 2022: Impact scenarios vs. Baseline (absence of *C. nebraskensis*) in Romania. Price applied: 279.80 €/tonne

Item	Table B1 (Baseline)	Table B8 Scenario A	Loss (A vs. Baseline)	% Loss (A vs. Baseline)	Table B8 Scenario B	Loss (B vs. Baseline)	% Loss (B vs. Baseline)
Production (1000 t)	8,037.13	8,032.688	4.442	0.06%	7,908.437	128.693	1.60%
Production Value (1000 €)	2,248,788.974	2,247,546.102	1,242.872	0.06%	2,212,780.673	36,008.301	1.60%

13.3 Overall magnitude of impact in the EPPO region

The EWG rated the magnitude of impact in the EPPO region for the optimistic and pessimistic scenarios (see description of scenarios in ANNEX 14). At the scale of the EPPO region, the optimistic or pessimistic scenarios may apply depending on areas.

Pessimistic scenario, impact would be similar to US ‘outbreak’ years or specific severe cases.

Rating of the magnitude of impact in the area of potential establishment	Very low ☐	Low ☐	Moderate ☐	High x	Very high ☐
Rating of uncertainty			Low ☐	Moderate x	High ☐

Optimistic scenario. Yield losses exceeding normal variation are expected and some targeted measures would likely be necessary.

Rating of the magnitude of impact in the area of potential establishment	Very low ☐	Low ☐	Moderate x	High ☐	Very high ☐
Rating of uncertainty			Low ☐	Moderate x	High ☐

Uncertainty (same in both cases): whether economic impact assessment applies to other EPPO countries; impact in other climatic conditions; speed of capacity-building/knowledge/awareness raising in EPPO countries.

14 Identification of the endangered area

Describe the endangered area: Potentially, all areas where maize is grown in the EPPO region are at risk of establishment and impact, although some uncertainty remains. Köppen Geiger climate types under which *C. nebraskensis* has had impact in its current distribution (see Fig. 9 in section 9.1) occur over large areas where maize is grown in the EPPO region, and impact under other climatic conditions cannot be excluded.

However, the exact extent of the endangered area cannot be determined because establishment and impact depend not only on the presence of maize, but also on the growing of susceptible maize types and local agricultural practices (such as continuous maize production and reduced tillage). The endangered area would therefore depend on where and when these practices are used. There is an uncertainty on whether economic impact would occur where agricultural practices that do not favour the pest (such as crop rotation and tillage) are widely used.

15 Overall assessment of risk

Summary of ratings:

	Likelihood	Uncertainty
Entry (overall)		
Seeds of <i>Zea mays</i>	moderate	moderate
Grain of <i>Zea mays</i> (kernels for processing or consumption, either separated or attached to the cobs (ears) including sweet corn with or without husks)	low	moderate
Establishment outdoors	very high	moderate
Establishment in protected conditions	not relevant	
Magnitude of spread	moderate	moderate
Magnitude of impact in the current area of distribution	moderate	moderate
Magnitude of potential impact in the PRA area		
Scenario A – ‘optimistic scenario’	moderate	moderate
Scenario B – ‘pessimistic scenario’	high	moderate

Clavibacter nebraskensis is a seed-transmitted bacterium occurring in North America and South Africa whose main host is maize (*Zea mays*). Other natural hosts are *Setaria viridis* and shattercane (*Sorghum bicolor*) and many experimental hosts have been found through inoculation, but the role of these as alternative hosts is not clear. The primary phytosanitary risk of *C. nebraskensis* is associated with maize. The main source of inoculum where the pathogen is present is infested crop debris, although maize seeds may play a role in introducing the disease into new areas. No completely resistant maize cultivars exist, and susceptibility amongst cultivars varies. Some maize types (such as popcorn or sweet corn) appear to be more susceptible, possibly because selection of resistant cultivars is less likely due to a narrower genetic pool.

Seeds (for planting) of *Z. mays* was identified as the most likely entry pathway, with a moderate likelihood and moderate uncertainty. The EWG noted in particular that some commercial seeds (for sale to growers) are imported into the EPPO region from countries where the pest occurs. Successful entry with grain of *Z. mays* (kernels for processing or consumption, but not for planting) requires a chain of unlikely events for transfer to a host to occur, although the risk of transfer is higher when associated with husks or maize plant debris. The likelihood of entry on grain was rated as low with a moderate uncertainty.

The likelihood of establishment was rated as very likely with a moderate uncertainty. Maize is widely cultivated in many EPPO countries and in its current distribution, *C. nebraskensis* occurs under a wide range of climatic conditions. Subsequently, climate was generally not considered to be a limiting factor for establishment in areas of the EPPO region where maize is cultivated. The pathogen is known to occur under certain Köppen Geiger climate types that also occur in the EPPO region (*BSk*, *Cfa*, *Dfa*, *Dfb* – see section 9.1). These areas of the EPPO region were considered to be suitable for establishment with a higher degree of certainty than areas of the EPPO region which cultivate maize under climate types from which the pest has not been reported. The EWG considered that the extent of maize cultivation and agricultural practices in maize cultivation may have a greater effect on establishment than climate. Establishment is most likely to occur if the pathogen enters an area where there is a high density of maize cultivation and where agricultural practices such as continuous maize production (without crop rotation) and/or reduced or no-tillage are common. Although it is not possible to precisely delimit where favourable agricultural practices are widely used, they are known to occur in some areas, which would increase the establishment potential.

The magnitude of spread was rated as moderate with a moderate uncertainty. Spread would occur naturally and through human-assisted means (such as infected seeds or grain, green forage, silage, debris, contamination of machinery). It is noted that extreme weather events (strong winds, hail and storms) move infested crop debris and damage plants promoting disease development, which have an important role in the U.S. Midwest, may not happen at a comparable scale and frequency in the EPPO region, although their frequency is likely to increase as a result of climate change. In the EPPO region, like in South Africa, *C. nebraskensis* may not be detected immediately, allowing for significant spread and multiple outbreaks before detection.

Overall, impact in the current area of distribution was rated as moderate with a moderate uncertainty. In the past in the USA, initial outbreaks and reemergence events have had a high impact in terms of crop losses. Currently, direct economic losses are relatively low in the USA where management practices are in place, although there is higher impact on a local scale in certain areas due to the cultivation of certain maize types that are more susceptible, or to the occurrence of severe weather events. In South Africa where the pathogen was first found in 2024, the disease has to date affected trade and can disrupt production.

For the potential economic impact, two scenarios, optimistic and pessimistic¹⁵ were assessed. Under the pessimistic scenario, the magnitude of impact in the area of potential establishment was rated as high with a moderate uncertainty. Under this scenario impacts were expected to be similar to US ‘outbreak’ years or specific severe cases. Under the optimistic scenario, the magnitude of potential impact was rated as moderate with a moderate uncertainty. Under this scenario yield losses exceeding normal variation were expected and some targeted measures would likely be necessary.

The phytosanitary risk for the endangered area (based on a three-level scale) was assessed to be moderate with a moderate uncertainty. No key uncertainty (see section 17) was identified that could affect this conclusion.

Based on all the information in this PRA, the EWG concluded that *C. nebraskensis* fulfils the criteria to be recommended as a quarantine pest, noting that maize is a major crop in the EPPO region. Phytosanitary measures were recommended.

Stage 3. Pest risk management

16 Phytosanitary measures

16.1 Measures on individual pathways to prevent entry

Considering the likelihoods of entry and uncertainties, the EWG recommended specific measures for maize seeds. For maize grain, only a phytosanitary certificate is recommended. A higher level of protection can be provided if needed by requiring absence of plant debris in grain consignments.

Measures were studied in detail for maize seeds (see 0). Measures are recommended for *Zea mays*, but if other relevant hosts are confirmed, this may have to be reconsidered.

¹⁵ From Annex 14, Step 1. *Optimistic scenario*: the pathogen is detected early. Resistant maize cultivars rapidly become widely available and are adopted quickly over large areas. Major maize-producing regions have low monoculture rates or can implement effective crop rotation in most of their territory. Tillage is possible in many areas. Impact is similar to the current overall US situation.

Pessimistic scenario: Under which the pathogen remains undetected for several years (which is realistic), allowing significant build-up and spread, introduction in a region with high maize monoculture and no-till practices, the development of resistant cultivars is slow or not possible at a large scale, and extreme weather events exacerbate the problem before management is implemented

The following measures were identified:

Pathway	Measures identified
Seeds of <i>Zea mays</i>	Pest free area (PFA) (ISPM 4, ISPM 29) (see requirements below) OR The seed lot has been tested (see EPPO Standard PM 3/78 in relation to sampling). The test should be indicated on the phytosanitary certificate. For small seed lots, means of verification of the pest status of the lot should be agreed by bilateral agreement with the importing country.
Grain of <i>Zea mays</i>	Phytosanitary certificate (PC) only. A higher level of protection can be provided if needed by requiring absence of plant debris in grain consignments.

In addition to phytosanitary measures to be implemented by exporting countries, importing EPPO countries are encouraged to implement the following measures:

- Used shipping containers, machinery, vehicles and equipment, travellers' footwear entering an area/place/site of production of maize should be cleaned/disinfected.
- Maize should not be unloaded outdoors in the vicinity of maize-growing areas and spillage of grain/debris/waste should be avoided during transport, processing and storage.
- Biosecure waste management should be implemented in areas that receive maize plant parts/debris from the known distribution that could be infested.
- Awareness raising campaigns to growers and official inspection of maize-growing areas would be useful to increase the likelihood that the bacterium is detected early.

Requirements for establishing a PFA:

Clavibacter nebraskensis has a limited distribution in countries where it is present. In countries where the pest is present, establishing a PFA may be possible e.g. in specific areas separated by natural obstacles (such as West of the Rocky Mountains, USA, where the pest has not been recorded to date). There is insufficient data to recommend a minimum distance between a PFA and the closest area where the pest is present, for example for wind-driven spread. A sufficient buffer zone should be established covering the risk of natural displacement of infested debris with the wind. In addition, the presence of the pest varies from year to year in states and provinces where it has been found.

- To establish and maintain the PFA (ISPM 4, ISPM 29), general surveillance in the area in the three years prior to establishment of the PFA and continued surveillance and monitoring every year at suitable periods for detection may be sufficient.
- In specific cases and in countries where the pest has been reported, specific targeted surveillance should also be carried out in the zone between the PFA and known infestation to demonstrate pest freedom. The detection surveys to establish and maintain the PFA should be targeted for the pest and be based on visual examination and testing of maize plants, seeds and debris.
- Detection surveys should include sufficient numbers of maize fields in the area to have confidence of the absence of the pest and be carried out at suitable growth stages for detection (e.g. after silking). In particular surveys should target more susceptible maize types such as popcorn and sweetcorn. Testing should be performed upon detection of symptoms during visual surveillance.
- There should be restrictions on the movement of maize commodities such as maize seeds, grain, green forage or silage (originating from areas where the pest is known to be present) into the PFA, and in the area between the PFA and the closest area of known infestation.
- There should be restrictions on the movement of machinery (such as harvesters), footwear, equipment and shipping containers into the area.

16.2 Eradication and containment

Early detection would be essential for the eradication of *C. nebraskensis*, but it is unlikely to occur (as in South Africa) for the following reasons:

- Low levels of infection are difficult to detect. Following introduction, it may take several years before the disease is sufficient levels to aid detection.
- Confusion of symptoms with other diseases and abiotic factors will likely further delay detection.
- Identification may not be possible in the initial stages of any introduction, due to the low levels of infection. This will provide more opportunity for the bacterium to spread further through the exchange of infected material, contaminated equipment or natural spread.
- *C. nebraskensis* could build-up inoculum levels within a maize-growing area before it is identified.

Eradication may only be possible in specific areas, for instance where infections are isolated from major maize-production areas and where crop rotation and restrictions on maize cultivation is more feasible. Containment is unlikely to succeed, as inoculum would build-up and eventually disperse from the area to potentially infest other areas. There are also uncertainties surrounding the role of other Poaceae in the disease's epidemiology.

If *C. nebraskensis* is detected, it should be assumed that it is already present in neighbouring crops. Surveys should be conducted, and any suspicious material should be tested.

Eradication would require intensive monitoring of the site and its surroundings (with a sufficient distance around the infested site), including all maize crops and some Poaceae weeds and the adoption of management measures such as the destruction of maize plants and Poaceae, deep ploughing of any maize debris, restrictions on maize cultivation for 2 years in the infested area and buffer zone and restrictions on the movement of machinery and equipment out of the infested area.

In case of extreme weather events in the first two years and due to the risk that inoculum has been transported by the wind, it should be considered if eradication is still feasible.

Public information and outreach campaigns may help earlier reporting and better implementation of measures.

17 Uncertainty

The EWG used the categories of main sources of uncertainties (under development) discussed by the EPPO Panel on Phytosanitary Measures in October 2023:

- *Key uncertainties*: likely to significantly affect the overall conclusions (including overall risk and overall uncertainty) of the PRA (i.e. the determination of whether the pest has the characteristics of a quarantine pest, and the pathways that should be managed);
- *Other main uncertainties*: not likely to affect the overall conclusions of the PRA but likely to impact conclusions of individual part(s) of the risk assessment or risk management.

Key uncertainties	Other main uncertainties
	Whether experimental hosts are natural hosts
	The price of maize in relation to economic impact
	Prevalence of <i>C. nebraskensis</i> in seed production areas in the countries where it is present
	Factors potentially limiting establishment, spread, impact
	The extent of impact in uncertain climate types in the EPPO region
	Duration of the latent phase / undetected occurrence following introduction
	Ratio of commercial seeds vs. breeding with regard to imports into the EPPO region
	Which cultivars are resistant and whether they are grown in the EPPO region

18 Remarks

This section includes work that would address some main sources of uncertainty in the PRA or improve detection and response to outbreaks in the EPPO region. It was not discussed during the meeting, but ideas were assembled afterwards.

- Development of an EPPO Diagnostic protocol
- Production of awareness raising materials
- Engagement with industry
- Duration of survival of *Clavibacter nebraskensis* in maize seeds.

Possible areas of research identified in North America and South Africa are listed below:

- Epidemiology of the disease under South African conditions (Njom *et al.*, 2025).
- Foliar-applied treatments helping to minimize the effect of hail (based on Harding *et al.*, 2018).
- Competitive inhibition and exclusion, or antibiosis by biocontrol agents may help to reduce levels of primary inoculum, or the multiplication of the bacteria within the host (Harding *et al.*, 2018).
- Using microbial agents to accelerate the decomposition of maize debris to reduce the primary inoculum (Harding *et al.*, 2008).
- Disease resistance priming/biopriming, i.e. using weakly aggressive strains to activate strong defence responses in susceptible maize plants. In experiments, the priming process led to an inhibition of the elongated lesions by highly aggressive strains. Such biopriming could be an environmentally-friendly method to control the disease, and still allow the use of susceptible cultivars (El Shetehy *et al.*, 2023).

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ANNEX 1. Evaluation of possible phytosanitary measures for the main identified pathways, using EPPO Standard PM 5/3

The table below summarizes the consideration of possible measures for the pathway ‘Maize seeds’ (based on the EPPO Standard PM 5/3). Measures for maize grain and sweetcorn are addressed directly in section 16 of the PRA.

When a measure is considered appropriate, it is noted “yes”, or “yes, in combination” if it should be combined with other measures in a systems approach. “No” indicates that a measure is not considered appropriate. A short justification is included.

Option	Maize seeds
Existing measures in the PRA area	Partly. Israel regulates the pest.
	Options at the place of production
Visual inspection at place of production	Yes, in combination. Symptoms may appear at any point during the growing season, especially after severe weather events. The optimal time for visual examination at the place of production is before senescence (the same period recommended for <i>P. stewartii</i>). However, limiting inspections to this narrow window may be impractical for inspection services. Low levels of infection or small clusters of infected plants may not be detected. There may also be latent infection and epiphytic populations which will not be detected by visual inspection.
Testing at place of production	Yes, in combination Testing methods exist. Any test used should be designed to be able to detect low levels of infection. As for visual examination, the optimal timing for testing is before senescence. Remark: Each seed lot represents a unique production location and crop year. However, it is possible that seeds from different fields can be blended (Euroseeds, pers. comm.).
Treatment of crop	No. No treatment is effective to eliminate the bacterium.
Resistant cultivars	Yes, in combination. If a cultivar is resistant, seeds are less likely to be infected (transmission from plant to seed is lower). The term ‘resistant’ means a good tolerance level but not complete resistance (see section 2.6.1). For this measure to be feasible, the cultivars traded should be rated for tolerance against <i>C. nebraskensis</i>. For some countries this may not be feasible. For instance, in the framework of a PRA on <i>P. stewartii</i>, the USDA informed EFSA (EFSA, 2019b) that ‘APHIS is unable to certify seed resistance on a phytosanitary certificate.’, ‘It is APHIS PPQ policy to not recognize and certify varietal resistance and genetic composition on phytosanitary certificates. For the Authorised Certifying Official, it is nearly impossible to conduct an inspection of corn seed and validate/determine whether or not it is from a resistant seed variety. Other USDA agencies, such as the Biotechnology Regulatory Services

Option	Maize seeds
	and/or the Agricultural Marketing Service, may recognize resistant varieties for specific pathogens; however, APHIS would not be the authority'. In the USA, ratings are provided by the seed companies and are made using different scales. No information was sought for other countries where <i>C. nebraskensis</i> is present.
Growing under physical isolation	Only in theory, for research or breeding purposes, when done according to EPPO Standard PM 5/8 <i>Guidelines on the phytosanitary measures 'plants grown under physical isolation'</i> .
Specified age of plant, growth stage or time of year of harvest	No. Seeds are harvested at specific development stages. In addition, the seed moisture level was not found to influence the bacterium.
Produced in a certification scheme	Yes. However, this should include other measures identified such as inspection and testing for different categories of material. See corresponding options.
Pest freedom of the crop	Yes, in combination. See several options related to pest freedom of the crop are already reviewed in this table under: - Visual inspection at the place of production - Testing at the place of production - Resistant cultivars Cultural practices (rotation, residue management, control of volunteer maize plant)
Pest free production site	No. Theoretically, a pest-free production site could be established, isolated from infested areas with a sufficient buffer zone, free from the pest and regularly surveyed. Pathogen-free seeds should be used. Because <i>C. nebraskensis</i> may be transported with the wind, a sufficient buffer zone should be established covering the risk of natural displacement of infested debris with the wind. The suitable size of the buffer zone cannot be determined, and establishing such sites may not be feasible. However, because of epiphytic populations on maize and of other Poaceae hosts (possibly asymptomatic), it would be difficult to ensure absence of the pest in the site and in the buffer zone. It would be too demanding in areas where the pest is present, and in areas where the pest is not present, a pest free area could be established (see below).
Pest free place of production	No, as for pest-free production site.
Pest free area	Yes <i>Clavibacter nebraskensis</i> has a limited distribution in countries where it is present. In countries where the pest is present, establishing a PFA may be

Option	Maize seeds
	possible e.g. in specific areas separated by natural obstacles (such as West of the Rocky Mountains, USA, where the pest has not been recorded to date). There is insufficient data to recommend a minimum distance between a PFA and the closest area where the pest is present, for example for wind-driven spread. A sufficient buffer zone should be established covering the risk of natural displacement of infested debris with the wind. In addition, the presence of the pest varies from year to year in states and provinces where it has been found. • To establish and maintain the PFA (ISPM 4, ISPM 29), a general surveillance in the area in the three years prior to establishment of the PFA, and continuing surveillance and monitoring every year at a suitable period for detection may be sufficient. • In specific cases and in countries where the pest has been reported, specific targeted surveillance should also be carried out in the zone between the PFA and known infestation to demonstrate pest freedom. The detection surveys to establish and maintain the PFA should be targeted for the pest and be based on visual examination and testing of maize plants, seeds and debris. Detection surveys should include sufficient numbers of maize fields in the area to have confidence of the absence of the pest and be carried out at suitable growth stages for detection (e.g. after silking). In particular surveys should target more susceptible maize types such as popcorn and sweetcorn. Testing should be performed upon detection of symptoms during visual surveillance. • There should be restrictions on the movement of maize commodities such as maize seeds, grain, green forage or silage (originating from areas where the pest is known to be present) into the PFA, and in the area between the PFA and the closest area of known infestation. • There should be restrictions on the movement of machinery (such as harvesters), footwear, equipment and shipping containers into the area.
	Options after harvest, at pre-clearance or during transport
Visual inspection of consignment	No. The pest cannot be detected on seed by inspection. Sorting and quality control checks would likely remove heavily infected seeds and remaining seeds would generally be asymptomatic.
Testing of commodity	Yes. The minimum size of the sample has to be determined so that the composite sample (aggregated primary samples) contains at least the minimum amount of seed required for the requested laboratory test (EPPO, 2021b). The intensity of sampling should allow for the detection of low infection levels of the pest. The appropriate sampling and testing regime should be determined. Work on developing seed testing procedures is being carried out at least in Italy and Germany (see section 2.10). Seed testing procedures are applied in the USA. Guidance on sampling for laboratory testing is included in EPPO Standard PM 3/78 (2) <i>Consignment inspection of seed and grain of cereals</i> (EPPO, 2021b): ‘Table 3 or 4 in ISPM no. 31 Methodologies for sampling of consignments (IPPC, 2005b) can be used to determine the sample size needed to detect a specified level of infection in a lot of seed or grain. For seed, a more stringent level should be chosen than for grain. If 2995 seeds are inspected from a lot of grain this provides a 95% confidence of detecting an infection present in 0.1% of the seeds. For seed, a sample size of 4603 seeds would provide a 99% confidence of detecting an infection present in 0.1% of the seeds.’ EU requirement for several bacteria incl. <i>P. stewartii</i> subsp. <i>stewartii</i> is that a representative sample of the seeds should be tested and found free. ‘The size of the sample for inspection shall be such as to enable at least the detection of 0.5 % level of infestation with a level of confidence of 99

Option	Maize seeds
	%. However, in the case of seed lots smaller than 8000 seeds, a representative sample of 10 % of the lot has been tested and found free’. This may also apply to <i>C. nebraskensis</i> if it is confirmed that both pests share a similar plant-to-seed transmission rate. For large lots that are sufficiently mixed and assuming a binomial distribution, sampling and testing 1000 seeds from a lot will give approximately 99.3% confidence level of detecting infected seeds at a 0.5% infection level. For a lot of 8000 seeds, testing 800 seeds would provide approximately 98.5% confidence level of detecting the pest at a 0.5% infection level. Similarly, for a lot of 4000 seeds, testing 400 seeds would provide approximately 87.9% confidence level of detecting the pest at a 0.5% infection level. (see calculation tools S1 and S2 provided as supplementary material to EPPO Standard PM 3/70 (EPPO, 2025d), and ISPM 31 (FAO, 2008)).
Treatment of the consignment	Yes, in combination. Treatment (e.g. hot air, hot water or ethanol) may surface-disinfect the seed but may not be completely effective and would not have an effect on internal infection. In addition, it may only be feasible for small consignments. One requirement proposed as option for maize seed treatment from France to New Caledonia against some bacteria is hot water treatment (50°C during 20 min) (Lataste <i>et al.</i>, 2023).
Pest only on certain parts of plant/plant product, which can be removed	No. Remark: It could also be requested that maize seed should be free from debris and seeds of other host plants. However, this is not considered to pose a major additional risk.
Prevention of infestation by packing/handling method	No. Theoretically, seeds could be kept until <i>C. nebraskensis</i> dies. It can survive in kernels for at least 1 year, with survival gradually decreasing over time (see section 2.3.3). However, a suitable time period cannot be determined, because the maximum survival period is unknown. Also, the storage of kernels for long periods may not be feasible.
	Options that can be implemented after entry of consignments
Post-entry quarantine	No, generally not relevant for this commodity. Although rare, certain high-risk pathogens (e.g., <i>Pantoea stewartii</i>) have prompted some countries to apply post-entry quarantine testing or screening. ISF (2003), with regard to <i>P. stewartii</i>, mention that seed can be grown in post entry quarantine with the first generation of seed harvested and released if found healthy (this is not suitable for hybrid seed lines). However, the EWG noted that since seed transmission is very low, the number of plants would need to be very high (in order to have a chance of detecting the pest by visual inspections for symptoms or testing), which would not be possible under post-entry quarantine conditions.
Limited distribution of consignments in time and/or space or limited	No. Limiting the distribution to areas where the pest is not likely to establish is not possible.

Option	Maize seeds
use	
Surveillance and eradication in the importing country	No. Detection is difficult, especially at early stages of infestation.

Possible combinations of measures identified as ‘Yes in combination’ *The individual measures identified above as ‘Yes in combination’ were:

Maize seeds
Visual inspection
Testing at the place of production
Cultural practices (rotation, residue management, control of volunteer maize plant)
Resistant cultivars
Treatment of the consignment

The EWG considered that these measures could not be combined to achieve a suitable level of protection because there are too many uncertainties on the effectiveness of the individual measures.

ANNEX 2. Illustrative pictures of *Clavibacter nebraskensis*



Goss's blight (T. Jackson-Ziems, Nebraska-Lincoln University, USA)



Goss's blight shiny exudate (T. Jackson-Ziems, Nebraska-Lincoln University, USA)



Goss's blight with freckling (T. Jackson-Ziems, Nebraska-Lincoln University, USA)



Infection through hydathodes (A. Robertson, Iowa State University, USA)



Goss's systemic infection discolored vascular bundles (T. Jackson-Ziems, Nebraska-Lincoln University, USA)



Dark brown vascular elements colonized with *Clavibacter nebraskensis* (A. Robertson, Iowa State University, USA)



Goss's systemic wilt (T. Jackson-Ziems, Nebraska-Lincoln University, USA)



Goss's systemic wilt (T. Jackson-Ziems, Nebraska-Lincoln University, USA)

ANNEX 3. Details on seed transmission studies

Block *et al.* (2019) assessed the percentage of infection in seed harvested from plants of resistant, susceptible and moderately resistant maize hybrids grown in plots. The plots were either inoculated with the bacterium or left uninoculated. Plants were inoculated at the 6th-leaf stage by sand-blasting (wounding) and spraying the plants with a suspension of *C. nebraskensis* (10^8 CFU ml⁻¹). Non-inoculated plots relied on infections from inoculated plots. Seed transmission from resulting infested seed lots was also assessed.

The foliar disease severity ranged from 1.6 to 87.9% for ‘inoculated’ plots, and from 1.2 to 26.7% for ‘non-inoculated’ plots, respectively for resistant and susceptible hybrids. Infected seeds were not found in every plot, although they were found for every treatment. Some infected seeds were recovered from plants with low foliar disease severity which can occur in *P. stewartii* infections but this was not expected during infection with *C. nebraskensis*.

Seed infection (transmission from plant to seed) was as follows:

	Seed infection in inoculated plots	Seed infection in non-inoculated plots (natural infection from inoculated plots)
Susceptible hybrid	21.4%±4%	5.15±2.2%
Resistant hybrid	2.5%±1.5%	0.8%±0.8%
Two moderately resistant hybrid	3.3%±1.8% and 6.0%±2.3 %	1.3%±1.1 % and 1.0%±0.9%

Experiments on seed transmission were conducted in the field and greenhouse using seeds harvested from the hybrids with highest levels of seed infection (seed lots from inoculated and non-inoculated susceptible hybrid, and from an inoculated moderately resistant hybrid). Each seed lot was tested to determine the percentage of infection, which ranged from 3.6 to 37%. Seed lots were planted in the field in June 2013, July 2013 and June 2014, and scouted weekly for symptoms.

In the field experiment, 11 seed transmission events were observed for 135,950 plants in June 2013 (0.0081%). The adjusted seed transmission rate (seed transmission events by potential infected plants, based on the percentage of infected seeds in the lots used for planting) was 0.062%. Transmission was observed in three subplots, two from an inoculated susceptible hybrid, and one from an inoculated moderately resistant hybrid, with initial seed infection levels of 18.4%, 37.0% and 7% respectively. If considering only these subplots, seed transmission was 0.016% and 0.024% for the susceptible hybrid, and 0.006 % for the moderately resistant hybrid, and if considering only infected seeds 0.084%, 0.065%, 0.079%. No seed transmission events were found in subplots planted in July 2013 and in June 2014. The reasons for which are unknown. In glasshouse experiments, there was 1 transmission event for 8250 plants (0.012%, or 0.066% considering only infected seeds).

Over all the trials, the seed transmission rate was 12 events for 241,850 plants grown (0.005%), i.e. 1 seed transmission for 20,000 plants, and the seed transmission rate adjusted to infected seed (seed transmission events divided by potential infected plants) was 0.04%. The authors extrapolate that if a seed lot consists only of infected seeds, the prediction would be that 1 seed transmission would occur for every 2500 seeds planted.

Shepherd (1999). In a greenhouse experiment, a naturally-infected seed lot with an incidence of seed infection of 29% (Golden Harvest 2390 – estimated for 400 kernels) showed a seed to plant transmission rate of 0.04% (1 seedling out of 2568), or if considering only infected seeds in the seed lot, 0.134%. For a naturally-infected seed lot with 3% infection (Pioneer 3730 – for 400 kernels), none of the seedlings from 1421 seeds planted was found infected (Shepherd, 1999).

Schuster (1975). The author reports that 31.6% of 399 ears from five lots of commercial field maize in Nebraska carried the bacterium, and 20.8% of 2,480 kernels tested (from the above ears) were infected. Seeds from infected ears grown to seedlings led to 1.6% of 1,934 seedlings showing disease symptoms in a greenhouse experiment. Since the average percentage of seed actually infected was 48.1 %, the seed transmission was in reality 0.8 %. In addition, 416 of the 2,350 seed planted did not germinate, and the authors note that severe infection may have affected germinability.

Biddle *et al.* (1990). Levels of infection of seeds from inoculated plants reached around 17% for seed harvested at 38% moisture content (dried at 35°C to 10% or not dried) and 23-31% for seed harvested at

25% moisture content (dried at 35°C to 10% or not dried). Neither harvest moisture nor drying treatment had any significant effect on internal populations of the pathogen or the percentage of seeds infected. The mechanism for transmission of the pathogen from the plant to seeds is not clear, but the transmission was relatively efficient and infected seeds are likely to occur frequently on infected plants. The authors note that seeds in the study by Schuster (1975) had orange discoloration or bacterial exudate and may have carried a higher inoculum load than in their own study.

No seedling infection was obtained from these seed lots, in greenhouse (9000 seeds) and field experiments (3000). Transmission from seed to seedling succeeded for seeds vacuum infiltrated with *C. nebraskensis* and planted in a greenhouse, with a transmission rate of 0.1 to 0.4%, from seed infestation levels of 69.7% and 73.2%.

Robertson *et al.* (2012). No infection was detected in seeds from the low disease plot samples (0-5% leaf severity). Low amounts of seed infection (<1%) were noted in the more heavily infested field plots (over 5% leaf infection). No seed transmission was detected in greenhouse plantings.

ANNEX 4. Maize trade data

Table 1. Maize seeds (100510 maize (corn), seed)

From UN COMTRADE for non-EU countries – black and grey, and Eurostat for EU countries – purple. Yellow: quantities over 50 tonnes in 2023 or 2024.

Net weight in kg (rounded figures; 0 is between 0 and 1). Countries without imports were deleted. For the EU, no imports from the countries concerned recorded by UN Comtrade nor Eurostat for Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, Slovenia.

	Canada				Mexico				USA				South Africa			
Country	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024
Austria	0				9336	7040	11179	19636	5674	3435	8269	351102		110		7
Austria	0				9336	7040	11179	19636	1237	1254	1680	350906		110		7
Azerbaijan									1498	40	1090	1930				
Belgium	0	0	12						50	8	49	28				
Belgium	0	0	12						51	8	49	27				
Bulgaria												10115	1750	2054	1475	2084
Bulgaria												1002	1750	2054	1494	2084
Croatia									2041	3084	4175	5557				
Croatia									2041	3084	4175	5557				
Czech Rep.							252	1				682				
Czech Rep.																
Denmark									24	18	19	20				
Denmark									24	18	19	18				
Finland									43		1	9				
Finland									42		1	6				
France	533	527	77	131	122074	278564	142007	113367	20758	24273	20870	13642	258	304	218	290
France	508	527	77	131	122074	278531	141951	113296	20758	24272	20870	13189	258	304	30	21
Georgia											19950					
Germany					10634	10736	9819	7193	45152	12580	2633	5767				
Germany					10601	10736	9819	7193	45148	5802	1935	1004				
Greece									11138	879		1364			10786	
Greece									11138	879		1364			10786	
Hungary		4			9453	10589	28911	29350	61669	99705	49997	85307	1	3	23	21
Hungary	2	4	7		9455	10589	28950	26390	61669	99703	49987	72949	0	2	21	21
Ireland		20							40	52044	50	11	679	1059	1200	1820
Ireland		0							38	29	48	16	679	1059	1200	1820
Israel									447779							

	Canada				Mexico				USA				South Africa			
Country	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024
Italy					5531	6141	7405	3865	4780	5645	5214	3230				
Italy					5531	6141	7405	3865	4780	5645	5214	3230				
Jordan									29534							
Kazakhstan									151867	143418	212295				5328	
Kyrgyzstan									5190							
Montenegro												5				
Morocco					15	1	20		36677	2531	2200		225	29929		
Netherlands	75	452	7	1		17	5		67257	92503	34022	9953		1		
Netherlands	75	275	7	1		17	195713		1419969	1515492	373853	263880		1		
North Macedonia									2171		50					
Norway									234	175	192	50				
Poland								11	22573	12	87223	2573				
Poland								0	9	12	18	8				
Portugal									1369	1340	3130	2676				
Portugal									1369	1340	3130	2676				
Rep. of Moldova								18							11646	
Romania	5	24	140	219	346	205			889	28141	84779	4			2	
Romania	5	24	140	219	347	205			889	28055	84779	4			2	
Russian Federation					22											
Serbia					716	143	62445		6319	5023	3824					
Slovakia												11				
Slovakia																
Spain			4						3814	10408	794	9349				3
Spain			5						3810	10408	796	9353	32			3
Sweden									155	262	6123	12822				
Sweden		0	0						128	131	5618	11535				
Switzerland						3			140	259	250	25				
Türkiye					2625	3495	7	304	148388	159702	400070	887475				
Ukraine	1946				1		75	256	18169	1148	210	7281				
United Kingdom			37719	3004			13842		1811143	1680262	1179846	456994	72500			1000
Uzbekistan									114227	151650	200					
Total of non-EU (UN Comtrade) + EU (Eurostat)	2536	830	37967	3355	160723	316901	471406	170958	4346436	3840340	2372349	2090484	75444	33459	30507	4956

Table 2. Maize seeds by subcategories of 100510 into EU countries from Eurostat (in kg) (rounded figures; 0 is between 0 and 1)

		Canada				Mexico				USA				South Africa			
		2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024
10051013 Three-cross hybrid maize seed for sowing	Austria												1 39461				
10051015 Simple hybrid maize seed for sowing	Austria	0				9335	7040	10604	19629	1175	1186	1614	70793				1
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Austria								2		68		1 40651				6
10051090 maize seed for sowing (excl. hybrid)	Austria					1	0	575	5	62	0	66	1		110		
10051013 Three-cross hybrid maize seed for sowing	Belgium		0							1	2	11	4				
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Belgium	0															
10051090 maize seed for sowing (excl. hybrid)	Belgium			12						50	6	38	23				
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Bulgaria													1750	2054	1475	23
10051090 maize seed for sowing (excl. hybrid)	Bulgaria												1000			19	2061
100510xx Trade of subheading 100510, not elsewhere specified	Bulgaria												2				
10051015 Simple hybrid maize seed for sowing	Croatia									2041	3084	4173	5557				
10051090 maize seed for sowing (excl. hybrid)	Croatia											2					
10051013 Three-cross hybrid maize seed for sowing	Denmark									4							
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Denmark										017	5					
10051090 maize seed for sowing (excl. hybrid)	Denmark									20	1	14	18				
100510xx Trade of subheading 100510, not elsewhere specified	Denmark										0		0				
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Finland									1							
10051090 maize seed for sowing (excl. hybrid)	Finland									41		1	6				
10051013 Three-cross hybrid maize seed for sowing	France							109		13							
10051015 Simple hybrid maize seed for sowing	France	508	518	61	130	52842	2 25022	68775	59403	15853	16349	18752	10523	33		0	
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	France	0				12997	11752	6168	204	1305	782	1309	577	193	237		
10051090 maize seed for sowing (excl. hybrid)	France	0	9	16	1	56235	41757	66899	53689	3587	7141	809	2089	32	67	30	21
10051013 Three-cross hybrid maize seed for sowing	Germany																
10051015 Simple hybrid maize seed for sowing	Germany					291	233	330	6597	31360							
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Germany								0	708	66	126	146				
10051090 maize seed for sowing (excl. hybrid)	Germany					10310	10503	9489	596	13080	5736	1809	858				
10051015 Simple hybrid maize seed for sowing	Greece									11138	878					10786	
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Greece												1364				
10051013 Three-cross hybrid maize seed for sowing	Hungary											004					

10051015 Simple hybrid maize seed for sowing	Hungary								61379	96249	48663	70215				
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Hungary					8805		4028	20493	226	3376	1295	2675			21
10051090 maize seed for sowing (excl. hybrid)	Hungary	2	4	7		650	10589	24922	5897	064	78	25	059	000	2	21
10051013 Three-cross hybrid maize seed for sowing	Ireland										0	1				
10051015 Simple hybrid maize seed for sowing	Ireland									7		16				
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Ireland		0							27	4	10				
10051090 maize seed for sowing (excl. hybrid)	Ireland									4	25	21	16	679	1059	1200
10051015 Simple hybrid maize seed for sowing	Italy					5531	6141	7405	3865	2074	1914	2287				
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Italy									1432	2328	1727	2237			
10051090 maize seed for sowing (excl. hybrid)	Italy									1274	1403	1200	993			
10051015 Simple hybrid maize seed for sowing	Netherlands							195708		1221543	14 80659	1 50828	24047			
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Netherlands	5	172							5	26	1			1	
10051090 maize seed for sowing (excl. hybrid)	Netherlands	70	103	7	1		17	5		1 98421	34807	2 23024	2 39833			
10051013 Three-cross hybrid maize seed for sowing	Poland									0						
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Poland											10				
10051090 maize seed for sowing (excl. hybrid)	Poland								0	9	12	8	8			
10051015 Simple hybrid maize seed for sowing	Portugal									1369	1340	3130	2676			
10051013 Three-cross hybrid maize seed for sowing	Romania															
10051015 Simple hybrid maize seed for sowing	Romania	5	24	140		347	205			889	28055	84779	4			2
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Romania				219											
10051013 Three-cross hybrid maize seed for sowing	Spain										1194					
10051015 Simple hybrid maize seed for sowing	Spain									3765	7904	16	9272	32		3
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Spain									45						
10051090 maize seed for sowing (excl. hybrid)	Spain			5							1310	780	81			
10051013 Three-cross hybrid maize seed for sowing	Sweden												1			
10051015 Simple hybrid maize seed for sowing	Sweden			0						62	97	5566	11511			
10051018 Hybrid maize seed for sowing (excl. three-cross and simple hybrid seed)	Sweden									8	16	2	2			
10051090 maize seed for sowing (excl. hybrid)	Sweden		0							58	18	50	21			

Table 3. Sweetcorn seeds (07129011 *dried sweetcorn, hybrid, for sowing*). From Eurostat. In kg (rounded figures. 0 is between 0 and 1)

Countries and years without data were deleted

	Canada		Mexico				USA							
	2021	2023	2021	2022	2023	2024	2021	2022	2023	2024	2022	2023	2024	
Germany	:	:	:	:	:	:	138188	54846	153737	237984	:	:	:	:
Spain	:	:	:	:	:	:	75311	47349	23612	92021	:	:	:	:
France	:	:	:	:	:	:	492037	26754	12346	69604	:	:	:	:
Greece	:	:	:	:	:	:	4507	1229	399	2334	:	:	:	:
Hungary	:	:	:	1	8	17	90310	1 29882	43792	86328	:	:	:	109
Ireland (Eire)	:	:	:	:	:	:	:	:	1	10	:	:	:	:
Netherlands	4	6	1	:	:	1	342766	503511	614106	430193	149859	98940	14381	:
Poland	:	:	:	:	:	:	:	:	:	353	:	:	:	:
Sweden	838	:	:	:	:	:	7757	10858	:	42	:	:	:	:
Slovakia	:	:	:	:	:	:	2	0	:	:	:	:	:	:

Table 4. Maize (corn), other than seed (100590). From UN COMTRADE. Net weight in kg (rounded figures. 0 is between 0 and 1)

	CAN				MEX				USA				ZAF			
	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024
Austria	240				598				95902	13022508	4203190	645		972		
Azerbaijan											15					19200
Belgium	98441	4	1	2612120	27	1	121	2	220664	209537	162079	181012	3904	5	265663	32726
Bosnia Herz.										2860	3632	20003				54
Bulgaria		76	108	180					128468	65000	90602	328327		34	129	6
Croatia														52000	96000	
Cyprus									20814	25401	72882	104183				
Czech Rep.					9	42			56	2	244	301236			1320000	432000
Denmark					378	7578	11320	12381	93032	166660	166344	115052				
Estonia									5	39123		63993	415250	266000	316800	308000
Finland	140	98		2	2410				649	482	153	34				
France	6440	12712	6081	9906	9063	5504	6727	15103	57787	62326	2071912	53122	3401570	4836506	12137141	9287568
Georgia												20412	286000	130000	208000	104000
Germany		5464	31915	7423	7846	3018	1560	1285	1919506	1585007	13795699	1114476	554462	1101670	1545833	1255744
Greece					23	10			110506	55074	279051	521948			52000	
Hungary		4						3	63797	40279	662714	120415		299000	1968240	504920
Ireland	486434000	548888000	774701000	847563000	1147	16232	10209	14270	1259990	70724500	17831300	82427700	33572	52671	123531	156015
Israel									83823017	195305717	680180	1090337				
Italy	188	19254400			2000	4000			719	70281400	12598500	10716900	166703000	211863000	176837000	126000
Jordan									58551276	818343	666251		1070733	1418473	1639882	
Kazakhstan											41731					
Latvia									30618	30270	56270	128508	130000	182000	442000	313000
Lithuania										40824	20412	1		26000	130000	104000
Luxembourg							44		13	5	5	4				
Malta									4	12	1	13	26111		26000	
Montenegro							2				2419					
Morocco									547944515	246704117	228008400					
Netherlands	7299	65992600	76348700	552167	3253	858087	15731	85729	1330370	46201500	67216600	37717600	556455	1155600	1114690	2158920
North Mac.											73032					
Norway						3059	788		381901	400369	436156	424006	680	180		
Poland									858088	1205753	1868255	1077284			902000	25200
Portugal	156909800	189799467	179656635	114881000			2		577	25032907	19780846	333573336		52371384	50	
Rep. Moldov											17				74000	
Romania								5	1000	5105605	342012	576275			1995	
Russian Fed													423799			
Serbia											2179					
Slovakia					180				18	3						
Slovenia	0		50							20412	1				2	
Spain	367076929	329110031	659307130	178348503	22975	187440	114890		407910	503120335	58390600	1072679882	103088011		2	14786573
Sweden	1000	17989	1000	3581	5877	571			261457	302000	342786	22476	5000	5000	9000	
Switzerland	3		60	1723	1223	1242	206		287457	281342	387804	371797		993		109
Tunisia									173823300	100169900			256000	156000	104000	
Türkiye	12								2172641	4	40947	230755	1326000	520015	1040400	124020
Ukraine	813		2404	2886	2534	805	1217	1586	380704	247438	679343	507881			21894	
UK	367557190	509138100	447272059	610104000	43361	75242	98213	215976	9938017	30952768	63574910	196636394	682250	1280201	3261138	4803900
Uzbekistan											41730	165460	114128			74820
Total	1378092495	1662218945	2137327083	1754084828	103404	1162812	262066	346546	884164779	1312219784	494518171	1741364499	279076925	275717704	203637390	34616775

Table 5. Sweet corn, fresh or chilled (07099960). From Eurostat. In kg. Countries and years without data were deleted

	Mexico			USA			South Africa
	2021	2022	2023	2021	2022	2023	2023
Finland					11		
France	1798	806	3360	6275	11222	2843	
Netherlands	860			30564	54128		17
Spain		3072	3456	8283	8976	1536	
Sweden					1044	180	
Total	2658	3878	6816	45122	75381	4559	17

Table 6. Green corn (maize). From FAOStat. In tonnes. Countries and years without data were deleted.

Note that the commodity green corn of FAOStat is defined as '*maize harvested green for food. Saccharata variety is commonly known as sweet corn.*' Data for Finland and France are similar to Eurostat (Table 5 above).

	Canada	Mexico			South Africa			USA		
	2022	2021	2022	2023	2021	2022	2023	2021	2022	2023
Finland									0,01	
France		1,8	0,81	3,36						
Netherlands					29.76	32.71	29.35			
Norway									0.73	
Spain			3.07	3.46				8.28	8.98	1.54
UK	0.56	790.58	190.99	135.12	22.78	20.57	11.87	1216.19	777.74	442.32
Total	0.56	792.38	194.87	141.94	52.54	53.28	41.22	1230.75	798.68	446.7

Table 7. Dried sweetcorn *Zea mays* var. *saccharata*, whether or nor cut or sliced, but not further prepared (excl. hybrids for sowing) (07129019). From Eurostat. In kg. Countries and years without data were deleted.

	Canada			Mexico		USA			South Africa		
	2021	2022	2023	2021	2023	2021	2022	2023	2021	2022	2023
Germany	:	:	:	:	:	:	5	:	:	:	:
Denmark	:	:	:	:	:	:	12	1	:	:	:
Spain	:	:	:	:	:	:	1	1	:	:	:
Finland	:	:	:	:	:	:	:	4	:	:	:
France	:	:	:	1	:	1717	959	985	:	:	:
Hungary	:	:	:	:	:	:	44	34	1	:	:
Ireland	1422	:	:	:	:	:	1	17	:	:	:
Italy	:	:	:	:	:	:	:	32	:	:	:
Netherlands	9	187	100	:	227	612	2127	1512	:	1	9
Sweden	:	:	:	:	0	:	108	6	:	:	:
Total	1431	187	100	1	227	2329	3257	2592	1	1	9

ANNEX 5. Maize area and production in the EPPO region (from FAOStat)

Area in hectares/ha, production in tonnes/t. From FAOStat.

Maize (corn) [0112] in the category Cereals, maize and products)

Green corn (maize) [01290.01] in the category for vegetables and other products

	<i>Maize (corn)</i>						<i>Green corn (maize)</i>					
	Area harvested (ha)			Production (t)			Area harvested (ha)			Production (t)		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
Albania	58288	56617	55570	414270,8	401419	409115,9						
Algeria	3606	2000	2000	18491	11000	12000						
Austria	218200	215330	212000	2434900	2113960	2105060						
Azerbaijan	32059	30488	28615	279248,3	269600,1	287001,3						
Belarus	222000	232000	180000	1148000	975000	1000000						
Belgium	48220	62870	52650	449890	500390	517490						
Bosnia and Herz.	200376	115599	100185	893124	987215	698289	121	121	121	737,08	736,57	736,06
Bulgaria	573020	520460	534640	3427310	2554370	2448780						
Croatia	287980	268050	269090	2242120	1641890	1991270	25130	28700		873180	765700	
Czech Rep.	102440	80450	64370	988040	639470	507540						
Denmark	6400	8400	7500	45270	60690	40820						
Estonia	0	0	0	0	0	0						
Finland				0	0	0						
France	1549470	1456090	1314680	15358290	10877190	12834600	22139	21739		460902	412777	
Georgia	76400	73900	72400	233000	152900	190900						
Germany	430700	456700	466400	4462400	3837400	4498900						
Greece	120090	126750	130560	1350250	1340950	1416690						
Hungary	1054570	816640	770690	6424630	2765600	6242410						
Ireland	0	0	0	0	0	0						
Israel	3660	3220	2964	68291	50018	51410	3018	2264	2345	68291	50018	51410
Italy	588600	563700	498450	6079960	4697170	5348700						
Jordan	0	0	0	0	0	0	599	1265	1294	22510,8	22869	22920
Kazakhstan	188703	189271	190376	1129508,48	1098041,37	1189083	33	33	33	869,39	858,81	864,71
Kyrgyzstan	105994	107220	112559	691139	732633	799936						
Latvia	0	0	0	0	0	0						
Lithuania	17870	18800	11260	104680	99790	91330						
Luxembourg	70	180	170	460	910	950						
Malta	0	0	0	0	0	0						
Moldova	486324	433411	481855	2792723	752297	1351477	594	604	599	4260,41	4246,94	4262,21
Montenegro	620	620	588	2631	2813,3	2682,3						
Morocco	91658	114959	84140	48637,3	35783,2	60093,9						
Netherlands	17200	20100	14800	171420	176900	151930						

	<i>Maize (corn)</i>						<i>Green corn (maize)</i>					
	Area harvested (ha)			Production (t)			Area harvested (ha)			Production (t)		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
North Macedonia	30827	30769	29077	134036	146980	133176	9	9	9	95,16	95,27	95,17
Norway							32	35	39	266	212	184
Poland	998470	1196030	1255630	7321910	8344890	8981890						
Portugal	74470	74640	75390	752490	717990	767210						
Romania	2554680	2437220	2196110	14820690	8037130	8744000						
Russian Fed.	2901084	2644243	2400000	15237582,7	15862434,1	16600000						
Serbia	1020337	952216	922980	6027130,66	4283293	6630984	2712	2710	2814	55478,74	55485,24	57664,64
Slovakia	203160	158690	138450	1579120	683700	1105660						
Slovenia	41400	41560	44250	388830	277820	389030						
Spain	358270	314290	239900	4597660	3590260	2835360						
Sweden	1740	1770	1970	14900	12200	15700						
Switzerland	12500	12666	15674	98216	125317	135314	235	272	351	469	539	677
Türkiye	758032	911499	958017	6750000	8500000	9000000						
Ukraine	5481800	4124500	3975200	42109850	26186930	31030440	4900	3500	5200	64540	48610	74670
Uzbekistan	65027	62772	61355	590016	656414,35	781413,67						

ANNEX 6. Maize area and production in the EU and associated countries (from Eurostat)

Data in Eurostat is provided for all EU countries as well as Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Norway, Serbia, Switzerland, UK, Türkiye. Area = Area (cultivation/harvested/production) (ha); Production = Harvested production in EU standard humidity (tonnes)

	Grain maize and corn-cob-mix						Green maize					
	Area (ha)			Production (t)			Area (ha)			Production (t)		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
<i>Albania</i>	58300	56600	55600	414300	401400	409100	20500	22000	20400	409070	423360	429430
<i>Austria</i>	218200	215330	212000	2434900	2113960	2105060	85130	82650	94890	3662510	3549660	3645260
<i>Belgium</i>	48220	62870	52650	449890	500390	517490	183080	178380	170330	7539560	8178460	8039590
<i>Bosnia and Herzeg.</i>	200810	115600	102820	903510	808080	725010	35050	15590	17070	639090	359230	393560
<i>Bulgaria</i>	573020	520460	534640	3427310	2554370	2448780	30110	27350	28230	575640	659010	550850
<i>Croatia</i>	287980	268050	269090	2242120	1641890	1991270	25130	28690	27470	873180	765680	956680
<i>Cyprus</i>	0	0	0	0	0	0	130	150	130	13150	14570	12790
<i>Czech Rep.</i>	102440	80450	64370	988040	639470	507540	216980	211790	222930	8431660	7615120	7189810
<i>Denmark</i>	6400	8400	7500	45270	60690	40820	173900	167700	179800	11113300	10464300	10452040
<i>Estonia</i>	0	0	0	0	0	0	13020	16190	19190	305900	425340	496650
<i>Finland</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>France</i>	1549470	1456090	1314680	15358290	10877190	12834600	1241450	1286620	1257670	50395420	39271540	49726130
<i>Germany</i>	430700	456700	466400	4462400	3837400	4498900	2219600	2028300	2000000	104839300	73206700	84270000
<i>Greece</i>	120090	126750	130560	1350250	1340950	1416690	106310	107810	107810	3799830	3904900	3899680
<i>Hungary</i>	1054570	816640	770690	6424630	2765600	6242410	67540	81190	66950	2062450	1719660	2323370
<i>Ireland</i>	0	0	0	0	0	0	14420	15720	19530	988430	830700	1305670
<i>Italy</i>	588600	563700	498450	6079960	4697170	5348700	375560	368850	354730	24017570	21060380	22904430
<i>Kosovo</i>	39710	39800	39840	170390	175230	161670	7270	7280	7280	121810	122900	121080
<i>Latvia</i>	0	0	0	0	0	0	24900	22100	23400	719300	672600	637200
<i>Lithuania</i>	17870	18800	11260	104680	99790	91330	29390	32910	39570	813000	875000	1142000
<i>Luxembourg</i>	70	180	170	460	910	950	17070	15670	15250	776050	553450	665830
<i>Malta</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Montenegro</i>	620	620	640	2660	2850	3200	#VALEUR!	0	0	#VALEUR!	0	0
<i>Netherlands</i>	17200	20100	14800	171420	176900	151930	183260	182800	179920	8306840	8230050	8639380
<i>North Macedonia</i>	30830	30770	29080	135590	148690	133180	7050	9380	8760	154030	286460	195610
<i>Norway</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poland</i>	998470	1196030	1255630	7321910	8344890	8981890	691920	636790	610870	28682700	26047470	24424220
<i>Portugal</i>	74470	74640	75390	752490	717990	767210	71060	69990	67440	2286660	2256150	2143450
<i>Romania</i>	2554680	2437220	2196110	14820690	8037130	8744000	51370	48770	50250	1351610	996230	1077140
<i>Serbia</i>	1020340	952220	922980	6027130	4283290	6630980	33120	30760	27340	524650	462570	540480
<i>Slovakia</i>	203160	158690	138450	1579120	683700	1105660	65850	70800	63190	1310960	1129390	1419410
<i>Slovenia</i>	41400	41560	44250	388830	277820	389030	29660	29630	29800	1272060	942510	1188410

	Grain maize and corn-cob-mix						Green maize					
	Area (ha)			Production (t)			Area (ha)			Production (t)		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
Spain	358270	314290	239900	4597660	3590260	2835360	118250	120100	113520	4418250	4237010	4032380
Sweden	1740	1770	1970	14900	12200	15700	19220	20470	23780	698860	630290	825140
<i>Switzerland</i>	12500	12670	15650	99360	125320	135140	50210	49810	47140	2730080	2071570	2494260
Türkiye	759000	912000	959000	6554750	8252910	8739340	531000	533000	530000	27439000	24576000	24636860
<i>United Kingdom</i>	:	:	:	:	:	:	:	:	:	:	:	:

Other vegetables cultivated for fruit (sweet corn, *Cucumis metuliferus* and *Physalis*).

This category covers sweet corn according to EU (2023). No yield data is provided. Non-EU countries in italics

	<i>Other vegetables cultivated for fruit (sweet corn, Cucumis metuliferus and Physalis).</i>							
	Area (cultivation/harvested/production) (ha)				Harvested production in EU standard humidity (t)			
	2021	2022	2023	2024	2021	2022	2023	2024
<i>Albania</i>								
Austria	800	940	960	900	15100	19240	18990	17210
Belgium	0	0	0	0	0	0	0	0
Bosnia & Herz.	0	0	0	0	0	0	0	0
Bulgaria	1040	760	650	790	5600	6540	4910	4230
Croatia	1020	520	590	960	12740	5830	6460	7870
Cyprus	20	20	20	20	310	300	310	310
Czech Rep.	0	0	750	710	0	0	4550	5190
Denmark	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0
France	23240	890	23850	21480	472410	10850	469910	409620
Germany	2200	2170	2100	2080	23440	20440	21510	22910
Greece	840	560	400	960	4860	3800	2800	5470
Hungary	120	120	80	80	3350	3590	4260	4480
<i>Iceland</i>	0		0	0	0		0	0
Ireland	0	0	0	0	0	0	0	0
Italy	0		0	0	0		0	0
<i>Kosovo</i>	0	0	0	0	0	0	0	0
Latvia	0	100	80	0	0	100	130	
Lithuania	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0
Malta	0	0	0	0	620	680	710	720
<i>Montenegro</i>	0	0	0	0	0	0	0	0
Netherlands	1330	1520	1320	1360	11470	12840	11690	11350

<i>North Macedonia</i>								
<i>Norway</i>		0				0		
<i>Poland</i>	100	100	100	100	1600	2000	1700	1500
<i>Portugal</i>	580	700	580	660	10090	9310	10400	17100
<i>Romania</i>	30	50	110	40	330	300	1080	310
<i>Serbia</i>	0	0	0	0	0	0	0	0
<i>Slovakia</i>	2140	2920	3500	3090	24620	27520	37960	29510
<i>Slovenia</i>	0	0	0	0	0	0	0	0
<i>Spain</i>	9150	7120	7370	6780	207570	135720	125000	106820
<i>Sweden</i>	110	100	120	120	950	910	790	930
<i>Switzerland</i>	0	0			0	0		
<i>Türkiye</i>	7000	7000	7000	7000	72000	70000	73000	75000
<i>UK</i>								

ANNEX 7. Maize areas in 2022 from FAOStat, Eurostat, EU Crop maps

Areas in ha

EPPO countries	FAOStat			Eurostat			EU Crop Maps
	Maize (corn)	Green corn (maize)	Total	Grain maize and corn-cob-mix	Green maize	Total	
Albania	56617		56617	56600	22000	78600	
Algeria	2000		2000				
Austria	215330		215330	215330	82650	297980	393900
Azerbaijan	30488		30488				
Belarus	232000		232000				
Belgium	62870		62870	62870	178380	241250	278600
Bosnia and Herz.	115599	121	115720	115600	15590	131190	
Bulgaria	520460		520460	520460	27350	547810	669200
Croatia	268050	28700	296750	268050	28690	296740	415100
Cyprus				0	150	150	500
Czech Rep.	80450		80450	80450	211790	292240	414600
Denmark	8400		8400	8400	167700	176100	202400
Estonia	0	0	0	0	16190	16190	22300
Finland			0	0	0	0	23300
France	1456090	21739	1477829	1456090	1286620	2742710	3031000
Georgia	73900		73900				
Germany	456700		456700	456700	2028300	2485000	2820200
Greece	126750		126750	126750	107810	234560	210100
Hungary	816640		816640	816640	81190	897830	1544900
Ireland	0		0	0	15720	15720	23000
Israel	3220	2264	5484				
Italy	563700		563700	563700	368850	932550	1380000
Jordan	0	1265	1265				
Kazakhstan	189271	33	189304				
Kyrgyzstan	107220		107220				
Latvia	0		0	0	22100	22100	36000
Lithuania	18800		18800	18800	32910	51710	87300
Luxembourg	180		180	180	15670	15850	13400
Malta	0		0	0	0	0	
Moldova	433411	604	434015				
Montenegro	620		620	620	0	620	
Morocco	114959		114959				
Netherlands	20100		20100	20100	182800	202900	277000
North Macedonia	30769	9	30778	30770	9380	40150	
Norway		35	35	0	0	0	
Poland	1196030		1196030	1196030	636790	1832820	2498400
Portugal	74640		74640	74640	69990	144630	122000
Romania	2437220		2437220	2437220	48770	2485990	2695700
Russian Fed.	2644243		2644243				
Serbia	952216	2710	952216	952220	30760	982980	
Slovakia	158690		158690	158690	70800	229490	303800
Slovenia	41560		41560	41560	29630	71190	83800
Spain	314290		314290	314290	120100	434390	464400
Sweden	1770		1770	1770	20470	22240	51500
Switzerland	12666	272	12666	12670	49810	62480	
Tunisia(Hammami et al., 2025)			1240				
Türkiye	911499		911499	912000	533000	1445000	
Ukraine	4124500	3500	4128000				11533900
United Kingdom				-	-	-	
Uzbekistan	62772		62772				

ANNEX 8. Analysis of relevant Köppen-Geiger climate types

Table 1. Certain and uncertain climate types relevant to the PRA

	Elements influencing the analysis of presence	Presence of <i>C. nebraskensis</i>
<i>BSk</i> arid, steppe, cold	Present in several US States where the pest has been found. Dominant climate type in Wyoming (70%). The one record in Coahuila, Mexico. Present in South Africa administrative areas.	certain
<i>Cfa</i> temperate, without dry season, hot summer	Only climate type in Louisiana, also present in other states where the pest has been found. Present in South Africa administrative areas (Eastern Cape and KwaZulu-Natal, uncertain record)	certain
<i>Dfa</i> cold, without dry season, hot summer	Only climate type in Iowa, dominant climate type in other US states where the pest has been found.	certain
<i>Dfb</i> cold, without dry season, warm summer	Climate type relevant for maize-growing in Manitoba. Dominant climate types in US states where the pest has been found	certain
Uncertain presence of <i>C. nebraskensis</i>, some maize in EPPO		
<i>Cfb</i> temperate, without dry season, warm summer	Not present in North America. In South Africa, 31% of Eastern Cape, and 1% of Free State. The record in Eastern Cape was based only on visual inspection. Also 13% in KwaZulu-Natal (uncertain record) Major maize cultivation in part of EPPO – ANNEX 9	uncertain
<i>BSh</i> arid, steppe, hot	In North America, present only in Texas (26%), where other climate types are more favourable to maize-growing. Present in South Africa administrative areas (8 to 57% depending on area), but no details on distribution. Limited maize in EPPO, at least Cyprus and Spain – ANNEX 9	uncertain
<i>BWk</i> arid, desert, cold	Very small areas of administrative areas concerned in the USA and South Africa. Desertic climate less relevant for maize-growing than others at origin. (although some limited maize in EPPO, at least in Spain– ANNEX 90)	uncertain
<i>BWh</i> arid, desert, hot	Very small areas of administrative areas concerned in the USA and South Africa Coahuila in Mexico, but the precise location in that state is in BSk, not BWh). Desertic climate less relevant for maize-growing than others at origin (although limited maize in the EPPO, at least in Spain, see ANNEX 9)	uncertain
<i>Dfc</i> cold, without dry season, cold summer	USA, Canada. Subarctic or very northern climate. In Manitoba, northern part where maize is probably not grown. However, limited maize in EPPO, at least Finland and Sweden - ANNEX 90	uncertain
Climate type not in administrative areas in the current distribution, present in EPPO		
<i>Csa</i> temperate, dry summer, hot summer	Some maize in the southern part of EPPO (Mediterranean area) – ANNEX 9	uncertain
<i>Csb</i> temperate, dry summer, warm summer	Some maize in the southern part of EPPO (Mediterranean area) – ANNEX 9	uncertain
<i>Cfc</i> temperate, without dry	Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain

season, cold summer		
<i>Dsa</i> cold, dry summer, hot summer	Limited percentages of this climate types in EPPO non-EU countries (no data on whether maize cultivated under this climate)	uncertain
<i>Dsb</i> cold, dry summer, warm summer	Only from an uncertain record, and minor percentages of administrative area (3% of Montana, USA). Some maize in Greece – ANNEX 9. Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain
<i>Dsc</i> cold, dry summer, cold summer	USA, Canada. Subarctic or northern climate, no maize growing. In Manitoba, northern part only. Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain
<i>Dwb</i> cold, dry winter, warm summer	Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain
<i>Dwc</i> cold, dry winter, cold summer	Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain
<i>Dwd</i> cold, dry winter, very cold winter	Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain
<i>Dfd</i> cold, dry without dry season, very cold winter	Limited percentages of this climate types in EPPO non-EU countries (no detailed data on whether maize cultivated under this climate)	uncertain

Table 2. Not relevant for the PRA. Climate types present in administrative areas where *C. nebraskensis* occurs, but not present in EPPO or unlikely to be suitable for maize

<i>ET</i> polar, tundra	USA, Canada. Subarctic, northern or high mountain, no maize growing
<i>Af</i> tropical, rainforest	From unconfirmed records in Mexico. Not present in the EPPO region.
<i>Am</i> tropical, monsoon	From unconfirmed records in Mexico. Not present in the EPPO region.
<i>Aw</i> tropical, savannah	From unconfirmed records in Mexico and KwaZulu-Natal. Not present in the EPPO region.
<i>Cwa</i> temperate, dry winter, hot summer	In administrative areas in South Africa (also Tlaxcala in Mexico but this record is in Cwb, not Cwa). Not present in the EPPO region.
<i>Cwb</i> temperate, dry winter, warm summer	In administrative areas in South Africa, and the one record in Tlaxcala (Mexico). Not present in the EPPO region.
<i>Dwa</i> cold, dry winter, hot summer	From uncertain records. Not present in the EPPO region.
<i>Dwb</i> cold, dry winter, warm summer	From uncertain records. Not present in the EPPO region.

ANNEX 9. Maize under Köppen-Geiger climate types in the EU and Ukraine

Data from Ghassemi *et al.* (2024) and Beck *et al.* (2023) were used to obtain an indication of the Köppen-Geiger climate types in which maize is grown. It is noted that data from Ghassemi *et al.* (2024) is for 2022 and data from Beck *et al.* (2023) is from 1991-2020 (J. Tuomola, Ruokavirasto).

See details in section 9.1 and analysis in ANNEX 9 regarding certain, uncertain and not relevant climate types.

All empty cells are 0 (deleted for readability)

Note that small areas in Table 2 resulting in a percentage below 1% are not in this table (e.g. Dsb for Greece)

Table 1. Percentage of maize production area under each climate type in the EU and Ukraine

	Certain (presence of C.n. at origin)				Uncertain (uncertain presence)					Uncertain (not in current distribution)			Not relevant	
Countries	BSk	Cfa	Dfa	Dfb	BSh	Cfb	BWk	BWh	Dfc	Csa	Csb	Dsb	ET	TOTAL
Austria		4		68		28								100
Belgium						100								100
Bulgaria	4	70	23	3										100
Croatia		96				3								100
Cyprus					82					18				100
Czech Republic				95		5								100
Denmark						100								100
Estonia				100										100
Finland				78					22					100
France		8				91				1				100
Germany				14		86								100
Greece	49	8								42				100
Hungary		46	41	10		3								100
Ireland						100								100
Italy	2	88								10				100
Latvia				100										100
Lithuania				100										100
Luxembourg						100								100
Malta										100				100
Netherlands						100								100
Poland				95		5								100
Portugal										58	42			100
Romania	14	15	40	31										100
Slovakia		26	6	62		5								100
Slovenia		43		15		41								100
Spain	62	3			3		0	0		9	23			100
Sweden				74		23			3					100
Ukraine	14		25	61										100
total area	8	12	16	40	0	22	0	0		1	1			100

Table 2. Maize production area under each climate type (in km²; total in ha)

	Likely (presence of C.n. at origin)				Uncertain climate types (uncertain presence)					Uncertain (not in current distribution)			Not rele van t	
Countries	BSk	Cfa	Dfa	Dfb	BSH	Cfb	BWk	BWh	Dfc	Csa	Csb	Dsb	ET	TOTAL (ha)
Austria		170		2685		1084								393900
Belgium						2786								278600
Bulgaria	279	4675	1556	168		7			1	7				669200
Croatia		4002		2		128				19				415100
Cyprus					4					1				500
Czech Rep.				3946		200								414600
Denmark						2024								202400
Estonia				223										22300
Finland				182					51					23300
France		2530		9		27541			3	218	9			3031000
Germany				3810		24392								2820200
Greece	1039	169		4		10				873	5	1		210100
Hungary		7142	6353	1529		425								1544900
Ireland						230								23000
Italy	225	12087		24		61			2	1377	24			1380000
Latvia				360										36000
Lithuania				873										87300
Luxembourg						134								13400
Malta														
Netherlands						2770								277000
Poland				23835		1149								2498400
Portugal										709	511			122000
Romania	3743	3961	10818	8369		66								2695700
Slovakia		791	185	1895		167								303800
Slovenia		363		128		347								83800
Spain	2876	120			146	11	2	6	3	421	1059			464400
Sweden				380		120			15					51500
Ukraine	16456		28559	70324										1153390 0
total area	24618	36010	47471	118746	150	63651	2	6	75	3624	1608	1	1	295962

ANNEX 10. Köppen-Geiger climate types in administrative areas where *Clavibacter nebraskensis* occurs and in EPPO countries

The tables provides the percentages of the total area of an administrative area (current distribution) or EPPO country covered by the different Köppen-Geiger climate types. Prepared by J. Tuomola, Ruokavirasto.

Table 1. KG climate types in administrative areas in current distribution of the pest (% of total area)

For details about the confirmed and uncertain locations, see section 6.

area	country	KG climate types																			
		Af	Am	Aw	BWh	BWk	BSh	BSk	Csb	Cwa	Cwb	Cfa	Cfb	Dsb	Dsc	Dwa	Dwb	Dfa	Dfb	Dfc	ET
Confirmed presence of the pest in the administrative area																					
Eastern Cape	ZA	0	0	0	4	8	8	38	0	0	5	6	31	0	0	0	0	0	0	0	0
Free State	ZA	0	0	0	0	0	9	58	0	1	32	0	1	0	0	0	0	0	0	0	0
Gauteng	ZA	0	0	0	0	0	14	4	0	8	74	0	0	0	0	0	0	0	0	0	0
North West	ZA	0	0	0	7	0	57	32	0	1	3	0	0	0	0	0	0	0	0	0	0
Mpumalanga	ZA	0	0	0	0	0	23	1	0	8	68	0	0	0	0	0	0	0	0	0	0
Colorado	US	0	0	0	0	2	0	65	0	0	0	0	0	0	0	0	0	0	17	16	1
Illinois	US	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	82	1	0	0
Indiana	US	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	80	0	0	0
Iowa	US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0
Kansas	US	0	0	0	0	0	0	21	0	0	0	24	0	0	0	1	0	55	0	0	0
Louisiana	US	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Michigan	US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	77	5	0
Minnesota	US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	34	63	0	0
Missouri	US	0	0	0	0	0	0	0	0	0	0	52	0	0	0	0	0	48	0	0	0
Nebraska	US	0	0	0	0	0	0	21	0	0	0	0	0	0	0	10	0	69	0	0	0
North Dakota	US	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	7	7	70	0	0
South Dakota	US	0	0	0	0	0	0	31	0	0	0	0	0	0	0	9	1	53	6	0	0
Texas	US	0	0	0	7	1	26	20	0	0	0	45	0	0	0	0	0	0	0	0	0
Wisconsin	US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	69	0	0
Wyoming	US	0	0	0	0	7	0	70	0	0	0	0	0	0	0	0	0	7	15	1	0
Alberta	CA	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	44	46	3	0
Manitoba	CA	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	42	47	0	0
Coahuila*	MX	0	0	0	43	0	43	13	0	0	0	0	1	0	0	0	0	0	0	0	0
Tlaxcala*	MX	0	0	0	0	0	0	16	0	0	84	0	0	0	0	0	0	0	0	0	0
* The precise location of the 1 record in Coahuila is in BSk, and of the 1 record in Tlaxcala is in Cwb																					
Uncertain presence of the pest in the administrative area																					
Limpopo	ZA	0	0	0	7	0	77	2	0	9	6	0	0	0	0	0	0	0	0	0	0
Ohio	US	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	88	1	0	0
Montana	US	0	0	0	0	0	0	68	0	0	0	0	0	3	0	0	0	18	11	0	0
Sinaloa	MX	0	0	25	6	0	45	0	0	21	3	0	0	0	0	0	0	0	0	0	0
Veracruz	MX	7	35	44	0	0	0	0	0	1	4	4	4	0	0	0	0	0	0	0	0
Durango	MX	0	0	2	16	0	19	22	1	8	32	0	0	0	0	0	0	0	0	0	0
Oaxaca	MX	3	17	38	0	0	6	1	0	2	31	1	1	0	0	0	0	0	0	0	0

Table 2. KG climate types in EPPO countries (% of total area of the country)

	KG climate types																				
Country	BWh	BWk	BSh	BSk	Csa	Csb	Cfa	Cfb	Cfc	Dsa	Dsb	Dsc	Dwb	Dwc	Dwd	Dfa	Dfb	Dfc	Dfd	ET	EF
Albania	0	0	0	0	45	10	13	9	0	0	3	0	0	0	0	0	18	2	0	0	0
Algeria	88	4	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austria	0	0	0	0	0	0	1	10	0	0	0	0	0	0	0	0	63	20	0	6	0
Azerbaijan	0	13	0	53	3	0	5	0	0	0	2	0	0	0	0	1	15	4	0	1	0
Belarus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Belgium	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Bosnia & Herz.	0	0	0	0	2	0	27	29	0	0	0	0	0	0	0	0	41	1	0	0	0
Bulgaria	0	0	0	3	3	0	54	1	0	0	0	0	0	0	0	12	26	1	0	0	0
Croatia	0	0	0	0	10	1	61	19	0	0	0	0	0	0	0	0	9	0	0	0	0
Cyprus	0	0	21	0	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Rep.	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	96	1	0	0	0
Denmark	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	76	0	0	0
France	0	0	0	0	5	2	5	82	0	0	0	0	0	0	0	0	3	2	0	1	0
Georgia	0	0	0	5	0	0	29	3	0	0	0	0	0	0	0	3	43	13	0	4	0
Germany	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	0	20	0	0	0	0
Greece	0	0	0	16	58	9	7	2	0	0	3	0	0	0	0	0	4	0	0	0	0
Guernsey	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	40	6	0	0	0	0	0	0	0	35	20	0	0	0	0
Ireland	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Israel	47	2	19	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	7	36	6	28	9	0	0	0	0	0	0	0	0	7	5	0	2	0
Jersey	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Jordan	80	6	6	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kazakhstan	0	42	0	45	0	0	0	0	0	1	0	0	0	0	0	0	9	2	0	1	0
Kyrgyzstan	0	1	0	27	0	0	0	0	0	0	7	6	0	1	0	0	6	13	0	37	1
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moldova	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	63	31	0	0	0	0
Montenegro	0	0	0	0	7	0	12	19	0	0	0	0	0	0	0	0	55	7	0	0	0
Morocco	35	15	13	10	23	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
North Macedonia	0	0	0	23	2	1	29	4	0	0	1	0	0	0	0	0	37	3	0	0	0
Norway	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	14	71	0	11	0
Poland	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	90	0	0	0	0
Portugal	0	0	0	0	61	38	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	10	0	0	12	1	0	0	0	0	0	0	0	24	50	4	0	0	0
Russian Fed.	0	0	0	2	0	0	0	0	0	0	0	4	3	10	1	1	15	52	1	10	0
Serbia	0	0	0	0	0	0	61	7	0	0	0	0	0	0	0	0	31	1	0	0	0
Slovakia	0	0	0	0	0	0	7	2	0	0	0	0	0	0	0	2	85	5	0	0	0
Slovenia	0	0	0	0	0	0	16	41	0	0	0	0	0	0	0	0	39	4	0	0	0
Spain	1	1	1	43	21	17	3	11	0	0	0	0	0	0	0	0	1	1	0	0	0
Sweden	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	32	63	0	2	0
Switzerland	0	0	0	0	0	0	1	38	0	0	0	0	0	0	0	0	23	20	0	17	0
Tunisia	74	2	7	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Türkiye	0	0	0	24	32	2	3	3	0	7	19	1	0	0	0	0	8	1	0	0	0
Ukraine	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	23	60	1	0	0	0
UK	0	0	0	0	0	0	0	97	3	0	0	0	0	0	0	0	0	0	0	0	0
Uzbekistan	0	73	1	15	6	0	0	0	0	1	3	1	0	0	0	0	0	0	0	0	0

ANNEX 11. Map of Köppen-Geiger climate types associated with *Clavibacter nebraskensis* in its current range

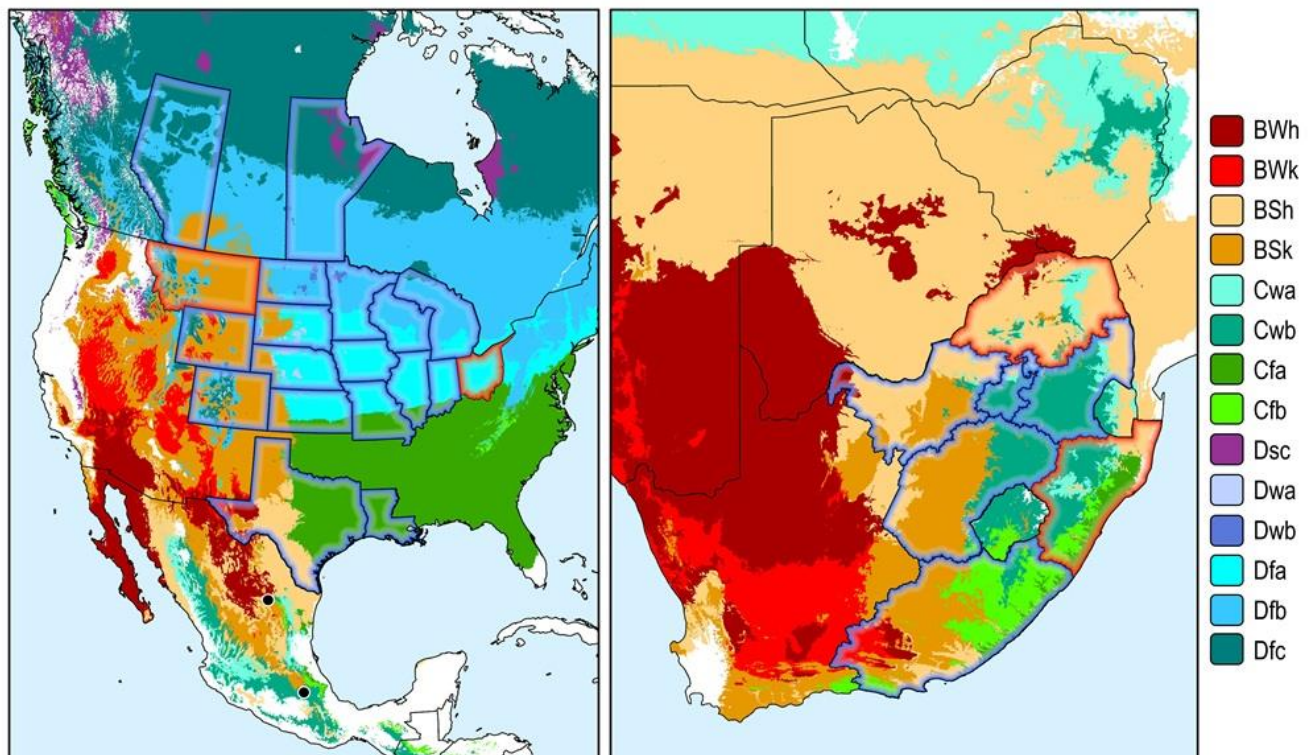
Map 1. KG climate types in administrative areas of the current distribution (confirmed and uncertain records) in the recent climate (1991–2020) (prepared by J. Tuomola - Ruokavirasto, Finland). Distribution in the recent climate (1991–2020). Data for Köppen-Geiger types were sourced from Beck et al. (2023) at a resolution of 0.1° (about 11 km at the equator).

(a) North America; **(b)** South Africa

Administrative areas of confirmed presence in blue, of uncertain presence in red for USA, Canada and South Africa. Two dots for precise location records in Mexico (Flores-López et al., 2024)

The country borders on the map were sourced from GADM (2020). See section 9.2 for details on climates not present in the EPPO region.

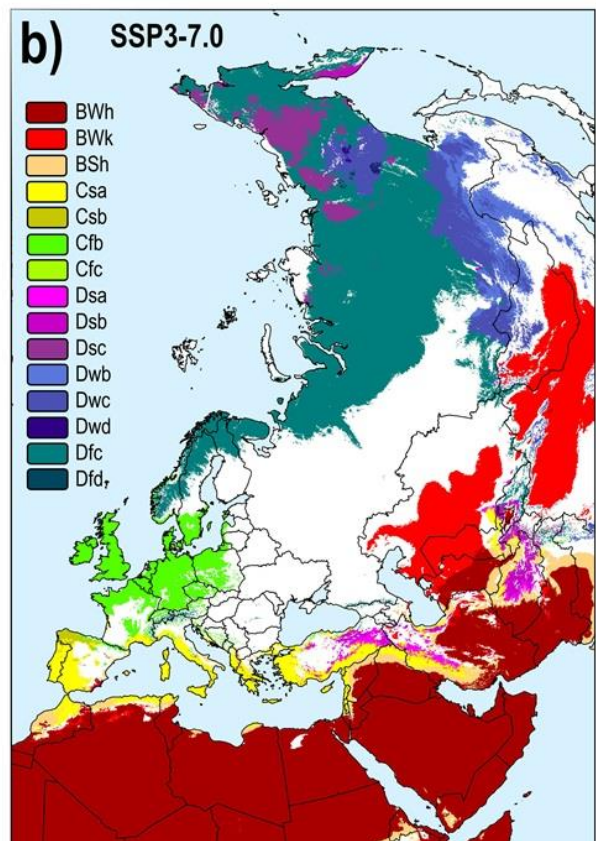
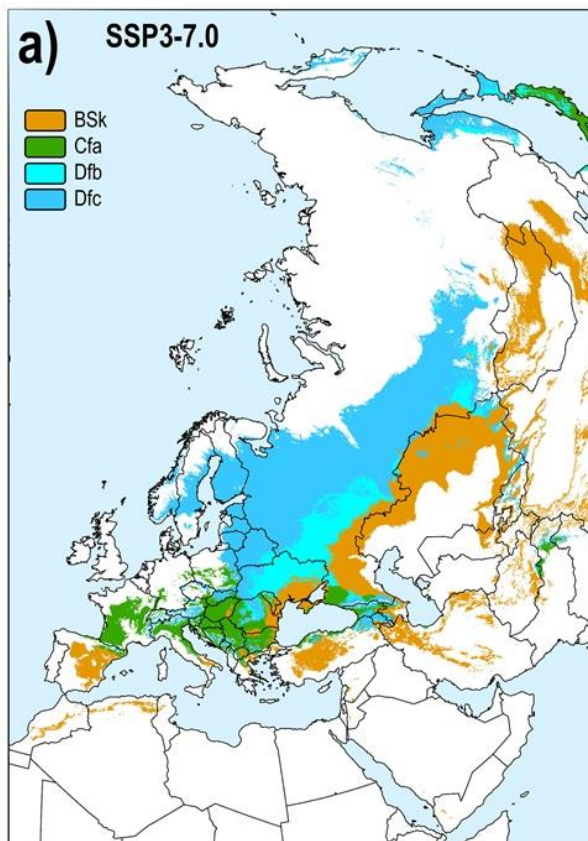
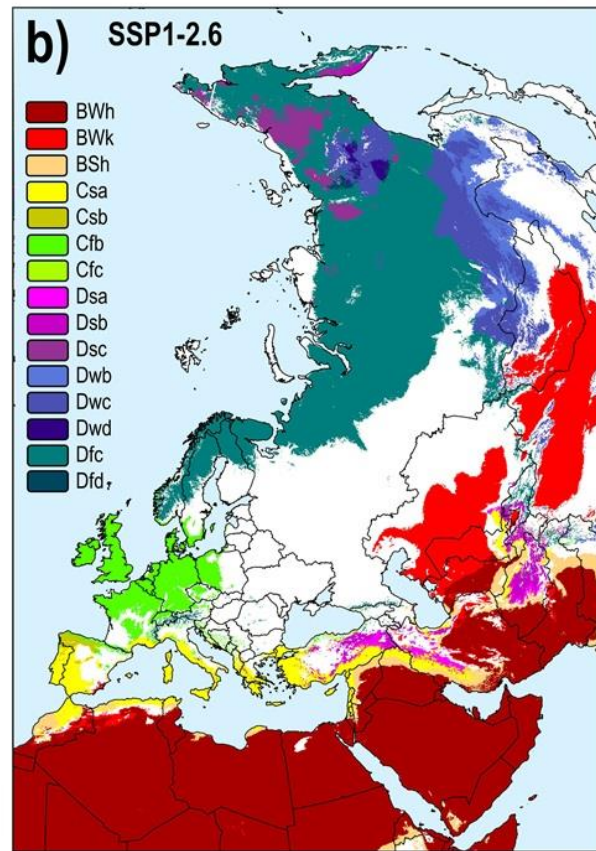
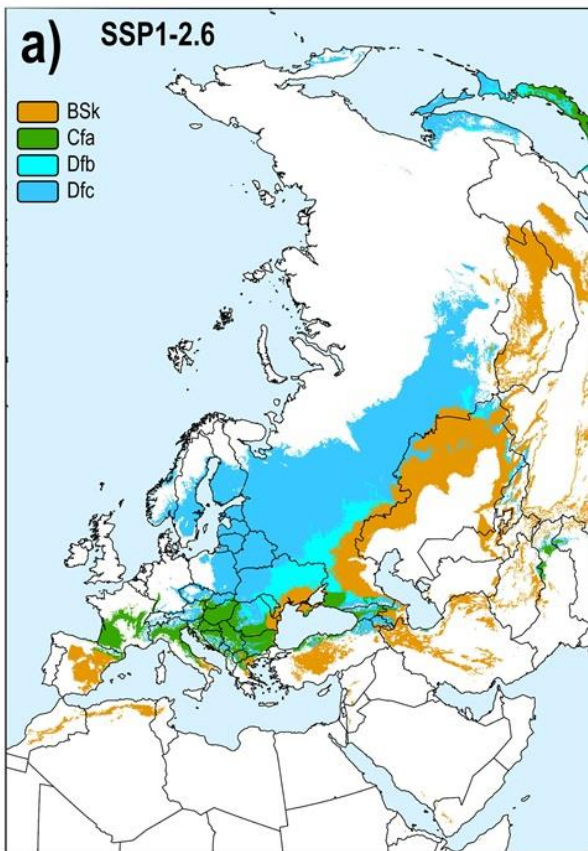
Descriptions of climate types are provided in the text.



ANNEX 12. Projection of Köppen-Geiger climate types for the EPPO region for the years 2041-2070

a) certain climate types b) uncertain climate types

Data for Köppen-Geiger types were sourced from Beck *et al.* (2023) at a resolution of 0.1° (about 11 km at the equator). Descriptions of climate types are provided in section 9.3.1.



ANNEX 13. Data on losses from the literature

Table 1. Yield losses reported in the literature

Yield losses at field level	Context and year	Reference
As high as 40 to 60% prior to the availability of resistant dent maize hybrids	Production, early 1980s	Mallowa <i>et al.</i> , 2016 citing Claflin <i>et al.</i> , 1978
Reported as 50% on susceptible hybrids	Production (Iowa), 2012	Mallowa <i>et al.</i> , 2016 citing pers. comm. by AE Robertson
Up to 60 bushels/acre (3700 kg/ha) in northwestern Indiana	Production, 2008	Wise <i>et al.</i> , 2010
Approaching 50% during severe epidemics in fields planted with susceptible cultivars	Production (Nebraska Extension)	Jackson <i>et al.</i> , 2007b
Can exceed 30%	Production (Minnesota extension services)	Malvick, 2018
May exceed 50% for very susceptible hybrids	Production, general statement	Claflin, 1999
For the most susceptible hybrid, yield 55% lower in inoculated plots than non inoculated plots	Inoculated field trials	Malvick <i>et al.</i> , 2014
Up to around 44% on susceptible inbred lines	Field trial with pinprick inoculation	Carson & Wicks, 1991
With inoculation at V6 to V10 stage, yield losses of 34-41% on the susceptible hybrid, 22-25% on the moderately susceptible hybrid, and 6-11 % on the resistant hybrid. For every 1% increase in the disease severity at R1 on the susceptible hybrid, yield was reduced by 117 kg/ha (1.9 bu/acre)	In North Dakota, in 6 field experiments with inoculation 2015-2017	Bauske & Friskop, 2021
For a susceptible hybrid inoculated at the 3- to 5-leaf stage, reduction of the number of marketable sweet corn ears of 27, 50 and 95% in three different years, About 30% only in one year for two moderately susceptible hybrids		Suparyono & Pataky (1989b)

Table 2. Estimated losses in 2020-2024 (Crop Protection Network, 2021 to 2025)

Expressed in million bushels. 1 bushel = 25.4 kg

The data covers (depending on years) 24 to 29 maize-producing US states as well as Ontario (Canada) (where the bacterium does not occur), and each year representing various percentages of all maize produced in the USA and Ontario. Losses for the US states covered in % were estimated below by removing Ontario

	2016	2017	2018	2019	2020	2021	2022	2023	2024
Loss in millions bushels#	90.8	70.5	68.2	9.8	4.6	3.6	12.8	2.2	1.5
millions kg	2306,32	1790,7	1732,28	248,92	116,84	91,44	325,12	55,88	38,1
Total production for area covered in USA&CA (millions bushels)#	15100	14700	14500	13800	14400	15300	14000	15600	15200
representing % of US+Ontario production#	97,7%	98,1	98	98,1 %	98.8%	98,9%	99.0	99,2%	99,2
Number US states#	24	25	25	26	28	28	28	29	29
Total Ontario (millions bushels)	Assumed 400	Assumed 400	Assumed 400	Assumed 400	400	400	400	400	400
Calculated area to which losses apply in the USA	14700	14300	14100	13500	14000	14900	13600	15200	14800
Estimated loss (%) for the US area covered (rounded to three decimals)	0.618	0.493	0.484	0.073	0.033	0.024	0.094	0.014	0.010

provided in the sources. Others are calculated.

Table 3. All states with losses, out of 35 US states covered (Crop Protection Network Disease loss calculator)

Year	% loss	Bushels lost	\$(USD) Loss	\$(USD) Loss per Acre
2012	0.49%	61,839,925	417,135,226	4.51
2013	0.73%	102,808,589	443,352,970	4.90
2014	1.30%	196,964,925	724,248,117	8.41
2015	0.95%	139,795,799	486,597,454	5.80
2016	0.55%	90,772,681	297,653,482	3.33
2017	0.45%	70,532,002	228,058,656	2.62
2018	0.42%	68,440,840	237,063,992	2.76
2019	0.06%	9,820,667	36,190,223	0.42
2020	0.03%	4,598,114	20,263,200	0.23
2021	0.02%	3,645,649	20,268,370	0.22
2022	0.09%	12,842,853	87,580,692	1.01
2023	0.01%	2,162,237	10,389,155	0.11
2024	0.01%	1,492,287	6,887,344	0.08

Table 4. Only Illinois, Nebraska, Iowa (Crop Protection Network Disease loss calculator)

Year	% loss	Bushels lost	\$(USD) Loss	\$(USD) Loss per Acre
2012	0.41%	20,436,816	140,066,630	3.79
2013	0.49%	31,561,979	141,703,270	3.99
2014	1.62%	105,846,953	394,681,299	11.31
2015	0.74%	51,421,536	182,256,472	5.27
2016	0.24%	18,577,588	62,259,689	1.76
2017	0.41%	28,375,869	93,955,182	2.76
2018	0.53%	41,357,127	145,276,443	4.30
2019	0.03%	2,175,152	8,265,576	0.24
2020	0.00%	190,484	851,841	0.02
2021	0.01%	986,502	5,327,110	0.16
2022	0.05%	3,573,921	24,608,675	0.74
2023	0.01%	627,626	3,079,904	0.09
2024	0.01%	486,449	2,150,044	0.06

Table 5. Only Nebraska (Crop Protection Network Disease loss calculator)

Year	% loss	Bushels lost	\$(USD) Loss	\$(USD) Loss per Acre
2012	1.20%	17,229,333	118,020,933	11.80
2013	1.00%	17,755,226	79,365,864	7.98
2014	2.00%	33,151,578	124,981,459	13.44
2015	0.50%	9,424,062	33,926,623	3.61
2016	0.10%	1,947,194	6,523,099	0.66
2017	0.01%	178,776	598,899	0.06
2018	0.50%	10,529,974	37,381,409	3.89
2019	0.10%	1,893,782	7,196,372	0.71
2020	0.01%	185,887	830,915	0.08
2021	0.05%	984,020	5,313,709	0.54
2022	0.20%	3,060,092	21,114,632	2.20
2023	0.02%	359,173	1,777,905	0.18
2024	0.01%	193,324	860,294	0.09

Table 6. Only Texas (Crop Protection Network Disease loss calculator)

Year	% loss	Bushels lost	\$(USD) Loss	\$(USD) Loss per Acre
2012	0.01%	20,152	143,484	0.08
2013	0.00%	0	0	0.00
2014	0.01%	29,487	130,334	0.06
2015	0.01%	26,627	110,502	0.05
2016	0.05%	163,165	611,869	0.21
2017	0.01%	31,638	117,062	0.05
2018	0.00%	0	0	0.00
2019	0.00%	0	0	0.00
2020	0.00%	0	0	0.00
2021	0.00%	0	0	0.00
2022	0.00%	0	0	0.00
2023	0.00%	0	0	0.00
2024	0.00%	0	0	0.00

ANNEX 14. Stepwise framework for direct economic impact

Prepared by Michel Frem.

For this PRA, the quantitative impact assessment approach has been carried out following the step-by-step framework outlined below:

Step 1. Defining impact scenarios

Scenarios are a fundamental tool in risk assessment to capture uncertainty and a range of plausible futures. They move beyond a single estimate to provide a more realistic and useful assessment for decision-makers. In this context, at this first step in the quantitative assessment of potential yield losses caused by *C. nebraskensis*, we considered 2 scenarios for the quantitative assessment as follows:

Scenario A (optimistic / managed impact): The pathogen is detected early. Resistant maize cultivars rapidly become widely available and are adopted quickly over large areas. Major maize-producing regions have low monoculture rates or can implement effective crop rotation in most of their territory. Tillage is possible in many areas. Impact is similar to the current overall US situation.

Scenario B (pessimistic / significant impact): The pathogen remains undetected for several years, allowing significant build-up and spread. Introduction occurs in a region with high maize monoculture, and no-till practices. The development of resistant cultivars is slow or not possible at a large scale. A series of extreme weather events (hailstorms) exacerbate the problem before management is implemented. Impact is similar to US "outbreak" years or specific severe cases.

In both scenarios, it may be that some cultivars used in the EPPO region are already resistant, but this is not known.

Step 2. Identifying analogous climatic risk zones

As the second step in the quantitative assessment of potential yield losses caused by *C. nebraskensis*, the distribution of maize under KG climate types based on EU Crop Maps data was considered (see section 9.1 and ANNEX 9). This first step recognizes that the pathogen's impact is closely tied to specific climatic conditions, as evidenced by its prevalence and severity in the US "Goss's Wilt Belt.". By aligning European and Ukrainian maize-growing regions with Köppen-Geiger climate zones, the assessment identifies the following areas of analogous risk in the EPPO region:

- Primary risk zones: *BSk* (cold semi-arid) and *Dfa* (hot summer humid continental), were considered most at risk due to their similarity to the U.S. regions where the highest yield losses have been recorded. These zones formed the core of the quantitative analysis, serving as the basis for extrapolating loss rates.
- Secondary risk zones: *Cfa* (humid subtropical) and *Dfb* (warm summer humid continental), were included with the expectation of lower impact, acknowledging climatic differences that may reduce disease pressure.
- Uncertain risk zones: Zones such as *Cfb*, *BSh*, *BWh*, *BWk*, *Csa*, and *Csb* were excluded from the estimation due to high uncertainty regarding the pathogen's ability to establish and cause damage in these conditions.

Step3. Extrapolating observed yield losses to analogous climate zones

As the third step in the quantitative assessment of potential yield losses caused by *C. nebraskensis*, using empirical data from regions where the pest is already established provides the most credible basis for estimating potential losses in new regions, assuming analogous agro-ecological conditions. This approach, which involves scaling data from other regions to the area of interest, is therefore a crucial step in quantitatively justifying impact projections for the EPPO region. Table A1 synthesises data from the US Crop Protection Network reports over the past decade (2014–2023) to present average maize production loss rates attributed to Goss's wilt, categorised by the predominant climate zone of each state or province. These annual publications, titled Corn Disease Loss Estimates, serve as the source for the aggregated loss percentages.

Consequently, we used the Crop Protection Network's "Corn Disease Loss Calculator" and, analysed the data for *C. nebraskensis* for the last 10 available years (2014–2023) in the United States, following this procedure:

- Data extraction: we gathered the annual % yield loss for each state from 2014 to 2023.
- The mapping of states for climatic suitability was used (see section 9.1 and 9.3 of the PRA).
BSk (arid, steppe, cold): Primarily Nebraska, Western Kansas, Eastern Colorado, parts of South Dakota.
Dfa (cold, without dry season, hot summer): Iowa, Illinois, Indiana, Ohio, parts of Missouri.

Cfa (temperate, without dry season, hot summer): Southeastern states (contributed minimally to losses).

Dfb (cold, without dry season, warm summer): Wisconsin, Minnesota, Michigan, New York.

- Weighted average calculation: we calculated the average yield loss for each zone based on the proportion of US maize acreage in states within that zone, providing a more accurate representation than a simple average of state percentages.

In terms of key findings, Table A1 clearly shows that the Primary Risk Zones (*BSk* and *Dfa*) experience significantly higher and more consistent losses. The Secondary Risk Zones (*Cfa* and *Dfb*) have notably lower average losses, with many years showing 0.0% loss. The overall 10-year average annual yield loss for the USA due to Goss's Wilt, weighted by maize production area, is approximately 0.16%.

Table A1: Synthesis of 10-year average annual yield loss rates (in %) by primary and secondary risk climate zone used in our assessment.

Climate Zone	Scenario A (Optimistic / Managed Impact)	Scenario B (Pessimistic / Significant Impact)
Primary Risk Zones		
<i>BSk</i>	0.20%	2.5%
<i>Dfa</i>	0.15%	2.0%
Average	0.17%	2.25
Secondary Risk Zones		
<i>Cfa</i>	0.05%	0.8%
<i>Dfb</i>	0.08%	1.2%
Average	0.06	1%

Source: <https://loss.cropprotectionnetwork.org/> (Accessed on 30/09/2025).

Step 4. Quantifying maize production baselines

As the fourth step in the quantitative assessment of potential yield losses caused by *C. nebraskensis*, it is essential to quantify the current state of maize production, specifically in terms of yield. This baseline enables the measurement of potential deviations and impacts. For this purpose, data from the 2022 Eurostat (for EU and associated countries) and FAOStat (for other EPPO countries) can be utilised. Although geospatially explicit data would allow for yield estimation by climatic zone, such granularity was not feasible due to the lack of publicly available production data disaggregated by climatic zone. Therefore, country-level yield figures are the most consistent and reproducible baseline across the EPPO region.

Step 5. Calculating direct economic impact in tonnes and euros

Based on the above steps, the direct economic impact of *C. nebraskensis* in tonnes and Euros was calculated by integrating data on baseline production, climate-specific risk, and projected yield losses. As such, the calculation began with the baseline agricultural data (Table B1 in ANNEX 15), establishing the normal production (in tonnes) and value (in Euros) for grain maize in each country without the pest. The total cultivated area was then stratified into specific climate zones (Tables B2 & B3 in ANNEX 15), which were classified as either Primary or Secondary Risk based on their suitability for the bacterium's establishment. For each of these risk categories, distinct yield loss rates were applied (Table B4 in ANNEX 15) to create two impact scenarios: an optimistic (Scenario A) and a pessimistic (Scenario B). These loss rates were used to calculate new, reduced yields for every climate zone (Table B5 in ANNEX 15). Finally, the impacted production in tonnes was determined by multiplying the climate zone-specific area by its corresponding impacted yield. The direct economic impact in Euros was then derived by multiplying this new production quantity by the country-specific market price (Tables B6, B7 & B8 in ANNEX 15).

ANNEX 15. Stepwise tables for direct economic impact calculations

Prepared by M. Frem.

Table B1. Grain Maize data in some selected EPPO European countries for 2022

Selected EPPO Country	Area (1000 ha)	Production (1000 tonne)	Yield (tonne/ha)	Production (1000 €)	Price (€/tonne)
Bulgaria	520.46	2,554.37	4.91	738,723.804	289.20
Hungary	816.64	2,765.60	3.39	803,406.8	290.50
Romania	2,437.22	8,037.13	3.30	2,248,788.974	279.80

Source: Data retrieved from the 2022 Eurostat Crop production in EU standard humidity

Table B2. Grain maize area (in %) by different Köppen-Geiger climate types in some selected EPPO European countries in 2022

Selected EPPO Country	Primary Risk Climate Zones		Secondary Risk Climate Zones	
	<i>Bsk</i>	<i>Dfa</i>	<i>Cfa</i>	<i>Dfb</i>
Bulgaria	4%	23%	70%	3%
Hungary	0%	41%	46%	10%
Romania	14%	40%	15%	31%

Source: Beck *et al.*, (2023); Ghassemi *et al.* (2024) (see ANNEX 9).

Table B3. Grain maize area (in 1000 ha) by Köppen-Geiger climate types in some selected EPPO European countries

Selected EPPO Country	Primary Risk Climate Zones		Secondary Risk Climate Zones	
	<i>Bsk</i> (1000 ha)	<i>Dfa</i> (1000 ha)	<i>Cfa</i> (1000 ha)	<i>Dfb</i> (1000 ha)
Bulgaria	20.82	119.71	364.32	15.61
Hungary	0.00	334.82	375.65	81.66
Romania	341.21	974.89	365.58	755.54

Table B4. Summary of yield loss rates (in %) by primary and secondary risk climate zone applied in our assessment

Primary Risk Climate Zones		Secondary Risk Climate Zones	
Scenario A (Optimistic / Managed Impact)	Scenario B (Pessimistic / Significant Impact)	Scenario A (Optimistic / Managed Impact)	Scenario B (Pessimistic / Significant Impact)
0.17%	2.25%	0.06%	1%

Source: <https://loss.cropprotectionnetwork.org/> (Accessed on 30/09/2025)

Table B5. Impacted grain maize yield (tonne/ha) by climate zone and impact scenario

Selected EPPO Country	Normal Yield (t/ha)	Primary Risk Climate Zones		Secondary Risk Climate Zones	
		Yield Scenario A (Optimistic / Managed Impact) (tonne/ha)	Yield Scenario B (Pessimistic / Significant Impact) (tonne/ha)	Yield Scenario A (Optimistic / Managed Impact) (tonne/ha)	Yield Scenario B (Pessimistic / Significant Impact) (tonne/ha)
Bulgaria	4.910	4.902	4.800	4.907	4.861
Hungary	3.390	3.384	3.314	3.388	3.356
Romania	3.300	3.294	3.226	3.298	3.267

Source for normal yields: based on 2022 Eurostat data. Source for loss rates: Adapted from Table B4 (summary of yield loss rates).

Table B6. Impacted grain maize production and value by climate zone and impact scenario in Bulgaria (Price: 289.20 € /tonne)

Climate zone	Risk category	Area (1000 ha)	Scenario	Yield (tonne/ha)	Production (1000 tonne)	Production value (1000 €)
<i>Bsk</i>	Primary	20.82	A	4.902	102.050	29,512.756
			B	4.800	99.936	28,901.491
<i>Dfa</i>		119.71	A	4.902	586.806	169,704.417
			B	4.800	574.608	166,176.634
<i>Cfa</i>	Secondary	364.32	A	4.907	1,787.718	517,008.115
			B	4.861	1,770.960	512,161.493
<i>Dfb</i>		15.61	A	4.907	76.578	22,146.435
			B	4.861	75.880	21,944.557
Total		520.46	A		2,553.152	738,371.723
			B		2,521.384	729,184.175

Table B7. Impacted grain maize production and value by climate zone and impact scenario in Hungary (Price: 290.50 € /tonne)

Climate zone	Risk category	Area (1000 ha)	Scenario	Yield (tonne/ha)	Production (1000 tonne)	Production Value (1000 €)	
Dfa	Primary	334.82	A	3.384	1,133.031	329,145.470	
			B	3.314	1,109.585	322,334.582	
Cfa	Secondary	375.65	A	3.388	1,272.702	369,619.989	
			B	3.356	1,260.681	366,227.947	
81.66		A	3.388	276.664	80,370.915		
		B	3.356	274.051	79,611.804		
Total in areas at risk		792.13	A		2,682.397	779,136.374	
			B		2,644.317	768,174.333	
Total in areas not at risk		24.50	A	3.39	83.055	24,127,4775	
			B	3.39	83.055	24,127,4775	
TOTAL		816.64	A		2,765.452	803,263.852	
			B		2,727.372	792,301.811	

Table B8. Impacted grain maize production and value by climate zone and impact scenario in Romania (Price: 279.80 €)

Climate zone	Risk category	Area (1000 ha)	Scenario	Yield (tonne/ha)	Production (1000 tonne)	Production Value (1000 €)
<i>Bsk</i>	Primary	341.21	A	3.294	1,123.946	314,480.098
			B	3.226	1,100.743	307,987.980
<i>Dfa</i>		974.89	A	3.294	3,211.288	898,518.382
			B	3.226	3,144.995	879,969.601
<i>Cfa</i>	Secondary	365.58	A	3.298	1,205.683	337,349.659
			B	3.267	1,194.350	334,179.130
<i>Dfb</i>		755.54	A	3.298	2,491.771	697,157.503
			B	3.267	2,468.349	690,603.901
Total		2,437.22	A		8,032.688	2,247,546.102
			B		7,908.437	2,212,780.673