Bulletin OEPP/EPPO Bulletin (2013) **43** (2), 197–201 ISSN 0250-8052. DOI: 10.1111/epp.12043

European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

EPPO Data Sheets on pests recommended for regulation
Fiches informatives sur les organismes recommandés pour réglementation

'Candidatus Liberibacter solanacearum'

Identity

Name: '*Candidatus* Liberibacter solanacearum' (Liefting *et al.*, 2009c)
Synonym: '*Candidatus* Liberibacter psyllaurous' (Hansen *et al.*, 2008)
Taxonomic position: Bacteria: Proteobacteria: Alphaproteobacteria: Rhizobiales: Rhizobiaceae
Common names: zebra chip (English), zebra complex (English), psyllid yellows (English), punta morada (Spanish), papa manchada (Spanish), papa rayada (Spanish)
EPPO code: LIBEPS
Phytosanitary categorization: EPPO A1 list no 365 (for Solanaceae haplotypes).

Hosts

'*Candidatus* Liberibacter solanacearum' is known to primarily infect solanaceous species, including potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), pepper (*Capsicum annuum*), eggplant (*Solanum melongena*), tomatillo (*Physalis peruviana*), tamarillo (*Solanum betaceum*), tobacco (*Nicotiana tabacum*), and several weeds in the family Solanaceae (Hansen *et al.*, 2008; Liefting *et al.*, 2008a,b, 2009a,c; Abad *et al.*, 2009; Crosslin & Munyaneza, 2009; Lin *et al.*, 2009; Munyaneza *et al.*, 2009a,b,c; Secor *et al.*, 2009; Wen *et al.*, 2009; Brown *et al.*, 2010; Crosslin *et al.*, 2010; Munyaneza, 2010, 2012; Rehman *et al.*, 2010; Sengoda *et al.*, 2010). This *Liberibacter* species is transmitted to solanaceous species by the potato/tomato psyllid, *Bactericera cockerelli* (Šulc). Recently, '*Ca*. L. solanacearum' has been detected in carrot plants (*Daucus carota*) in Finland and is vectored by the carrot psyllid, *Trioza apicalis* Förster (Munyaneza *et al.*, 2010a,b, 2011b). Subsequently, this bacterium was also detected in carrots and *T. apicalis* in Sweden and Norway (Munyaneza *et al.*, 2012b,c). Most recently, '*Ca*. L. solanacearum' has been reported in carrot, celery (*Apium graveolens*) and the psyllid *Bactericera trigonica* in the Canary Islands and mainland Spain (Alfaro-Fernández *et al.*, 2012a,b). These recent findings on the association of '*Ca*. L. solanacearum' with non-solanaceous species and other psyllids suggest that it is likely to have more insect vectors and host plants than currently known.

Geographical distribution

'*Ca*. L. solanacearum' has been detected in several European countries in carrot crops (and to a lesser extent in celery) in association with other psyllid species (*Bactericera trigonica* and *Trioza apicalis*). However, '*Ca*. L. solanacearum' has not been detected in potato or tomato crops in the EPPO region.
EPPO region: Finland, France (transient; only in 2 carrot fields), Norway, Spain (mainland and Canary Islands), Sweden.
North America: Mexico, USA (Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, Oregon, Texas, Washington Wyoming.
Central America: Guatemala, Honduras, Nicaragua.
Oceania: New Zealand (recently introduced).

Biology

'*Ca.* L. solanacearum' is a phloem-limited, Gram-negative, unculturable bacterium that is spread from infected to healthy plants by psyllid insect vectors (Hansen *et al.*, 2008; Munyaneza *et al.*, 2008, 2010b; Secor *et al.*, 2009; Munyaneza, 2012). It may be spread experimentally by grafting (Crosslin & Munyaneza, 2009; Secor *et al.*, 2009). This Liberibacter species has also been shown to be transmitted both vertically (transovarially) and horizontally (from feeding on infected plant hosts) in *B. cockerelli* (Hansen *et al.*, 2008; Munyaneza, unpublished data). No information is currently available on vertical transmission for *T. apicalis* and *B. trigonica*. Although only limited experiments have been conducted on Liberibacter transmission, it appears that '*Ca.* L. solanacearum' is not transmitted through true seed from infected plants (Munyaneza, 2012).

Four geographic haplotypes of '*Ca*. L. solanacearum' have recently been described (Nelson *et al.*, 2011, 2012). Two haplotypes (LsoA and LsoB) are associated with diseases caused by this bacterium in potatoes and other solanaceous plants, whereas the other two (LsoC and LsoD) are associated with diseased carrots. Haplotype LsoA has been found primarily from Honduras and Guatemala through Western Mexico to Arizona, California, Oregon, Washington, Idaho and in New Zealand. Haplotype LsoB is currently found from Eastern Mexico and northwards through Texas. These two haplotypes show some range overlap in Texas, Kansas and Nebraska. Haplotype LsoC has been found in Finland, Sweden and Norway (Nelson *et al.*, 2011, 2012) and is associated with *T. apicalis*. LsoD was very recently described from infected carrots and the psyllid *B. trigonica* in Spain and the Canary Islands (Nelson *et al.*, 2012). The four haplotypes are not yet known to elicit biological differences in the plant or insect hosts. These apparently stable haplotypes suggest separate long-lasting populations of the bacterium. Interestingly, LsoA and LsoC were found to be genetically very close, despite their large geographic separation and the differences in both plant and insect hosts (Nelson *et al.*, 2012). Furthermore, a study on the genetic diversity of Lso strains using simple sequence repeat (SSR) markers identified two major lineages of this bacterium in the United States and only one lineage in Mexico (Lin *et al.*, 2012).

Effects of environmental conditions on '*Ca*. L. solanacearum' are not well known. However, temperature has a significant effect on development of this bacterium. Compared to citrus greening Liberibacter species, '*Ca*. L. solanacearum' appears heat sensitive as it seems not to tolerate temperatures above 32°C (Munyaneza *et al.*, 2012a). *B. cockerelli*, the insect vector of this bacterium in the Americas and New Zealand, appears to have similar sensitivity to heat.

Detection and identification

Symptoms

The characteristic above-ground plant symptoms of '*Ca*. L. solanacearum' infection in potato, tomato and other solanaceous species resemble those caused by phytoplasmas (see Fig. 1) and include stunting, erectness of new foliage, chlorosis and purpling of foliage with basal cupping of leaves, upward rolling of leaves throughout the plant, shortened and thickened terminal internodes resulting in plant rosetting, enlarged nodes, axillary branches or aerial tubers, leaf scorching, disruption of fruit set, and production of numerous, small, misshapen, and poor quality fruits (Munyaneza *et al.*, 2007a,b; Liefting *et al.*, 2009a; Secor *et al.*, 2009; Crosslin *et al.*, 2010; Munyaneza, 2010, 2012). In potato, the below-ground symptoms include collapsed stolons, browning of vascular tissue concomitant with necrotic flecking of internal tissues and streaking of the medullary ray tissues, all of which can affect the entire tuber (see Fig. 2). Upon frying, these symptoms become more pronounced and crisps or chips processed from affected tubers show very dark blotches, stripes, or streaks, rendering them commercially unacceptable (Munyaneza *et al.*, 2007a,b, 2008; Secor *et al.*, 2009; Crosslin *et al.*, 2010; Miles *et al.*, 2010; Munyaneza, 2012; Munyaneza & Henne, 2012). The symptoms in potato tubers have led to the disease being named 'zebra chip' (Munyaneza *et al.*, 2007a,b; Munyaneza, 2012).

Symptoms in carrots infected with '*Ca*. L. solanacearum' include leaf curling, yellowish, bronze and purplish discoloration of leaves, stunting of the carrot shoots and roots, and proliferation of secondary roots (Munyaneza *et al.*, 2010a,b, 2012b,c; Alfaro-Fernández *et al.*, 2012a,b). Collectively, these symptoms resemble those caused by leafhopper-transmitted phytoplasmas and *S. citri* in carrots (Font *et al.*, 1999; Lee *et al.*, 2006; Cebrián *et al.*, 2010; Munyaneza *et al.*, 2011b).

Morphology

Similarly to other Liberibacters, scanning electron microscopy images of '*Ca*. L. solanacearum' in sieves of infected plants revealed that this bacterium has a rod-shaped morphology (Liefting *et al.*, 2009a; Secor *et al.*, 2009). The bacterium is about 0.2 μm wide and 4 μm long (Liefting *et al.*, 2009a).

Detection and inspection methods

The whole genome of '*Ca*. L. solanacearum' isolated from zebra chip-infected potatoes has recently been sequenced

Fig. 1 Tomato plant infected by '*Candidatus* Liberibacter solanacearum' (photo courtesy of JE Munyaneza).

Fig. 2 Zebra chip infected potato tuber (photo courtesy of JE Munyaneza).

(Lin *et al.*, 2011). Detection methods for '*Ca*. L. solanacearum' have been developed and include conventional and quantitative real-time polymerase chain reaction (PCR) (Hansen *et al.*, 2008; Crosslin & Munyaneza, 2009; Li *et al.*, 2009; Liefting *et al.*, 2009a; Lin *et al.*, 2009; Wen *et al.*, 2009; Crosslin *et al.*, 2011; Munyaneza, 2012). Uneven distribution and variation in the Liberibacter titer in different parts of infected plants has been observed, making detection of this bacterium by PCR sometimes inconsistent (Crosslin & Munyaneza, 2009; Li *et al.*, 2009). Development of better and more accurate detection methods is currently underway. Visual symptom inspections in some infected plants such as potato tubers can be very reliable (see symptoms above). Mixed infections of '*Ca*. L. solanacearum' and phytoplasmas have been reported in potato (Liefting *et al.*, 2009b; Munyaneza, unpublished data) and carrot (Munyaneza *et al.*, 2011b). Furthermore, mixed infections of Liberibacter, phytoplasmas, and *S. citri* have been detected in carrots in the Mediterranean region (Alfaro-Fernández *et al.*, 2012a).

Pathways for movement

'*Ca*. L. solanacearum' can be moved by its vectors or in host plants meant for propagation.

During international trade, infected planting material could carry the disease, or possibly also infective vectors (most likely as eggs). Seed potatoes infected with '*Ca*. L. solanacearum' generally do not germinate but, in rare cases, may produce infected plants (Henne *et al.*, 2010; Pitman *et al.*, 2011). However, these seed-borne infected plants are often weak and short-lived and do not significantly contribute to the disease spread (Munyaneza, 2012). Most importantly, the psyllids have to be present to spread the bacterium.

Pest significance

Economic impact

'*Ca.* L. solanacearum' was first identified in 2008 (Hansen *et al.*, 2008; Liefting *et al.*, 2008a,b) and shown to be associated with zebra chip disease of potato, which has been observed since the 1990s with increasing impacts and linked to *B. cockerelli* for the first time in 2007 (Munyaneza *et al.*, 2007a,b). A comprehensive review of the history and association of this bacterium with zebra chip and other diseases of solanaceous crops was provided by Crosslin *et al.* (2010), Munyaneza (2010, 2012), and Munyaneza & Henne (2012). First reported in Mexico in the 1990s, zebra chip was documented causing serious economic damage in parts of Southern Texas in 2004-2005. The disease is now widespread in the South-Western, Central, and North-Western USA, Mexico, Central America, and New Zealand (Munyaneza *et al.*, 2007a,b, 2009a; Liefting *et al.*, 2009a; Secor *et al.*, 2009; Crosslin *et al.*, 2010, 2012a,b; Munyaneza, 2010, 2012; Rehman *et al.*, 2010). This Liberibacter species also severely affects other important solanaceous crops, including tomato, pepper, eggplant, tamarillo (Liefting *et al.*, 2009a; Munyaneza *et al.*, 2009b,c; Brown *et al.*, 2010), and tobacco (Munyaneza, unpublished data). It has been established that '*Ca*. L. solanacearum' is transmitted to solanaceous species by the psyllid *B. cockerelli*. Recently, Munyaneza *et al.* (2010a,b) detected '*Ca*. L. solanacearum' in carrots affected by the psyllid *T. apicalis* in Finland, which constitutes the first report of Liberibacter in Europe and '*Ca*. L. solanacearum' in a non-solanaceous species. The bacterium was subsequently detected in carrots and *T. apicalis* in Sweden and Norway (Munyaneza *et al.*, 2012a,b). Most recently, '*Ca*. L. solanacearum' has been detected in carrot, celery and the psyllid *B. trigonica* in the Canary Islands and mainland Spain (Alfaro-Fernández *et al.*, 2012a,b; EPPO, 2012); symptoms in diseased plants had previously been attributed to phytoplasmas and spiroplasmas in this area.

The complex bacterium/vectors has caused serious damage to the potato and tomato industries in the Americas and New Zealand (Munyaneza *et al.*, 2007a,b, 2008; Liefting *et al.*, 2009a; Secor *et al.*, 2009; Crosslin *et al.*, 2010; Rehman *et al.*, 2010; Guenthner *et al.*, 2012) and to the carrot industry in Europe (Munyaneza, 2010; Munyaneza *et al.*, 2010a,b, 2012b,c; Alfaro-Fernández *et al.*, 2012a,b). In the case of potato, plant growth is negatively affected; crisps or chips made from zebra chip-infected tubers show dark stripes that become markedly more visible upon frying, and hence are commercially unacceptable. Whole crops might be rejected because of high levels of the disease, occasionally leading to abandonment of entire potato fields. Potatoes for the fresh market are severely affected by zebra chip (Munyaneza *et al.*, 2011a). Infected tubers usually do not sprout and if they do, produce hair sprouts or weak plants (Henne *et al.*, 2010; Pitman *et al.*, 2011). The bacterium is also associated with economically damaging diseases of other important solanaceous crops, including tomato, pepper, eggplant, tobacco, and tamarillo. In Europe, damage to carrots by Liberibacter-infected carrot psyllids can cause up to 100% crop loss (Munyaneza *et al.*, 2010a,b, 2012b,c; Alfaro-Fernández *et al.*, 2012a,b).

Control

At present, applications of insecticides targeted against the potato and carrot psyllids are the only means to effectively manage diseases associated with '*Ca*. L. solanacearum' (Munyaneza, 2012). See the datasheet for *B. cockerelli* for details. No plant resistance to the disease has yet been identified (Munyaneza *et al.*, 2011a).

Phytosanitary risk

'*Ca*. L. solanacearum' and its insect vector *B. cockerelli* have been found to be serious and economically important pests of potatoes, tomatoes, and other solanaceous crops in Western and Central USA, Mexico, Central America and New Zealand. They would result in similar damage if introduced in the EPPO region. Quarantine considerations have already emerged in some regions where '*Ca*. L. solanacearum' has been documented. Some countries are now requiring specific testing for '*Ca*. L. solanacearum' prior to allowing import of potatoes (Crosslin *et al.*, 2010; Munyaneza, 2012). Furthermore, Australia put in place additional quarantine requirements for the importation of fresh tomato and pepper from New Zealand after 2006, where growers need to ensure that crops for export have been produced in areas free of *B. cockerelli* or the exported produce must be free of the psyllid.

'*Ca*. L. solanacearum' has already been documented in carrots in Finland, France, Sweden, and Norway and it is suspected that this bacterium is more likely to be widespread in parts of Northern and Central Europe where its insect vector *T. apicalis* occurs or at least in regions where damage by this psyllid has been observed. Very recently, this bacterium was reported in carrots and the psyllid *B. trigonica* in Spain and the Canary Islands. Nevertheless results of a preliminary study indicate that inoculation of '*Ca*. L. solanacearum' to potato by *T. apicalis* is not possible (Munyaneza, unpublished data). These observations suggest that the main pathway of introducing '*Ca*. L. solanacearum' into solanaceous species would be the introduction of infective *B. cockerelli* into the EPPO region.

Phytosanitary measures

EPPO recommends that vegetative material for propagation and produce (such as fruits) of Solanaceae should come from areas free of *B. cockerelli* and '*Ca.* L. solanacearum'. Seed and ware potatoes should come from areas free of zebra chip. Alternatively high grade seed potato may be imported under post-entry quarantine, and ware potatoes may be imported only for industrial processing purposes.

Acknowledgement

This datasheet was prepared by J.E. Munyaneza, Research Entomologist, United States Department of Agriculture (USDA)/Agricultural Research Service (ARS), Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Road, Wapato, WA 98901, USA.

References

Abad JA, Bandla M, French-Monar RD, Liefting LW & Clover GRG (2009) First report of the detection of '*Candidatus* Liberibacter' species in zebra chip disease-infected potato plants in the United States. *Plant Disease* **93**, 108.

Alfaro-Fernández A, Cebrián MC, Villaescusa FJ, Hermoso de Mendoza A, Ferrándiz JC, Sanjuán S *et al.* (2012a) First report of '*Candidatus* Liberibacter solanacearum' in carrot in mainland Spain. *Plant Disease* **96**, 582.

Alfaro-Fernández A, Siverio F, Cebrián MC, Villaescusa FJ & Font MI (2012b) '*Candidatus* Liberibacter solanacearum' associated with *Bactericera trigonica*-affected carrots in the Canary Islands. *Plant Disease* **96**, 581.

Brown JK, Rehman M, Rogan D, Martin RR & Idris AM (2010) First report of "*Candidatus* Liberibacter psylaurous" (syn. "*Ca*. L. solanacearum") associated with the 'tomato vein-greening' and 'tomato psyllid yellows' diseases in commercial greenhouse in Arizona. *Plant Disease* **94**, 376.

Cebrián MC, Villaescusa FJ, Alfaro-Fernández A, Hermoso de Mendoza A, Cárdoba-Selleés MC, Jorda C *et al.* (2010) First report of *Spiroplasma citri* in carrot in Europe. *Plant Disease* **94**, 1264.

Crosslin JM & Munyaneza JE (2009) Evidence that the zebra chip disease and the putative causal agent can be maintained in potatoes by grafting and in vitro. *American Journal of Potato Research* **86**, 183–187.

Crosslin JM, Munyaneza JE, Brown JK & Liefting LW (2010) Potato zebra chip disease: A phytopathological tale. *Online. Plant Health Progress*. doi:10.1094/PHP-2010-0317-01-RV.

Crosslin JM, Lin H & Munyaneza JE (2011) Detection of '*Candidatus* Liberibacter solanacearum' in the potato psyllid, *Bactericera cockerelli* (sulc), by conventional and real-time PCR. *Southwestern Entomologist* **36**, 125–135.

Crosslin JM, Hamm PB, Eggers JE, Rondon SI, Sengoda VG & Munyaneza JE (2012a) First report of zebra chip disease and "*Candidatus* Liberibacter solanacearum" on potatoes in Oregon and Washington State. *Plant Disease* **96**, 452.

Crosslin JM, Olsen N & Nolte P (2012b) First report of zebra chip disease and "*Candidatus* Liberibacter solanacearum" on potatoes in Idaho. *Plant Disease* **96**, 453.

EPPO (2012) EPPO Reporting Service no. 2012/121. EPPO Paris.

Font I, Abad P, Albiñana M, Espino AI, Dally EL, Davis R *et al.* (1999) Amarilleos y anrojecimientos en zanahoria: una enfermedad a diagnóstico. *Boletín de Sanidad Vegetal Plagas* **25**, 405–415.

Guenthner J, Goolsby J & Greenway G (2012) Use and cost of insecticides to control potato psyllids and zebra chip on potatoes. *Southwestern Entomologist* **37**, 263–270.

Hansen AK, Trumble JT, Stouthamer R & Paine TD (2008) A new huanglongbing species, '*Candidatus* Liberibacter psyllaurous' found to infect tomato and potato, is vectored by the Psyllid *Bactericera cockerelli* (Sulc). *Applied Environmental Microbiology* **74**, 5862–5865.

Henne DC, Workneh F, Wen A, Price AA, Pasche JS, Gudmestad NC *et al.* (2010) Characterization and epidemiological significance of potato plants grown from seed tubers affected by zebra chip disease. *Plant Disease* **94**, 659–665.

Lee IM, Bottner KD, Munyaneza JE, Davis RE, Crosslin JM, du Toit LJ *et al.* (2006) Carrot purple leaf: a new spiroplasmal disease associated with carrots in Washington State. *Plant Disease* **90**, 989–993.

Li W, Abad JA, French-Monar RD, Rascoe J, Wen A, Gudmestad NC *et al.* (2009) Multiplex real-time PCR for detection, identification and quantification of '*Candidatus* Liberibacter solanacearum' in potato plants with zebra chip. *Journal of Microbiological Methods* **78**, 59–65.

Liefting LW, Perez-Egusquiza ZC, Clover GRG & Anderson JAD (2008a) A new '*Candidatus* Liberibacter' species in *Solanum tuberosum* in New Zealand. *Plant Disease* **92**, 1474.

Liefting LW, Ward LI, Shiller JB & Clover GRG (2008b) A new '*Candidatus* Liberibacter' species in *Solanum betaceum* (tamarillo) and *Physalis periviana* (cape gooseberry) in New Zealand. *Plant Disease* **92**, 1588.

Liefting LW, Sutherland PW, Ward LI, Paice KL, Weir BS & Clover GRG (2009a) A new '*Candidatus* Liberibacter' species associated with diseases of solanaceous crops. *Plant Disease* **93**, 208–214.

Liefting LW, Veerakone S, Ward LI & Clover GRG (2009b) First report of '*Candidatus* Phytoplasma australiense' in potato. *Plant Disease* **93**, 969.

Liefting LW, Weir BS, Pennycook SR & Clover GRG (2009c) '*Candidatus* Liberibacter solanacearum', associated with plants in the family Solanaceae. *International Journal of Systematics and Evolutionary Microbiology* **59**, 2274–2276.

Lin H, Doddapaneni H, Munyaneza JE, Civerolo E, Sengoda VG, Buchman JL *et al.* (2009) Molecular characterization and phylogenetic analysis of 16S rRNA from a new species of "*Candidatus* Liberibacter" associated with Zebra chip disease of potato (*Solanum tuberosum* L.) and the potato psyllid (*Bactericera cockerelli* Sulc). *Journal of Plant Pathology* **91**, 215–219.

Lin H, Lou B, Glynn JM, Doddapaneni H, Civerolo E, Chen C *et al.* (2011) The complete genome sequence of '*Candidatus* Liberibacter solanacearum', the bacterium associated with potato zebra chip disease. *PLoS ONE* **6**, e19135. doi:10.1371/journal.pone.0019135.

Lin H, Islam MS, Bai Y, Wen A, Lan S, Gudmestad NC *et al.* (2012) Genetic diversity of '*Candidatus* Liberibacter solanacearum' strains in the United States and Mexico revealed by simple sequence repeat markers. *European Journal of Plant Pathology* **132**, 297–308.

Miles GP, Samuel MA, Chen J, Civerolo EL & Munyaneza JE (2010) Evidence that cell death is associated with zebra chip disease in potato tubers. *American Journal of Potato Research* **87**, 337–349.

Munyaneza JE (2010) Psyllids as vectors of emerging bacterial diseases of annual crops. *Southwestern Entomologist* **35**, 417–477.

Munyaneza JE (2012) Zebra chip disease of potato: biology, epidemiology, and management. *American Journal of Potato Research* **89**, 329–350.

Munyaneza JE & Henne DC (2012) Leafhopper and psyllid pests of potato. In: *Insect Pests of Potato: Global Perspectives on Biology and Management* (Eds Giordanengo P, Vincent C & Alyokhin A), pp. 65–102. Academic Press, San Diego, CA.

Munyaneza JE, Crosslin JM & Upton JE (2007a) Association of *Bactericera cockerelli* (Homoptera: Psyllidae) with "zebra chip", a new potato disease in southwestern United States and Mexico. *Journal of Economic Entomology* **100**, 656–663.

Munyaneza JE, Goolsby JA, Crosslin JM & Upton JE (2007b) Further evidence that zebra chip potato disease in the lower Rio Grande Valley of Texas is associated with *Bactericera cockerelli*. *Subtropical Plant Science* **59**, 30–37.

Munyaneza JE, Buchman JL, Upton JE, Goolsby JA, Crosslin JM, Bester G *et al.* (2008) Impact of different potato psyllid populations on zebra chip disease incidence, severity, and potato yield. *Subtropical Plant Science* **60**, 27–37.

Munyaneza JE, Sengoda VG, Crosslin JM, De la Rosa-Lozano G & Sanchez A (2009a) First report of '*Candidatus* Liberibacter psyllaurous' in potato tubers with zebra chip disease in Mexico. *Plant Disease* **93**, 552.

Munyaneza JE, Sengoda VG, Crosslin JM, Garzon-Tiznado J & Cardenas-Valenzuela O (2009b) First report of '*Candidatus* Liberibacter solanacearum' in tomato plants in Mexico. *Plant Disease* **93**, 1076.

Munyaneza JE, Sengoda VG, Crosslin JM, Garzon-Tiznado J & Cardenas-Valenzuela O (2009c) First report of '*Candidatus* Liberibacter solanacearum' in pepper in Mexico. *Plant Disease* **93**, 1076.

Munyaneza JE, Fisher TW, Sengoda VG, Garczynski SF, Nissinen A & Lemmetty A (2010a) First report of "*Candidatus* Liberibacter solanacearum" in carrots in Europe. *Plant Disease* **94**, 639.

Munyaneza JE, Fisher TW, Sengoda VG, Garczynski SF, Nissinen A & Lemmetty A (2010b) Association of "*Candidatus* Liberibacter solanacearum" with the psyllid *Trioza apicalis* (Hemiptera: Triozidae) in Europe. *Journal of Economic Entomology* **103**, 1060–1070.

Munyaneza JE, Buchman JL, Sengoda VG, Fisher TW & Pearson CC (2011a) Susceptibility of selected potato varieties to zebra chip potato disease. *American Journal of Potato Research* **88**, 435–440.

Munyaneza JE, Lemmetty A, Nissinen AI, Sengoda VG & Fisher TW (2011b) Molecular detection of aster yellows phytoplasma and "*Candidatus* Liberibacter solanacearum" in carrots affected by the psyllid *Trioza apicalis* (Hemiptera: Triozidae) in Finland. *Journal of Plant Pathology* **93**, 697–700.

Munyaneza JE, Sengoda VG, Buchman JL & Fisher TW (2012a) Effects of temperature on '*Candidatus* Liberibacter solanacearum' and zebra chip potato disease symptom development. *Plant Disease* **96**, 18–23.

Munyaneza JE, Sengoda VG, Stegmark R, Arvidsson AK, Anderbrant O, Yuvaraj JK *et al.* (2012b) First report of "*Candidatus* Liberibacter solanacearum" associated with psyllid-affected carrots in Sweden. *Plant Disease* **96**, 453.

Munyaneza JE, Sengoda VG, Sundheim L & Meadow R (2012c) First report of "*Candidatus* Liberibacter solanacearum" associated with psyllid-affected carrots in Norway. *Plant Disease* **96**, 454.

Nelson WR, Fisher TW & Munyaneza JE (2011) Haplotypes of "*Candidatus* Liberibacter solanacearum" suggest long-standing separation. *European Journal of Plant Pathology* **130**, 5–12.

Nelson WR, Sengoda VG, Alfaro-Fernandez AO, Font MI, Crosslin JM & Munyaneza JE (2012) A new haplotype of "*Candidatus* Liberibacter solanacearum" identified in the Mediterranean region. *European Journal of Plant Pathology*. doi:10.1007/s10658-012-0121-3.

Pitman AR, Drayton GM, Kraberger SJ, Genet RA & Scott IAW (2011) Tuber transmission of '*Candidatus* Liberibacter solanacearum' and its association with zebra chip on potato in New Zealand. *European Journal of Plant Pathology* **129**, 389–398.

Rehman M, Melgar J, Rivera C, Urbina N, Idris AM & Brown JK (2010) First report of "*Candidatus* Liberibacter psyllaurous" or "*Ca.* Liberibacter solanacearum" associated with severe foliar chlorosis, curling, and necrosis and tuber discoloration of potato plants in Honduras. *Plant Disease* **94**, 376.

Secor GA, Rivera VV, Abad JA, Lee IM, Clover GRG, Liefting LW *et al.* (2009) Association of '*Candidatus* Liberibacter solanacearum' with zebra chip disease of potato established by graft and psyllid transmission, electron microscopy, and PCR. *Plant Disease* **93**, 574–583.

Sengoda VG, Munyaneza JE, Crosslin JM, Buchman JL & Pappu HR (2010) Phenotypic and etiological differences between psyllid yellows and zebra chip diseases of potato. *American Journal of Potato Research* **87**, 41–49.

Wen A, Mallik I, Alvarado VY, Pasche JS, Wang X, Li W *et al.* (2009) Detection, distribution, and genetic variability of '*Candidatus* Liberibacter' species associated with zebra complex disease of potato in North America. *Plant Disease* **93**, 1102–1115.