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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

Bactericera cockerelli

Identity

Name: *Bactericera cockerelli* (Šulc)
Synonym: *Paratrioza cockerelli* Šulc
Taxonomic position: Insecta, Hemiptera, Psylloidea, Triozidae
Common names: potato psyllid, tomato psyllid
EPPO code: PARZCO
Phytosanitary categorization: EPPO A1 list no 366
Note: *B. cockerelli* is a pest in itself (feeding damage), but more importantly it transmits '*Candidatus* Liberibacter solanacearum' to solanaceous plants.

Hosts

Bactericera cockerelli is found primarily on plants within the family Solanaceae. It attacks, reproduces, and develops on a variety of cultivated and weedy plant species (Essig, 1917; Knowlton & Thomas, 1934; Pletsch, 1947; Jensen, 1954; Wallis, 1955), including crop plants such as potato (*Solanum tuberosum*), tomato (*Solanum lycopersicon*), pepper (*Capsicum annuum*), eggplant (*Solanum melongena*), and tobacco (*Nicotiana tabacum*), and non-crop species such as nightshade (*Solanum* spp.), groundcherry (*Physalis* spp.) and matrimony vine (*Lycium* spp.). Adults have been collected from plants in numerous families, including Pinaceae, Salicaceae, Polygonaceae, Chenopodiaceae, Brassicaceae, Asteraceae, Fabaceae, Malvaceae, Amaranthaceae, Lamiaceae, Poaceae, Menthaceae and Convolvulaceae, but this is not an indication of the true host range of this psyllid (Pletsch, 1947; Wallis, 1955; Cranshaw, 1993). Beside solanaceous species, *B. cockerelli* has been shown to reproduce and develop on some Convolvulaceae species, including field bindweed (*Convolvulus arvensis*) and sweet potato (*Ipomoea batatas)* (Knowlton & Thomas, 1934; List, 1939; Wallis, 1955; Puketapu & Roskruge, 2011; J. E. Munyaneza, unpublished data).

Geographical distribution

Bactericera cockerelli is thought to be native to South-Western USA and Northern Mexico (Pletsch, 1947; Wallis, 1955). In Canada, this psyllid may survive all year round under protected indoor conditions but outdoor populations only occur late in the growing season, following the insect migration from Northern Mexico and the USA. *B. cockerelli* cannot overwinter in Canada, and is not considered as established there. In addition, it must be noted that the pathogen '*Candidatus* Liberibacter solanacearum' has never been observed on potatoes or tomatoes in Canada (Ferguson & Shipp, 2002; Ferguson *et al.*, 2003). In the USA, The potato psyllid had previously been reported to only occur west of the Mississippi River (Richards & Blood, 1933; Pletsch, 1947; Wallis, 1955; Cranshaw, 1993; Capinera, 2001); however, this insect was recently collected on yellow sticky traps near potato fields in Wisconsin late in the summer of 2012 (Henne *et al.*, 2012), which constitutes the first documentation of this insect east of Mississippi.
EPPO region: absent.
EU: absent.
North America:

- Canada: Alberta, British Columbia, Ontario, Quebec, Saskatchewan
- Mexico: Baja California, Chihuahua, Coahuila, Guanajuato, Jalisco, Nuevo León, Sinaloa, Sonora, Tlaxcala (Tuthill, 1945; Cadena-Hinojosa *et al.*, 2003; Rubio-Covarrubias *et al.*, 2006; Munyaneza *et al.*, 2007a; Trumble, 2008; Munyaneza *et al.*, 2009b,c,d; Munyaneza, 2012; Butler & Trumble, 2012; Munyaneza & Henne, 2012)
- USA: Arizona, California, Colorado, Idaho, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, Wyoming (Pletsch, 1947; Wallis, 1955; Cranshaw, 1993; Abdullah, 2008; Munyaneza *et al.*, 2009a; Crosslin *et al.*, 2010, 2012a,b; Munyaneza, 2010, 2012; Butler & Trumble, 2012; Munyaneza & Henne, 2012).

Central America: Guatemala, Honduras (departments of Intibucá, Ocotepeque and Francisco Morazán), and Nicaragua (Pletsch, 1947; Wallis, 1955; Secor & Rivera-Varas, 2004; Trumble, 2008, 2009; Jackson *et al.*, 2009; Secor *et al.*, 2009; Espinoza, 2010; Munyaneza, 2010, 2012; Rehman *et al.*, 2010; Butler & Trumble, 2012; Munyaneza & Henne, 2012). The psyllid is also suspected to occur in neighbouring countries, including El Salvador (Munyaneza, unpublished data).
Oceania: New Zealand (North and South Island). First detected in May 2006 (Gill, 2006; Teulon *et al.*, 2009; Thomas *et al.*, 2011).

Biology

The eggs are deposited singly principally on the upper or lower surface of leaves, usually near the leaf edge, but some eggs can be found on all above ground parts of suitable host plants. Following egg hatching, the young nymph crawls down the egg stalk to search for a place to feed. Nymphs are found mostly on the lower surface of leaves and usually remain sedentary during their entire development. These nymphs prefer sheltered and shaded locations. Nymphs, and also adults, produce characteristic and large quantities of whitish excrement particles which may adhere to foliage and fruit. Adults are active in contrast to nymphal stages. These insects are good fliers and readily jump when disturbed. The pre-oviposition period is normally about 10 days, with oviposition lasting up to 53 days. Total adult longevity ranges from 20 to 62 days and females usually live twice to three times as long as males, depending on which host plants they are reared on (Pletsch, 1947; Abernathy, 1991; Abdullah, 2008; Yang & Liu, 2009). Females lay an average of 300–500 eggs over their lifetime (Knowlton & Janes, 1931; Pletsch, 1947; Abdullah, 2008; Yang & Liu, 2009). A sex ratio of 1:1 has been reported (Abernathy, 1991; Yang & Liu, 2009). *B. cockerelli* overwinters as an adult.

Weather is an important element influencing the biology of *B. cockerelli* and its damage potential. The potato psyllid seems to be adapted for warm, but not hot weather. Cool weather during migrations, or at least the absence of elevated temperatures, has been associated with several outbreaks of this insect (Pletsch, 1947; Wallis, 1955; Capinera, 2001; Cranshaw, 2001). Optimum psyllid development occurs at approximately 27°C, whereas oviposition, hatching, and survival are reduced at 32°C and cease at 35°C (List, 1939; Pletsch, 1947; Wallis, 1955; Cranshaw, 2001; Abdullah, 2008). A single generation may be completed in 3–5 weeks, depending on temperature. The number of generations varies considerably among regions, usually ranging from three to seven. However, once psyllids invade an area, prolonged oviposition by adults causes the generations to overlap, making it difficult to distinguish generations (Pletsch, 1947; Wallis, 1955).

In North America, *B. cockerelli* appears to migrate annually primarily with wind and hot temperatures in late spring from its overwintering and breeding areas in Western Texas, Southern New Mexico, Arizona, California, and Northern Mexico to northerly regions of the USA and Southern Canada, especially through the mid-western states and Canadian provinces along the Rocky Mountains (Romney, 1939; Pletsch, 1947; Jensen, 1954; Wallis, 1955). In these regions, damaging outbreaks of potato psyllid in potatoes and tomatoes occurred at regular intervals beginning in the late-1800s and extending into the 1940s (List, 1939; Wallis, 1946; Pletsch, 1947). In more recent years, outbreaks have also occurred in regions outside of the midwestern USA, including in Southern California, Baja California, Washington, Oregon, Idaho, and Central America (Trumble, 2008, 2009; Munyaneza *et al.*, 2009a; Wen *et al.*, 2009; Crosslin *et al.*, 2010, 2012a,b; Munyaneza, 2010, 2012; Butler & Trumble, 2012; Munyaneza & Henne, 2012).

Up to now 3 biotypes have been described in USA: western, central and northwestern. Information on *B. cockerelli* migration movements within Mexico and Central America is lacking. In South-Western USA, potato psyllids reappear in the overwintering areas between October and November, presumably dispersing southward from northern locations (Capinera, 2001); however, their origin has not been determined. In countries and regions where there is no winter, temperatures are relatively cool, and suitable host plants are available (e.g., Mexico, Central America), *B. cockerelli* is able to reproduce and develop all year around. It is not known whether migration of this psyllid occurs within New Zealand.

Detection and identification

Symptoms

Bactericera cockerelli has historically been associated with psyllid yellows disease of potato and tomato, (Richards & Blood, 1933). Psyllid yellows disease is thought to be associated with feeding by psyllid nymphs (List, 1925) and may be caused by a toxin associated with the insect (Carter, 1939), although the actual etiology of the disease is yet to be determined (Sengoda *et al.*, 2010). More recently, this psyllid has been found to be associated with the bacterium '*Candidatus* Liberibacter solanacearum'; see datasheet on '*Candidatus* Liberibacter solanacearum' for details.

The characteristic above-ground plant symptoms of infestation by *B. cockerelli* in potatoes (Fig. 1) and tomatoes include retarded growth, erectness of new foliage, chlorosis and purpling of new foliage with basal cupping of leaves, upward rolling of leaves throughout the plant, shortened

Fig. 1 Potato plant with zebra chip and psyllid yellows symptoms (photo courtesy of: JE Munyaneza).

and thickened terminal internodes resulting in rosetting, enlarged nodes, axillary branches or aerial potato tubers, disruption of fruit set, and production of numerous, small, and poor quality fruits (List, 1939; Pletsch, 1947; Daniels, 1954; Wallis, 1955). The below-ground symptoms on potato include setting of excessive number of tiny mis-shapen potato tubers, production of chain tubers, and early breaking of dormancy of tubers (List, 1939; Pletsch, 1947; Wallis, 1955). Additional potato tuber symptoms associated with transmission of '*Candidatus* Liberibacter solanacearum' 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. 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); see datasheet on '*Candidatus* Liberibacter solanacearum' for details.

Morphology

Egg

Eggs are oval and borne on thin stalks which connect one end of the egg to the leaf (Fig. 2). The eggs initially are light-yellow, and become dark-yellow or orange with time. The egg measures about 0.32–0.34 mm long, 0.13–0.15 mm wide, and with a stalk of 0.48–0.51 mm. Eggs hatch 3–7 days after oviposition (Pletsch, 1947; Wallis, 1955; Capinera, 2001; Abdullah, 2008; Butler & Trumble, 2012; Munyaneza, 2012; Munyaneza & Henne, 2012).

Nymph

Nymphs are elliptical when viewed from above, but very flattened in profile, appearing like almost scale-like. Potato psyllid nymphs can also be confused with nymphs of white-flies, although the former move when disturbed. There are five nymphal instars, with each instar possessing very similar morphological features other than size. Nymphal body width is variable, ranging from 0.23 to 1.60 mm, depending on different instars (Rowe & Knowlton, 1935; Pletsch, 1947; Wallis, 1955; Butler & Trumble, 2012; Munyaneza, 2012; Munyaneza & Henne, 2012). Initially nymphs are orange, but become yellowish-green and then green as they mature. The compound eyes are reddish and quite prominent. During the third instar, the wing pads which are light in colour become evident and get more pronounced with each molt. A short fringe of wax filaments is present along the lateral margins of the body. Total nymphal development time depends on temperature and host plant and has been reported to have a range of 12–24 days (Knowlton & Janes, 1931; Abdullah, 2008; Yang & Liu, 2009).

Fig. 2 *Bactericera cockerelli* adults with eggs and white granule excrements (photo courtesy of: JE Munyaneza).

Adult

The adults are quite small, measuring about 2.5–2.75 mm long. In general, the adults resemble tiny cicadas, largely because they hold their wings angled and roof-like over their body (Wallis, 1955; Butler & Trumble, 2012; Munyaneza, 2012; Munyaneza & Henne, 2012). They have two pairs of clear wings. The front wings are considerably larger than the hind wings. The antennae are moderately long, about the length of the thorax. Body colour ranges from pale green at emergence, to dark green or brown within 2–3 days, and grey or black thereafter. White or yellow lines are found on the head and thorax, and whitish bands on the first and terminal abdominal segments. These white markings are distinguishing characteristics of *B. cockerelli*, particularly the broad, transverse white band on the first abdominal segment and the inverted *V*-shaped white mark on the last abdominal segment (Pletsch, 1947; Wallis, 1955).

Pathways for movement

Adult *B. cockerelli* are good fliers and can disperse over considerable distances, especially with the onset of wind and hot temperatures. Adults have been shown to migrate massively to northern and western states of the USA and southern Canadian provinces in the spring from the insect overwintering sites in the South-Western USA and Northern Mexico (i.e. several hundreds of km). Immature stages of *B. cockerelli* are essentially sedentary and do not actively disperse. Long distance transport of different life stages of this insect pest is possible, particularly by commercial trade of plants in the family Solanaceae, which constitute major hosts for *B. cockerelli*. This insect was introduced into New Zealand, and was proabably transported with plant material from Western USA, possibly as eggs (Crosslin *et al.*, 2010; Thomas *et al.*, *2011*). Entry on fruit of host species (e.g. tomato, pepper) is possible, especially when they are associated with green parts (e.g. truss tomato). No life stages of *B. cockerelli* are associated with potato tubers or soil.

Pest significance

Economic impact

Historically, the extensive damage to solanaceous crops that was observed during the outbreak years of the early 1900s in Mid-Western USA is thought to have been due to *B. cockerelli*'s association with a physiological disorder in plants referred to 'psyllid yellows' Infected tomato plants produce few or no marketable fruits (List, 1939; Daniels, 1954). In potatoes, psyllid yellows results in yellowing or purpling of foliage, early death of plants, and low yields of marketable tubers (Eyer, 1937; Pletsch, 1947; Daniels, 1954; Wallis, 1955). In areas of outbreaks of psyllid yellows, the disorder was often present in 100% of plants in affected fields, with yield losses exceeding 50% in some areas (Pletsch, 1947). Many of the outbreaks in the early 1900s occurred well north of the insect's overwintering range, such as the states of Montana and Wyoming (Pletsch, 1947), which is a testimony to the dispersal capabilities of the psyllid.

In recent years, potato, tomato, and pepper growers in a number of geographic areas have suffered extensive economic losses associated with outbreaks of *B. cockerelli* (Trumble, 2008, 2009; Munyaneza *et al.*, 2009b,c,d; Crosslin *et al.*, 2010; Munyaneza, 2010, 2012; Butler & Trumble, 2012; Munyaneza & Henne, 2012). This increased damage is due to a previously undescribed species of the bacterium Liberibacter, tentatively named '*Candidatus* Liberibacter solanacearum' (syn. '*Ca.* L. psyllaurous') (Hansen *et al.*, 2008; Liefting *et al.*, 2009), now known to be vectored by *B. cockerelli* (Munyaneza *et al.*, 2007a,b; Buchman *et al.*, 2011a,b; Munyaneza, 2012); see datasheet on '*Candidatus* Liberibacter solanacearum' for details. Potato psyllids acquire and spread the pathogen by feeding on infected plants (Munyaneza *et al.*, 2007a,b; Buchman *et al.*, 2011a,b). The bacterium is also transmitted transovarially in the psyllid (Hansen *et al.*, 2008), which contributes to spread the disease between geographic regions by dispersing psyllids and helps maintain the bacterium in geographic regions during the insect's overwintering period (Crosslin *et al.*, 2010; Munyaneza, 2012).

Symptoms associated with Liberibacter in tomatoes and pepper include chlorosis and purpling of leaves, leaf scorching, stunting or death of plants, and production of small, poor-quality fruit (Liefting *et al.*, 2009; McKenzie & Shatters, 2009; Munyaneza *et al.*, 2009c,d; Brown *et al.*, 2010; Crosslin *et al.*, 2010; Butler & Trumble, 2012). During the outbreaks of 2001–2003, tomato growers in coastal California and Baja California suffered losses exceeding 50–80% of the crop (Trumble, 2009; Butler & Trumble, 2012). In potatoes, Liberibacter foliar symptoms closely resemble those caused by psyllid yellows and purple top diseases (Munyaneza *et al.*, 2007a,b; Sengoda *et al.,* 2010). However, tubers from Liberibacter-infected plants develop a defect referred to as 'zebra chip', which is not induced by the potential toxin causing psyllid yellows (Munyaneza *et al.*, 2007a,b, 2008; Sengoda *et al.,* 2009). Tubers show a striped pattern of necrosis, which is particularly noticeable when the tuber is processed for crisps or chips (Munyaneza *et al.*, 2007a,b, 2008; Miles *et al.*, 2010). Crisps or chips from zebra chip-affected plants are not marketable. The defect was of sporadic importance until 2004, when it began to cause millions of dollars in losses to potato growers in the USA, Central America, and Mexico (Rubio-Covarrubias *et al.*, 2006; Munyaneza *et al.*, 2007a, 2009b; Crosslin *et al.*, 2010; Munyaneza, 2010, 2012; Munyaneza & Henne, 2012). In some regions, entire fields have been abandoned because of zebra chip (Secor & Rivera-Varas, 2004; Munyaneza *et al.*, 2007a; Crosslin *et al.*, 2010; Munyaneza, 2010, 2012; Munyaneza & Henne, 2012). The potato industry in Texas estimates that zebra chip could affect over 35% of the potato acreage in Texas, with potential losses annually to growers exceeding 25 million dollars (CNAS, 2006). Finally, quarantine issues have begun to emerge in potato psyllid-affected regions because some countries now require that shipments of solanaceous crops from certain growing regions are tested for the pathogen before the shipments are allowed entry (Crosslin *et al.*, 2010; Munyaneza, 2012).

Control

Monitoring *B. cockerelli* is essential for effective management of this insect pest. Early season management is crucial to minimize damage and psyllid reproduction in the field. The adult populations are commonly sampled using sweep nets or vacuum devices, but egg and nymphal sampling requires visual examination of foliage. The adults can also be sampled with yellow water-pan traps. Typically, psyllid populations are highest at field edges initially, but if not controlled, the insects will eventually spread throughout the crop (Henne *et al.*, 2010; Butler & Trumble, 2012; Workneh *et al.*, 2012).

Bactericera cockerelli control is currently dominated by insecticide applications (Goolsby *et al.*, 2007; Gharalari *et al.,* 2009; Berry *et al.*, 2009; Butler *et al.*, 2011; Munyaneza, 2012; Butler & Trumble, 2012; Munyaneza & Henne, 2012; Guenthner *et al.*, 2012) but psyllids have been shown to develop insecticide resistance due to the high fecundity and short generation times (McMullen & Jong, 1971). Therefore, alternative strategies should be considered to limit the impact of the potato psyllid and its associated diseases. Even with conventional insecticides, *B. cockerelli* tends to be difficult to manage. It has been determined that Liberibacter is transmitted to potato very rapidly by the potato psyllid and a single psyllid per plant can successfully transmit this bacterium to potato in as little as 6 hours, ultimately causing zebra chip (Buchman *et al.*, 2011a,b). Just a few infective psyllids feeding on potato for a short period could result in substantial spread of the disease within a potato field or region (Henne *et al.*, 2010). Most importantly, conventional pesticides may have limited direct disease control as they may not kill the potato psyllid quickly enough to prevent Liberibacter and zebra chip transmission, although they may be useful for reducing the overall population of psyllids. The most valuable and effective strategies to manage zebra chip would likely be those that discourage vector feeding, such as use of plants that are resistant to psyllid feeding or less preferred by the psyllid. Unfortunately, no potato variety has so far been shown to exhibit sufficient resistance or tolerance to zebra chip or potato psyllid (Munyaneza *et al.*, 2011). However, some conventional and biorational pesticides, including plant and mineral oils and kaolin, have shown some substantial deterrence and repellency to potato psyllid feeding and oviposition (Gharalari *et al.*, 2009; Yang *et al.*, 2010; Butler *et al.*, 2011; Peng *et al.*, 2011) and could be useful tools in integrated pest management programs to manage zebra chip and its psyllid vector.

Good insecticide coverage or translaminar activity is important because psyllids are commonly found on the underside of the leaves. Insecticides controlling adults do not necessary controls nymphs or eggs. Active ingredients used in the USA against *B. cockerelli* include imidacloprid, thiamethoxam, spiromesifen, dinotefuran, pyriproxyfen, pymetrozine, and abamectin (Goolsby *et al.*, 2007; Liu & Trumble, 2007; Liu *et al.*, 2006; Butler & Trumble, 2012; Munyaneza & Henne, 2012; Guenthner *et al.*, 2012). In New Zealand, the list of products to control *B. cockerelli* includes acephate, metamidophos, imidacloprid, thiacloprid, buprofezin, abamectin, cypermethrin, deltamethrin, lambda-cyhalothrin, esfenvalerate, spinosad, and spirotetramat (Berry *et al.*, 2009). Several predators and parasites of *B. cockerelli* are known, though there is little documentation of their effectiveness. In some areas such as Southern Texas, early planted potato crops are more susceptible to psyllid injury than crops planted mid- to late season (Munyaneza *et al.*, 2012); however, the reasons behind this differential in the impact of *B. cockerelli* depending on planting timing are not well understood.

Phytosanitary risk

Bactericera cockerelli has been found to be a serious and economically important pest in potatoes, tomatoes, and other solanaceous crops in the Western USA, Mexico, Central America and New Zealand, because of its direct feeding impact and as a vector of '*Ca*. L. solanacearum' (Guenthner *et al.*, 2012; Munyaneza, 2012). Given the impact of *B. cockerelli* in regions where it occurs, its introduction in the EPPO region would be disastrous, especially if the insects were carrying '*Ca*. L. solanacearum'. Suitable host plants are widespread in the region and, given its current distribution in the Americas and New Zealand, it is thought that *B. cockerelli* would be able to establish and overwinter outdoors in the Southern and Central European part of EPPO region, as well as in areas with mild winters in the Northern part of the region, comparable to those of the South Island in New Zealand. It could also establish under protected conditions in the entire EPPO region. Moreover, the migratory behavior of *B. cockerelli* which favours quick and long distance dispersal of this insect would put the EPPO region at a high risk, if the psyllid was introduced.

Phytosanitary measures

EPPO recommends that vegetative material for propagation and produce (such as fruits) of Solanaceae should come from areas free of *B. cockerelli*. 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.

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