EPPO Datasheet: *Conotrachelus nenuphar*

Last updated: 2021-02-26

IDENTITY

Preferred name: *Conotrachelus nenuphar*
Authority: (Herbst)
Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta: Coleoptera: Curculionidae: Molytinae
Common names: plum curculio, plum weevil
view more common names online...
EPPO Categorization: A1 list
view more categorizations online...
EU Categorization: A1 Quarantine pest (Annex II A)
EPPO Code: CONHNE

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HOSTS

Conotrachelus nenuphar, a native weevil of North America, was originally a pest of native rosaceous plants. However, the introduction of exotic rosaceous plants into North America, notably cultivated plants such as apple (*Malus domestica*) and peach (*Prunus persica*) trees, widened the host range of *C. nenuphar* and demonstrated its adaptability to new hosts (Maier, 1990).

The distribution of *C. nenuphar* broadly conforms to the distribution of its native wild hosts *Prunus nigra, Prunus americana* and *Prunus mexicana* (Smith and Flessel, 1968). Other wild hosts include *Amelanchier arborea, A. canadensis, Crataegus* spp., *Malus* spp., *Prunus alleghaniensis*, *P. americana*, *P. maritima*, *P. pensylvanica*, *P. pumila*, *P. salicina*, *P. serotina*, *P. virginiana* and *Sorbus aucuparia* (Maier, 1990). Important cultivated hosts are apples, pears (*Pyrus*), peaches, plums and cherries (*Prunus*) and blueberries (*Vaccinium corymbosum*).

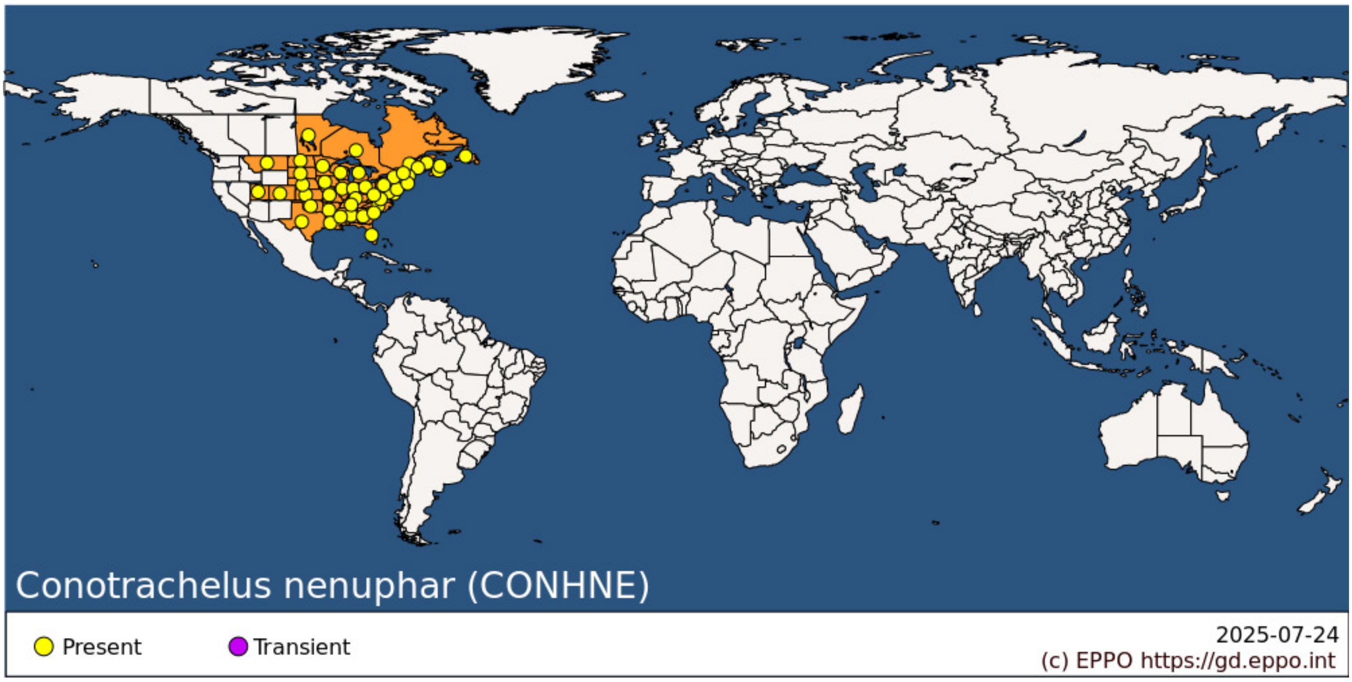
In addition to its rosaceous main hosts, *C. nenuphar* can also be found on blackcurrants (*Ribes* spp. - Grossulariaceae) and blueberries (*Vaccinium* spp. - Ericaceae) (Maier, 1990). Second generation *C. nenuphar* adults appear to attack a narrower range of some cultivated species than the first generation (Lampasona *et al.*, 2020).

Prunus, *Pyrus* and *Malus* spp. are widely cultivated throughout the Euro-Mediterranean region. In addition, if the pest was introduced to this region, the adaptability of the species to new hosts would probably result in an extended host range.

Host list: *Amelanchier arborea*, *Amelanchier canadensis*, *Crataegus aestivalis*, *Cydonia oblonga*, *Malus domestica*, *Prunus alleghaniensis*, *Prunus americana*, *Prunus angustifolia*, *Prunus armeniaca*, *Prunus avium*, *Prunus cerasus*, *Prunus domestica*, *Prunus maritima*, *Prunus mexicana*, *Prunus mume*, *Prunus nigra*, *Prunus pensylvanica*, *Prunus persica var. nucipersica*, *Prunus persica*, *Prunus pumila*, *Prunus salicina*, *Prunus serotina*, *Prunus umbellata*, *Prunus virginiana*, *Pyrus communis*, *Ribes*, *Sorbus aucuparia*, *Vaccinium corymbosum*, *Vaccinium stamineum*, *Vitis rotundifolia*

GEOGRAPHICAL DISTRIBUTION

The distribution of the plum curculio is restricted to North America, mostly east of The Rocky Mountains (see map below). One population was found west of the Rocky Mountains in Utah (Kim & Alson, 2008). A map showing the distribution of the northern and southern strains (Quaintance & Jenne, 1912) was updated by Chapman (1938). A map showing mtCOI haplotypes of plum curculio strains (Zhang *et al.*, 2008) redefined the boundaries delineated by Chapman (1938). As of 2020, the southern strain distribution extended northward of the Chapman (1938) boundary to New Jersey and West Virginia (Nielsen & Akotsen-Mensah, pers. corresp., *in* Lampasona *et al.*, 2020).



North America: Canada (Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Québec), United States of America (Alabama, Arkansas, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, West Virginia, Wisconsin)

BIOLOGY

The key papers on the biology of the plum curculio are: Quaintance and Jenne (1912), Chapman (1938), Racette *et al.* (1992), Vincent *et al*. (1999), Leskey *et al*. (2009) and Lampasona *et al*. (2020).

Plum curculio overwinter as adults. Overwintered adults resume activities around the time of flowering of cultivated host trees. After fruit set, females generally lay one egg per developing fruitlet. Females may lay up to 400 eggs during their lifetime, thus damaging up to 400 fruitlets (Lampasona *et al.*, 2020). Some fruits containing one larva fall to the ground, allowing completion of larval development and pupation to occur. In attacked fruits that remained on trees until harvest, a characteristic half-moon damage is observed. Fruits that remain on trees until harvest do not contain larvae. There are two strains of *C. nenuphar* (Quaintance & Jenne, 1912). The northern and southern strains have marked differences in their biology, some of which impact protection programmes. Individuals of the northern and southern strains can be distinguished by their mtCOI sequence (Zhang *et al.*, 2008). They are largely reproductively incompatible due to differences in their *Wolbachia* strains (McClanan *et al.*, 2004). The northern and southern strains have respectively an obligatory and facultative diapause. The northern strain does not mate or begin oogenesis until after spring emergence, while the southern strain does not require diapause to initiate reproductive development. Thus, oviposition damage by summer adults of the southern strain is a threat to be addressed. The number of generations per year depends on climate and availability of hosts. *C. nenuphar* has one generation per year in the northern part of its range, a partial second generation in the central part (Delaware to Virginia), and two generations from Virginia southwards (Lampasona *et al*., 2020).

In Quebec, studies using the radioisotope Zn^{65} indicated that *C. nenuphar* migrates in autumn to nearby woods where it overwinters in thick litter layers (Lafleur *et al.*, 1987). In spring the pest migrates in the reverse direction and reinfests orchards or seeks new feeding sites (Lafleur & Hill, 1987). From full bloom to 9 days after fruit set, adults are active mainly during the night (Racette *et al.*, 1992).

In cage experiments in New York State, 33-62% of adults emerged on a single day, but it is not known if this phenomenon occurs naturally; high temperatures and humidity favoured emergence (Schoof, 1942). Peak emergence, in Quebec, occurred when mean daily air temperatures were 16°C and the soil temperature at 2.5 cm depth was 14.5°C (Paradis, 1956; 1957). Larvae hatched in 3-12 days at 18-25°C, and adults lived for 5-24 months (17 months in Ontario) (Armstrong, 1958). In Missouri, by the end of July, eggs and larvae of the second generation may be found in mummified peaches; a few adults emerge from late September to mid-October and then enter winter diapause.

In North Carolina, eggs hatch in 2-11 days and adults emerge about 55 days after oviposition. The first-generation adults reach a peak in numbers in June-July, and 40-42% of them enter diapause. A second generation occurs if the host plant has suitable fruit available in the field for longer than usual (Mampe & Neunzig, 1967).

In Missouri, overwintered adults are first observed in the field at the end of April, about 15 days after petal-fall of the peach crop. Oviposition occurs in fruits primarily in May, and eggs hatch within 5-10 days. By the end of May, adult populations decline. The larvae develop in fallen and rotting fruits and, when mature 3-5 weeks later, usually at the beginning of June, eat their way out into the soil where they pupate at a depth of 10-15 cm. Larvae cannot survive in dry soil. First-generation adults emerge from the beginning of July to August; they feed on fruits until mid-August and oviposit only infrequently, usually in peaches affected by brown rot.

Dispersal of adults has been reviewed by Racette *et al.* (1992). In spring, most overwintered males and females move to apple orchards from nearby hibernation sites (leaf debris on the ground) mainly by walking (Lafleur and Hill, 1987). They first explore apple trees at the periphery of orchards for resources, and gradually, disperse in the entire orchard. *C. nenuphar* is a poor flier, and short distance flights may occur (above 20°C) between the canopy of host plants and the ground (Racette *et al.*, 1992; Chen *et al*., 2006).

DETECTION AND IDENTIFICATION

Symptoms

Adults feed on flowers, leaves and young fruits. In the latter, crescent-shaped, rather than circular, oviposition marks can be observed. Oviposition damage frequently looks like a half-moon on the apple surface. The appearance of plum curculio damage is highly variable. In blind tests, comparisons of the assessments of damage to apple fruits at harvest by experts had the lowest agreement for plum curculio (i.e. 71.8%) (Vincent & Hanley, 1997). Small exit holes are common on the under-surface of fallen fruit abandoned by the larvae. Fruits, except cherries, drop prematurely, allowing larvae to complete their development and pupate in the soil.

Morphology

Larva

Cylindrical, whitish and legless, usually bent in a semi-circle, and possessing a small brown head. There are four larval instars that can be distinguished by head capsule width. Fully-grown larvae measure 6-9 mm long (Quaintance & Jenne, 1912).

Pupa

The pupa is yellowish-white with dark spots in the position of the eyes and measures 5-7 mm long (Quaintance & Jenne, 1912).

Adult

The adult is 0.7 cm long with a typical rostrum. The postmedian band of the elytra consists of reddish-brown or reddish-yellow and white recumbent setae; small areas of the elytra are intensely black with humps. There are two femoral teeth, rarely one absent. Male and females can be differentiated by examining the size and shape of the supra-anal plates and the tibial spur on the metathoracic leg (Thomson, 1932). When disturbed, adults feign death and drop to the ground.

Detection and inspection methods

Detection and identification of *C. nenuphar* is detailed in the IPPC Diagnostic protocol (FAO, 2018). Identification is based on the morphological examination of adults (FAO, 2018). There are no keys for the identification of eggs, larvae or pupae. Molecular methods are still under development (FAO, 2018).

There are several methods to monitor plum curculio. Jarring (i.e. beating branches with a stick and collecting fallen adults) is seldom practiced by growers because it damages trees and dislodge fruits, and its efficacy is limited by time of day and the experience of those using the technique (Racette *et al.*, 1990; Lampasona *et al.*, 2020).

Visual assessment of oviposition scars on fruitlets few weeks after fruit set can provide a reliable estimate of the risk in order to time insecticide applications (Vincent *et al.*, 1997).

Behavioural management based on visual and olfactory cues have been researched extensively with the aim of designing a reliable monitoring method (Leskey *et al.*, 2009; Lampasona *et al.*, 2020). Briefly, black pyramidal traps designed by Tedders and Wood (1994) are based on visual cues to attract adults. Leskey and Prokopy (2002) developed a branch-mimicking trap for the plum curculio.

Several abiotic factors modulate unbaited pyramidal trap captures. Photoperiod has an important predictive value for plum curculio captures with pyramidal traps (Lafleur *et al.*, 2007). Captures of adults with pyramidal traps are higher at night during warmer periods (i.e., 20 and 25^{O}C), when wind velocity is low and during or shortly after rainfall (Lamothe *et al.*, 2008). Pesticide residues on pyramidal traps may impair walking behaviour of adults (Leskey *et al.*, 2012), thus making trap catches difficult to interpret.

As for olfactory cues, since Eller and Bartelt (1996) found that grandisoic acid acted as a male-produced aggregation pheromone in the plum curculio, several research projects have been undertaken to find an olfactory cue that, combined with various trap models, would provide a reliable monitoring method. Leskey *et al*. (2001) evaluated 16 individual volatile components of unripe plum odour in the laboratory.

Leskey *et al*. (2008) proposed the concept of trap-tree where applications of insecticides are reduced to a few perimeter row trap trees rather than the entire perimeter row or full orchard block. Trees in orchards in New Hampshire were baited with benzaldehyde and grandisoic acid. Timing of insecticide sprays was based on a day-degree model (Reissig *et al.*, 1998).

Comparing several monitoring methods, Chouinard *et al*. (2019) concluded that visual examination of fruitlets appeared superior in terms of effectiveness (i.e. number of activity signs detected), while trapping appeared equivalent to visual examination of fruitlets in terms of efficiency (i.e., number of activity signs detected per unit of time spent monitoring).

PATHWAYS FOR MOVEMENT

C. nenuphar is not a strong flier, and natural spread would occur at a local scale. Long-distance dispersal may occur through human-assisted pathways: as pupae in soil on its own or associated with plants for planting; as overwintering adults in the litter associated with plants; or as adults in packing material used to transport plants or fruit. Dormant plants are unlikely to carry adults, but may carry pupae if associated with growing medium (EFSA, 2018).

Infested fruit often drop prematurely or rot, and would not be found in fruit consignments. However, when eggs are laid on maturing fruit, the fruit may be harvested before the fruit would drop due to the presence of larvae or rot, and harvested fruit may harbour larvae. This is mentioned by Lampasona *et al.* (2020) for blueberry, peach and cherry, and Quaintance and Jenne (1912) for apple. The IPPC Diagnostic protocol mentions late season fruit, especially from the southern part of the *C. nenuphar* range (FAO, 2018). In such cases, pupae may also be associated with the packaging if larvae pupate during transport (EFSA, 2018).

PEST SIGNIFICANCE

Economic impact

C. nenuphar is a serious pest of stone and pome fruits including peaches, plums, nectarines, apples, cherries, and blueberries. Damage may arise by feeding of adults or egg laying. The appearance of damage varies according to the fruit attacked. The surface of apples may be scarred or distorted by the feeding of adults. The whole fruit may effectively be destroyed by the boring of the larvae. Most infested fruits drop prematurely, but this effect may partially be masked by the normal early drop from physiological causes. Cherries may rot on the trees. Damage from feeding on leaves and on blossom is usually not important. In addition, damage predisposes fruit to infection by brown rot.

Wherever present, plum curculio is generally a major driver of protection programmes for several cultivated fruits, notably apples, peaches, nectarines, cherries and plums (Racette *et al*., 1992; Vincent *et al*., 1999; Leskey *et al*., 2009; and Lampasona *et al*., 2020). In Quebec in 1957, 70 and 57% of fruit in heavily and lightly infested trees, respectively, dropped prematurely. In the absence of insecticide applications, up to 85% of apples showed plum curculio damage at harvest in a Quebec orchard (Vincent & Roy, 1992). The plum curculio is a pest of concern of cultivated highbush blueberries (Rodriguez-Saona *et al.*, 2019).

The northern and the southern strains cause oviposition damage on developing fruitlets a few weeks after fruit set. In addition, summer adults of the southern strain cause oviposition on fruits in the summer (e.g. August). In terms of economic impact, oviposition damage is generally much more important than feeding damage.

As of 2020, the plum curculio was absent from major fruit-producing areas west of the Rockies, such as California and Washington State, allowing considerable production of apples and peaches without programmes addressing this pest.

Control

Management programmes are frequently based on adulticidal sprays of a number of active ingredients (Lampasona *et al*., 2020). As of 2020, there were no reports of plum curculio populations resistant to insecticides.

Alpha-cypermethrin (Bostanian *et al.,* 1989), cypermethrin, fenvalerate and permethrin have been reported to be effective (Rivard & Clément, 1980) against *C. nenuphar*. The organophosphate azinphosmethyl, used as an adulticide post-bloom from the mid- 1950s until its phasing out in 2013 in the USA and Canada, provided adequate control (Lampasona *et al*., 2020). The neonicotinoids thiamethoxam, clothianidin, imidacloprid and acetamiprid also provide good adulticidal control when applied post-bloom (Lampasona *et al.*, 2020).

Novaluron, typically applied at petal fall against the tortricids oblique-banded leafroller (*Choristoneura rosaceana*) or codling moth (*Cydia pomonella*), sterilizes eggs of *C. nenuphar* (Wise *et al.*, 2007). It does not prevent damage caused to the fruitlet by the overwintered adults, but it reduces populations, destructive larval feeding, and injury caused by adults of the summer generation.

In New York and Michigan (northern strain), timing of pesticide applications against overwintered adults is typically based on cumulative degree-day (>10^{o}C) models with a fruit phenology biofix (typically petal fall) coupled with information about residual activity of pesticide (Reissig *et al.*, 1998; Hoffman *et al.*, 2004).

Lan *et al.* (2004) developed a temperature-dependent model to predict the emergence of the summer generation adults (southern strain) in the South-Eastern United States.

Treatment of blocks of apple trees at the periphery versus full-block treatment of orchards have been researched to decrease the quantities of insecticides per hectare (Chouinard *et al.*, 1992). This approach has been successfully validated in commercial apple orchards in Quebec by visual assessment of oviposition scars on fruitlets (Vincent *et al.*, 1997). Treatment of border trees having a threshold of 1% oviposition scars provided control levels comparable to full-block treatment, resulting in a 75% reduction of insecticides. However, this low-tech method is time consuming.

Non-insecticidal alternatives. Although there have been several research projects to manage plum curculio with non-insecticidal alternatives, none are currently implemented in large-scale production. Several apple cultivars have been reported to be resistant (Goonewardene & Povish, 1988).

Steinernema carpocapsae sprayed on foliage at different dates in early season against the plum curculio and the apple sawfly (*Hoplocampa testudinea*) provided inconsistent results (Bélair *et al*., 1998). Applied to the soil, the entomopathogenic nematodes *Steinernema carpocapsae, S. feltiae, S. rarum* and *S. riobrave* effectively killed soil dwelling stages (e.g. Shapiro-Ilan *et al*., 2002, 2011). Integration of an attract-and-kill approach with entomopathogenic nematodes to control several life stages showed promising results in multi-site apple orchards of New England (Piñero *et al.*, 2020).

The entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* caused a high mortality rate in larvae of *C. nenuphar* (Tedders *et al.*, 1982) and other *Conotrachelus* spp. (Bastos *et al*., 1988).

Physical control by exclusion methods showed potential in some pre-harvest situations. For example, Benoit *et al.* (2006) deployed cellulose sheets under the canopy of apple trees, thus preventing plum curculio larvae in fallen apples from completing their development in the soil. While this method is time consuming and thus difficult to implement in large orchards, it is a viable non-insecticidal method for small orchards such as those in sub-urban situations. In a 5-year study conducted in Quebec, there was less plum curculio damage in apple trees covered with exclusion nets than in non-covered (control) trees (Chouinard *et al.*, 2017).

Phytosanitary risk

Judging from its distribution in North America, *C. nenuphar* would appear to be capable of surviving throughout a large part of the EPPO region. The intensive cultivation of *C. nenuphar* host plants throughout the region could provide a basis for rapid multiplication of the pest and could possibly lead to immense losses and additional costs of control measures.

PHYTOSANITARY MEASURES

Possible measures include that host plants and fruits are imported from a pest free area, a pest free place of production or a pest free production site (including under complete physical isolation – EPPO, 2016). As in the case of similar pests, it may also be possible to develop systems approaches for some commodities, by combining options such as treatment of the crop, visual examination in the field or visual inspection of consignments (EFSA, 2018).

Possible additional measures include that host plants for planting with roots are dormant and free from growing media and litter, or the growing medium is free from *C. nenuphar*. Finally, plants for planting should be kept in conditions preventing their reinfestation. Some EPPO countries, such as those in the European Union (EU), require that plants for planting should be dormant and free from fruits (EFSA, 2018).

For fruits, treatments against *C. nenuphar* have been described and can be required. Larvae in apples were killed after storage for 33 days at 0-3°C (and in less than 33 days at 0°C) in a controlled atmosphere containing 3% O_2 and 2-8% CO_2 (Glass *et al*., 1961). In addition, an IPPC Phytosanitary treatment recommends the irradiation of host fruit of *Conotrachelus nenuphar* at 92 Gy minimum absorbed dose to prevent the reproduction in adults (FAO, 2016). From a quarantine post-harvest perspective, Hallman (2003) determined that the estimated dose to kill southern strain plum curculio adults in one day is approximately 4 kGy. Diapausing northern strain plum curculios were prevented from reproducing after treatment at 40 Gy, while reproduction of southern strain plum adults was prevented following a dose of approximately 80 Gy. Hallman (2005) determined a 20-fold reduction in the reproductive susceptibility of southern strain adults to ionizing radiation (40Gy) when conducted under hypoxia, compared to ionizing radiation conducted under ambient atmosphere.

Handling and packaging methods should be applied in combination with relevant phytosanitary measures in order to prevent contamination by adults during storage and transport, and to ensure that the packaging itself is free from life stages of *C. nenuphar*.

Soil on its own originating from North America is prohibited in a number of EPPO countries, including those in the EU (EFSA, 2018).

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