EPPO Datasheet: *Popillia japonica*

Last updated: 2020-11-25

IDENTITY

Preferred name: *Popillia japonica*
Authority: Newman
Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta: Coleoptera: Scarabaeidae
Common names: Japanese beetle
view more common names online...
EPPO Categorization: A2 list
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EU Categorization: Quarantine pest ((EU) 2019/2072 Annex II B)
EPPO Code: POPIJA



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Notes on taxonomy and nomenclature

Popillia japonica is a member of the order *Coleoptera*, family *Scarabaeidae*, subfamily *Rutelinae* and tribe *Anomlini*.

HOSTS

Popillia japonica is a highly polyphagous species and the adults can be found feeding on a wide range of trees, shrubs, wild plants and crops (EPPO, 2016). The odour and the location in direct sun play a pivotal role in the selection of host plants by the beetle. The host range of *P. japonica* includes more than 300 different ornamental and agricultural plant hosts. Adults have been recorded feeding on the foliage, flowers, and fruits, larvae on grass roots (USDA, 2020). In its native area (Japan), the host range appears to be smaller than in North America.

In the EPPO region, the adults of *P. japonica* feed on vines, fruit trees, forest plants, crops, vegetables, ornamental plants and wild species. In 2006, EPPO stated that *Vitis* spp. and *Zea mays* are the main hosts of concern in Europe (EFSA, 2019). In Italy, adults were recently found ready to emerge from the soil of rice paddies, but no damage has been recorded.

Host list: *Acer palmatum, Acer platanoides, Actinidia, Aesculus hippocastanum, Alcea rosea, Alnus glutinosa, Alnus japonica, Althaea officinalis, Ampelopsis japonica, Asparagus officinalis, Asparagus, Berchemia racemosa, Betula populifolia, Castanea crenata, Castanea dentata, Clethra alnifolia, Corylus avellana, Cyperaceae, Dioscorea esculenta, Fallopia convolvulus, Filipendula kamtschatica, Fragaria x ananassa, Glycine max, Hibiscus palustris, Hibiscus syriacus, Hibiscus, Humulus lupulus, Hypericum japonicum, Juglans nigra, Kerria japonica, Lagerstroemia indica, Malus baccata, Malus domestica, Malus floribunda, Malva pusilla, Medicago sativa, Melia azedarach, Ocimum basilicum, Oenothera biennis, Oenothera, Parthenocissus quinquefolia, Parthenocissus, Persicaria lapathifolia, Persicaria orientalis, Persicaria pensylvanica, Phaseolus vulgaris, Platanus orientalis, Platanus x hispanica, Poaceae, Populus maximowiczii, Populus nigra var. italica, Prunus armeniaca, Prunus avium, Prunus cerasifera var. pissardii, Prunus cerasus, Prunus domestica, Prunus japonica, Prunus persica var. nucipersica, Prunus persica, Prunus salicina, Prunus serotina, Prunus serrulata, Prunus spinosa, Pteridium aquilinum, Quercus acutissima, Quercus variabilis, Reynoutria japonica, Rheum rhaponticum, Robinia pseudoacacia , Rosa multiflora, Rosa, Rubus crataegifolius, Rumex, Salix discolor, Salix viminalis, Sassafras albidum, Smilax china, Solanum lycopersicum, Solanum melongena, Sorbus americana, Tilia americana, Tilia cordata, Tilia japonica , Tilia miqueliana, Toxicodendron pubescens, Trifolium pratense, Ulmus americana, Ulmus parvifolia, Ulmus procera, Urtica, Vaccinium corymbosum, Vaccinium, Vitis aestivalis, Vitis ficifolia var. lobata, Vitis labrusca, Vitis vinifera, Wisteria floribunda, Wisteria, Zea mays, Zelkova serrata*

GEOGRAPHICAL DISTRIBUTION

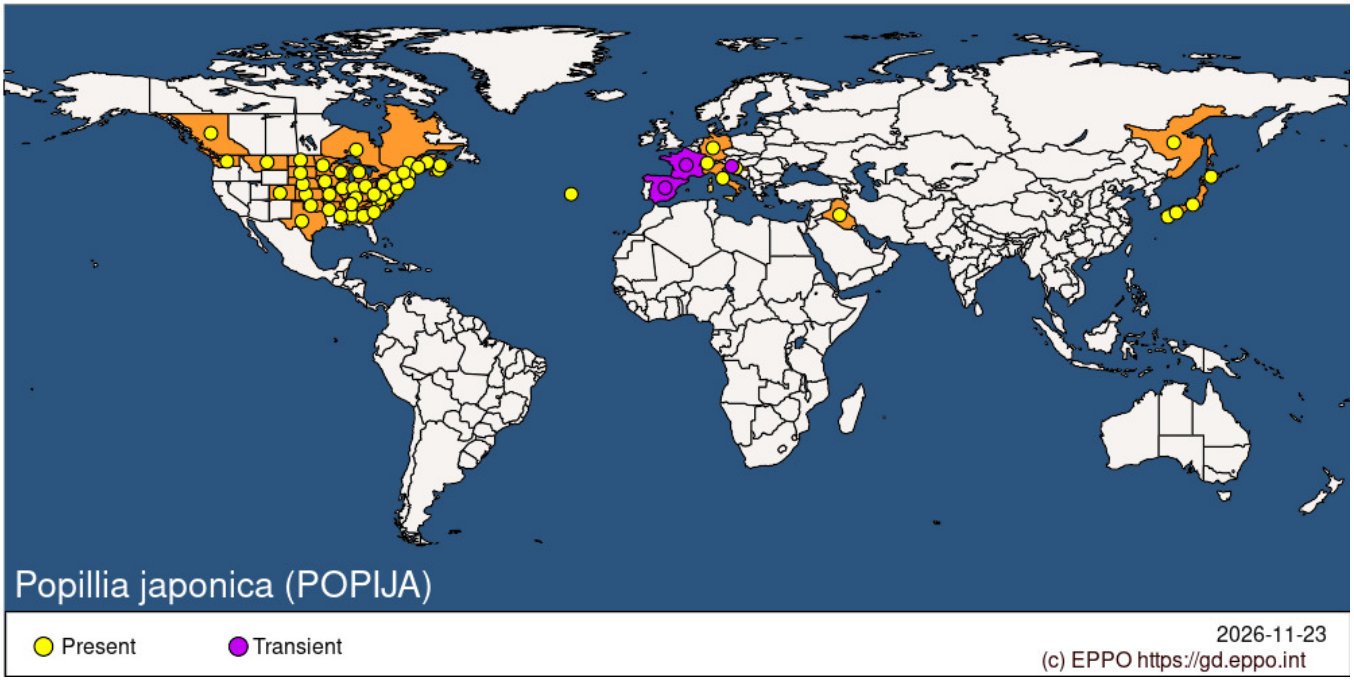
P. japonica originates from North-Eastern Asia where it is native to Japan and the far east of Russia (Fleming, 1972). *P. japonica* is not known to occur in continental Russia but only on the Russian island of Kunashir which is found less than 30 km to the east of Hokkaido (Northern Japan) (EFSA, 2018).

At the beginning of 20th century, *P. japonica* was introduced into North America. It was first reported in New Jersey in 1916, but larvae may have arrived a few years earlier in soil associated with iris plants for planting (Dickerson & Weiss, 1918) or other nursery stock from Japan (Metcalf & Metcalf, 1993; CABI, 2019). *P. japonica* has become a more serious pest in the USA than in its area of origin (EPPO, 2006). However, in California, Nevada and Oregon, it has been possible to eradicate outbreaks (Porter & Held, 2002).

In the EPPO region, *P. japonica* was accidentally introduced into the Azores (Terceira Island, Portugal) in the early 1970s (Martins & Simoes, 1988; Jackson, 1992) via a US military airbase (Porter & Held, 2002). Subsequently, it was reported from islands of Faial, Flores, Pico, Sao Jorge, Corvo and Sao Miguel (EPPO, 2016); in 2019, *P. japonica* was reported in the mainland (Graciosa Island; EPPO RS, 2019a).

In July 2014, *P. japonica* was found in Italy (EPPO RS, 2014; Pavesi, 2014); this is the first time that this pest is recorded on the European mainland. The outbreak area was located in the Ticino Valley Natural Park, along the Ticino river, in the two contiguous Italian regions of Lombardy and Piedmont. How *P. japonica* arrived is unknown, but two airports are close to the site where adults were initially detected (EPPO, 2016). Although control measures were taken immediately, the European Commission considered eradication not to be feasible given the extent of the infestation and the well-established population. *P. japonica* remains under official control in Italy and measures seek to contain the pest and prevent spread (European Commission, 2016). In 2020 two adults of *P. japonica* have been found in Parma province (Emilia-Romagna Region). These findings were considered an incursion without establishment (EPPO RS, 2020).

In Switzerland, *P. japonica* was first reported in Ticino in June 2017 (EPPO RS, 2017) and adults have been regularly trapped since then (EPPO RS, 2019b). In July 2020, adults of *P. japonica* were found in two different vineyards on *Vitis vinifera* plants, and also in traps, in the municipality of Genestrerio-Mendrisio (Canton of Ticino).



EPPO Region: Croatia, France (mainland), Germany, Italy (mainland), Portugal (Azores), Russian Federation (Far East), Slovenia, Spain (mainland), Switzerland
Asia: Iraq, Japan (Hokkaido, Honshu, Kyushu, Shikoku)
North America: Canada (British Columbia, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Québec), United States of America (Alabama, Arkansas, Colorado, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, 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, Vermont, Virginia, Washington, West Virginia, Wisconsin)

BIOLOGY

P. japonica is generally an univoltine species (for instance in Japan or Italy), but in cooler areas most individuals have a 2-year life cycle (Clausen *et al*., 1927; King, 1931; Fleming, 1972). Similar behaviour is reported both in the USA (e.g., Massachusetts, New England) and Canada, where in cooler years the life cycle can take 1 or 2 years (Vittum, 1986; Campbell *et al*., 1989; Potter & Held, 2002).

Adult emergence as well as mating, oviposition and larval development times vary with latitude and from year to year according to temperature (Fleming, 1972). In general, adults emerge in the summer (June-July) and fly or climb to feed on foliage at the top of low growing hosts before later moving to feed on trees.

In Italy adults are active between June and September with an activity peak in mid-July (EPPO, 2016; Regione Lombardia, 2020a). In the Azores, the flight period of adult beetles can extend from late May through to early November – the peak number of adults caught in traps was in the second half of July and the first half of August (Martins & Simoes, 1988; Vieira, 2008). Adults live for 30-45 days and can mate more than once (Potter & Held, 2002; EFSA, 2019). Adults tend to aggregate to feed and mate on individual host plants such that some will be heavily infested whilst the nearby hosts of the same species are not attacked (Campbell *et al*., 1989). *P. japonica* feeds less on cloudy and windy days and does not feed on rainy days. When the temperature is between 21°C and 35°C, and the relative humidity is above 60% on clear summer days, beetles feed actively (CFIA, 2017).

40-60 eggs per female (Campbell *et al*., 1989), are usually laid in moist grassland in the summer singly or in small clusters. Sometimes, females form a burrow in the upper 10 cm of soil to deposit the eggs (Metcalf & Metcalf, 1993). The eggs viability decreases with temperatures below 10°C; seven days at 0°C led to 100% egg mortality (Fleming, 1972). Depending on the temperature, eggs usually hatch after about 10-14 days.

P. japonica overwinters as a larva. There are three larval instars; the first instar develops in 2-3 weeks; the second in 3-4 weeks (Potter & Held, 2002). The third larval instar burrows deeper and overwinters at depths of 10-20 cm to avoid cooler temperatures (Regione Lombardia, 2020a). In the spring, as the soil warms, larvae rise to shallower depths in the soil where they form a chamber in which they pupate. In cases where development takes 2 years, second and third instars overwinter during the first and second winters, respectively (Vittum, 1986).

DETECTION AND IDENTIFICATION

Symptoms

Symptoms of *P. japonica* are associated with the activities of its different life stages. In particular, feeding holes in host leaves represent the clearest symptom of adult presence. Adults feed gregariously, usually beginning to feed at the top of a host and working downwards (Fleming, 1972). When the population density is high, leaves can be skeletonized (EPPO, 2016, EFSA, 2019) and only the mid-vein is left intact. Severely damaged leaves soon turn brown and fall or remain attached (EPPO, 2016). On flower petals, the beetles consume large, irregularly shaped parts.

On maize, the adults feed on the maturing silk, preventing pollination, and therefore resulting in kernel malformation and yield reduction (Smith *et al*., 1997; CABI, 2019). Adults feed between leaf veins of soybean leaves. Heavy infestations can cause significant levels of defoliation, which can lead to reduced soybean yield. Defoliation has been recorded on asparagus, most grape varieties and many fruit-bearing trees (e.g., apple, cherry, plum, peach). In addition, adults can aggregate and feed in large numbers on the fruit of early-ripening varieties of apple, peach, nectarine, plum, raspberries, and quince. This feeding renders fruit unmarketable.

The larvae feed just below the soil surface causing root damage of host plants. The larval food source is mostly determined by which plants are growing in the area where the female beetle oviposits (Fleming, 1972). Symptoms are not at all specific (Fleming, 1972). In infested turf symptoms include thinning, yellowing, and wilting,

culminating in large patches of dead, brown grass that appears in late summer or early autumn because of water stress, and less often in the following spring when more moisture is normally available (CABI, 2019). Severe infestations can result in the death of the turf (Vail *et al*., 1999).

Morphology

Egg

Eggs are variable in size and shape: spheroids with a diameter of 1.5 mm, ellipsoids 1.5 mm long by 1.0 mm wide, or nearly cylindrical. Colour ranges from translucent to creamy white and the external surface is marked with hexagonal areas. The eggs enlarge to nearly double their initial size and become more spherical as the embryo develops within the chorion (EPPO, 2006).

Larva

P. japonica has three larval instars. The first larval instar is completely white, 1.5 mm in length with biting mouthparts, three pairs of thoracic legs and 10 abdominal segments. The larval body shows the typical scarabaeiform C-shape. The body is covered with a scattering of long brown hairs and interspersed short blunt spines. The ventral side of the tenth abdominal segment bears two medial rows usually of 6-7 spines (4-9 may be possible) in a characteristic V-shape, one of the most important morphological characters used to distinguish *P. japonica* from other species of scarab larvae (Sim, 1934; Klausnitzer, 1978). The first larval instar is distinguishable from the subsequent instars by the presence of a rigidly pointed process on each side of the metathoracic scutellum and lack of a concave respiratory plate surrounding a bulla with a curved spiracle slit.

The second and third instar larvae can be separated by head capsule size: in the former it is 1.9 mm wide and 1.2 mm long, in the latter 3.1 mm wide and 2.1 mm long.

Prepupa

During the prepupa instar, the mature larva stops eating. Excrements are evacuated and activity is reduced as internal changes occur (EPPO, 2006).

Pupa

The pupae are very similar to adults, but wings, legs and antennae are held close to the body and functionless. The colour changes from white cream to tan; sometimes they are metallic green as observed in the adults. Pupae are 14 mm in length and 7 mm in width on average and exarate in form. Males have a three-lobed eruption covering the developing genitalia on the posterior ventral abdominal segments so can be distinguished from females (EPPO, 2006).

Adult

The adult beetle is brightly coloured metallic green and coppery bronze, oval in shape, and varies in size from 8 to 11 mm in length and 5 to 7 mm in width. The female is typically larger than the male. Along each lateral side of the elytra, there are five tufts of white hair present and two dorsal spots of white hair on the last abdominal segment. Male and female beetles can be differentiated from each other by the shape of the tibia and tarsus on the foreleg. The male tibial spur is more sharply pointed, and the tarsi are shorter and stouter than those of the female (EPPO, 2006).

The adult of *P. japonica* is similar to *Phyllopertha horticola* though it can be distinguished from the latter by its shiny golden green thorax, lateral tufts of white hair on the abdomen, and two patches of white hair on pygidium.

Detection and inspection methods

Visual inspections and traps

Visual inspections of the most attractive plants (e.g., vines, roses, *Parthenocissus* spp.) are pivotal for delimiting surveys in areas of outbreaks. In the absence of adults, the signs on leaves and flowers can be confused with those

caused by other organisms, in particular insects and gastropods.

Traps baited with a sex pheromone and a floral lure are very useful in attracting adult beetles for detection survey (early detection) (Porter & Held, 2002; EFSA, 2019). However, traps are not recommended for delimiting survey in buffer areas of outbreaks to avoid extending the infestation.

Soil sampling is necessary to collect larvae and useful to estimate the consistency of population in the infested areas, but is not recommended for the detection survey. Larval populations are aggregated and often occur in the vicinity of plants that had adults aggregating on them to feed and mate during the summer; well drained moderately textured soils in sunlight also favour higher densities of larvae. Soil with high levels of organic matter tends to have lower larval densities (Dalthorp *et al*., 2000; Porter & Held, 2002).

Finally, activities to raise professional and public awareness concerning the threat of *P. japonica* and the measures adopted to prevent its introduction and spread in the EPPO region are recommended. For instance, in the Lombardy Region (Italy), citizens support the surveillance of *P. japonica* through the citizen science app FitoDetective (Regione Lombardia, 2020b).

Identification of Popillia japonica

Morphological identification of *P. japonica* is possible on larvae and adults. For this purpose, a number of useful taxonomical keys and guides are available in the literature. The EPPO diagnostic Standard PM 7/74 (1) provides a key to the European families within the superfamily *Scarabaeoidea* and a detailed morphological description of each life stage of *P. japonica* and very useful illustrations (EPPO, 2006). Fleming (1972) provides descriptions for each life stage. A complete description of all developmental stages of *P. japonica* (including egg and pupa) is available in the EPPO national regulatory control systems Standard PM 9/21(1) (EPPO, 2016); very useful illustrations are available in the EPPO diagnostic standard PM 7/74 (1). However, no key to species is available and because the genus consists of more than 300 species, many from Africa and Asia, there is a chance of misidentifying some specimens (EPPO, 2016).

Molecular identification of specimens can be performed using DNA barcoding (EFSA, 2019). Folmer *et al*. (1994) published a diagnostic protocol for conventional PCR (LCO1490/HCO2198). In the Barcode of Life Data System (BOLDSYSTEMS), sequences of *P. japonica* haplotypes are available. In EPPO-Q-bank, sequences from 10 curated specimens are available (EPPO-Q-bank, 2020).

PATHWAYS FOR MOVEMENT

The adults disperse locally by flight. Although beetles can fly up to 8 km, most adult flights cover short distances (Fleming, 1972). In the Azores, Lacey *et al*. (1994, 1995) recaptured 70% of beetles within 50 m of the release point in a mark-release-recapture study; less than 1% were recaptured at 1 km. Sara *et al*. (2013) found adult density decreased significantly with increasing distance from a field edge. A high spread rate (16-24 km per year) was detected in the decade after *P. japonica*'s establishment in the USA (EPPO, 2006). The infested area in Italy increases by about 10 km every year (Regione Lombardia, 2020a). Temperature and in particular soil moisture are the main factors that may limit the potential spread of the beetle into new areas. *P. japonica* is adapted to regions where the mean soil temperature is between 17.5°C and 27.5°C during the summer, and above -9.4°C in the winter (CABI, 2019).

The greatest flight activity is reported to be on clear days and when the temperature is between 29°C and 35°C (Kreuger & Potter, 2002), relative humidity >60% and wind is <20 km h^{-1} (CABI, 2019). However, if disturbed adults will fly at 21°C (Fleming, 1972).

In international trade, *P. japonica* adults have been intercepted on agricultural produce, on packaging and on ships and aircraft (EPPO, 2016). Larvae may be transported in soil around the roots of plants for planting.

PEST SIGNIFICANCE

Economic impact

P. japonica is a serious pest in North America with millions of US dollars being spent in limiting its spread. It is less of a pest in Japan, its native area. Costs due to larvae were estimated to be 234 million USD per year (USDA/APHIS, 2015) consisting of 78 million USD for control costs and 156 million USD for the replacement of damaged turf and ornamental plants. Substantial insecticide usage, especially on home lawns, golf courses, and in urban landscapes, was observed to control *P. japonica* (Potter & Held, 2002). In the case of maize, the field crop most seriously damaged in North America, USDA/APHIS (2015) estimated adult *P. japonica* causes losses of 226 million USD per year.

In Lombardy Region (Italy), there have been attacks on irrigated meadows and on maize and soya crops, although damage has generally not exceeded the economic damage threshold. Strong defoliation was recorded on fruit trees, in particular cherry trees, and vines in family gardens of houses near the meadow area, as well as on ornamental trees and shrubs (linden, birch, wisteria, roses) in the same areas. Some cultivations of small fruits, bordering lawns, have recorded damage on leaves, flowers and fruits (raspberry, blackberry, cranberry). The presence of pest also affected a viticultural area, with a strong presence of adults on the vines in June and July causing leaf erosion (EUROPHYT Outbreaks, 2020).

P. japonica has not caused extensive damage in the Azores (CABI, 2019).

P. japonica infestations also have an indirect economic impact on nurseries because of the cost of applying the phytosanitary measures adopted to prevent the movement of plants with soil containing beetle larvae. Professional manufacturers of grassy turf for ornamental and sports, inside the infested area, should implement a rigorous procedure to ensure that the turf produced is free of larvae.

Control

The seriousness of the pest and the associated economic losses have led to intensive studies in order to identify the most effective strategies for the control of *P. japonica*.

The best environmentally friendly control strategy is the physical protection of host plants with nets. It can be used in family gardens and orchards, but also in professional orchards and vineyards. In private gardens, the manual collection of adults can be used and their suppression in basins with soapy water.

Chemical control against adults can be achieved by using several different plant protection products belonging to the pyrethroid and neonicotinoid families. Azadirachtin has shown some control efficacy in addition to its repellent effect (Ciampitti *et al*., 2018). Chemical control against larvae is complicated by the difficulty of product distribution in the soil. Chlorantraniliprole and neonicotinoid insecticides are used in the USA to control larvae in the turf and show some efficacy in preharvest soil surface treatment of nursery plants grown in field soil (Oliver *et al*., 2013; Vittum, 2013; Ciampitti *et al*., 2016). In Piedmont Region (Italy), a specific insecticide treatment in June was tested in professional vineyards where the insect is able to destroy all the vegetation of the upper part of the plants in a few days (Bosio *et al*., 2020). Experiments showed that pyrethroids are the most effective. In presence of medium-low infestations of *P. japonica*, kaolin clay showed pest control efficacy and could be useful to organic farms (Bosio *et al* ., 2020).

Biocontrol agents, in particular the entomoparasitic nematode *Heterorhabditis bacteriophora* and the entomopathogenic fungus *Metarhizium anisopliae*, seem more effective in controlling larvae than chemicals (Wright *et al*., 1988; Ciampitti *et al*., 2016; Marianelli *et al*., 2017; Paoli *et al*., 2017; Barzanti *et al*., 2019). In 2017, a new species of mermithid nematode, *Hexamermis popilliae*, has been described in Italy and it will be evaluated as a potential biological control agent in Integrated pest management (IPM) programs (Mazza *et al*., 2017).

The use of mass capture traps could be effective, but should be included in an area-based strategy, under the supervision of the phytosanitary services. The trap attracts more adults than it captures and therefore the use of traps in private gardens and sports grounds or near orchards and nurseries is not recommended,. Traps should also be avoided near sites with a risk of causing passive spread of the pest, i.e. sites such as car parks or delivery yards from

which the infestation could be accidentally spread from a distance by car or truck (EPPO, 2016).

In Italy, traps with lasting insecticide-treated nets have been successfully used to implement an attract and kill strategy; this type of trap should be also used exclusively in an area-based strategy (Marianelli *et al*., 2018).

In the EPPO region, the EPPO PM 9/21(1) (EPPO, 2016) describes procedures for official control with the aim of detecting, containing and eradicating *P. japonica*.

Phytosanitary risk

P. japonica is highly polyphagous. The availability of host plants is not a limiting factor for its establishment and spread in the EPPO countries as instead might be the climatic conditions, especially temperature and soil moisture (CABI, 2019).

Larvae of *P. japonica* could be accidentally transported and introduced into new areas through the soil associated with plants for planting with roots, though not necessarily of their preferred hosts. Even though adults can feed on leaves, flowers and fruit from a wide range of hosts, they can be easily detected during inspections, therefore harvested plant parts (cut flowers and branches, fruit, etc.) are not considered as pathways of this pest (DEFRA, 2015).

When the population density of *P. japonica* is higher, in the middle of the flight season, adults may be hitchhikers using various means of transport such as trucks or planes.

PHYTOSANITARY MEASURES

When the presence of *P. japonica* adults is confirmed, consignments leaving the infested areas should be carefully inspected to ensure that they are pest free.

The movement of plants with soil from an infested area to outside the area should be banned. Nurseries located in infested areas should be able to move plants only if they apply an official protocol which includes, the following measures: 1) removal of all soil residue that could contain pre-imaginal stages of the insect, 2) growth during their entire life cycle in a production area equipped with complete physical protection, 3) the surface of the containers covered by anti-insect netting, mulching fabric or other mulching material, and kept isolated from the underlying soil, and 4) insecticide treatments (Mipaaf, 2018).

The risk that adults of *P. japonica* may be spread by aircraft departing from airports located in infested areas should be assessed very carefully. Procedures for disinfestation of aircraft holds and cabins should be agreed with airport operators and air carriers through official agreements.

The EPPO Standard PM 9/21(1) (EPPO, 2016) describes containment measures to avoid the spread of *P. japonica* outside infested areas.

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