Nederlandse Voedsel- en Warenautoriteit
Ministerie van Landbouw, Natuur en Voedselkwaliteit

> Retouradres Postbus 43006 3540 AA Utrecht

To the Director of Nature of the Ministry of Agriculture, Nature and Food Quality

Advice of the Director of the Office for Risk Assessment and Research on

the risks of four Asian knotweeds in the Netherlands

Office for Risk Assessment & Research

Catharijnesingel 59
3511 GG Utrecht
Postbus 43006
3540 AA Utrecht
www.nvwa.nl

Contact

T 088 223 33 33
risicobeoordeling@nvwa.nl

Our reference
TRCVWA/2020/2784

Datum
29 May 2020

Background

A number of taxa (species or varieties) of Asian knotweeds can be found in the wild in the Netherlands. These taxa are closely related, and include Japanese knotweed (*Fallopia japonica*), giant knotweed (*Fallopia sachalinensis*), Bohemian knotweed (*Fallopia x bohemica*) and Himalayan knotweed (*Persicaria wallichii*) (Beringen et al., 2019). Many of the specimens identified as Japanese knotweed may in fact have been Bohemian knotweed, which was not recognised as a separate species in the Netherlands until 1999 (Probos Foundation, 2020a;2020b).

Japanese knotweed is considered to be one of the most invasive species in the world (Lowe S. et al., 2000; Wageningen University & Research, 2020). Along with the similar giant knotweed, it was introduced to the Netherlands from Asia in the nineteenth century, and spread throughout Europe as an ornamental plant (Beringen et al., 2019; Probos Foundation, 2020b). The plant was then inadvertently spread further through the transport of root and stem fragments, and began to grow in the wild. In the context of the European policy on invasive alien species, work has already been done on risk assessments for Japanese knotweed (DEFRA, UK, 2011a; Environment, 2015a) and giant knotweed (DEFRA, UK, 2011b; Environment, 2015b). However, at the time the European Commission considered that there was insufficient evidence that inclusion on the European Union list of invasive alien species of concern would effectively contribute to the prevention, minimisation or mitigation of negative effects, and the species was therefore not recommended for insertion in the list (European Commission, 2016).

Knotweed has only become established in the wild in the Netherlands on a large scale since 1950 (Probos Foundation, 2020b). Today, Japanese knotweed, giant knotweed and the hybrid Bohemian knotweed are found throughout the Netherlands in both urban and wild areas and in a diverse range of soil types. Once established, the plants are difficult to control. Although the different species have been controlled in many places and numerous control trials have been conducted both in the Netherlands and abroad, the results vary significantly from one location to the next (Probos Foundation, 2020c).

The Ministry of Agriculture, Nature and Food Quality (LNV) wrote to the Office for Risk Assessment & Research (BuRO) of the Netherlands Food and Consumer Product Safety Authority (NVWA), indicating a need for substantiation of the risks in the Netherlands to support possible policy measures. In spite of all the attention around Asian knotweeds, no scientific risk assessment had been performed in the Netherlands. The risks for biodiversity and ecosystem services in the Netherlands had not been identified in a scientific manner. In addition, in 2018 the BuRO received reports of seed formation of Japanese knotweed in the wild, in places where male plants were not known to be present. The BuRO turned this information into research questions, covering both seed formation and the risk assessment.

Male pollen in 2008 and question about seed formation in 2018

It was initially assumed that only female clones of Japanese knotweed (*Fallopia japonica* var. *japonica*) had spread in Europe, and therefore no seed formation was taking place. The only known means of spreading were planting and the transport of root and stem fragments in grass clippings, contaminated soil or drainage of surface water.

However, in 2008 fertile male Japanese knotweed plants were found. Upon investigation, it appeared that these were hybrids between the functional female Japanese knotweed plants (*Fallopia japonica* var. *japonica*) and a variety that also had functional male plants and was sold as a cultivated plant: the dwarf variety *Fallopia japonica* var. *compacta.* In a test under controlled conditions, it was found that the male plants of *Fallopia japonica* var. *compacta* were able to fertilise the female plants of *Fallopia japonica* var. *japonica*, and the seeds thus formed were capable of germinating (Duistermaat et al., 2012). In theory, this created a new route of spread.

In response to these reports of circumstances which could lead to an increase in the likelihood of spread and an increase in risk, the BuRO posed the following question:

Question 1: *What risks are raised by the seed formation of Asian knotweeds in the wild in the Netherlands?*

Need for a Dutch risk assessment

The scientific community has published numerous reports about species of *Fallopia* (Beringen et al., 2019). In the context of the European policy on invasive alien species, work has been done on risk assessments for Japanese knotweed (DEFRA, UK, 2011a; Environment, 2015a) and giant knotweed (DEFRA, UK, 2011b; Environment, 2015b).

After publications in the media about the possible harmful effects of Japanese knotweed (see, for example, (Blijdorp, 2014; Cobouw, 2017; NOS, 2019)), the House of Representatives asked questions of the Ministry of Agriculture Nature and Food Quality (LNV) about the Dutch policy with regard to this species (Minister of LNV, 2019), and a motion was proposed to ban sales of the plant (House of Representatives, 2019).

No scientific risk assessment had yet been performed for the Netherlands. The LNV Ministry indicated a need for substantiation of the risks. In response, the BuRO commissioned a scientific risk assessment, based on the following question:

Question 2: *What are the risks of four Asian knotweed species in the Netherlands for biodiversity, ecosystem services and other social values?*

Approach

To identify the risks posed by seed formation (Question 1), the BuRO commissioned the Probos Foundation and Wageningen University & Research to investigate whether the seeds found in the wild in 2018 were capable of germinating and could grow into adult plants. The results are set out in the report 'Investigation into the germination of Japanese knotweed seeds' (Penninkhof et al., 2019).

For the assessment of the risks for biodiversity and ecosystem services (Question 2), the BuRO commissioned FLORON (the Dutch Botanical Research Foundation) to prepare a risk assessment for the four most significant Asian knotweed species in the Netherlands, in accordance with the European assessment system. This assessment used the Harmonia$^+$ protocol, developed by (D'hondt B. et al., 2014). Part of this protocol is the assessment and classification of the risks by a team of experts, in this case the authors of the assessment (Ruud Beringen (FLORON), Rob Leuven (Radboud University), Baudewijn Odé (FLORON), Michiel Verhofstad (FLORON) and Johan van Valkenburg (NVWA). The results of the risk assessment are set out in the report 'Risk assessment of four Asian knotweeds in Europe' (Beringen et al., 2019). The risk assessment was able to make use of the 'Investigation into the germination of Japanese knotweed seeds' report referred to above.

This advice is largely based on the germination investigation and the risk assessment.

As well as the germination investigation and the risk assessment, this advice also contains frequent references to the investigation referred to above from 2012 into the spread and risks of fertile male *Fallopia japonica* plants (Duistermaat et al., 2012). For the sake of readability, for general information this text also refers to other sources already known to the writers of this advice, such as the website www.bestrijdingduizendknoop.nl, which is a useful source of information about control and eradication, risk assessments from other countries and media articles. In view of the significant quantity of information readily available, it was not considered necessary to perform a search of the scientific literature in addition to the investigations conducted.

For an estimate of the financial costs and benefits in the Netherlands, an existing overview of the social and financial costs and benefits (Beringen et al., 2019) was used. In addition, the BuRO has compiled its reflections and reasoning. In terms of costs, the information used was already known to the authors of this advice from media reports and other sources. In terms of benefits, on 18 February 2020 the BuRO scanned the Internet for signs of a possible Dutch trade in Japanese knotweed. This involved searches on Google (first ten pages), Marktplaats, Intratuin, Directplant.nl and Tuinplant.nl using the keywords 'te koop' (for sale) in combination with 'duizendknoop' (knotweed), 'fallopia', 'reynoutria' and 'polygonum'. Additional Google searches were also performed for the keywords

'voedselgewas' (food crop) and 'energiegewas' (energy crop) in combination with 'duizendknoop' (knotweed), 'fallopia', 'reynoutria' and 'polygonum'.

Findings

- Several taxa (species and varieties) of Asian knotweeds are found in the Netherlands. The most common are:
  - Japanese knotweed (*Fallopia japonica*);
  - Giant knotweed (*Fallopia sachalinensis*);
  - Bohemian knotweed (*Fallopia x bohemica*). This is a hybrid between Japanese knotweed and giant knotweed;
  - Himalayan knotweed (*Persicaria wallichii*).
- It is suspected that prior to 1999, the hybrid Bohemian knotweed was mistaken for Japanese knotweed.
- Japanese knotweed has long been known in Europe and the United States for its invasiveness. The species grows quickly in spring, forms dense clumps and is difficult to eradicate because small fragments of roots or stems can grow into new plants. To date, there is no control method that can be effectively and efficiently used in all locations.
- The assessment of risks for biodiversity and ecosystems was performed using the Harmonia$^+$ protocol, which is in line with European Commission requirements for European risk assessments of invasive alien species. The effect of Japanese knotweed, giant knotweed and Bohemian knotweed on biodiversity is assessed as significant. These species form dense clumps leading to the displacement of native plant species, a reduction in invertebrates and the alteration of ecosystems.
- In addition to ecological effects, there are also social and economic effects. Japanese knotweed, giant knotweed and Bohemian knotweed can have harmful effects on infrastructure. Dams and dykes can be susceptible to erosion, and paved paths and stony slopes can be broken apart under pressure from growing roots.
- Measures to control Asian knotweed species are being applied in many places, but control is costly. No information was found on any benefits of Asian knotweeds. Compared to the costs, the benefits are presumed to be minimal.
- Little information is available in the literature about the effects of Himalayan knotweed. The likelihood of natural spread via seeds is low, since the species only flowers late in the year and few, if any, fruit form. The effect on biodiversity is estimated to be moderate and the effect on infrastructure low.
- Japanese knotweed and giant knotweed were introduced and spread to the wild in the nineteenth century. Since 1950, they have become established in the wild on a large scale.
- Japanese knotweed, giant knotweed and the hybrid Bohemian knotweed have spread and become established throughout the Netherlands. They are found in both urban and wild areas, and in a diverse range of soil types. The likelihood of further spread is high, particularly through human actions such as earthmoving, grass mowing and dumping of garden waste. Fragments can be spread by flowing water.
- Himalayan knotweed is also found throughout the Netherlands, but is less widespread.
- Since 2012, several sources of male pollen have been identified in the Netherlands that could fertilise female specimens of Japanese knotweed and thus produce seeds capable of germinating under controlled conditions: the

ornamental plant Russian vine (*Fallopia baldschuanica*), the ornamental *compacta* variety and male specimens of giant knotweed.
- In 2018, Japanese knotweed plants with seeds were found in the wild. Russian vine was an important source of pollen for the seeds that formed in 2018.
- The cross between Russian vine and Japanese knotweed (the hybrid *Fallopia x conollyana*) is barely capable of germinating in the field, has little ability to compete and has not yet been found in the wild in the Netherlands.
- The hybrid of Japanese knotweed and the *compacta* variety is difficult to distinguish from Japanese knotweed. In 2008, the first male specimens of this variety were found in the Netherlands with well-developed stamens producing viable pollen.
- The hybrid of Japanese knotweed and giant knotweed, known as Bohemian knotweed, is fertile and could cross back with both Japanese knotweed and giant knotweed.
- The current Dutch climate appears suitable for successful seed setting and ripening of Japanese knotweed, giant knotweed and Bohemian knotweed. Due to climate change the growing season may lengthen, increasing the likelihood of full seed ripening of Himalayan knotweed.
- If seeds capable of germinating are formed, they could easily be spread by water and wind.

Response to the questions

Question 1: *What risks are raised by the seed formation of Asian knotweeds in the wild in the Netherlands?*

Since 2012, several sources of male pollen have been identified in the Netherlands that could fertilise female specimens of Japanese knotweed and thus produce seeds capable of germinating: the ornamental plant Russian vine, the ornamental *compacta* variety and male specimens of giant knotweed.

The germination investigation (Penninkhof et al., 2019) showed that Russian vine was an important source of pollen for the seeds that formed in 2018. The likelihood of field germination of seeds of the hybrid of Japanese knotweed and Russian vine currently seems small, probably due to factors such as drought, late spring frost and competition for light. The hybrid seems to have little ability to compete and has not yet been found in the wild in the Netherlands.

Seed formation due to cross-pollination between Japanese knotweed and the ornamental *compacta* variety, giant knotweed or Bohemian knotweed gives rise to two new dangers. The first is that seed formation may produce an additional means of propagation and spread, alongside spread via root and stem fragments. Seeds are more easily spread by wind and water than pieces of rhizomes or stems. Over time, a consequence of seed formation in the wild could be that Asian knotweeds could spread more quickly and to more locations. The second danger is that generative reproduction of Japanese, Bohemian and giant knotweed, and the possibility of backwards cross-pollination, could increase genetic variety, allowing Asian knotweeds to achieve a broader habitat spectrum. The formation of seeds capable of germinating could contribute to the emergence of a greater and genetically broader hybrid swarm, increasing the plants' ability to compete.

Question 2: *What are the risks of four Asian knotweed species in the Netherlands for biodiversity, ecosystem services and other social values?*

The assessment of risks was performed using the Harmonia$^+$ protocol, which is in line with European Commission requirements for European risk assessments of invasive alien species.

The risks for biodiversity and ecosystem services from Japanese knotweed, giant knotweed and Bohemian knotweed are assessed as high. These species produce shoots early in spring and exhibit rapid linear growth. The formation of leaf cover so dense that little or no sunlight can penetrate it means that other vegetation is entirely overgrown and eventually suppressed. The number of invertebrate species (such as wood ants, butterflies and insects) is also reduced if one of these species dominates the growing site. In natural biotopes such as stream and riverbanks, this has a harmful effect on biodiversity.

By out-competing other vegetation (including grass) on dykes, riverbanks and other embankments, these species can undermine the structures' stability.

The presence of these knotweeds leads to extra costs for control and precautionary measures to prevent further spreading.

The risk from Himalayan knotweed is estimated to be lower. The dominance of the vegetation is probably less than with Japanese knotweed, giant knotweed or Bohemian knotweed, but little information is available about the effects on biodiversity.

Advice BuRO

To the Director of Nature of the Ministry of Agriculture, Nature and Food Quality:

- Take measures to prevent hybridisation and generative reproduction through seed formation, for example by identifying and controlling, or encouraging the identification and control of male specimens of Japanese knotweed, giant knotweed and Bohemian knotweed;
- Take or encourage measures to combat establishment in new locations and further spread of the three aforementioned Asian knotweed species or of viable parts, for example by:
  - halting the trade in Japanese knotweed (including *Fallopia japonica* var. *compacta*), giant knotweed and Bohemian knotweed;
  - taking measures in relation to soil transport, garden waste, green waste, compost and the trade in stems.
- Consider organising the measures in such a way that they also apply to species that cannot or can barely be visually distinguished from the species named above, unless it is conclusively demonstrated that these subspecies or hybrids carry no risks for nature in the Netherlands or for other social values.
- Submit Japanese knotweed, giant knotweed and Bohemian knotweed to the European Commission for inclusion on the European Union list of invasive alien species of concern.

Yours faithfully

Office for Risk Assessment & Research

Datum
29 May 2020

Onze referentie
TRCVWA/2020/2784

Office for Risk Assessment & Research
Dr Antoon Opperhuizen

Substantiation

Asian knotweed species

Several *taxa* (species and varieties) of Asian knotweeds are found in the Netherlands. The most common are:

- Japanese knotweed (*Fallopia japonica*);
- Giant knotweed (*Fallopia sachalinensis*);
- Bohemian knotweed (*Fallopia x bohemica*), which is a hybrid between Japanese knotweed and giant knotweed;
- Himalayan knotweed (*Persicaria wallichii*, also known as *Koenigia polystachya*) (Beringen et al., 2019).

These knotweeds are native to Asia, and now grow worldwide after being introduced as an ornamental plant in the nineteenth century. They have since become established in the wild in many places, including the Netherlands. It is suspected that Bohemian knotweed was for a long time mistaken for Japanese knotweed in the Netherlands, since Bohemian knotweed was only recognised as a distinct species in 1999 (Probos Foundation, 2020a).

In addition to the species and varieties named above, the following are relevant to this advice:

- A variety of Japanese knotweed: the dwarf form *Fallopia japonica* var. *compacta*. This is sold as a garden plant and can fertilise Japanese knotweeds. The hybrid *(Fallopia japonica* var. *japonica* x var. *compacta*) is difficult to distinguish from *Fallopia japonica* var. *japonica* (Forman & Kessili, 2003; Duistermaat et al., 2012).
- Russian vine *(Fallopia baldschuanica)* can hybridise with Japanese knotweed, Bohemian knotweed and giant knotweed. Russian vine is traded as a garden plant. It has been found in the wild in certain locations in the Netherlands, but as far as is known it is not invasive (Beringen et al., 2019).
- *Muehlenbeckia* species sold as ground covers and observed in the wild in a small number of locations in the Netherlands. In New Zealand, it has been discovered that *Muehlenbeckia axillaris* can hybridise with Japanese knotweed (Beringen et al., 2019).

Spread via pieces of roots or stems

Japanese knotweed, Bohemian knotweed and giant knotweed are known for their vegetative propagation ability: small pieces of rhizomes weighing just a few grams, or pieces of stem with a single node, can grow into new plants (Beringen et al., 2019). Until a few years ago, it was assumed that only female clones of Japanese knotweed (*Fallopia japonica* var. *japonica*) had spread in Europe, and therefore no seed formation was taking place. Other than through deliberate planting, the species had spread via root or stem fragments in soil, grass clippings, dirty or poorly-cleaned machinery and inadequately composted fragments (Probos Foundation, 2020d).

Less is known about the vegetative dispersal of Himalayan knotweed. In the United Kingdom, this species has very rarely become established in new locations and most growing sites are abandoned gardens or places where garden waste has been dumped (Beringen et al., 2019).

Aim and approach of investigation into germination of Japanese knotweed

The aim of the 'Investigation into the germination of Japanese knotweed seeds' study (Penninkhof et al., 2019) was to answer the following questions:

1 What factors affect seed setting, germination and the growth of seedlings of Asian knotweeds (*Fallopia japonica, Fallopia x bohemica, Fallopia sachalinensis)*?
2 Were the Japanese knotweed seeds collected in autumn 2018 in the Netherlands capable of germinating?
3 If so, were any seedlings or pollination sources found at the field sites where the seeds were collected, and did seed setting occur again in 2019?

To answer the first question, the investigators performed a literature review to find information from previous experiments into sexual reproduction of Asian knotweed species. The documents were compiled from Probos' internal database of knotweed research and via search engines such as Google Scholar, Research Gate and the Wageningen University & Research search engine.

To answer the second question, the investigators conducted a germination test and growth experiment.

To answer the third question, field monitoring was carried out.

Aim and approach of risk assessment of four Asian knotweed species

To identify the risks from the four major Asian knotweed species in the Netherlands for biodiversity, ecosystem services and other social values, the BuRO commissioned FLORON (the Dutch Botanical Research Foundation) to conduct a risk assessment that meets the European criteria. In accordance with the European criteria, the investigators looked at the likelihood of introduction, establishment and spread as well as the effects on biodiversity and ecosystems, plant cultivation, domestic animals, public health and other effects, such as effects on infrastructure. The results of the risk assessment are set out in the report 'Risk assessment of four Asian knotweeds in Europe' (Beringen et al., 2019).

The risk assessment started with the drafting of documents containing the information necessary for the risk assessment. The investigators conducted a search in the Web of Science for the most common scientific names of the four Asian knotweed species. Google and Google Scholar were used to find references that were not accessible via the Web of Science. Other scientific assessments of the risks from the four Asian knotweed species were found by searching for all combinations of the scientific names and the search terms 'risk assessment', 'risk analysis' and 'risk classification' (in several languages).

In the risk assessments and classifications of the four Asian knotweed species, the Harmonia$^+$ protocol was used. This protocol is a procedure for risk screening that is in line with the requirements of the European Commission. The positive effects that are not considered under this protocol are compiled in the information document and assessed in the component that considers effects on ecosystem services. The risk assessment was performed by a team of five experts. Each expert completed the protocol, using the information document. Differences were discussed in a meeting, so that for all criteria of the protocol agreement was reached on the scores and the reasoning behind them.

Risk: likelihood

Introduction
For all four Asian knotweed species, the likelihood of introduction to the Netherlands via natural spread from the area of origin is low. The likelihood of deliberate and accidental introduction by humans is high. The four species have already been introduced to many EU member states and other parts of the world as ornamental plants and as an energy crop (Beringen et al., 2019).

Establishment
There are already established populations of all four species in the Netherlands. Japanese knotweed is common everywhere. As previously mentioned, the populations primarily consist of female specimens which reproduce vegetatively. Giant knotweed is less widespread. There are several genetic strains, both hermaphroditic plants and functional female plants which do not produce fertile pollen (Duistermaat et al., 2012). Little is known about the extent of the spread of the hybrid Bohemian knotweed, due to its late discovery and its resemblance to both parent species (Beringen et al., 2019). This hybrid produces fertile pollen and can cross back with Japanese knotweed (Bailey et al., 2009). Himalayan knotweed is rare in the Netherlands. It is not a *Fallopia* species, and there are no indications that this species can cross-breed with the other species named above.

Spread
For all four species, the likelihood of spread through *human* activities is high. In the Netherlands, spread is primarily related to human activities, such as earthmoving, grass mowing and dumping of garden waste (Beringen et al., 2019). Floral arrangements with knotweed stems can also lead to spread, via improper processing of green waste (Van Iersel, 2019a). A notable case in Düsseldorf involved stems in bouquets left on a grave, which led to a local infestation in the cemetery (Van Iersel, 2019b).

The likelihood of natural spread of Japanese, giant and Bohemian knotweed in the Netherlands is assessed as high (Beringen et al., 2019). For example, fragments of plants and roots could be spread by water when a riverbank erodes due to high water levels. In the assessment, it was assumed that natural spread will also increasingly occur through the spread of seeds (Beringen et al., 2019). Seeds are more easily spread by wind and water than pieces of rhizomes or stems, meaning that in the future Asian knotweed species could spread more quickly if seedlings can successfully become established (Penninkhof et al., 2019).

The likelihood of natural spread of Himalayan knotweed is assessed as low. There have been few instances of Himalayan knotweed becoming established naturally in North-West Europe.

Seed setting
On average, current Dutch weather conditions appear to be suitable for successful seed setting and ripening of Japanese, giant and Bohemian knotweed (Penninkhof et al., 2019). Due to climate change the growing season may lengthen, increasing the likelihood of full seed ripening. A key factor for successful seed formation is the presence of pollen sources.

Fallopia japonica var. *compacta* can fertilise female Japanese knotweed plants (*Fallopia japonica* var. *japonica*) (Duistermaat et al., 2012). The hybrid of these

two varieties is difficult to distinguish from *Fallopia japonica* var. *japonica*. In the Netherlands, suspected male hybrids of *Fallopia japonica* var. *japonica* and *Fallopia japonica* var. *compacta* have been found, which have produced viable pollen (Duistermaat et al., 2012).

The germination investigation (Penninkhof et al., 2019) showed that Russian vine was an important source of pollen for the seeds that formed in 2018. The likelihood of field germination of seeds of the hybrid of Japanese knotweed and Russian vine (*Fallopia* × *conollyana*) seems small, probably due to factors such as drought, late spring frost and competition for light. There are no known reports in the Netherlands of *Fallopia* × *conollyana* growing in the wild.
In 2019, seed setting again occurred in several locations. As in 2018, in 2019 the weather conditions for seed setting were above average.

Himalayan knotweed only flowers late in the year, meaning that fruit formation doesn't happen, or happens rarely (Beringen et al., 2019).

Risk: effect

Biodiversity and ecosystems
The effect of Japanese knotweed, giant knotweed and Bohemian knotweed on biodiversity and ecosystems is significant (Beringen et al., 2019). These species grow rapidly in height in spring, then form dense leaf cover. Below, the species build up a litter of dead leaves and stems that does not easily break down. The dense, monotonous vegetation leaves no room for other species; they can thus entirely displace native species and fundamentally change ecosystems (Beringen et al., 2019). When riverside grasslands and woodland become overgrown with Japanese knotweed, giant knotweed or Bohemian knotweed, not only do fewer plant species grow, but there are also fewer invertebrates present. There are no indications that the four species have an effect on Red List species or protected species (Beringen et al., 2019). The three species have significant effects on the integrity of ecosystems due to changes in biotic and abiotic factors (Beringen et al., 2019).

The effect of Himalayan knotweed on biodiversity and ecosystems appears to be moderate, but there is little certainty due to the scarcity of available information (Beringen et al., 2019).

Plant cultivation
The effect on cultivated plant species is assessed as low for Japanese knotweed and moderate for giant knotweed and Bohemian knotweed. The likelihood of effects on cultivated plants due to hybridisation is assessed as moderate when giant knotweed and Bohemian knotweed are grown together on a large scale as an energy crop (Beringen et al., 2019). It is not inconceivable that in the future, the species named above could develop into difficult root-spreading weeds in certain locations (Beringen et al., 2019).

Domestic animals
There are no known effects on animal welfare or production due to harmful plant substances or the transmission of parasites or pathogens for any of the four Asian knotweed species.

Public health
There are no known effects on public health.

Other effects
The effect on infrastructure is assessed as high for Japanese knotweed, giant knotweed and Bohemian knotweed (Beringen et al., 2019). The plants can cause damage to paving, buildings, foundations and infrastructure structures (such as dykes and embankments). However, the assertion that Japanese knotweed is capable of 'growing through concrete' has not been substantiated by any evidence. The top of the rhizome is remarkably soft and flexible and able to grow around obstacles and through existing cracks and joints (Beringen et al., 2019). On dams and dykes that have been overgrown with these three Asian knotweed species, the grass has been displaced. This means that when the vegetation dies in autumn, the structures are more susceptible to erosion. The banks of watercourses can also become more susceptible to erosion if they are overgrown with Asian knotweed species (Beringen et al., 2019). Individual stones in paved paths and stony slopes can become dislodged under pressure from the rhizomes growing below (Beringen et al., 2019).

Himalayan knotweed has a low effect on infrastructure. No data was found to indicate any possible damage to infrastructure (Beringen et al., 2019).

Effect of formation of seeds capable of germinating
The effect of the formation of seeds capable of germinating is that the speed of spread could increase. Seeds are spread more easily than rhizomes or stem fragments (Duistermaat et al., 2012). The formation of seeds capable of germinating would increase the genetic variety, meaning that the species could achieve a broader habitat spectrum. Fertile male specimens of Bohemian knotweed, for example, could cross back with both parent species, further increasing genetic diversity (Duistermaat et al., 2012).

Based on the genetic and morphological variation of Japanese, giant and Bohemian knotweed, it seems that generative reproduction is taking place in many European countries. There is evidence that viable seeds are often formed. What is much less clear is the circumstances under which germination and establishment could occur in the field (Beringen et al., 2019).

The hybrid of Japanese knotweed and Russian vine (*Fallopia x conollyana*), discovered in the germination investigation (Penninkhof et al., 2019), has properties of both the upright-growing mother and creeping-and-climbing father plants, and seems less able to compete than the hybrid of Japanese knotweed and giant knotweed (the Bohemian knotweed). Germination in the field seems to occur rarely, if at all (Penninkhof et al., 2019).

Estimate of financial costs and benefits

Financial costs and benefits do not form part of the Harmonia$^+$ protocol, and were also not part of the risk assessment. However, (Beringen et al., 2019) includes a list of costs and benefits, both social and financial. Supplementary to that list, the BuRO's reflections and reasoning are set out below.

The financial costs of Asian knotweed species consist of damage and the expense of control and eradication in the Netherlands. There is no central or uniform source of data on these costs, and no aggregated data from studies is available. In the investigation by (Beringen et al., 2019), calculations were performed based on certain guidelines that illustrate that the costs of control can be high, depending on the method used. The cost range is wide and the level of uncertainty high: based on various scenarios, the result for the Netherlands is €1m to €300m per year.

From public debate and media reports over the past few years, it seems that Japanese, giant and Bohemian knotweed are being controlled in many places in the Netherlands. There is extensive debate among public authorities, citizens and green entrepreneurs about suitable control methods, and many new methods are being trialled. Thus far there is no single method that works in all circumstances (Oldenburger et al., 2017). The best method may be different depending on the situation; a combination of measures is usually required, and the measures must be implemented for several consecutive years (Beringen et al., 2019). Three examples illustrate the costs that may be associated with eradication: between 2020 and 2023, the City of Amsterdam has budgeted €7.1m for control (City of Amsterdam, 2019), the City of Amersfoort set aside €307,000 for a 2017–2019 control trial (Municipal Executive of the City of Amersfoort, 2017), and the City of Zaanstad estimated city-wide control on public and private land would cost €280,000 (Municipal Executive of the City of Zaanstad, 2019).

The financial benefits consist of the beneficial use and commercial value of Asian knotweed species. Here, too, there is no central or uniform source of figures. (Beringen et al., 2019) listed the known useful applications of Asian knotweeds. The cultivar *Fallopia japonica* var. *compacta* is sold as a garden plant (Beringen et al., 2019). As far as is known, giant knotweed is not offered for sale in the Netherlands as a garden plant, Bohemian knotweed is offered for sale on at least one Dutch website, and Himalayan knotweed is offered by several growers (Beringen et al., 2019). Two cultivars of giant knotweed have been developed as a biomass crop. Experiments have been conducted in the Netherlands on cultivation as a biomass crop (Matthews et al., 2015). It is not known whether commercial cultivation for this purpose is currently occurring in the Netherlands. Stems of Asian knotweed species are sold (under the name 'Dutch bamboo') and used in floral bouquets (Beringen et al., 2019).

A quick scan of the Internet for a possible Dutch trade in Asian knotweed species, conducted by the BuRO on 18 February 2020 as a supplement to this analysis, did not uncover any indications of trade in Asian knotweeds, with the exception of the *Fallopia japonica* var. *compacta*, Russian vine and sale of stems already mentioned. It also seems that tinctures, teas and capsules made from Japanese knotweed are offered for sale online.

The rhizomes of *Fallopia japonica* contain resveratrol, among other substances, and in traditional East Asian medicine are used to treat inflammation, infections, influenza, skin diseases, burns, snake bites and high cholesterol (Beringen et al.,

2019). Under Regulation (EC) No. 1924/2006[1], in Europe health claims relating to a possible beneficial effect of resveratrol in food are not permitted.

Conclusions

Japanese knotweed, giant knotweed and the hybrid Bohemian knotweed have harmful effects on biodiversity and infrastructure. The species are being eradicated in a large number of places, at significant cost. Japanese knotweed, giant knotweed and Bohemian knotweed are sold on a small scale. The plants are sold as ornamental plants, the stems are used in floral arrangements, and experiments have been conducted in the Netherlands on the cultivation of giant knotweed as a biomass crop. This may contribute to the further spread of the species. Fertile male plants can also produce seeds capable of germinating, promoting further spread. The formation of seeds capable of germinating could contribute to the emergence of a greater and genetically broader hybrid swarm, increasing the plants' ability to compete.

There are no indications that the commercial value of the three species is substantial; it is suspected to be minimal compared to the costs of control.

[1] Regulation (EC) No. 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods.

Bibliography

Municipal Executive of the City of Amersfoort, 2017. Council information letter: City-wide approach to controlling Japanese knotweed, 2017–2019. City of Amersfoort, Amersfoort.

Municipal Executive of the City of Zaanstad, 2019. Council information letter on control of Japanese knotweed. Zaanstad. Available online: https://zaanstad.raadsinformatie.nl/document/7565011/1/Bestrijding%20Japanse%20duizendknoop

Bailey JP, Bímová K & Mandák B, 2009. Asexual spread versus sexual reproduction and evolution in Japanese Knotweed s.l. sets the stage for the "Battle of the Clones". Biological Invasions, 11, 1189—1203.

Beringen R, Leuven RSEW, Odé B, Verhofstad M & Valkenburg JLCHv, 2019. Risk assessment of four Asian knotweed species in Europe. Nijmegen.

Blijdorp V, 2014. https://www.vtvblijdorp.nl/waarschuwing-japanse-duizendknoop/ [Web page, 25/02/2014]. VTV Blijdorp. Available online: https://www.vtvblijdorp.nl/waarschuwing-japanse-duizendknoop/ [Consulted on: 23 January 2020].

Cobouw, 2017. https://www.cobouw.nl/bouwbreed/nieuws/2017/07/duizendknoop-breekt-door-asfalt-101251059?_ga=2.114911492.2029517865.1579790255-1125923211.1579790255 [Webpagina, 24-07-2017]. Cobouw. Available online: https://www.cobouw.nl/bouwbreed/nieuws/2017/07/duizendknoop-breekt-door-asfalt-101251059?_ga=2.114911492.2029517865.1579790255-1125923211.1579790255 [Consulted on: 23 January 2020].

D'hondt B., Vanderhoeven S, Roelandt S, Mayer F, Versteirt V, Ducheyne E, Martin GS, Grégoire J-C, Stiers I, Quoilin S & Branquart E, 2014. Harmonia+ and Pandora+: risk screening tools for potentially invasive organisms. Brussels. Available online: https://doi.org/10.1007/s10530-015-0843-1

UK DEFRA, 2011a. Fallopia japonica - GB Non-native Species Risk Assessments. www.nonnativespecies.org. Available online: https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp?FormPrincipal:_idcl=FormPrincipal:_id1&FormPrincipal_SUBMIT=1&id=60b0ab4c-5664-4785-b21c-be6aae80cd36&javax.faces.ViewState=VpHk5rSF0PFEXPza94uygawtrdsjVnydXvUnjhqRDiw5T%2BARjx%2B5Pp9ye5A4pBYMQSnoxMcTTtt75Tk6Tf%2BMLhZbzff43xM0COkLfiXG5RMdb7y0az9Fh6yVuXmHclyePfQXOjC2Omm8IRyMtExpfms%2BgvI%3D

UK DEFRA, 2011b. Fallopia sachalinensis - GB Non-native Species Risk Assessments. UK DEFRA. Available online: https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp?FormPrincipal:_idcl=FormPrincipal:_id1&FormPrincipal_SUBMIT=1&id=9115dba8-0816-48bf-89ea-566bc8adc88a&javax.faces.ViewState=VpHk5rSF0PFEXPza94uygawtrdsjVnydXvUnjhqRDiw5T%2BARjx%2B5Pp9ye5A4pBYMQSnoxMcTTtt75Tk6Tf%2BMLhZbzff43xM0COkLfiXG5RMdb7y0az9Fh6yVuXmHclyePfQXOjC2Omm8IRyMtExpfms%2BgvI%3D

Duistermaat H, Soes DM, Valkenburg Jv, Heuven BJv, Zonneveld B & Kessler PJA, 2012. Current spread and risks from fertile male *Fallopia japonica* (P Polygonaceae) plants. NCB Naturalis, Leiden. Available online: https://www.nvwa.nl/documenten/dier/dieren-in-de-natuur/exoten/risicobeoordelingen/rapport-japanse-duizendknoop

Environment EC-D, 2015a. Fallopia japonica - IAS workshop. European Commission - DG Environment. Available online: https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp?FormPrincipal:_idcl=FormPrincipal:_id1&FormPrincipal_SUBMIT=1&id=60b0ab4c-5664-4785-b21c-be6aae80cd36&javax.faces.ViewState=VpHk5rSF0PFEXPza94uygawtrdsjVnydXvUnjhqRDiw5T%2BARjx%2B5Pp9ye5A4pBYMQSnoxMcTTtt75Tk6Tf%2BMLhZbzff43xM0COkLfiXG5RMdb7y0az9Fh6yVuXmHclyePfQXOjC2Omm8IRyMtExpfms%2BgvI%3D

Environment EC-D, 2015b. Fallopia sachalinensis - IAS workshop. European Commission - DG Environment. Available online: https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp?FormPrincipal:_idcl=FormPrincipal:_id1&FormPrincipal_SUBMIT=1&id=9115dba8-0816-48bf-89ea-566bc8adc88a&javax.faces.ViewState=VpHk5rSF0PFEXPza94uygawtrdsjVnydXvUnjhqRDiw5T%2BARjx%2B5Pp9ye5A4pBYMQSnoxMcTTtt75Tk6Tf%2BMLhZbzff43xM0COkLfiXG5RMdb7y0az9Fh6yVuXmHclyePfQXOjC2Omm8IRyMtExpfms%2BgvI%3D

European Commission, 2016. Adoption of the first list of invasive alien species of Union concern - Questions and answers. European Commission - DG Environment. Available online: https://ec.europa.eu/environment/pdf/13_07_2016_QA_en.pdf

Forman J & Kessili R, 2003. Sexual reproduction in the invasive species Fallopia japonica (Polygonaceae). American Journal of Botany, 90 (4), 586–592. Available online: https://doi.org/10.3732/ajb.90.4.586

City of Amsterdam, 2019. 2020 Budget. Available online: https://www.amsterdam.nl/bestuur-organisatie/financien/begroting-2020/

Lowe S., M. B, S. B & M. DP, 2000. 100 of the World's Worst Invasive Alien Species. A selection from the Global Invasive Species Database, Auckland, New Zealand. Available online: http://www.issg.org/pdf/publications/worst_100/english_100_worst.pdf

Matthews J, Beringen R, Huijbregts M, Van der Mheen H, Odé B, Trindade L, Van Valkenburg J, Velde G & Leuven R, 2015. Horizon scanning and environmental risk analyses of non-native biomass crops in the Netherlands.

Minister of Agriculture, Nature and Food Quality, 2019. Answer to questions from Members Geurts and Von Martels about the control of Japanese knotweed. House of Representatives, The Hague. Available online: https://www.tweedekamer.nl/kamerstukken/kamervragen/detail?id=2018Z22898&did=2019D05679

NOS, 2019. https://nos.nl/artikel/2284747-japanse-duizendknoop-volop-bestreden-maar-wondermiddel-ontbreekt-nog.html [Web page, 15/05/2019]. NOS. Available online: https://nos.nl/artikel/2284747-japanse-duizendknoop-volop-bestreden-maar-wondermiddel-ontbreekt-nog.html [Consulted on: 23 January 2020].

Oldenburger J, Penninkhof J, de Groot C & Fons V, 2017. Praktijkproef bestrijding duizendknoop: Resultaten en kostenefficiëntie van zeven bestrijdingsmethoden voor duizendknoop en varianten daarop (Knotweed control field trial: Results and cost-effectiveness of seven control methods for knotweed and its variants). Probos Foundation, Wageningen. Available online: http://www.probos.nl/images/pdf/rapporten/Rap2017_Bestrijdingsproef_Duizendknoop.pdf

Penninkhof J, Dijk Cv, Visser Wd, Kremers J, Kleine Cd & Boosten M, 2019. Onderzoek ontkieming zaden Japanse duizendknoop (Investigation into the germination of Japanese knotweed seeds). Results of literature review, greenhouse trial and field investigation. Wageningen.

Probos Foundation, 2020a. https://bestrijdingduizendknoop.nl/duizendknoop/actuele-verspreiding-in-nederland/ [Web page]. Available online: https://bestrijdingduizendknoop.nl/duizendknoop/actuele-verspreiding-in-nederland/ [Consulted on: 21 January 2020].

Probos Foundation, 2020b. https://bestrijdingduizendknoop.nl/duizendknoop/herkomst-en-historie/ [Web page]. Available online: https://bestrijdingduizendknoop.nl/duizendknoop/herkomst-en-historie/ [Consulted on: 02/03/2020].

Probos Foundation, 2020c. https://bestrijdingduizendknoop.nl/bestrijding/methoden/ [Web page]. Available online: https://bestrijdingduizendknoop.nl/bestrijding/methoden/ [Consulted on: 03/03/2020].

Probos Foundation, 2020d. https://bestrijdingduizendknoop.nl/voorkomen-verdere-verspreiding/ [Web page]. Available online: https://bestrijdingduizendknoop.nl/voorkomen-verdere-verspreiding/ [Consulted on: 21 January 2020].

House of Representatives, 2019. Motion by member of parliament Bromet. House of Representatives, https://zoek.officielebekendmakingen.nl/kst-33576-171.pdf. Available online: https://zoek.officielebekendmakingen.nl/kst-33576-171.pdf

Van Iersel W, 2019a. Levende stokken Japanse duizendknoop gewoon te koop bij bloemist ('Living sticks' of Japanese knotweed readily available from florists). Stad en Groen. Available online: https://www.stad-en-groen.nl/upload/artikelen/sg5levendestokken.pdf

Van Iersel W, 2019b. Parliament wants to ban the sale of knotweed, Schouten stands firm. Stad en Groen. Available online: https://www.stad-en-groen.nl/article/31714/kamer-wil-verbod-verkoop-duizendknoop-schouten-houdt-voet-bij-stuk

Wageningen University & Research, 2020. https://www.wur.nl/nl/artikel/Japanse-duizendknoop-Wat-kun-je-eraan-doen.htm [Web page]. Available online: https://www.wur.nl/nl/artikel/Japanse-duizendknoop-Wat-kun-je-eraan-doen.htm [Consulted on: 23 January 2020].