Risk assessment
Ailanthus altissima (Mill.) Swingle

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Risk assessment *Ailanthus altissima* (Mill.) Swingle

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This report was commissioned by the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority.

1. Introduction

Exotic, invasive plant species have a negative impact on biodiversity, economy and/or public health. *Ailanthus altissima* is a potential invasive alien plant species. For this reason the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority has requested a risk assessment for *Ailanthus altissima*.

The current risk assessment will focus on the situation in the Netherlands and discuss the following subjects:
- Probability of entry
- Probability of establishment in the Netherlands
- Probability of spread
- Identification of endangered areas based on the results of the three previous subjects
- Impact of *Ailanthus altissima* in respect to ecological, economical and public health aspects
- Management options to eradicate the species
- Management options to control further spread and reduce impact.

This report is based on published literature, either in print or in the internet.

2. Ailanthus *altissima*: description, ecology and history

2.1. Description

Ailanthus altissima (tree-of-heaven (UK); hemelboom (NL)) is a species belonging to the *Simaroubaceae* family. This deciduous, dioecious tree can grow up to 25(-30) m tall with a smooth bark with pale stripes; branches with soft hairs and an orange pith, young twigs stout, particularly those originating from root sprouts. Leaves are alternate and pinnate, up to 60(-90) cm long, glabrous or puberulous, exstipulate; petiole 7-15 cm long; leaflets 13-25, 7-12 cm long, top leaflet regularly missing, when present much smaller than other leaflets, leaflets entire, but remotely dentate in lower ¼th, lanceolate to ovate-acute, with (generally) two large glands at the margin just above the base, upper side dark green in colour, lower side greyish to bluish-green; terminal bud absent, leaf scars large and triangular with numerous bundle scars. Inflorescences large, unisexual and sexes on different trees, female inflorescence is a terminal yellowish-green panicle of 30 flowers, flowers actinomorphic, 5-merous, greenish or yellowish-white, 5-8 mm large; male flowers have an unpleasant odour; male trees have 3-4 times as many flowers, in much larger panicles, as female trees. Fruits are red-brown winged nutlets ('samaras') 3-5 × 0.8 cm, spirally twisted, and are borne together in large bunches up to 30 cm across; ripe fruits turn from yellowish-green to bright orange-red (de Groot & Oldenbruger, 2011; de Koning et al., 2009; SEPPC, 2012; Q-Bank, 2012; Hu, 1979).

Tree-of-heaven suckers freely, especially when the roots are wounded. *Ailanthus altissima* may be confused with other tree species with large pinnately compound leaves, e.g. *Juglans regia* (common walnut (UK), walnoot, okkernoot (NL)), *Fraxinus excelsior* (ash (UK), es (NL)) and *Rhus typhina* (stag's-horn sumach (UK); fluweelboom, azijnboom (NL)) but the evil smelling glands and the bad smell of crushed leaves of the tree-of-heaven makes it easy to recognize (Q-Bank, 2012; EPPO, 2005).

2.2. Ecology

Ailanthus altissima is a native species of north and central China, Taiwan and North Korea, representing subtropical to warm-temperate climates where there is no frost. The mean annual rainfall is 400-1400 mm and it can withstand a dry season of 4-8 months. The preferred mean annual temperature is 7-18 °C, but it can tolerate heavy frosts to an absolute minimum temperature of -35 °C. Dieback due to freezing of particularly younger shoots and seedlings, however, is a common phenomena in Central Europe (Kowarik & Säumel, 2007). *A. altissima* grows best on loose and porous soils, but can grow on a variety of soil types from heavy clays, sandy or clayey loams to calcareous dry and shallow soils. It even grows on barren rocky hills if annual rainfall is over 750 mm. It adapts easily to drought stress by combining morphological plasticity (extended root system, biomass allocation to roots with higher temperatures) with some physiological adaptations (e.g. stomatal behaviour, ring-porous wood) (Kowarik & Säumel, 2007).

It was introduced into France in the 1740's as an ornamental tree and for shade, shelter and erosion control. It can establish and develop in a wide range of soils, but cannot establish in marshes. It is particularly tolerant of poor air quality and to environmentally stressful conditions, and is therefore favoured for urban planting. The tree has a pioneer character, but the tree has the extraordinary combination of a high, shade-plant like photosynthetic efficiency with high photosynthetic capacity in high irradiance (Hamerlynck (2001) in: Kowarik & Säumel, 2007). In West Virginia, the USA, a population of trees had established in a dense, closed forest. It appeared that seedlings did not survive, but that the population was composed of clonal ramets, i.e. a clonal colony originating from one root system. (Kowarik, 1995). The tree has also been introduced in North America and Australia, mainly for ornamental purposes. (EPPO)

In the Netherlands urban planting has also been done since the introduction of *Ailanthus altissima* in Europe and for these plantings female trees were favoured as they did not emit the unpleasant odour of male flowers.

Figure 1 Winter habit.

3. Risk assessment

3.1. Entry

For several centuries tree-of-heaven has been intentionally introduced from China to North America, Europe and Oceania as an ornamental, production and protection species, and it is likely to be further introduced internationally (EPPO). Currently, in the Netherlands it is mainly planted as a roadside or a park tree. The tree can be purchased with commercial Dutch growers. A few cultivars are available on the Dutch market. The tree is likely to be used by landscape architects and horticulturists and not so much by private persons.

Overall, the probability of entry is very high.

3.2. Establishment

Establishment of seedlings in the Netherlands has only been observed for the first time in 1996 in Rotterdam. In this city 1800 trees-of-heaven have been planted, much more than in other cities and therefore spontaneous establishment of seedlings was noticed here for the first time. The seedlings were found in areas strongly influenced by man, like public gardens and parks, pavements (near light posts and alongside the front of buildings), and stony slopes. A quarter of the studied trees occurred further than 500 m of a large, seeding tree and therefore it is concluded that seeds disperse easily and far, even in an urban setting (Andeweg, 1997). An unresolved issue is that the planted trees are female, as the male-flowering trees have a bad smell (Vos, 2007). Apparently male trees do occur in the Netherlands but it is not known what ratio of established trees is male, the vast majority of observed trees is female and produces seed.

Ailanthus altissima is found naturalized in the following countries (see Figure 4):

- Europe: Albania, Austria, Belgium, Czech Republic, France, Germany, Greece, Hungary, Italy, Moldova, Netherlands, Portugal, Romania, Russian Federation, Serbia and Montenegro, Spain, Switzerland, Ukraine, United Kingdom
- Asia: China (widespread, native), India, Indonesia, Iran, Japan, Korea Republic (native), Malaysia, Pakistan, Russian Federation
- Africa: South Africa
- North America: Canada, Mexico, USA
- South America: Argentina, Chile
- Oceania: Australia, New Zealand.

Distribution in the Netherlands is given in Figure 5; this map shows both data from field inventories and those from herbarium vouchers (FLORON & NHN, 2012). It is likely that the actual distribution is wider as invasive exotic species are less well studied.

The probability of establishment is very high, and has already occurred.

3.3. Spread

Ailanthus altissima easily spreads by root sprouts and over longer distances by its winged seeds.
A single tree can produce an enormous amount of seeds, estimates go up to 1 million seeds. Trees start producing seeds after 10-20 years. Every winged fruit contains a single seed and is therefore dispersed independently of the other seeds. (Hunter, 2000). Some of the fruits overwinter on the tree (Hunter 1995), although in the Netherlands this seems to differ from tree to tree. This allows for dispersal in time of the ripe seeds. Viability of seed is good, cold stratification (temperatures of 0-5 °C for 40 days in the USA) is necessary for good germination. Seeds do not remain dormant for more than a year, so there is no risk of the development of a persistent soil seed bank (Hunter, 2000). In the Netherlands seedlings develop particularly on somewhat warmer micro-habitats, viz. in cities along fences and walls. Outside urban areas, the tree has been occasionally observed to spread along rivers and roads.

Seedlings may grow up to 1 m in height annually during the first four years (Fryer 2010) and are considered to be shade intolerant (Hunter, 1995).
In general, *Ailanthus* seedlings establish best in an open or urban landscape with a high degree of disturbance (Kaufman & Kaufman, 2007). In an experimental design, with higher temperatures saplings invested considerably more biomass in

Figure 2 Spontanious established tree in urban environment.

Figure 3 Typical niche for seedling.

Figure 5 Distribution in the Netherlands

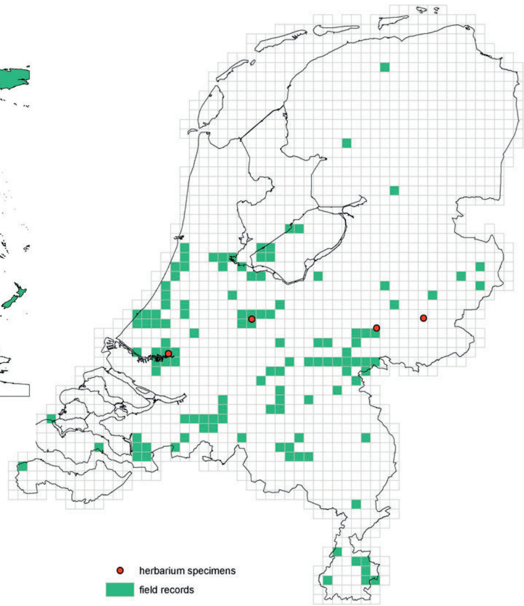
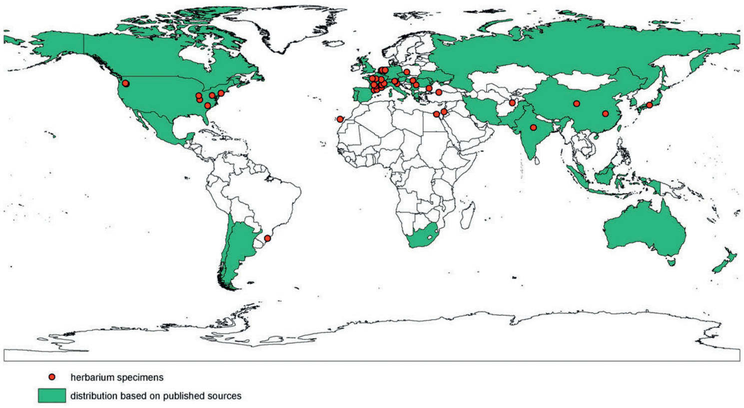


Figure 4 World distribution



roots and less in leaves, thus enhancing rooting depth, increasing main root elongation and increasing lateral soil exploration (Kowarik & Säumel, 2007). This might imply that under urban conditions, trees develop their root system relatively fast and eradication becomes more difficult.

Root sprouts may develop up to 15 m from the mother tree. Initial growth of root sprouts is 1 m/year (Hunter, 2000), but when larger trees are cut resulting sprouts can reach up to 4 m the first year (Hunter, 1995). Root suckering is also triggered by damage of the superficial roots. Formation of a taproot is mentioned, but other sources only note the superficial and lateral roots (Kowarik & Säumel, 2007).
In Hannover, Germany, 21 saplings were cut, inducing 551 sprouts the following year and 772 sprouts in the second year after cutting (Kowarik & Säumel, 2007). The roots to which the sprouts are attached are thick and have a rope-like structure (Hunter, 1995). The production of multiple trunks from root sprouts allows genetic individuals to occupy a considerable area, sometimes over 0,4 ha, for a prolonged period of time. (Hunter, 2000). Even seedlings of less than 1 year old respond to cutting with a remarkably early development of stump shoots and suckers (Bory et al. (1991) in: Kowarik & Säumel, 2007). Buried stem fragments of 1-2-year old stems developed shoots in 33-75% of the cases, so even cuttings of twigs can be a means of dispersal (Kowarik & Säumel (2006) in: Kowarik & Säumel, 2007).

Hunter (1995) suspects that seedling establishment in natural areas is relatively infrequent and that the presence of *Ailanthus* in the landscape relies heavily upon the ability of individuals to persist through the production of successive root sprouts. The formation of monocultures, as seen in the USA,

Figure 6 Root sprout.

Figure 7 Regeneration in beech forest in Hungary.

Figure 8 In a semi-natural area in France (centre of picture).

provokes heavy shade and therefore displaces the native vegetation.

In addition to its prolific vegetative reproduction, *Ailanthus* has allelopathic effects i.e. excreting chemical substances toxic to other plants, on many other tree species and may consequently inhibit succession (SEPPC 2012).

Significant genetic alteration has occurred since the introduction of *Ailanthus altissima* to the USA 200 years ago though there was no evidence of inbreeding depression (Feret and Bryant, 1974 in: EPPO, 2005) Albright et al. (2009) have modelled the distribution of *Ailanthus altissima* in the USA based on natural habitats in China. For the habitats less suited the model underestimated the distribution in the USA and the tree was found in much larger numbers than anticipated. These results suggest that the ecological niche of the tree-of-heaven has widened and the species adapts to local conditions. The model further predicts the possibility of the tree-of-heaven to spread much further in the USA.

In Spain, *Ailanthus altissima* also showed considerable plasticity with regard to the Mediterranean climate. The Mediterranean climate is characterized by persistent summer droughts and unpredictable soil water. *Ailanthus altissima* proved to be able to outcompete native woody species, which have evolved structural and physiological mechanisms to cope with these environmental constraints. Water-use efficiency and high rehydration could allow for better growth and improve the tree's competitive abilities against native species under drought stress (Constán-Nava et al., 2010).

The probability of rapid spread by seed is 1 km per generation, although seed production only starts at the age of 10. Spread by root suckers is approximately 1 m/year.

3.4. Endangered areas

In Europe, habitats occupied by *Ailanthus altissima* include managed grasslands, natural grasslands, managed forests, natural forest, riverbanks/canalsides, rail/roadsides, wastelands and urban areas. *Ailanthus altissima* establishes readily on artificially disturbed sites such as roadsides and ditches, cracks and crevices of pavement, particularly in the Mediterranean region, such as in France (Kowarik, 1983), and in naturally forested areas it can become established in areas disturbed by storms or infestations. In Germany, the tree has established in the floodplains of the Danube (Gutte et al. (1987) in: Kowarik & Säumel, 2007), along streams and riverbeds in southern Switzerland (Arnaboldi et al. (2002) in: Kowarik & Säumel, 2007) and southwestern France (Tabacchi & Planty-Tabacchi (2003) in: Kowarik & Säumel, 2007).

In Central Europe, *Ailanthus altissima* typically invades urban areas, as these areas usually exhibit a higher temperature than rural areas and the tree thrives in subtropical and warm-temperate areas. In the Netherlands, the species is currently mainly seen in cities (Utrecht, Rotterdam, Den Haag, Maastricht), to a lesser extent in Amsterdam and Haarlem, around Nijmegen and along the river Waal. In the last decade, tree-of-heaven has also been found in the medians of motorways. Along rivers, the tree establishes near groynes; it is not known to establish permanently in outer-dike areas and reach maturity. Over the last years little changes in distribution have been observed (Vreeken & Beringen, 2009).

In Europe, young *Ailanthus* trees have also been observed in beech (*Fagus sylvatica*) forests in Hungary (van Valkenburg, pers. comm.), see figure 7. In these forests *Ailanthus* has established in gaps in the canopy of beech trees. Moreover, in France infestations have been observed along the edges of semi-natural oak and chestnut (*Quercus* spp., *Castanea sativa*) patches of woodland in a small-scale agricultural landscape (van Valkenburg, pers. comm.), see figure 8.

In the United Kingdom tree-of-heaven was first recorded wild as an escape in 1935, it escaped cultivation and currently it is invasive in the London area and south-east England (GB Non-native species secretariat, 2011).

In the USA *Ailanthus altissima* is the most wide-spread invasive tree. It adapts easily to poor soil moisture, soil nutrients, extended drought, and tolerates a minimum temperature of -35 °C. It is found thriving in cities as well as in forest, generally where disturbance has taken place, e.g. after logging (Pomp, 2008 in: Fryer, 2010). In the urban landscape of New York 1-year-old plants existed for 43% of seedlings and for 57% of root suckers, thus profiting from both ways of dispersal. In the urban environment, an additional advantage of connected root suckers is their collectively greater size which can more effectively occupy and compete for a site (Pan & Bassuk, 1986). In natural forest, *Ailanthus altissima* is locally dominant, e.g. in riparian woodlands in California, in disturbed calcareous forest in Virginia and is an important component of the tree composition of many other natural forest types. *Ailanthus altissima* is now also spreading in the southern states covering an estimated area of 86.600 ha in 2008 (Fryer, 2010). Tree-of-heaven is most invasive in eastern deciduous forests, but increasingly poses problems in riparian areas in the Southwest and it can displace native vegetation. It is uncertain whether the tree can establish in undisturbed forest, but dispersal generally follows human disturbance particularly along potential pathways for tree-of-heaven invasion: roadsides, trails, parking lots, fence lines, trails and waterways (Fryer, 2010).

In Africa, it invades forest margins, roadsides and riverbanks in cool, moist regions in South Africa (Henderson, 2001).

In conclusion, urban trees in the Netherlands still grow larger which implies larger seed production. As management becomes less intense and young trees are cut in stead of uprooted, new colonies from root suckers will eventually start producing seed. Increased urbanisation with plantings of *Ailanthus altissima* will further increase the production of seed and the risk of establishment in areas around towns. Current management of rivers with increased attention to natural processes also increases the risk of establishment and subsequent seed production of established trees. In these areas it is important to closely monitor seedling establishment and assure seedling removal.

3.5. Impact

3.5.1. Ecological impact

Ailanthus altissima has the following ecological impacts:

- Dense populations can shade out native vegetation and reduce plant diversity; thickets have been observed in urban areas in the Netherlands that maintain themselves as a result of inappropriate management.

- Competition with native vegetation through allelopathy and the extensive and fast-growing root system (up to 1 m/year, average 0,6 m/year in urban conditions, Pan & Bassuk, 1986).

The potential level of ecological impact is estimated to be localized at present levels of infestation. If the spread from urban areas along roads and rivers further increases, the risks for natural areas increases likewise. Observations in France and Hungary point to the potential risk for ecologically important forest fringes and natural regeneration in beech forest.

The potential ecological impact in the Netherlands is estimated to be low.

3.5.2. Economic impact

Ailanthus altissima is recorded as a weed of agricultural land, grasslands and forests, there is no information on economic impacts, loss in production or control costs. The roots are capable of damaging sewers and foundations and thus create economic costs (EPPO, 2012).

If *Ailanthus altissima* would be eradicated of controlled, costs would have to be made. In urban conditions seedlings are often cut in areas where the species is not wanted. Cutting triggers the formation of even more sprouts from roots and stumps, displacing other plants and thus increases future costs. Currently, in the Netherlands trees outside the urban centres are not specifically targeted by control measures, as economic impact is probably insignificant. Little information on this subject is available.

The potential level of direct economic impact in the Netherlands is estimated to be low.

Indirect economic impact due to costs for eradication or control is estimated to be limited as far as infestation outside urban areas is concerned; infestation is still localized and could be controlled with limited means. Not targetting these stands will increase future costs for control. With regard to urban infestations economic impact is also limited. Costs will be associated with infrastructure damage and increased management costs for urban plantings.

3.5.3. Social impact

Leaves and flowers of tree-of-heaven are known to cause dermatitis and this may have implications for the way control measures are implemented. How serious this problem is in practice is not known. Removal of mature trees may be controversial in view of the ornamental value of the species.

The potential level of social impact is estimated to be limited, provided personel charged with control of the species are properly protected.

4. Risk management

4.1. Prevention of deliberate plantings

Introduction to the Netherlands has been deliberate, mainly for urban plantings. Tree-of-heaven has outstanding characteristics for urban planting, viz. very tolerant to noxious gases and dusts, low demands in terms of soil nutrients and soil moisture and adaptability to a limited growing space. Nowadays *Ailanthus altissima* can still be obtained from tree growers, whether male or female trees are traded is not known. Other functions this tree may fulfil are the production of timber, medicinal products and erosion control (Hu, 1979).

4.2. Prevention of dispersal

Tree-of-heaven is found in the Netherlands. Only recently, since 1996, seedlings are regularly observed in the urban setting (Andeweg, 1997). If these seedling will not be removed, establishment and spread is likely to occur and eradication will become very difficult and costly.

An unresolved issue is the presence of male trees. There is no data to estimate the ratio of male and female trees. As a lot of trees set fruit, male trees must also be readily available. Where for other countries it has been suggested to cut female trees to reduce the production of seed, in the Netherlands the search and elimination of male trees might be a good option to prevent seed set in the female trees planted since the 18th Century.
Male trees produce 3-4 times as many flowers as female trees and male panicles are much larger than female ones (Hu, 1979), which may make localisation of male trees during flowering easier. Flowering in the Netherlands occurs in June-July.

In the next section on eradication it will be discussed in more detail why trees and seedlings should not just be cut without other measures, as this will increase the production of root and stump shoots and hence will promote the dispersal of the tree.

4.3. Eradication and control

The resprouting potential of *Ailanthus altissima* is well-known and just cutting a tree or a sapling will result in an enormous amount of stump and/or root sprouts. Damage to the superficial roots also triggers shoot formation. The disturbance of a Mediterranean population induced a shift from 19.660 to 128.650 ramets/ha within 4 months (Kowarik & Säumel, 2007).

Every programme to control or eradicate trees must contain a follow-up monitoring and treatment component. Regardless of the method selected, treated areas should be monitored one or more times a year, and any new suckers or seedlings treated as soon as possible, especially before they are able to rebuild root reserves. Establishing a thick cover of trees (non-invasive and preferably native) or grass cover will help shade out and discourage establishment of *Ailanthus* seedlings. Targeting large female trees for control will help reduce dispersal of *Ailanthus* by seed (Swearingen & Panhill, 2009).

To control or eradicate trees, the following measures can be taken:
- Manual
- Mechanical
- Chemical
- Biological

Manual measures
These involve the hand-pulling of newly established seedling; this is best done when the soil is moist and loose and when the seedlings are large enough to grasp. It is important that the entire root is removed as broken fragments can resprout (SEPPC, 2012).

The so-called 'Bradley' method is often mentioned in the context of controlling *Ailanthus altissima* infestations. The method consists of hand weeding, without replanting, selected small areas of vegetation in such a manner that after weeding, each area will be promptly re-inhabited and stabilized by the regeneration of native plants. But by working a little at a time, from the strongholds of natural vegetation towards the weeds, the native vegetation is favoured and its natural regenerative power will prevail over the weeds (Fuller & Barbe, 1985). However, this only seems plausible when the source of *Ailanthus* seeds has been removed.

Mechanical measures

As indicated earlier, cutting alone is insufficient and even counter-productive to eradicate *Ailanthus* infestations due to the large number of stump sprouts and roots suckers produced in response to the injury (SEPPC, 2012). However, for small infestations, repeated cutting of sprouts over time can exhaust plant reserves if continued for many years (Swearingen & Panhill, 2009). However, this opinion is not unanimously adhered to; Constán-Nava et al. (2010) experienced an increase in biomass when sprouts were cut once or twice a year during 5 consecutive years when compared to the control treatment.

Girdling of trees has been proposed, but this also causes the trees to sprout, more vigorously than before, from collar and roots (Swearingen & Panhill, 2009; SEPPC, 2012). Incomplete girdling has shown more positive results. Using this technique on 90% of the circumference of the tree the bark is removed, causing the tree to die in 2 years time without vigorous resprouting. Monitoring and treatment of sprouts, however, remains necessary (Pichet & Terrin, 2011).

Mechanical measures are often combined with or followed by chemical applications to increase effectiveness.

Chemical measures

The use of herbicides is regarded most effective. Killing the above-ground portion of the trees is relatively easy, but the root system must also be seriously damaged or killed to prevent or limit stump sprouting and root suckering. Herbicides may be applied as foliar spray, basal bark spray, cut stump application and a hack and squirt treatment.

Foliar sprays should be applied when the trees are in full leaf, but contact with neighbouring plants should be avoided. Rapid-growing *Ailanthus altissima* trees can have an important part of their foliage out of reach to be sprayed. Glyphosate is a non-selective herbicide and can kill or damage all plants. Triclopyr is selective for broadleaf and woody plants and will not kill grasses (Swearingen & Panhill, 2009).

Basal bark application is easy to perform as it does not require any cutting. Summer application requires lower concentrations of herbicide than late winter to early spring application. A 10-20% concentration of oil-soluble triclopyr should be sprayed in a 30 cm wide continuous band around the tree. Imazapyr is another herbicide which is effective for basal bark application. Follow-up foliar herbicide application to basal sprouts and root suckers may be necessary (Swearingen & Panhill, 2009).

Cut stump application involved the application of herbicides directly after cutting a tree on the newly exposed stump surface and is most effective when done during the growing season. After five years of consecutive treatment, the number of resprouts in a Mediterranean climate had not reduced but the resprout biomass, height and leaf area index had declined significantly (Constán-Nava et al., 2010). Herbicides effective using this method are triclopyr, dicamba, imazapyr and 2,4-D combined with picloram, whereas glyphosate proved little effective (Swearingen & Panhill, 2009).

The hack-and-squirt or injection method is very effective and minimizes sprouting and suckering when applied during the summer. This method requires first making downward-angled cuts into the sapwood around the tree trunk at a comfortable height, using a hand axe. A straight (100%) concentration of a water-soluble triclopyr product is squirted into the cuts within a minute or two, covering the bottom of the cut, but assuring liquid doesn't run out. The cuts should be spaced so that about 2,5-5 cm of uncut living tissue remains between them. A continuous line of cuts around the trunk would likely cause the tree to go into emergency response mode and react by producing basal sprouts and root suckers. Other herbicides which are effective using this method are dicamba, imazapyr and

2,4-D combined with picloram (Swearingen & Panhill, 2009).

Biological measures
A commercial stump treatment product based on the fungus *Cylindrobasidium leave* (Pers.) Chamuris has been used in South Africa, killing 80% of treated stumps (Lennox et al. (1999) in: Kowarik & Säumel, 2007). This fungus is a common wood rotting fungus in the Netherlands and is not a primary pathogen. Injection in the stem of *Verticillium albo-atrum* caused a 100% mortality, in both greenhouse and field conditions in the USA. Trees in the direct vicinity did not show any symptoms of the *Verticillium* wilt (Schall & Davis, 2009).

Two important insect pests recorded for *Ailanthus altissima* are *Eligma narcissus* and *Lycorma delicatula*. *E. narcissus* is a serious defoliator of saplings. *L. delicatula* is a serious pest borer, which attacks stems and branches and makes the bark darker in colour and susceptible to dry rot (CABI, 2011).

In conclusion, it is unrealistic to eradicate all planted urban trees, as they have an aesthetic function as ornamental tree. Eradication of small populations in urban areas or elsewhere is possible, but require a continuous effort for several years, necessitate use of herbicides and require monitoring and follow-up action to treat sprouts having survived previous treatments.

4.4. Conclusions

In the Netherlands, *Ailanthus altissima* is mainly found in urban areas. Areas outside cities where the tree has been found (along the river Waal, in the central reserve of motorways) should be subject to an eradication programme to prevent establishment in natural areas.

The impact of *Ailanthus altissima* as invasive species in the Netherlands is limited sofar; this implies that new infestations can still be controlled. From neighbouring countries, however, it is clear that by its invasive traits (high seed production and easy dispersal by wind, enormous capacity of resprouting from roots, stems and stumps) and its adaptability to different (and changing) environments, dispersal to natural and agricultural areas is a high risk.

It is recommended to stop planting *Ailanthus altissima* in all type of plantations to reduce risks of infestations and seed dispersal and to stop trade of this species as well.

It is not known whether *Ailanthus altissima* can produce viable seed without pollination; if pollination proves obligatory then eradication of male trees may be an option.

At present no eradication procedures in the Netherlands have been tested; it would be good to know more about this in cases where eradication is really necessary. Special attention may be given to potential biological measures for eradication.

5. References

Andeweg, R., 1997. De verwildering van *Ailanthus altissima* (Mill.) Swingle (Hemelboom) in Rotterdam. Gorteria 23: 106-108.

Burch, P.L. & Zedaker, S.M., 2003. Removing the invasive tree *Ailanthus altissima* and restoring natural cover. Journal of Arboriculture 29(1): 18-24.

CABI, 2011. Invasive Species Compendium (Beta). *Ailanthus altissima* (tree-of-heaven) last modified 18 May 2008. [Accessed 24 Janury 2012. http://www.cabi.org/isc/?compid=5&dsid=3889&loadmodule=datasheet&page=481&site=144

Constán-Nava, S., Bonet, A., Pastor, E. & Lledó, M.J., 2010. Long-term control of the invasive tree *Ailanthus altissima*: insights from Mediterranean protected forests. Forest Ecology and Management 206: 1058-1064.

Czerepanov, S.K., 1995. Vascular plants of Russia and adjacent states. Cambridge University Press, New York, USA. p. 486.

Department of Conservation and Recreation (DCR), Virginia & Virginia Native Plant Society, 2002. Tree-of-Heaven (*Ailanthus altissima* (Miller) Swingle). Invasive Alien Plant Species of Virginia. http://www.dcr.virginia.gov/natural_heritage/documents/fsaial.pdf [Accessed 30 January 2012]

EPPO, 2012. *Ailanthus altissima*. EPPO data sheet on Invasive Plants. http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRAdocs_plants/draftds/05-11828%20DS%20Ailanthus%20altissima.doc [Accessed 31 January 2012]

Fuller, T.C. & Barbe, G.D., 1985. The Bradley method of eliminating exotic plants from natural reserves. Fremontia 13(2): 24-25.

De Groot, C. & Oldenburger, J., 2011. De bestrijding van invasieve uitheemse plantensoorten. Stichting Probos, Wageningen. 90 pp.

De Koning, J., van den Broek, W., De Meyere, D. & Bruens, H., 2009. Dendrologie van de lage landen. 14e druk Nederlandse Dendrologie. KNNV Uitgeverij, Zeist. 547 pp.

FLORON, Stichting & Nationaal Herbarium Nederland (NHN), 2012. FlorBase. http://www.floron.nl [data not online accessible]

Fryer, J.L., 2010. *Ailanthus altissima*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. http://www.fs.fed.us/database/feis/plants/tree/ailalt/all.html#AuthorshipAndCitation [Accessed: 2 February 2012]

GB Non-native species secretariat, 2011. Tree-Of-Heaven, *Ailanthus altissima*. https://secure.fera.defra.gov.uk/nonnativespecies/factsheet/factsheet.cfm?speciesId=101 [Accessed: 7 February 2012]

Henderson, L., 2001. Alien weeds and invasive plants. Plant Protection Research Institute Handbook No. 12. Paarl Printers, Cape Town, South Africa. 300 pp.

Hu, S.Y., 1979. Ailanthus. Arnoldia 39(2): 29-50.

Hunter, J.C., 1995. *Ailanthus altissima* (Miller) Swingle: Its Biology and Recent History. CalEPPC News 5(3): 4-5.

Kaufman, S.R. & Kaufman, W., 2007. Invasive plants: a guide to identification and the impacts and control of common North American species. Stackpole Books, Mechanicsburg, USA. 458 pp.

Kowarik, I., 1995. Clonal growth in *Ailanthus altissima* on a natural site in West Virginia. Journal of Vegetation Science 6(6): 853-856.

Kowarik, I. & Säumel, I., 2007. Biological flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle. Perspectives in Plant Ecology, Evolution and Systematics 8(4): 207-237.

Meloche, C. & Murphy, S.D., 2006. Managing tree-of-heaven (*Ailanthus altissima*) in parks and protected areas: a case study of Rondeau Provincial Park (Ontario, Canada). Environmental Management 37(6): 764-72.

Miller, J.H., 1990. *Ailanthus altissima* (Mill.) Swingle. In: Burns, R.M. & Honkala, B.H. (tech. coords.). Silvics of North America: Vol. 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. pp. 101-104.

Pan, E. & Bassuk, N., 1986. Establishment and distribution of *Ailanthus altissima* in the urban environment. Journal of Environmental Horticulture 4(1): 1-4.

Pichet A., Terrin E. (2011). Fiche espèces invasives, Ailante, Faux verni du Japon. Conservatoire Botanique National Alpin, 6 p.

Q-Bank, 2012. *Ailanthus altissima*. [record from database on invasive plants] http://www.q-bank.eu/

Annex 1

cont. References

Plants/BioloMICS.aspx?Table=Plants%20-%20 Species&Rec=44&Fields=All [Accessed: 31 January 2012]

Southeast Exotic Pest Plant Council (SEPPC), 2012. Southeast Exotic Pest Plant Council Invasive Plant Manual: Tree-of-Heaven. http://www.se-eppc.org/manual/ailanthus.html [Accessed: 31 January 2012]

Swearingen, J.M. & Pannill, P., 2009. Weeds Gone Wild: Alien Plant Invaders of Natural Areas. Fact sheet Tree-of-heaven. Plant Conservation Alliance's Alien Plant Working Group. http://www.nps.gov/plants/alien/fact/aial1.htm [Accessed 23 January 2012]

Van der Molen, M., 2008. Donzige korstzwam - Cylindrobasidium leave. http://mycofiel.nl/detail/cylindrobasidium%20laeve.html [Accessed 17 February 2012]

van Valkenburg, J.L.C.H., 2001. *Ailanthus altissima* (Miller) Swingle. In: van Valkenburg, J.L.C.H. and Bunyapraphatsara, N. (Editors). Plant Resources of South-East Asia No. 12(2): Medicinal and poisonous plants 2. Backhuys Publisher, Leiden, The Netherlands, p. 48.

Vos, P.G., 2007. *Ailanthus altissima*: hemel- of helleboom? Arbor Vitae 17 (2), 15-22.

Vreeken, B. & Beringen, R., 2009. Actualisatie status en voorkomen van een aantal belangrijke invasieve plantensoorten in Nederland. Rapport 2009.010. Stichting Floron, Leiden. 37 pp.

Risk assessment scores using the ISEIA protocol.

The following risk assessments is based on E. Branquart (Editor), 2009. Guidelines for environmental impact assessment and list classification of non-native organisms in Belgium. version 2.6 dated 7-12-2009, commonly referred to as the ISEIA - Invasive Species Environmental Impact Assessment - protocol. These guidelines are published at: http://ias.biodiversity.be/documents/ISEIA_protocol.pdf.

This protocol aims to assess environmental risks only and do not take into consideration the direct impact of non-native species on human interests.

The risk categories are scored as follows:
Score 1: risk is low
Score 2: risk is medium
Score 3: risk is high

The different scores are detailed for every type of risk in the ISEIA protocol.

Risk	**Risk category**
Dispersion potential or invasiveness	2
Colonization of high conservation value habitats	2
Adverse impacts on native species	1
Alteration of ecosystem functions	1

<u>Dispersion potential or invasiveness</u>: *Ailanthus altissima* doesn't colonize remote places, except when assisted by man. The reproduction potential and vegetative reproduction capacities are high, allowing for medium risk (score 2) for this risk.

<u>Colonization of high conservation value habitats</u>: In Germany, France and Hungary, there are some examples of invasion of high conservation areas; in the Netherlands *Ailanthus* seems exclusively restricted to man-made habitats, but spontaneous dispersal started only 15 years ago. There is, however, a risk that *Ailanthus* spreads from the groynes in the river Waal to the surrounding riverine forests.

<u>Adverse impacts on native species</u>: Examples in West European countries are rare, the only one documented case is the displacement of certain species in natural alkaline grasslands in Germany where *Ailanthus* developed a relatively dense stand (Radkowitsch, 2006).

<u>Alteration of ecosystem functions</u>: There are no data suggesting that ecosystem functions are influenced. The fact that Ailanthus produces allelopathic substances merits further attention in his respect and may raise this risk category in the future from low risk (score 1) to medium risk (score 2).