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1 Introduction

In order to prevent introduction and spread of *Ambrosia artemisiifolia*, the knowledge of entry and spread pathways is essential. Seeds of the species are dispersed via a number of different mechanisms, several of which are aided by human activities. The introduction of ragweed from foreign countries and the spreading of already existing populations in a region may be realized with different mechanisms (Fig 1, Fig 2). A lot of information on these mechanisms is found in the literature (e.g. Kazinczi et al. 2008, Alberternst et al. 2006), but there is still a gap in knowledge, e.g. regarding spread of ragweed seeds with excavated material.

![Diagram showing important pathways of introduction and spreading routes of Ambrosia in Germany](image)

**Fig 1:** Pathways of introduction and spreading routes of *Ambrosia artemisiifolia* in Germany.

While the introduction with bird seed played a major role in the spreading process over the last years we currently observe a shift to an increased spread of Ambrosia seeds with soil in Germany.
To install effective and adequate control measures it is necessary to know the relevance of the different routes that the species uses to reach new sites. Spread of Ambrosia seeds with excavated soil is an important pathway for the species to reach new locations (Bohren 2005, 2007), and therefore this is investigated in this study. The aims of activity C.4 are to learn more about:

1. the role of construction activities in the spreading of Ambrosia in Europe with special regard to the situation in Germany
2. measures to prevent seed dispersal with excavated material
3. methods to decontaminate soil
4. prescriptions to prevent the spread of ragweed in soil already in force in European countries.

2 Methods

A literature survey was conducted which showed there is little published information on the question to what extent Ambrosia is spread with soil. So we tried to find out more using a questionnaire sent to experts in different countries. The situation in Germany is illustrated with some exemplary field studies.
2.1 Inquiry via questionnaire

In November 2012 a questionnaire (see appendix) with three questions dealing with the topic “relevance of soil and construction material for the spread of Ambrosia artemisiifolia” was sent to 103 experts currently working on the topic “Ambrosia” in 37 countries (Australia, Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Canada, China, Croatia, Czech Republic, Denmark, Finland, France, Georgia, Germany, Greece, Hungary, Iran, Israel, Italy, Lithuania, Luxembourg, Macedonia, Netherlands, Norway, Poland, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, USA). We used nearly the same email-list as for the inquiry about impacts of Ambrosia on biodiversity (deliverables DE.1 and DE.2).

The questionnaire asked for information on the following questions:

1. How important are the following spreading pathways for Ambrosia artemisiifolia in your country: building sector (construction material), building sector (seed loss during transportation), agriculture (seeds sticking at machineries), agriculture (seed loss with agricultural products), sowing material, traffic, bird seeds, others.

2. Is the building sector informed about the Ambrosia-problem? (e. g. occurrence of ragweed plants on soil depots or construction material, seed loss during soil transportations etc.)

3. Are there legal or other regulations to avoid dispersal of Ambrosia seeds with soil or construction material in your country?

We thankfully received 13 answers to the questionnaire from Maira Bonini (Italy), Bruno Chauvel (France), Bernard Clot (Switzerland), Chantal Déchamp (France), Alain Demierre Déchamp (France), Alain Demierre (Switzerland), Peter Kotanen (Canada), Beryl Laitung (France), Arnaud Monty & Grégory Mahy (Belgium), Sergey Reznik (Russia), Baruch Rubin (Israel), Ingrida Sauliene (Lithuania), Carsten Ambelas Skjøth (Denmark), Wil Tamis (Netherlands) and added our own estimation for Germany (Beate Alberternst & Stefan Nawrath). The information given by the experts in the questionnaire is described below.

The low number of replies indicates that the knowledge on this topic is currently low.

2.2 Field studies done in Germany

Field studies were conducted in Brandenburg (Niederlausitz, East-Germany) in an area where the most extended ragweed occurrence of Germany is present. Soil depots and road-sides were investigated here.

To compare the heavily infested area in the Niederlausitz with a region with relatively low ragweed occurrence, results from studies conducted in Bavaria for the Bavarian State Ministry of the Environment, Public Health and Consumer Protection (Nawrath & Alberternst 2008, 2009, 2011, 2012) since 2007 are considered in the following. In these studies pathways of introduction, spreading routes, the development of ragweed populations and the success of control measures were investigated. It was determined that ragweed already occurs at soil depots in Bavaria and that it is distributed via excavated material.
2.2.1 Soil depots
Between 20th and 24th September 2012 eleven soil depots were surveyed for ragweed occurrence (Tab 1). The depots consisted of soil that was excavated and stored in order to use it at a later date (“transient soil depots”). The area of the sites was inspected for Ambrosia on the soil dumps and at the ruderal sites. When the soil depots were not openly accessible, owners were asked for permission. If the area was not accessible, we walked around the site and looked for Ambrosia from outside.

2.2.2 Roadsides
In the study area south-west of Cottbus, various roads were inspected from a car for Ambrosia at the roadsides, with particular focus on newly built hard shoulders and roads under construction. The roads which were investigated are marked in yellow in the map in Fig 13. During the drive GPS values were taken with a navigation tool (Garmin GPS map 62s). The routes travelled were automatically registered by the navigation tool and are demonstrated in (Fig 13). Additionally, observations during the field work done for the biodiversity study in July 2011 were included.

3 Results
3.1 Inquiry
Question 1: Of what relevance are the following spreading routes for *Ambrosia artemisifolia* in your country?
Nine experts from France, Italy, Switzerland, Russia, Canada, the Netherlands, and Germany answered on question 1 that the dispersal of ragweed seeds with construction material such as sand, gravel, construction waste is of high importance for the spread of the species in their country (Fig 3). This is also relevant in Israel but a score was not possible here. In Denmark where ragweed is still rare, this pathway of spread is currently of low importance. Six experts thought that transport of ragweed seeds sticking to agricultural machinery is a more important pathway in their countries (Switzerland, Israel, Russia, France, Italy). Bird seed is mentioned to be an important pathway of introduction in the Netherlands, Belgium, Denmark, and also in Germany. In Switzerland this was a crucial pathway in former times, but due to legal regulations that prohibit animal feed to contain ragweed seeds (>0.005% ragweed seeds/kg) it is not relevant any more. In Canada, Russia, and Italy a loss of ragweed seeds during the transportation of agricultural products is important for the spread of Ambrosia, and this is mentioned as the most important spreading pathway in Russia (S. Reznik). In Russia and Italy the introduction of ragweed seeds with contaminated sowing material is important for the dispersal of the species.

The answers of the experts compiled in Fig 3 demonstrate that different pathways are relevant in the spreading process of Ambrosia. The spread of ragweed seeds with construction material is relevant in many countries.
Question 2: Is the building sector informed about the Ambrosia-problem?
Six experts mention that the building sector is not informed about the Ambrosia-problem in their country. Two have no information about this, but doubt that the sector is informed. Six experts say that the building sector has knowledge on the problem but does not conduct special control measures against the species. In France and Italy, in few cases only special control measures against Ambrosia are undertaken. In Italy, for example, operators sometimes plant antagonistic grasses to suppress ragweed (M. Bonini).

Question 3: Are there legal or other regulations to avoid dispersal of Ambrosia seeds with soil or construction material in your country?
Referring to the answers of eight experts, there are no or no special regulations regarding this question in Denmark, Belgium, The Netherlands, Germany, France (2x), Italy and Israel. Four persons had no information on this topic. In France regulations are set in force by local authorities in infested areas but no national regulation exist (B. Laitung). In Switzerland the use of soil contaminated with Ambrosia seeds is prohibited (A. Demierre). In the Lombardy region in Italy Ambrosia must be controlled by mowing between June and 20th August in general, but there are no special regulations to prevent the spread of Ambrosia with construction material (O.P.G.R. 29th March 1999, M. Bonini).
Unfortunately, we did not receive information from experts from heavily infested south-east European countries.
3.2 The role of construction activities in the spreading process of Ambrosia

Ambrosia achenes can be transported with excavated material over long distances and can reach new sites and areas far away from the initial seed source. From own investigations in Germany we learned that soil excavated at a construction site is often not directly used for construction work at other places but deposited at special sites and used later (Fig 2). Soil depots often provide suitable conditions for pioneer species such as Ambrosia, like disturbed, sunny vegetation-free sites where these species can grow and produce seeds. A large quantity of soil can become infested with ragweed seeds at the depots when contaminated soil is mixed with ragweed-free material. Contaminated material can be dispersed widely during construction works, and by this way ragweed can be transferred to many new locations (Fig 4 c, d, Fig 2).

In some cases soil from construction sites is dumped at agricultural fields (Fig 4 a, b). If the soil is contaminated with ragweed seeds the species can be introduced there.

Fig 4: Pathways of spreading for ragweed with excavated material.

a) Soil depot with ragweed occurrence, Strullendorf, Bavaria, 29th Oct. 2009
b) soil depot at an onion field, Griesheim, South Germany, 29th July 2007
c) construction site with ragweed occurrence, Griesheim, 27th June 2006
d) ragweed occurrence at the sides of a newly built road in a reconstructed mining area near Senftenberg, East Germany (10th July 2011).
3.2.1 Situation in Europe

As we know from other invasive plant species such as *Fallopia japonica*, the spread via soil is very effective and can result in a wide distribution of a species. According to Bassett & Crompton (1975), the achenes of Ambrosia are mostly dispersed by human activities with soil or seed transportation. Bohren et al. (2005) describe the transport of humus to construction sites and to gravel pits as an important spreading route in Switzerland. Spread with excavated material is also relevant in Switzerland. Transportation of soil and gravel between neighbouring countries is a common practice in parts of Europe, particularly between Switzerland, France and Italy, where construction materials and substrates near borders are exchanged across borders, which may lead to the establishment of ragweed on new sites (Bohren 2007, Buttenschøn et al. 2010). Bohren (2007) describes that machines for soil treatment are routinely exchanged between French regions of Lyon and the Swiss Basin Lemanique. Also, Essl et al. (2009) mention the transportation of soil as an important pathway for the spread of Ambrosia in Austria.

3.2.2 Relevance of ragweed spread with excavated material in relation to the scale of the Ambrosia infestation – an example from Germany

The relevance of spreading routes of Ambrosia often depends on the scale of the infestation in a country or a region. Our investigations conducted in Bavaria (where ragweed is not very common) had shown that the dispersal of Ambrosia seeds with excavated material was of lower importance compared to introductions with bird seed (Fig 5, unpublished data; Nawrath & Alberternst 2007 to 2012). 29 % of the large ragweed stands (> 100 ragweed plants) currently (2012) known in Bavaria were introduced with bird seed, whereas 18 % were introduced with soil/excavated material. For 109 stands at roadsides no pathway of introduction was detectable, but it is unlikely that the species came here with excavated material. However, during the last years the transfer of ragweed seed with soil has increasingly been observed in Bavaria. For regions where ragweed is common and already occurs in the system of soil transport and use, we expect that the spread with soil will become increasingly important.

Common ragweed is not evenly distributed in Germany. Whereas in Bavaria the species is still relatively rare, it is common in the “Niederlausitz”, an area south-east of Berlin, near the Polish border (Fig 6). In this region extensive ragweed populations occur, e.g. on agricultural fields, at ruderal sites, and also along roadsides (Brandes & Nitsche 2006, Jentsch 2007, Nitsche 2010, Lemke oral presentation 06/23/2010). To learn more about the spread of Ambrosia with excavated material in this highly infested region, and to find out whether this spreading route is more relevant than in regions with low infestations, investigations described in the following were conducted in 2012.
Fig 5: Pathways of introduction of n=279 large ragweed stands (>100 individuals) known in Bavaria till 2012.

Fig 6: Map of Germany with the federal states Brandenburg and Bavaria. Investigations were done in the “Niederlausitz” (marked in red). Results were compared with findings from studies conducted in Bavaria since 2007.
3.2.3 Relevance of transient soil depots for the spread of Ambrosia in Germany

3.2.3.1 Examples from the Niederlausitz (East-Germany)

*Ambrosia artemisiifolia* was found at 7 of the 11 (63.6 %) transient soil depots investigated in this study (Tab 1, Fig 7).

**Tab 1:** Transient soil depots operated by construction companies or road maintenance services, or used during construction work investigated in September 2012.

<table>
<thead>
<tr>
<th>No</th>
<th>Location</th>
<th>Type</th>
<th>Size (^1)</th>
<th>Method</th>
<th>Geographic coordinates WGS84</th>
<th>Ragweed occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cottbus, Industrial area „Am Gleis“</td>
<td>Depot of building material, operated by construction company</td>
<td>large, 24000 qm</td>
<td>premises inspected</td>
<td>51.770099 14.378945</td>
<td>extensive ragweed stand, rich in individuals, at storage place of construction material (Fig 8)</td>
</tr>
<tr>
<td>2</td>
<td>Cottbus, Industrial area „Am Gleis“</td>
<td>Transient soil depot of building company</td>
<td>large, ca. 14500 qm</td>
<td>premises inspected</td>
<td>51.771486 14.379283</td>
<td>extensive ragweed stand, rich in individuals, on soil heap (Fig 8)</td>
</tr>
<tr>
<td>3</td>
<td>SW of Drebkau</td>
<td>Transient soil depot and storage area of construction company</td>
<td>very large, 40000 qm</td>
<td>premises inspected</td>
<td>51.648756 14.203109</td>
<td>extensive ragweed stand, rich in individuals, on soil heap and in storage area (Fig 8)</td>
</tr>
<tr>
<td>4</td>
<td>W of Drebkau-Siewisch</td>
<td>Transient soil depot and storage area of construction company</td>
<td>large, 13000 qm</td>
<td>premises inspected</td>
<td>51.677955 14.190555</td>
<td>extensive ragweed stand, rich in individuals, in storage area</td>
</tr>
<tr>
<td>5</td>
<td>near junction Forst A 15 SW of Forst (Lausitz)</td>
<td>Transient soil depot of road maintenance service</td>
<td>small, ca. 1800 qm</td>
<td>premises inspected</td>
<td>51.711287 14.609634</td>
<td>small stand, locally numerous individuals, on soil heap</td>
</tr>
<tr>
<td>6</td>
<td>N of Peitz</td>
<td>Transient soil depot and area of construction company/concrete factory</td>
<td>small, 800 qm</td>
<td>Partially seen from outside</td>
<td>51.871657 14.411245</td>
<td>small stand on soil heap and in storage area</td>
</tr>
<tr>
<td>7</td>
<td>E of Burg (Spreewald) district Schmogrow-Fehrow, street L 501</td>
<td>Transient soil depot built during road construction (L 501)</td>
<td>small, 240 qm</td>
<td>premises inspected</td>
<td>51.852245 14.225585</td>
<td>small stand</td>
</tr>
<tr>
<td>8</td>
<td>N of Sielow, street L 50</td>
<td>Transient soil depot built during road construction (L 50) L 50</td>
<td>small, approx. 500 qm</td>
<td>premises inspected</td>
<td>51.840701 51.840701</td>
<td>not found</td>
</tr>
<tr>
<td>9</td>
<td>E of Spremberg</td>
<td>Transient soil depot operated by construction company</td>
<td>small, ca. 1700 qm</td>
<td>premises inspected</td>
<td>51.569115 14.413370</td>
<td>not found</td>
</tr>
<tr>
<td>10</td>
<td>E of Spremberg</td>
<td>Transient soil depot operated by construction company</td>
<td>medium-sized, ca. 2000 qm</td>
<td>premises inspected</td>
<td>51.571839 14.412445</td>
<td>not found</td>
</tr>
<tr>
<td>11</td>
<td>E of Spremberg</td>
<td>Transient soil depot and storage area operated by construction company</td>
<td>medium-sized, ca. 2700 qm</td>
<td>premises inspected</td>
<td>51.578519 14.406793</td>
<td>not found</td>
</tr>
</tbody>
</table>

\(^1\) size = area investigated for ragweed occurrence
Fig 7: Location and number (compare Tab 1) of the transient soil depots investigated for ragweed occurrence in the Niederlausitz near Cottbus, East-Germany, September 2012. At seven of the eleven sites investigated, ragweed plants were found.

At the sites 5, 6, and 7 only a small amount of Ambrosia-plants occurred. At the sites 1 to 4 in Drebkau, Siewisch, and Cottbus hundreds of ragweed plants were found at the transient depot sites. The ragweed plants mainly grew in ruderal sites and on soil heaps which were not removed for at least one year (Fig 8).

The maps illustrated in Fig 9 demonstrate the distribution of ragweed at the transient soil depots in Cottbus, Drebkau, Siewisch, and Drebkau. In Drebkau some heaps of construction material with ragweed stands were present at the margins of the site (Fig 9). In Siewisch and Cottbus Ambrosia was distributed nearly over the whole soil depot. In Cottbus the species was found on three different soil heaps which were used by different operators. Some of these operators are also involved in construction work at roads. A heap of humus rich material which was used to fill in verges at road margins (pers. communication with a foreman at a disposal site in 2012) was covered with Ambrosia. This strongly indicates that common ragweed is spread with construction material from the soil depots.
Fig 8: Ragweed occurrence at transient soil depots in Drebkau (a-c) and Cottbus (d), Sept 2012.
3.2.3.2 Examples from former studies in Bavaria (South-Germany)

To compare a region with high ragweed infestations with an area with low infestations, the results from former studies in Bavaria are presented (Nawrath & Alberternst 2008, 2009, 2011, 2012). In 2009 and 2010, Ambrosia plants occurred in 11 out of 68 (16.2 %) soil depots investigated in Bavaria. The populations were small and comprised of single plants or small stands up to 40 individuals (Nawrath & Alberternst 2011). In Bavaria, where compared to the situation in Brandenburg only a small amount of ragweed occurs, the species was found in relatively small quantities at soil depots.

It is not normally possible to track back the mechanism of introduction of Ambrosia into a given site, but it may be done where the degree of infestation is low and only few pathways need to be considered. We were able to demonstrate this with the example Hilpoltstein, a village in Bavaria: In the county 25 big (> 100 individuals) ragweed stands are known. Five of these stands and one population of less than 100 plants could be traced back to a single soil depot in Hilpoltstein that supplied soil for construction works in the county (Fig 12). Sometime before that, ragweed had entered the soil depot with soil from a construction site nearby. The construction site had been used as a cut flower field with sunflowers planted with seeds from bird seed. Ragweed was unintentionally introduced here by the farmer with the bird seed. Although it became known to the operator of the soil depot that this soil was contaminated with ragweed seeds, the soil was still sold.
**Fig 10:** Excavated soil at the construction site „Am Falkenhorst“ in Hilpoltstein.

In 2007 a large ragweed population was found at this construction site. Excavated material from here was transported to the transient soil depot in Hilpoltstein.

**Fig 11:** Soil depot with ragweed in Hilpoltstein in Bavaria.

The transient soil depot received soil from a construction site nearby („Am Falkenhorst“) that was built on a former cut-flower field. Sunflowers from bird seed that was used for sowing material were cultivated here.

**Fig 12:** Transient soil depot in Hilpoltstein (black dot) that was shown to be the origin of six new ragweed stands (red dots) in the county Roth, Bavaria (Germany) in 2012.
3.2.4 Spreading of Ambrosia enhanced by road construction work - examples from the Niederlausitz

Ragweed along roadsides in the Niederlausitz

In the study area in the Niederlausitz, *Ambrosia artemisiifolia* often occurs at road margins (Jentsch 2007, Nitzsche 2010, Lemke 2010). Also in 2012 extensive ragweed stands were found at roadsides (Fig 13). From the road sides Ambrosia is able to spread into other habitats such as agricultural fields or ruderal areas.

A map, provided in the internet by the Free University Berlin (FU Berlin 2013), shows the distribution of *Ambrosia artemisiifolia* in Berlin and Brandenburg. It can be seen that the most extended ragweed stands in the Niederlausitz occur around the town Drebkau south-west of the city Cottbus. Here many agricultural fields are heavily infested with *Ambrosia*. According to the FU maps, ragweed is less common in the surrounding areas. The species is rarely found in agricultural fields and occurs predominantly at road margins. The distribution of common ragweed in this region was not mapped consistently over the whole area, existing information is mainly based on voluntary reporting. This may result in a bias with ragweed stands in agricultural fields being reported less than roadside populations. However, the very high proportion of ragweed stands at road margins indicates that roadsides are very important spreading routes and can be the gateway to new regions.

How can ragweed colonize road margins and spread there?

There are different ways how ragweed seeds can reach the road margins. Ambrosia achenes may be lost during the transportation of agricultural products. They may also be spread by agricultural machines when seeds stick to them with or without soil and are lost on the road. Once ragweed has reached the road, it can be spread with mowing machines when these are used during the maturity of seeds (Vitalos & Karrer 2009, Nawrath & Alberternst 2011a). An important pathway of introduction at the road margins is the use of construction material which is contaminated with ragweed seeds. During our field work in 2011 and 2012 examples for this pathway were found in the study area.

Introduction of ragweed with construction material

In Tab 2 (compare Fig 13) newly built roads and roads with rebuilt verges are listed. At these sites ragweed plants were found during the investigations in 2011 and 2012. Ragweed was introduced here likely with contaminated soil. Two of these roads are described in more detail below.
**Fig 13:** Occurrence of *Ambrosia artemisiifolia* at road margins in the Niederlausitz near Cottbus, East-Germany, September 2012.

Marked in blue: Ragweed occurrence at newly built roads and at roads with new hard shoulders. Ambrosia was most probably introduced here with the construction material (Tab 2).

**Tab 2:** Ragweed stands at newly built roads which were most probably introduced here with contaminated construction material.

Investigations: July 2011 and September 2012

<table>
<thead>
<tr>
<th>No</th>
<th>Location</th>
<th>Type</th>
<th>Length of colonized road section</th>
<th>Method</th>
<th>geographische coordinates WGS84</th>
<th>Ragweed occurrence</th>
<th>Year of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NW of Schipkau, between Klettwitz and Kostebrau</td>
<td>Newly built road, road deallocated in 2010</td>
<td>&gt; 4.2 km</td>
<td>inspected from a car – from a bicycle – on foot</td>
<td>51.516357 13.838765 bis 51.535074 13.882989</td>
<td>Scattered, partially rich in individuals</td>
<td>2011</td>
</tr>
<tr>
<td>2</td>
<td>Near Drebeckau, B169</td>
<td>Road construction road deallocated in 2009</td>
<td>&gt; ca 8 km</td>
<td>inspected from a car</td>
<td>51.6661614.242706bis 51.630018 14.174699</td>
<td>Very rich in individuals</td>
<td>2012</td>
</tr>
<tr>
<td>3</td>
<td>W of Spremberg and Schwarze Pumpe, B97/new</td>
<td>Road construction, road deallocated in 2010/11</td>
<td>&gt; ca 12 km</td>
<td>inspected from a car, partially on foot</td>
<td>51.59768714.363081 bis 51.502121 14.332527</td>
<td>Single plants up to individual rich stands</td>
<td>2012</td>
</tr>
<tr>
<td>4</td>
<td>Nordöstlich Cottbus bei</td>
<td>Road construction, road</td>
<td>&gt; ca. 4.4 km</td>
<td>inspected from a car</td>
<td>51.757307 14.402565 bis</td>
<td>Single plants, rich in individuals</td>
<td>2012</td>
</tr>
<tr>
<td>No</td>
<td>Location</td>
<td>Type</td>
<td>Length of colonized road section</td>
<td>Method</td>
<td>geographische coordi-nates WGS84</td>
<td>Ragweed occurrence</td>
<td>Year of study</td>
</tr>
<tr>
<td>----</td>
<td>---------------------------------</td>
<td>-------------------------------</td>
<td>----------------------------------</td>
<td>----------------</td>
<td>---------------------------------------</td>
<td>---------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
<td>Merzdorf, B168neu</td>
<td>deallocated in 2012</td>
<td></td>
<td>partially on foot</td>
<td>51.790382 14.376286</td>
<td>mainly at areas aside of the road</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sielow, „Sielower Chaussee“</td>
<td>Road construction ca. 2011/2012</td>
<td>&gt; 750 m</td>
<td>inspected on foot</td>
<td>51.787729 14.309792</td>
<td>Single plants</td>
<td>2012</td>
</tr>
<tr>
<td>7</td>
<td>Turnow, „Wiesenweg“</td>
<td>Road construction ca. 2011</td>
<td>&gt; ca. 150 m</td>
<td>inspected on foot</td>
<td>51.872610 51.872610°</td>
<td>Low number of plants</td>
<td>2012</td>
</tr>
</tbody>
</table>

**Example 1: A newly built road located northwest of Schipkau**

At a newly built road in an extended reconstruction area between the villages Klettwitz and Kostebrau northwest of Schipkau in East-Germany ragweed was observed first in 2010, shortly after finishing the construction works (FU Berlin 2013). Also during the field work at 6th July 2011 many ragweed plants were observed at the margins of this road (Fig 14). The ragweed plants occurred predominantly on one side of the road whereas no or only a few plants were found on the opposite side of the road.

![Map basis: OpenStreetMap](image)

**Fig 14:** Newly built road in a reconstruction area connecting the villages Klettwitz and Kostebrau near Senftenberg (2011/0706).

At the road margins ragweed which was very likely introduced with construction material occurs.
At the roadside where the ragweed plants occurred, a humus-rich material was used to fill the hard shoulder (Fig 15). At the opposite side of the road no or only less of this material was used.

The road runs through an open, vegetation-poor area which provides good conditions for the pioneer species Ambrosia. Unfortunately it is not allowed to walk in the reconstruction area. So only the margins of this region could be inspected (Fig 15). In the visible area, ragweed plants were only registered at the margins of the road but not in surrounding areas. This indicates that Ambrosia was not introduced from the surroundings and supports the observation that ragweed was introduced with the humus-rich material used to fill in the road margins.

**Fig 15:** Newly build road in a reconstruction area connecting the villages Klettwitz and Kostebrau near Senftenberg (photo: 2011/07/06).

- a) Newly built road in a reconstructed mining area.
- b) Common ragweed occurs at the road margin.
- c) Common ragweed grows predominantly at the road side where brown humus was brought in while on the opposite road side no or less of this substrate was used.
- d) Vegetation-poor reconstruction area which is not allowed to enter. Looking from the road in this area, no ragweed plants were detected. The plants only occurred at the road margins.

**Example 2: A newly build road located east of Drebkau**

The newly build road B169 which bypasses the town of Drebkau over a length of 8 km was opened in December 2009 (BMVBS 2009). At this road millions of ragweed plants occurred
in 2011 and 2012 (Fig 13). *Ambrosia artemisiifolia* was introduced here probably with construction material and spread quickly over the last few years.

Fig 16: B169 near Domsdorf. At the margins of this newly built road millions of ragweed plants are present. Ragweed was probably introduced here with construction material and dispersed during the construction work (photo 2011/07/10).

### 3.2.5 Discussion

The investigation in Germany demonstrates that ragweed is often dispersed with soil in areas highly infested with the species. Where ragweed is still rare, a spread with soil takes place to a lesser extent. It may, however, be of larger importance and can be a main mechanism to allow colonization of a new area. The spread with excavated material is a very effective spreading route. Thus, in countries with low infestations measures to prevent ragweed spread with excavated material should be conducted in an early phase of the spread. Measures should aim at preventing ragweed from entering the soil distribution cycle of the building industry.

### 3.3 Measures to prevent seed dispersal with soil

There are different possibilities to avoid the dispersal of ragweed seeds with excavated material during construction works (Tab. 1). In a first step it is essential to detect a contamination of a site with ragweed seeds before seeds are spread via excavated material.

#### a) Detection of ragweed plants and seeds

If a population of ragweed plants is present on a site, it is very likely that the soil contains seeds of the species. The site where construction measures are planned should be checked for ragweed plants before the building works start.

A seed bank of ragweed can be present even when the plants are not visible, e.g. when they were outcompeted by native vegetation. If there is a suspicion that soil could be contaminated with ragweed seeds, the soil should be investigated. No standards or regulations exist currently on best practices how to find ragweed seeds in the soil.
When a soil sample is taken, the ragweed seeds must be detected in the soil. One possibility to find the seeds is to dry and sieve the soil, and afterwards search thoroughly for the achenes. This measure is very labour-intensive. Another option is to put the soil in flat bowls in order to germinate all seeds. For this method ideal growing conditions for the species must be provided and it takes time before the seeds germinate and results are achieved. It should be taken into consideration that Ambrosia seeds need stratification before they germinate properly.

It could also be possible to develop special DNA-tests to find ragweed seeds in soil samples. Currently we are lacking information on this topic.

b) Options to prevent spread of ragweed seeds in excavated material

Excavated material should be kept at the same site and it should be separated in order to avoid contamination of clean material (see Fig 17). Newly grown ragweed plants should be removed before seed set. A cover of the contaminated soil heaps with a dark membrane could help to prevent germination and seed set of Ambrosia plants. If possible, the contaminated soil should be used for fillings below the surface. If this is not possible, the material should only be used in areas where control of Ambrosia is ensured over several years until no ragweed plants grow up any more. A control of success is necessary. If it is not feasible to keep the soil at the same site, the material could be transported to a location where it is used in civil engineering processes and is deeply buried. Instead of burying, the soil could also be used for construction work in areas where no suitable growing conditions for the species are present (e.g. sealed areas, intensively used grassland). A mixture with uncontaminated soil should be avoided and the material should only be transported to a single site in order to prevent dispersal to different locations.

It is another option to finally dump the material at a special site, or to sterilise it. A compilation of possibilities to treat contaminated soil and an assessment of efficacy and effort is given in Tab 3.
Fig 17: Options to prevent the spread of Ambrosia in contaminated, excavated material.

Estimation of infestation with ragweed seeds (seed content, volume/amount of soil)
- separation of contaminated soil
- no mixture with clean soil

Soil is kept at site, no transportation
- advantages: no dispersal at new sites,
- no seed losses during transportation

Transportation to new site
- only one receiving site
- no interim storage

Soil disposal

Covering with uncontaminated soil / deep burial
- sufficient layer thickness must be considered

Use of soil at surface + combat of ragweed plants
- recommendable only in cases of low infestations
- at stands where ragweed can be removed easily, ragweed is sustainably suppressed or where growing conditions are not suitable for ragweed
- perennial control measures must be ensured, regular control of success

Soil sterilisation (e.g. steaming), composting (?)
Tab 3: Possibilities to treat contaminated soil and assessment and effort of measures.

<table>
<thead>
<tr>
<th>measure</th>
<th>assessment &amp; effort</th>
</tr>
</thead>
</table>
| final dumping at a special land fill, no further use of soil | • effective measure  
• risk of seed losses during transportation  
• loss of top soil for further use  
• cost for transport and final depot  
• cost for cleaning of the machines |
| deep burial, cover with non-contaminated material | • effective measure  
• loss of top soil for further use  
• relatively low effort when material is buried at same site  
• cost for transport if buried at other site  
• cost for cleaning of the machines  
• risk of seed losses during transportation |
| use of contaminated soil and control of Ambrosia at site | • only advisable at same site when ragweed control is ensured for several years  
• at sites where no suitable growing conditions for Ambrosia are present  
• only advisable at sites with small ragweed populations  
• not advisable at road sites, river channels  
• effort for combat depends on size/dispersal of the ragweed population and on consistency of control measures |
| sterilisation of soil | • effective  
• very laborious, high energy input, cost-intensive  
• risk of seed losses during transportation of material |

In general
• if possible use contaminated material at same site only  
• avoid transport due to risk of seed losses/dispersal  
• separate contaminated material in order to avoid contamination of clean material  
• if transport is necessary, only transport to a single site (no dispersal of contaminated material at different sites)  
• avoid seed losses during transportation, cleaning of machines  
• monitor sites where a ragweed contamination is known, control of success of control measures

3.4 Methods to sterilise soil

An effective non-chemical method to decontaminate soil of bacteria, viruses, fungi, nematodes and weed seeds is a treatment with hot steam. Most weed seeds exposed to temperatures of 70-80 °C over 15 minutes die (Gudehus 2005). Steaming of soil is a method which is often used in horticulture. It is possible to steam soil surfaces in place, or substrata can be transported to a special steaming facility.

3.4.1 Steaming of soil surfaces

There are different methods to sterilise soil surfaces such as steaming with foils, vapour hoods, steam harrows, steam ploughs, and steaming with negative pressure by using drainage pipes (Lampe 2011). The following descriptions of the steaming methods base on Gudehus (2005) and Lampe (2011).

To steam areas of 15 to 400 m² special heat-resistant sheets are put on the soil and weighed down with sand sacks. Hot steam is produced by a special steam-boiler and conducted un-
nder the sheet. Depending on the condition of the soil and the air temperature it takes 1 to 1.5 h per 10 cm of soil depth to reach 85 °C.

A vapour hood is a portable equipment which is put on the soil that should be treated. Depending on the model and the size of the vapour hood the equipment is put on the area that should be treated with a tractor or by hand. It takes 30 minutes to heat the soil to 90 °C up to a depth of 25 cm.

Small areas can be treated with a steam harrow. This machine is constructed with tines via those the hot steam is led into the soil.

Using a steam plough is the oldest procedure to decontaminate soil. This machine is usually used in glass houses. It is a rake-like construction that is pulled by a cable winch through the soil. Through the blades of the plough hot steam is led into the soil.

It is possible to steam soils up to a depth of 80 cm by using a special drainage system that is either installed on the soil surface or buried in the soil. The drainage pipes are used to aspirate the air in the soil. The soil that should be sterilised is covered with a special foil that is sealed at the edges. The vapour is conducted under the foil and due to the aspirated air a vacuum is build up and the hot steam flows into the soil (Gudehus 2005, Lampe 2011).

3.4.2 Steaming of substrata

Material such as excavated soil or compost that should be sterilised can either be transported to a steaming facility (Gudehus 2005), or a mobile steaming machine can be transported to the site. The material can be put on a sterilised ground (e.g. concrete) and then can be heated with hot steam supplied via pipe systems. Other options are to put the material in a steaming box or on a special tipping trailer where hot vapour is passed in.

3.4.3 Composting

In Baden-Württemberg, South Germany, soil containing rhizomes of the invasive Japanese Knotweed (*Fallopia japonica*) is composted in order to kill the rhizomes. The knotweed contaminated soil is enriched with fresh compost and composted at a temperature of 70 °C. During the composting procedure it is necessary to rearrange the compost 6 to 8 times (Email B. Walser 2012/12/18). This measure might also be used to decontaminate soil containing ragweed seeds. In trials it should be ensured that the ragweed seeds were killed by this method. If the temperature is not high enough, ragweed can survive the composting procedure as it was observed in Bavaria in 2012, where in July 2012 four vital ragweed plants were found on heaps of composted material (Fig 17). Further details are expected from HALT AMBROSIA Task B.
3.5 Regulations to prevent the spread of ragweed in soil in European countries

In our study we only found little information on legal regulations regarding the treatment of contaminated soil in European countries. Switzerland has the most comprehensive regulations, and in France legal regulations exist, but only on a regional level. The Lombardy region in Italy has regulations to control ragweed by mowing, but there are no special regulations regarding the prevention of spread with soil (O.P.G.R. 29th March 1999, N. 25522). Kazinczi et al. (2008b) give a short overview of authority arrangements in Hungary. A special regulation regarding the treatment of excavated material used for construction work is not mentioned by these authors. In Germany only voluntary programmes against Ambrosia exist.

3.5.1 Switzerland

The use of soil contaminated with Ambrosia seeds is prohibited in Switzerland. If Ambrosia is introduced at new sites during construction measures the owner of the site is legally obliged to remove the plants before they spread (result of inquiry: information given by A. Demierre). The control of Ambrosia is mandatory in Switzerland. In this country the polluter pays principle is used and the land owner, the user of the land, the building contractor or the haulier is obliged to remove Ambrosia. There are special regulations to avoid the spread of Ambrosia in soil, humus, excavated material, compost etc. in the Kanton Graubünden. The following regulations are in force (Amt für Natur und Umwelt Graubünden 2007):

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- soil contaminated with ragweed seeds must not be transported and reused at new sites but must be collected at controlled dumps where a combat is guaranteed,
- re-using contaminated soil is only allowed at locations where control is ensured for a long time (e.g. at small construction sites),
- machines must be cleaned from soil, to ensure that no ragweed seeds sticking to the machines are dispersed,
- before construction work, recultivation or other activities including earthworks take place, it has to be clarified whether the soil is contaminated with ragweed seeds. The import of soil from regions where extensive ragweed stands occur (Tessin, North-Italy...
and the Misox valley in the canton Graubünden) is not allowed (Amt für Natur und Umwelt Graubünden 2007).

The legal basis for the handling of Ambrosia in Switzerland is:

- The Plant protection act (Pflanzenschutzverordnung 28th Feb. 2001, Art. 27-29, Anhang 10)
- The Environmental act (Umweltschutzgesetz 7th Oct. 1983, Art. 29a, Abs. 1)
- The order of release of organisms (Freisetzungsverordnung (FrSV) 25th August 1999, Art. 4, Abs. 1; Art. 32. Abs. 1)

3.5.2 France

In France regulations are set in force by local authorities in infested areas but no national regulation exist (B. Laitung). In general, soil used by operators must theoretically be protected against weed seed rain in France (B. Chauvel). However, mostly no measures to avoid the spread of Ambrosia are conducted, and referring to an estimation of B. Chauvel from France only “powerful” structures such as mayors of big cities or motorway companies may force operators to avoid the spread of the species.

In France much information is available how to control Ambrosia (e.g. www.ambroisie.info.fr). On that webpage special information is provided on methods how to deal with Ambrosia at construction sites (http://www.ambroisie.info/docs/fiche_6.pdf).

3.5.3 Italy

In the Lombardy region (Italy) owners and land users are obliged to remove Ambrosia between the end of June and the 20th August. Mayors of municipalities affected by ragweed occurrence are obliged to survey the compliance of the regulations (O.P.G.R. 29th March 1999, N. 25522). There is no special prescription given to prevent the spread of Ambrosia with excavated material used for construction work.

3.5.4 Germany

In Germany action programmes exist that aim at the prevention of spread and the control of common ragweed (Starfinger 2012, STMUG 2013). These programmes also provide information on how to prevent the spread of ragweed with excavated material. In Germany the control of common ragweed is not mandatory and no legal regulations comparable to those in Switzerland exist. Currently there is no or only little awareness of the ragweed problem in the building sector in Germany. Authorities have no legal options to force control measures in order to prevent a spread during construction work. At soil depots usually no weed control takes place. Special information campaigns for the building sector are of high importance in order to avoid the spread with excavated material.
4 Recommendations

Spread of Ambrosia seeds with soil is very effective and can lead to the colonization of new sites and areas. Thus, concepts to avoid the spread with excavated material are needed. Experiences from Germany demonstrate that voluntary action programmes (national and federal state scale) against Ambrosia did not raise awareness in the building sector by now. The inquiry done in this study stresses this result for other European countries where no legal regulations regarding this issue exist. Switzerland has implemented legal regulations that include an ordinance for the building sector. The example of Switzerland where ragweed is controlled effectively demonstrates that it is necessary to create awareness of the Ambrosia problem in the building sector. There are different possibilities to prevent the spread of Ambrosia in excavated material as described above. However, most of these measures are cost- and/or labour-intensive and would not be done on a voluntarily basis. So, legal regulations for the building sector are needed.

Exemplary proceedings regarding biologically contaminated soil in Switzerland
In Switzerland a special legal obligation regarding the disposal of excavated material contaminated with organic material (Neobiota) exist in the canton Zürich (Baudirektion Kanton Zürich 2011). This regulation especially refers to invasive species such as *Fallopia* sp., *Polygonum polystachyum*, and *Rhus typhina*, but in our opinion it is exemplary, and it may also be used to prevent the spread of Ambrosia with excavated material.

The regulation says: If an invasive plant species occurs at a construction site the building owner has to fill in a declaration in collaboration with a special consultant and has to send to the authorities. Contaminated soil that cannot be used at the site has to be disposed of at authorized sites. In this case the proceeding is as follows:

- a) Before construction work starts the area contaminated with an invasive species and the amount of contaminated soil has to be quantified.
- b) A commitment to purchase the material has to be sought from the operator of an authorized dump site and a concept for the disposal has to be sent to the authorities.
- c) The affected area has to be marked at the construction site in order to avoid a contamination of clean material.
- d) Before construction work starts, the site has to be visited by the consultant, the foreman, the operator, and the excavator driver.

During the construction work the contaminated material must not be mixed with clean material and it has to be separated. During the excavation a consultant has to be present at the construction site. It has to be ensured that no contaminated material is lost during the transportation. After transportation to the dump, a form with a report has to be sent to the authorities. 1-2 month after the combat an authorized consultant has to control whether no invasive plants grow back at the site (Baudirektion Kanton Zürich 2011).

Involvement of Ambrosia in tenders for construction work
Instructions to prevent the spread of Ambrosia during construction work could be included in announcements. The building owner should be informed about Ambrosia and the problematic of spreading during construction work. He could be obliged to investigate the construction site for the occurrence of ragweed (or other invasive) plants in the vegetation period
(June – October, when Ambrosia is detectable) before any construction measures take place. The result should be sent to authorities that build up a data collection on Ambrosia, respectively on invasive species. A building owner should be obliged to seek for information on ragweed stands from the authorities. In case ragweed occurs at a site, the owner is obliged to prevent the spread (e.g. no transportation of soil, or safe disposal of soil at special site, or deep burial). In the performance description for building constructions of the Ministry of economy, family and youth in Austria (BMWFJ 2012) there is a regulation regarding soil depots (no 581311A). This says that soil depots fostered and hold free of weeds can be brought to account. Costs can be estimated in $m^3 \times$ weeks. This might also a basis for cost calculations for soil depots kept free of Ambrosia.

If no ragweed is present before the building work starts, the owner can oblige the building company to make sure that no ragweed is present after finishing the construction work. If soil with ragweed stands was introduced and detected during the construction phase, the building company can be obliged to prevent spread from this soil (see above). In case ragweed already occurs after finishing the construction work the construction company could be obligated to combat Ambrosia.

This proceeding should be communicated with the building sector.

## 5 Summary

- Spreading with excavated material is an effective spreading mechanism for common ragweed in Europe.
- The relevance of the soil pathway often increases when the infestation with ragweed in a region increases (e.g. in Germany).
- In the Niederlausitz in East-Germany construction measures at road margins led to an increase of the ragweed population at roadsides during the last years.
- The use of soil contaminated with ragweed seeds at soil surfaces should be avoided. Contaminated soil should be deeply buried, dumped or decontaminated. It could be used at sites, where no suitable growing conditions for Ambrosia are present.
- It should be avoided to transport contaminated soil in order to prevent seed losses during the transportation. If a transport is not avoidable contaminated soil should be transported only to a single site (no dispersal). If contaminated soil is used at the surface an effective combat of Ambrosia should be ensured over several years.
- In most of the European countries no special measures are conducted to prevent the spread of common ragweed with excavated material, by now. Comprehensive legal regulations currently exist in Switzerland. In many European countries the awareness of the Ambrosia problem in the building industry is low and even if the sector is informed, without legal regulations usually no control or prevention measures occur (cost- and labour-intensive).
- Management programmes on a voluntarily base often did not reach the building sector in Germany. In many cases ragweed plants were not or not sufficiently removed (with some exceptions).
6 References


ESSL, F., DULLINGER, S., KLEINBAUER, I. (2009): Changes in the spatio-temporal patterns and habitat preferences of *Ambrosia artemisiifolia* during its invasion in Austria. Preslia 81: 


Appendix: Questionnaire

Relevance of soil and construction material for the spread of *Ambrosia artemisiifolia*

Dear addressee,

seeds of the invasive and troublesome ragweed are dispersed via a number of pathways, several of them aided by humans. In the course of the EU funded project HALT AMBROSIA we are currently studying the role of construction activities in spreading the plant. As there is little published information available, we try to find out more with this short questionnaire. We hope you can find a few minutes to fill it in. You are also welcome to pass it on to colleagues who might know more or to give us additional contacts. Thank you very much for your help!

Name:
Institution/address:
Contact details:
Main field of work:

Please return the questionnaire to Beate Alberternst b.alberternst@online.de.
Postal address: Beate Alberternst, Hinter‘ m Alten Ort 9, 61169 Friedberg

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1) How important are the following spreading pathways for *Ambrosia artemisiifolia* in your country? Please fill in □

<table>
<thead>
<tr>
<th>Relevant 1</th>
<th>Relevance</th>
<th>spreading routes for <em>Ambrosia artemisiifolia</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>medium</td>
<td>high no info</td>
</tr>
</tbody>
</table>

a) **Building sector** (e.g. road building, constructions): Transport of Ambrosia seeds with soil or construction material (e.g. sand, gravel, construction waste; seed loss, growing/reproduction on earth fill)

b) **Building sector**: Transport and loss of ragweed seeds sticking to building machineries (e.g. tires)

c) **Agriculture**: Transport and loss of ragweed seeds sticking to agricultural machines (e.g. tires, mowing machines)

d) **Agriculture**: Transport and loss of ragweed seeds with agricultural products (during harvest)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>e) Agriculture: Use of sowing material contaminated with ragweed seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>f) Traffic: Transport and loss of ragweed seeds sticking to trucks, cars etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>g) Bird seeds</td>
</tr>
<tr>
<td></td>
<td>h) Other:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>i) Other:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>k) Other:</td>
<td></td>
</tr>
</tbody>
</table>

1) Relevant, but no estimation of importance possible
no info = no information of relevance for the spread of Ambrosia

What is the **most important spreading route** of the pathways mentioned above in your country? Please note the number a), b), c) etc:

Comments:

2) **Is the building sector informed about the Ambrosia-problem?** (Occurrence of ragweed plants on soil depots or construction material, reproduction and contamination of the soil with its seeds, important spreading route of Ambrosia via transport of soil etc.)

- I don’t know / no information
- No (operators are often badly informed about the problematic, no measures are undertaken)
- Yes:
  - Yes, operators are informed, but mostly **no measures** to avoid the spread are undertaken
  - Yes, operators are well informed, and measures to avoid the spread are mostly undertaken. Which measures are conducted?

3) **Are there legal or other regulations to avoid dispersal of Ambrosia seeds within soil or construction material in your country?**

- I don’t know / no information
- No
- Yes:
  - The use of soil contaminated with Ambrosia seeds is prohibited.
☐ It is compulsory to separate Ambrosia-contaminated soil from clean soil at soil depositions and to decontaminate it before reuse at other sites
☐ It is compulsory to remove ragweed plants from soil depositions to avoid contamination with its seeds
☐ If Ambrosia is introduced at new sites during construction measures, there is someone legally obliged to remove the plants before they spread (if yes, who?)

Could you give us some information on regulations (if existing), please? (e.g. link to regulation, pdf, or expert who could give us more details)

.................................................................
......
.................................................................
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Thank you very much for your help!!!