

Guidance for the Management of contaminated soil

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Introduction

In order to prevent introduction and spread of common ragweed, 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.

Important pathways of introduction and spreading routes of *Ambrosia artemisiifolia* in Germany

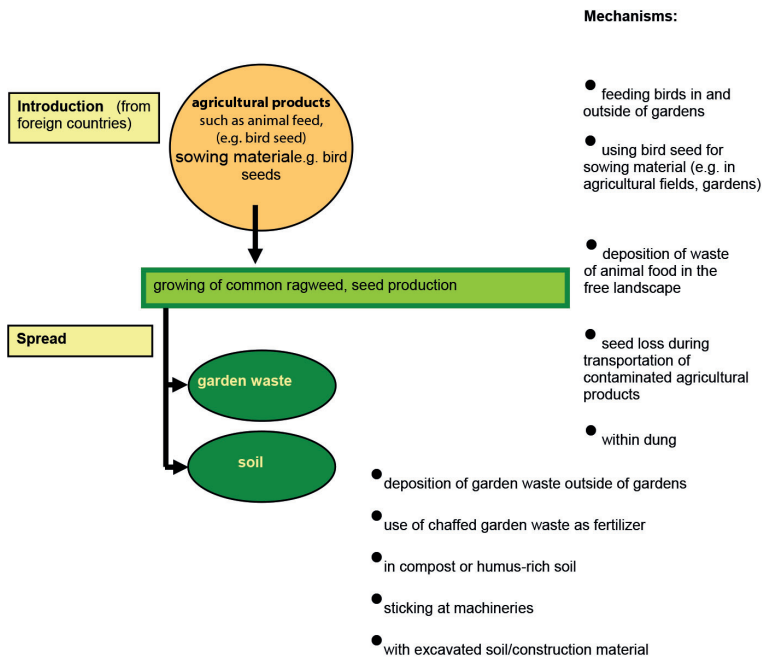


Fig 1: Pathways of introduction and spreading routes of *A. artemisiifolia* in Germany.

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 *A. artemisiifolia* seeds within soil in Germany.

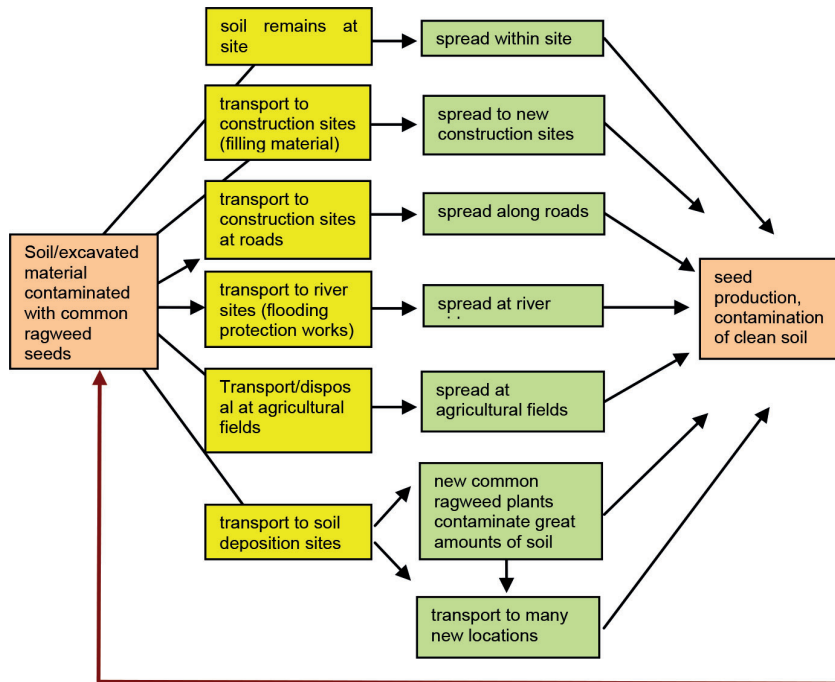


Fig. 2: Possibilities for *A. artemisiifolia* seeds to spread within excavated material.

To install effective and adequate control measures it is necessary to know the relevance of the different routes that the species uses, to enter new growing sites. Spread of *A. artemisiifolia* seeds within excavated material is an important pathway for the species to reach new locations (Bohren 2005, 2007), and thus this is investigated in this study. The aims of this part are, to learn more about:

1. the role of construction activities in the spreading process of *A. artemisiifolia* 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.

Methods

A literature survey was conducted which showed there is little published information on the question to what extent *A. artemisiifolia* 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.

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 common ragweed" 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 *A. artemisiifolia* on biodiversity. The questionnaire asked for information on the following questions:

- How important are the following spreading pathways for common ragweed 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.
- Is the building sector informed about the *A. artemisiifolia*-problem? (e. g. occurrence of ragweed plants on soil depots or construction material, seed loss during soil transportation etc.)
- Are there legal or other regulations to avoid dispersal of *A. artemisiifolia* 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 (Switzerland), Peter Kotanen (Canada), Beryl Laitung (France), Arnaud Monty & Grégory Mahy (Belgium), Sergey Reznik (Russia), Baruch Rubin (Israel), Ingrida Sauliene (Lithuania), Carsten Ambelas Skjoth (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.

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 roadsides 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.

Investigations in the Niederlausitz

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 *A. artemisiifolia* 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 *A. artemisiifolia* from outside.

Road sites

In the study area south-west of Cottbus, various roads were inspected from a car for *A. artemisiifolia* 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.

Results

Inquiry

Question 1: Of what relevance are the following spreading routes for *Ambrosia artemisiifolia* 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 1). This is also relevant in Israel but a score was not possible here. In Denmark where common ragweed is still rare, this pathway of spread is currently of low importance. Six experts note that a transport of common ragweed seeds sticking to agricultural machineries is a major spreading 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 food to contain common ragweed seeds (<0,005% common ragweed seeds/kg) it is not relevant any more. In Canada, Russia, and Italy a loss of common ragweed seeds during the transportation of agricultural products is important for the spread of *A. artemisiifolia*, and this is mentioned as the most important spreading pathway in Russia (S. Reznik). In Russia and Italy the introduction of common 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 *A. artemisiifolia*. The spread of common ragweed seeds with construction material is relevant in many countries.

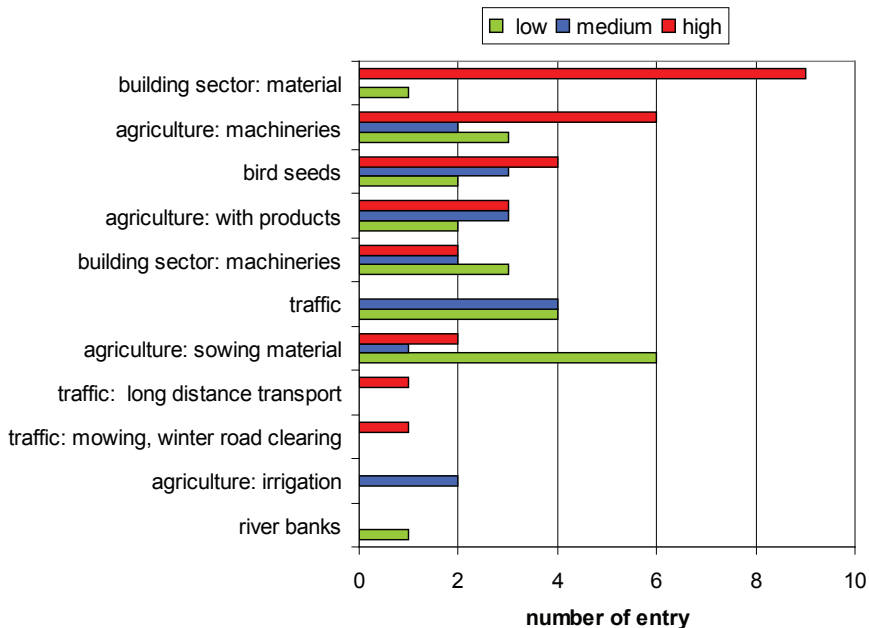


Fig. 3: Relevance of spreading routes for *A. artemisiifolia* (14 questionnaires, including 3 x France, 2 x Switzerland).

Question 2: Is the building sector informed about the *A. artemisiifolia*-problem?

Six experts mention that the building sector is not informed about the *A. artemisiifolia*-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 only in a few cases special control measures against *A. artemisiifolia* are undertaken. In Italy for example operators sometimes sow out antagonistic grasses (M. Bonini).

Question 3: Are there legal or other regulations to avoid dispersal of *A. artemisiifolia* seeds within 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 *A. artemisiifolia* seeds is prohibited (A. Demierre). In the Lombardy region in Italy *A. artemisiifolia* must be controlled by mowing between June and 20th August in general, but there are no special regulations to prevent the spread of *A. artemisiifolia* 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.

The role of construction activities in the spreading process of *A. artemisiifolia*

A. artemisiifolia achenes can be transported within excavated material over long distances and can reach new growing 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 depositions often provide suitable growing conditions for pioneer species such as *A. artemisiifolia*, like disturbed, sunny vegetation-free sites where these species can grow and produce seeds. A great amount of soil can be infested with common ragweed seeds at the deposition sites when contaminated soil is mixed with common ragweed-free material. Contaminated material can be dispersed widely during construction works, and by this way common ragweed can be introduced to many new locations (Fig 4 c, d, Fig 2).

In some cases soil from construction sites is disposed 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 disposal 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).

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 *A. artemisiifolia* 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, Buttenschön *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 *A. artemisiifolia* in Austria.

Relevance of common ragweed spread within excavated material in relation to the scale of infestation with *A. artemisiifolia* – an example from Germany

The relevance of spreading routes of *A. artemisiifolia* 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 *A. artemisiifolia* seeds with excavated material was of lower importance compared to introductions with bird seed (Fig 5, unpublished data; Nawrath & Alberterst 2007 to 2012). 29% of the large common ragweed stands (> 100 common 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 *A. artemisiifolia* 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.

Relevance of transient soil depots for the spread of *A. artemisiifolia* in Germany

Examples from the Niederlausitz (East-Germany)

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

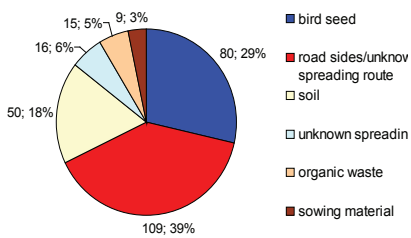


Fig 5: Pathways of introduction of n=279 big ragweed stands (>100 individuals) known in Bavaria till 2012.

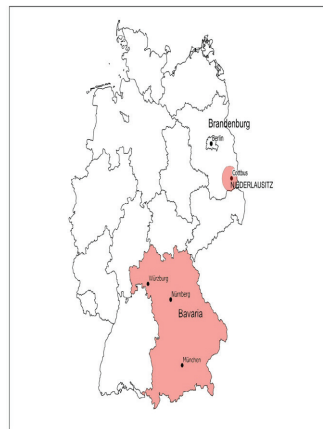
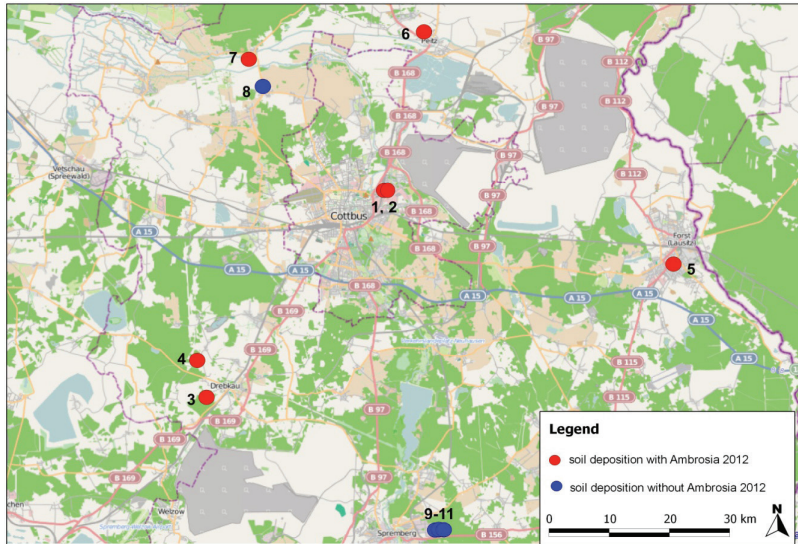


Fig 6: Map of Germany with the federal states Brandenburg and Bavaria where the investigations took place. In the red marked “Niederlausitz” the most extended common ragweed stands of Germany occur.

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

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

¹⁾ size= area investigated for common ragweed occurrences



map basis: OpenStreetMap

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, common ragweed plants were found

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

The maps illustrated in Fig 9 demonstrate the distribution of ragweed at the transient soil depositions in Cottbus, Drebkau, Siewisch, and Drebkau. In Drebkau some piles of construction material with ragweed stands were present at the margins of the site (Fig 9). In Siewisch and Cottbus *A. artemisiifolia* was dispersed nearly over the whole soil deposition. In Cottbus the species was found on three different soil piles which were used by different operators. Some of these operators are also involved in construction work at roads. A pile of humus rich material which was used to fill in banquetts at road margins (pers. communication with a foreman at a disposal site in 2012) was grown with *A. artemisiifolia*. This strongly indicates that common ragweed is spread with construction material from the soil depositions.

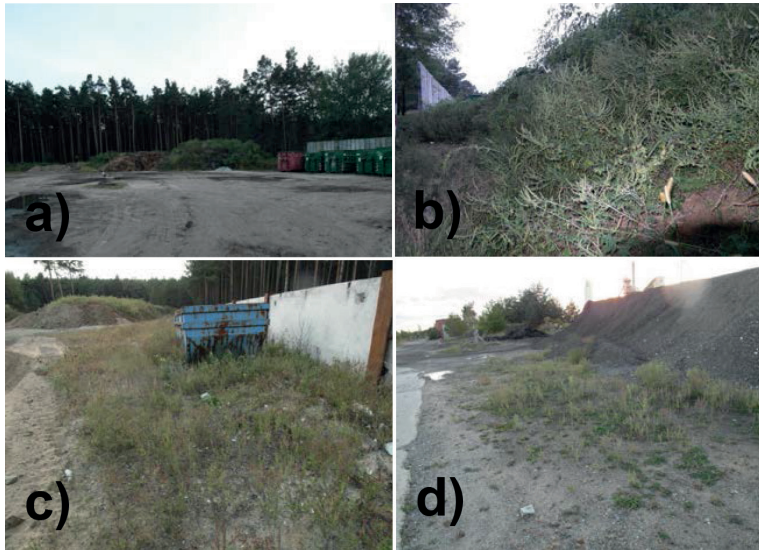


Fig 8: Common Ragweed occurrence at transient soil depot in Drebkau (a-c) and Cottbus (d), Sept 2012.

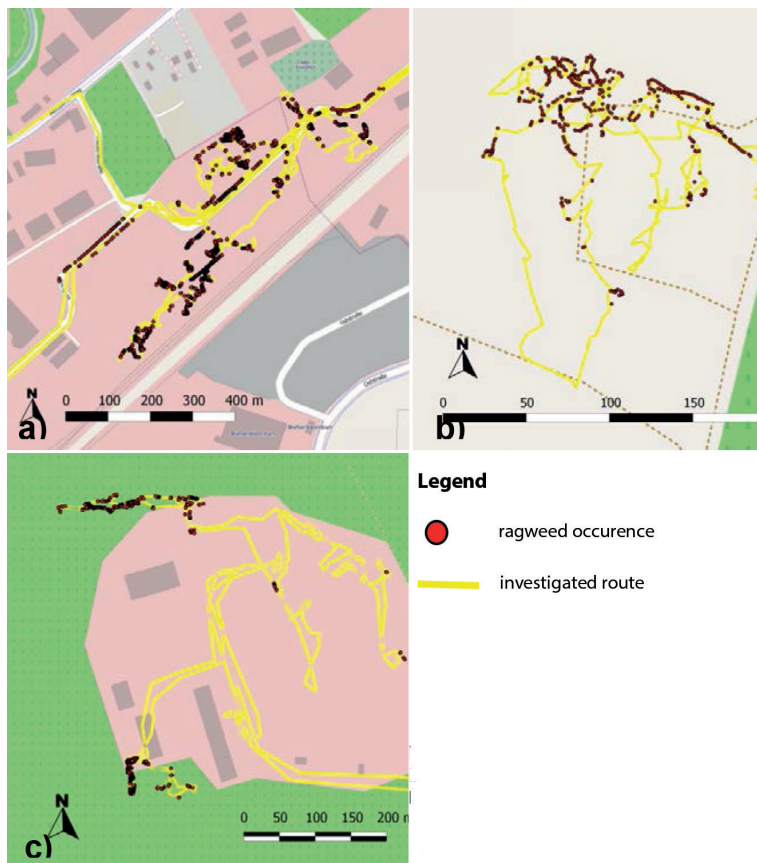


Fig 9 Occurrences of ragweed at soil depots in Cottbus (a), Drebkau-Siewisch (b) and Drebkau (c) in 2012.

Map basis: OpenStreetMap

Examples from 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, *A. artemisiifolia* 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 *A. artemisiifolia* 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 Hiltpoltstein, 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 Hiltpoltstein 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. Common 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 common ragweed seeds, the soil was still sold.



Fig 10: Excavated soil at the construction site „Am Falkenhorst“ in Hiltpoltstein.

In 2007 extensive ragweed occurrences grow at this construction site. Excavated material from here was transported to the transient soil depot in Hiltpoltstein.



Fig 11. Soil depot with ragweed occurrence in Hiltpoltstein 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.

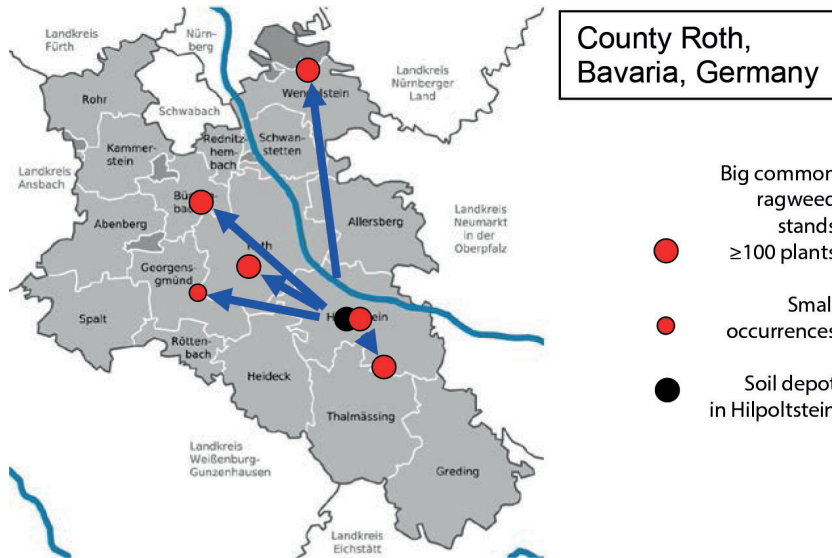


Fig 12: Transient soil depot in Hilpoltstein (black dot) that could be detected to be the origin of six new common ragweed stands (red dots) in the county Roth, Bavaria (Germany) in 2012.

Spreading of *A. artemisiifolia* promoted by road construction work - examples from the Niederlausitz

Common ragweed along roadsides in the Niederlausitz

In the study area in the Niederlausitz, common ragweed 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 *A. artemisiifolia* is able to spread into other habitats such as agricultural fields or ruderal areas.

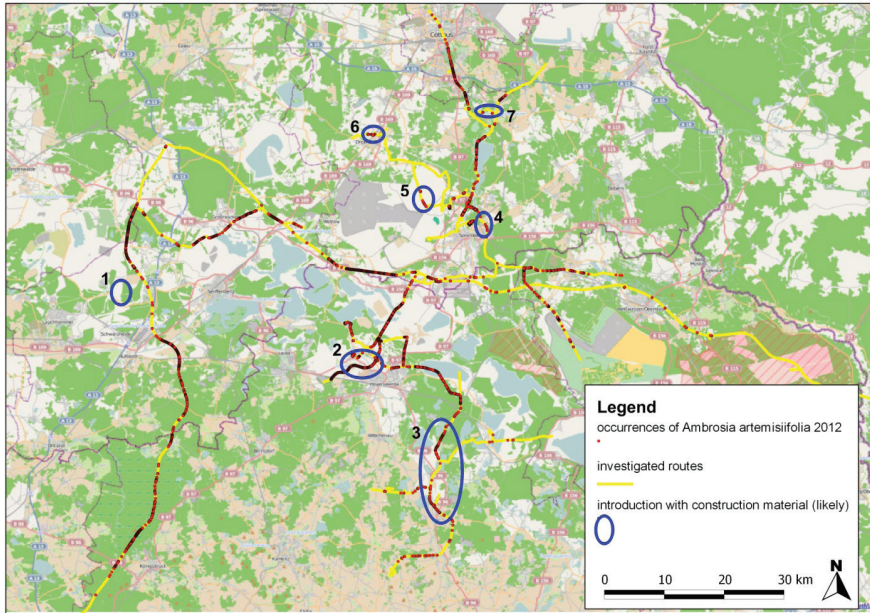
A map, provided in the internet by the Free University Berlin (FU Berlin 2013), shows the distribution of common ragweed in Berlin and Brandenburg. It can be seen that the most extended ragweed stands in the Niederlausitz occur around the town Drebkau south-west of the city Cottbus. Here many agricultural fields are heavily infested with *A. artemisiifolia*. 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 enter the road margins and spread there?

There are different ways how ragweed seeds can reach the road margins. *A. artemisiifolia* achenes could be lost during the transportation of agricultural products. They also could be spread by agricultural machines when seeds stick at them directly or mixed with soil and were lost during the drive 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 of spread were found in the study area.

Introduction of ragweed with construction material

In Tab 2 (compare Fig 13) newly built roads and roads with rebuild banquets 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 more precisely below.



Map basis: OpenStreetMap

Fig 13: Occurrence of common ragweed 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. *A. artemisiifolia* was most probably introduced here with the construction material (Tab 2).

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

investigations: July 2011 and September 2012

No	Location	Type	Length of colonized road section	method	geographic coordinates WGS84	Ragweed occurrence	Year of study
1	NW of Schipkau, between Klettwitz and Kostebrau	Newly built road, road deallocated in 2010	> 4,2 km	Inspected from car, partially walking	51.516357 13.838765 bis 51.535074 13.882989	dispersed, partially rich in individuals	2011
2	Near Drebkau, B169	Road construction road deallocated in 2009	ca 8 km	Inspected from car	51.666616 14.242706bis 51.630018 14.174699	Very rich in individuals	2012
3	W of Spremberg and Schwarze Pumpe, B97new	Road construction, road deallocated in 2010/11	ca 12 km	Inspected from car	51.597687 14.363081 bis 51.502121 14.332527	Single plants up to individual rich stands	2012
4	Nordöstlich Cottbus bei Merzdorf, B168neu	Road construction, road deallocated in 2012	ca. 4,4 km	Inspected from car	51.757307 14.402565 bis 51.790382 14.376286	Single plants, rich in individuals, mainly at areas aside of the road	2012
5	Sielow, „Sielower Chaussee“	Road construction ca. 2011/2012	750 m	inspected on foot	51.787729 14.309792	Single plants	2012
6	E of Schmogrow-Fehrow, „Dorfstrasse“	Road construction ca. 2011	330 m	inspected on foot	51.851869 14.230974	Medium-sized stand	2012
7	Turnow, „Wiesenweg“	Road construction ca. 2011	150 m	inspected on foot	51.872610 51.872610°	Low number of plants	2012

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 at one road side whereas no or only a few plants were found at the other road margins.

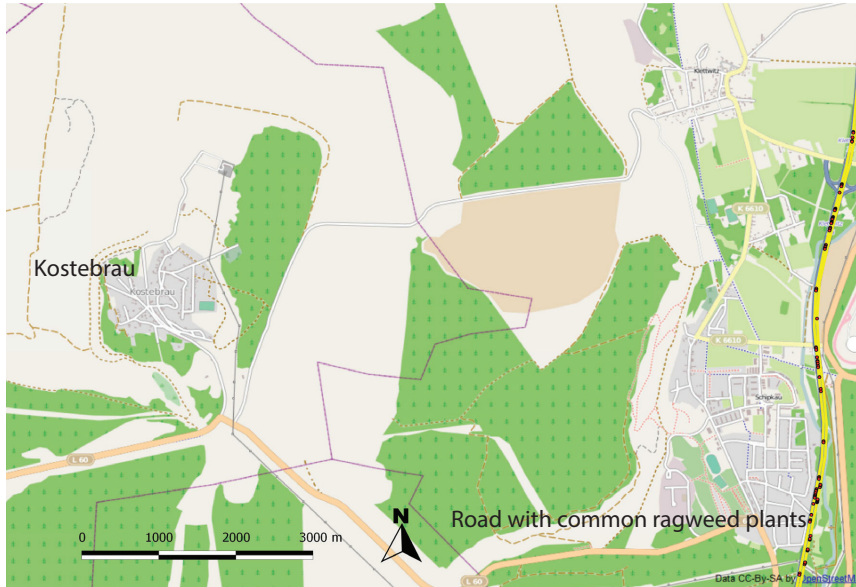


Fig 14: Newly built road in a reconstruction area connecting the villages Klettwitz and Kostebrau near Senftenberg (2011/0706).

At the roadside common ragweed which was very likely introduced with construction material occurs.

Map basis: OpenStreetMap

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 *A. artemisiifolia*. 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 *A. artemisiifolia* 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 built 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 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.

c) Road shoulder of the new road. Here a substrate rich in humus was used. Ragweed plants occurred here.

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 built road located east of Drebkau

The newly built road B169 which bypasses the city 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).

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 within soil takes place to a lesser extent. The spread within excavated material is a very effective spreading route. Thus, in countries with low infestations measures to prevent ragweed spread within excavated material should be conducted in an early phase of the spread. Measures should aim in a prevention of ragweed seeds to get into the soil distribution circle of the building industry.

Measures to prevent seed dispersal with soil

There are different possibilities to avoid the dispersal of ragweed seeds within 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 were spread via excavated material.

a) Detection of ragweed plants and seeds

If a population of ragweed plants is present on a ground, it is very likely that the soil contains seeds of the species. The ground, construction measures are planned on, should be checked for ragweed plants before the building works start. More complicated is it to detect soils which are contaminated with ragweed seeds when the plants are not visible, e.g. when plants were outcompeted by native vegetation but the seed bank is still present. If there is a suspicion that soil could be contaminated with ragweed seeds, the soil should be investigated. Actually no standards or regulations exist on best practices how to find ragweed seeds in the soil.

There is a similar problem for farmers to detect nematodes on their farmland. Possibly methods to find these organisms could also be used to find ragweed seeds in the soil. Chambers of agriculture in Germany provide recommendations how to take soil samples for nematode investigations. The chamber of agriculture North-West (Niedersachsen, LUFA 2008) gives recommendations as follows: 30 soil samples taken in the upper 0-30 cm in steady distances should be taken per ha. Nematodes are not equally dispersed in soil – similar to the seed distribution of *A. artemisiifolia*. Thus, it is important to take many soil samples and investigate a mixed sample. 30 soil samples should be mixed in a bucket and 1 kg should be investigated for nematodes. A similar procedure could be used to find ragweed seeds. However, an adequate measure should be tested.

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 germ and results are achieved. It should be taken into consideration that *A. artemisiifolia* seeds need a stratification before they germinate properly.

It could also be an option 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 a contamination of clean material (see Fig 17). Newly grown ragweed plants should be removed before seed set. A cover of the contaminated soil piles with a foil could help to prevent germination and seed set of *A. artemisiifolia* 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 a combat of *A. artemisiifolia* 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. varnished 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 an allocation at different locations.

It is another option to finally dispose 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 are given in Tab 3.

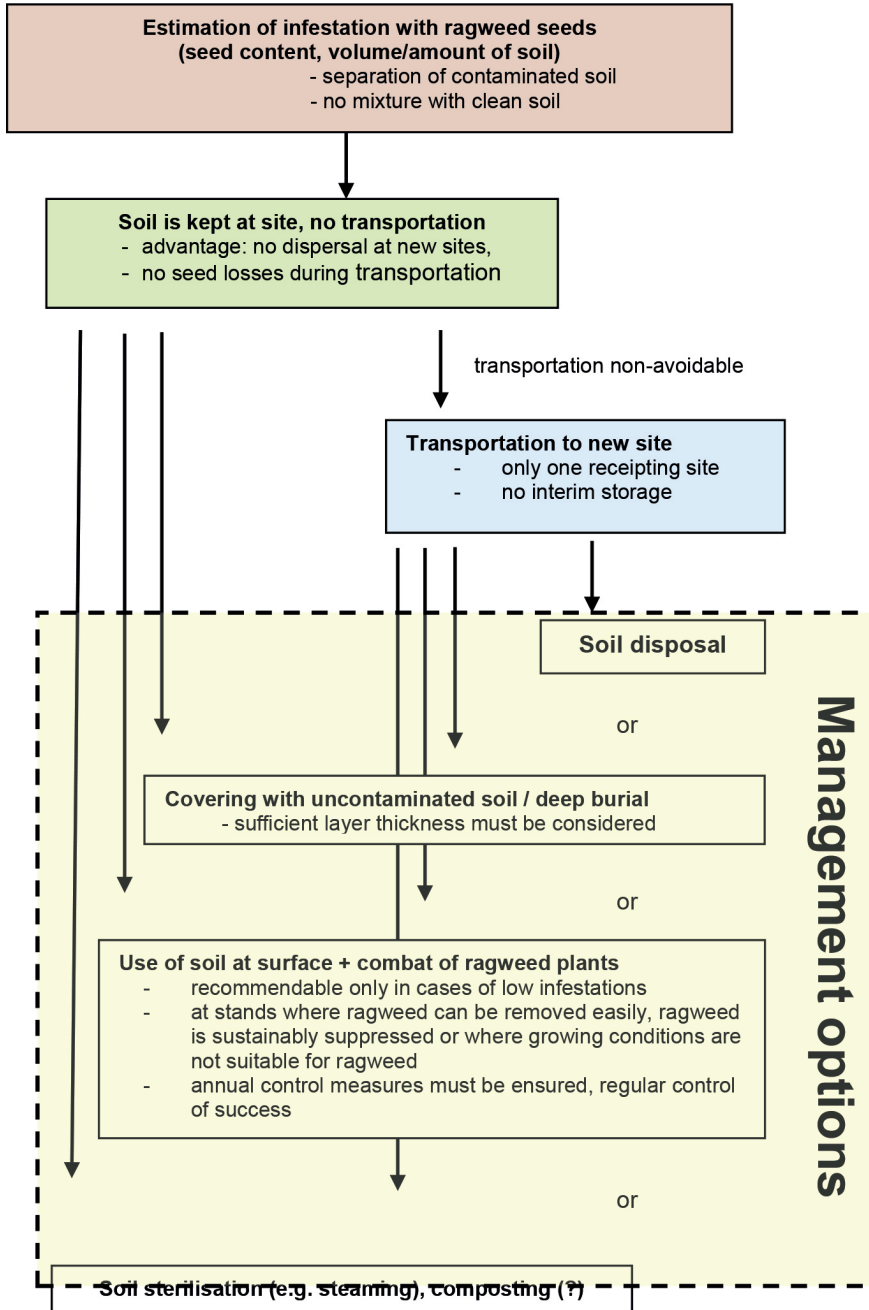


Fig 17: Options to prevent the spread of *A. artemisiifolia* in contaminated, excavated material.

Tab 3: Possibilities to treat contaminated soil and assessment and effort of measures.

measure	assessment & effort
final disposal at a special disposal site, no further use of soil	<ul style="list-style-type: none"> • effective measure • risk of seed losses during transportation • loss of top soil for further use • costs for transport and final disposal • costs for cleaning of the machines
deep burial, cover with non-contaminated material	<ul style="list-style-type: none"> • effective measure • loss of top soil for further use • relatively low effort when material is buried at same site • costs for transport if buried at other site • costs for cleaning of the machines • risk of seed losses during transportation
use of contaminated soil and control of <i>A. artemisiifolia</i> at site	<ul style="list-style-type: none"> • only advisable at same site when ragweed control is ensured for several years • at sites where no suitable growing conditions for <i>A. artemisiifolia</i> 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	<ul style="list-style-type: none"> • effective • very laborious, high energy input, cost-intensive • risk of seed losses during transportation of material

In general

- if possible only use of contaminated material at same site
- avoidance of transport due to risk of seed losses/dispersal
- separation of 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)
- avoidance of seed losses during transportation, cleaning of machines
- monitoring of sites where a ragweed contamination is known, control of success of control measures

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.

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 foils are put on the soil and weighed down with sand sacks. Hot steam is produced by a special steam-boiler and conducted under the foil. Depending on the condition of the soil and the air temperature it takes 1 to 1.5 h to reach 85 °C per 10 cm of soil depth.

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).

Steaming of substrata

Material such as excavated soil or compost that should be sterilised could either be transported to a steaming facility (Gudehus 2005), or a mobile steaming machine could 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.

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 afterwards composted at a temperature of 70 °C. During the composting procedure it is necessary to relocate 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 already 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 piles of composted material (Fig 18).



Fig 18: Piles of composted material near Salmdorf, Bavaria, 2012/07/18. Four living ragweed plants were found on top of the piles.

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.* 2008 b) 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 *A. artemisiifolia* exist.

Switzerland

The use of soil contaminated with *A. artemisiifolia* seeds is prohibited in Switzerland. If *A. artemisiifolia* 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 combat of *A. artemisiifolia* is obligate in Switzerland. In this country the “causative principle” is used and the land owner, the user of the land, the building contractor or the common carrier is obliged to remove *A. artemisiifolia*. There are special regulations to avoid the spread of *A. artemisiifolia* in soil, humus, excavated material, compost etc. in the Kanton Graubünden. The following regulations are in force (Amt für Natur und Umwelt Graubünden 2007):

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

The legal basis for the handling of *A. artemisiifolia* 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)

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 *A. artemisiifolia* 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 *A. artemisiifolia* (e.g. www.ambrosie.info.fr). On that webpage special information is provided on methods how to combat *A. artemisiifolia* at construction sites (http://www.ambrosie.info/docs/fiche_6.pdf).

Italy

In the Lombardy region (Italy) owners and land users are obliged to combat *A. artemisiifolia* between the end of June and the 20th August. Mayors of municipalities affected by common ragweed occurrences are obliged to surveil 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 *A. artemisiifolia* with excavated material used for construction work.

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 how to prevent the spread of common ragweed via excavated material. In Germany the control of common ragweed is not obligate and no legal regulations comparable to those in Switzerland exist. Currently there is no or only little awareness of the common 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. Due to this, authorities often do not even try to spur the building sector into action. At soil depositions 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.

Recommendations

Spread of *A. artemisiifolia* 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 *A. artemisiifolia* 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 common ragweed is controlled effectively demonstrates that it is necessary to create awareness of the *A. artemisiifolia* problem in the building sector. There are different possibilities to prevent the spread of *A. artemisiifolia* 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 could also be used to contain the spread of *A. artemisiifolia* within 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 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 disposal 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 disposal site 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).

Inclusion of *A. artemisiifolia* in announcements for construction work

Instructions to prevent the spread of *A. artemisiifolia* during construction work could be included in announcements. The building owner should be informed about *A. artemisiifolia* and the problematic of spreading during construction work. He could be obliged to investigate the construction site for the occurrence of common ragweed (or other invasive) plants in the vegetation period (June – October, when *A. artemisiifolia* is detectable) before any construction measures take place. The result should be sent to authorities that build up a data collection on *A. artemisiifolia*, respectively on invasive species. A building owner should be obliged to seek for information on common ragweed stands from the authorities. In case common ragweed occurs at a site, the owner has to be obliged to prevent the spread (e.g. no transportation of soil, or safe disposal 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 depositions (no 581311A). This says that soil depositions fostered and hold free of weeds can be brought to account. Costs can be estimated in m³ x weeks. This might also be a basis for cost calculations for soil depositions kept free of *A. artemisiifolia*.

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

This proceeding should be communicated with the building sector.

Summary

- Spreading within excavated material is an effective spreading route for common ragweed in Europe.
- The relevance of the soil pathway often increases when the infestation with common 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 common ragweed population at road sides during the last years.
- The use of soil contaminated with common ragweed seeds at soil surfaces should be avoided. Contaminated soil should be deeply buried, disposed or decontaminated. It could be used at sites, where no suitable growing conditions for *A. artemisiifolia* 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 *A. artemisiifolia* should be ensured over several years.
- In most of the European countries no special measures are conducted to prevent the spread of common ragweed within excavated material, by now. Comprehensive legal regulations currently exist in Switzerland. In many European countries the awareness of the *A. artemisiifolia* 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 voluntary base often did not reach the building sector in Germany. In many cases common ragweed plants were not or not sufficiently removed (with some exceptions).

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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

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

Relevant 1)	Relevance				spreading routes for <i>Ambrosia artemisiifolia</i>
	low	medium	high	no info	
					a) <u>Building sector</u> (e.g. road building, constructions): Transport of <i>A. artemisiifolia</i> seeds within soil or construction material (e.g. sand, gravel, construction waste; seed loss, growing/reproduction on earth fill)
					b) <u>Building sector</u> : Transport and loss of ragweed seeds sticking to building machineries (e.g. tires)
					c) <u>Agriculture</u> : Transport and loss of ragweed seeds sticking to agricultural machines (e.g. tires, mowing machines)
					d) <u>Agriculture</u> : Transport and loss of ragweed seeds with agricultural products (during harvest)
					e) <u>Agriculture</u> : Use of sowing material contaminated with ragweed seeds
					f) <u>Traffic</u> : Transport and loss of ragweed seeds sticking to trucks, cars etc.
					g) <u>Bird seeds</u>
					h) <u>Other</u> :
					i) <u>Other</u> :
					k) <u>Other</u> :

1) Relevant, but no estimation of importance possible

no info = no information of relevance for the spread of *A. artemisiifolia*

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 depositions or construction material, reproduction and contamination of the soil with its seeds, important spreading route of *A. artemisiifolia* 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 *A. artemisiifolia* seeds is prohibited.

It is compulsory to separate *A. artemisiifolia*-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 *A. artemisiifolia* 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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