Dietmar Brandes, Jens Nitzsche

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URL: http://www.digibib.tu-bs.de/?docid=00016647

Zuerst erschienen in:
Nachrichtenblatt des Deutschen Pflanzenschutzdienstes. – Stuttgart :
Ulmer. - 58 (11), S. 286-291, 2006.

Nachrichtenbl. Deut. Pflanzenschutzd., **58** (11), S. 286–291, 2006, ISSN 0027-7479.

Institut für Pflanzenbiologie, Technische Universität Braunschweig

Biology, introduction, dispersal, and distribution of common ragweed (*Ambrosia artemisiifolia* L.) with special regard to Germany

Biologie, Einschleppung, Ausbreitung und Verbreitung der Beifußblättrigen Ambrosie (*Ambrosia artemisiifolia* L.) unter besonderer Berücksichtigung von Deutschland

Dietmar Brandes, Jens Nitzsche

Abstract

Ambrosia artemisiifolia L. (common ragweed) is an annual species in the Asteraceae from the prairie regions of North America, which occurs in many European countries. It can cause hay fever through its pollen and dermatitis by contact to the inflorescence. Due to its late flowering the period of suffering for allergic persons is lengthened. Because of its potential as a competitive weed, it is under weed control in several countries.

Our study summarizes the knowledge about the population biology and ecology of *A. artemisiifolia*. Reactions to stress factors and to herbicides are pointed out. Bird seed is the most important pathway for the introduction into Germany. Currently, *A. artemisiifolia* shows three centres of distribution in Germany: the area Mannheim/Ludwigshafen, southern Brandenburg and south eastern Bavaria. There is no evidence for a threat to native species. At the present climatic conditions a continued occurrence of *A. artemisiifolia* in Central Europe is highly possible, even more so under global change conditions of elevated temperature and/or carbon dioxide.

Although *A. artemisiifolia* plays no important role as weed at the moment, it should be controlled because of its potential allergenic properties.

Key words: *Ambrosia artemisiifolia*, population biology, ecology, introduction, biocontrol, current distribution, weed, assessment, recommendations

Zusammenfassung

Ambrosia artemisiifolia L. (Beifußblättrige Ambrosie) ist eine einjährige Art der Asteraceae aus den Präriegebieten Nordamerikas, die inzwischen in zahlreichen europäischen Ländern auftritt. Da die Ambrosie Heuschnupfen durch ihre Pollen und Dermatitis bei Berühren des Blütenstandes auslösen kann und durch ihre späte Blütezeit den Leidenszeitraum der Allergiker verlängert, sie zudem ein konkurrenzkräftiges Ackerunkraut ist, wird sie in verschiedenen Ländern bekämpft.

Die Veröffentlichung stellt die Kenntnisse über Populationsbiologie und Ökologie von *A. artemisiifolia* zusammen; Reaktion auf Stressfaktoren sowie auf Herbizide werden aufgezeigt. Wichtigste Quelle für die Einschleppung nach Deutschland ist Vogelfutter. Gegenwärtig gibt es in Deutschland drei Häufungsschwerpunkte: Raum Mannheim/Ludwigshafen, südliches Brandenburg und Südostbayern. Bislang gibt es jedoch keine Hinweise auf eine Verdrängung einheimischer Arten. Bei den gegenwärtigen Klimabedingungen wird *A. artemisiifolia* mit hoher Wahrscheinlichkeit nicht wieder aus Mitteleuropa verschwinden, insbesondere nicht bei Anstieg von Temperatur und/oder Kohlendioxid-Konzentration.

Obwohl die Art derzeit keine größere Rolle als Ackerunkraut spielt, sollte eine Bekämpfung wegen ihres hohen allergenen Potenzials erfolgen.

Stichwörter: *Ambrosia artemisiifolia*, Populationsbiologie, Ökologie, Einschleppung, aktuelle Verbreitung, Ackerunkraut, Bewertung, Handlungsempfehlungen

1 Population biology and ecology of *Ambrosia artemisiifolia*

This paper is the result of a scientific project on introduction, dispersal and occurrence of *A. artemisiifolia* in Germany financed by the Biologische Bundesanstalt für Land- und Forstwirtschaft Braunschweig. In addition to literature reviewing and interviews of experts own field work and experiments were carried out for estimating the possibilities for establishing of ragweed in Germany.

The genus *Ambrosia* contains at least 40 species with numerous intraspecific taxa. Its centre of diversity lies in the south-western USA and the bordering Mexico respectively. Only one species (*A. maritima* L.) is native to the Old World (Mediterranean region and tropical Africa). Several authors separated the species *A. elatior* occurring as a ruderal in Central Europe from *A. artemisiifolia* [s. str.], but without constancy in the taxonomic literature. Therefore, this species is mostly referred to as *A. artemisiifolia* var. *elatior* in our country. In this paper all data refer to this taxon.

Ambrosia artemisiifolia is the most successful species of the genus in the adventive range. In Germany, the three species *A. artemisiifolia*, *A. coronopifolia* and *A. trifida* are frequently found. In addition several other species of the genus are found rarely: *A. bidentata* Michaux, *A. aptera* DC., *A. polystachya* DC., *A. tenuifolia* Sprengel and *A. maritima* L. (Wagenitz in Hegi, 1979).

Not all relevant data concerning morphology and population biology of common ragweed were found in the literature. Therefore several individuals from experiments in the botanical garden of the TU Braunschweig were measured and germination experiments were conducted under controlled conditions. *Ambrosia* *artemisiifolia* is an erect growing plant, usually richly ramified and shaggy-haired in the upper parts. It shows only a weak apical dominance (IRWIN and AARSSEN, 1996). The leaves are (normally) bi-pinnate. The numerous male capitula are arranged in leafless racemes, the female capitula are located solitary or in small groups in the shoulder of the upper leaves. We observed numbers of nodes between 15 and 23, and stem diameters at the basis between 2 and 4 cm. The plants keep on growing after the stimulation of flowering, but only by elongation of the internodes. Ramification starts at about 2–4 cm above floor level (at the first to the third node) and includes numerous side-branches (20–29). The stem breaks easily, because only the nodes are pith-filled and the internodes are hollow. According to our own observations *A. artemisiifolia* does not tolerate trampling very well: the snapped off stems wilt above the fracture. Common ragweed should be classified as mesomorphous, because after ten minutes of treatment in boiling water the stem remains erect, but the leaves are flaccid. The plant obviously invests little in supporting tissue, because the stem becomes flaccid after a relatively minor loss of water.

The maximum height is often underestimated. In Germany, *A. artemisiifolia* reaches heights of at least 1.75 m, in Slovenia we recorded more than 1.80 m in summer 2005, while ŠILC (2002) only specified 1.20 m. The height is strongly dependent on the habitat, especially water supply and competition. Because the species lacks storage organs and has a shallow root system it does not grow well during dry periods and on well drained soils (see also BOLLINGER et al., 1991).

A. artemisiifolia grows best in warm and moist conditions (DEEN et al., 1998b), while low temperature and inadequate water supply delay the development (DEEN et al., 1998a). Because of its rapid growth during the juvenile phase common ragweed quickly reaches a stem height of about 30 cm, granting it an advantage in competition (ARMESTO and PICKETT, 1985). Plants germinating later in the year develop more quickly than earlier germinated ones, but the leaf development decreases in favour of the stem development. A model for growth and development of common ragweed was developed by DEEN et al. (2001). Solitary growing individuals are shorter, but more ramified. The species reacts with high phenotypic plasticity to dense population and competition by other plants.

Ambrosia artemisiifolia responds to mycorrhiza inoculum in a positive way: the dry matter is increased significantly (CROWELL & BOERNER 1988). In presence of mycorrhiza the absorption of phosphate is supported and this leads to a significant stimulation of growing. An elevated CO_2-concentration seems to be positively correlated with an allocation of nitrogen to the reproductive parts; this possibly induces an earlier flowering (GARBUTT et al., 1990). Elevated CO_2-concentration did not lead to a significant increase of photosynthesis (HE et al., 2002).

The whole plant exhibits an aromatic odour. *Ambrosia artemisiifolia* is a short-day plant, whose flowering is induced by a dark period of app. 8 hours (DEEN et al., 1998a). According to the German literature and to our own observations the flowering period lasts from August to October. Under optimum conditions the plant takes only 30 days to of flowering and 50 days to maturity of seeds. According to WAGENITZ (in HEGI, 1979) the seeds do not ripen completely in Central Europe, which can be seen as the main reason for the establishment difficulties of the species. The beaked fruit displays several awl-shaped thorns (involucral bracts), which reach a length of app. 2–3 mm. The quantity of seed varies greatly with 60,000 per individual as a maximum (http://www.cps-skew.ch). In contrast to other annuals like *Artemisia annua* (BRANDES and MÜLLER, 2004) the number of seeds per plant is obviously strongly dependent on population density: 3,200 seeds at 0.75 plants/m², 1,770 seeds at 3.0 plants/m² (CHIKOYE et al., 1995).

The seeds remain germinable in the **seed bank** for at least 20 years (ŠILC, 2002), up to 30 years according to CHIKOYE et al. (1995), and German literature even states up to 35 years (OBERDORFER, 2001). In a seed bank *A. artemisiifolia* can occur in high density (SQUIERS, 1989: Indiana/USA). In Germany this stage probably has not yet been reached, or only at selected points of infestation. Where an adequate seed bank exists, ploughing in autumn or spring can result in *A. artemisiifolia*-dominated plant communities (ROTHROCK et al., 1993).

Ambrosia artemisiifolia shows a high germination rate. According to our experiments the species shows a broad amplitude in regard of the germination temperature (7 °C to 28 °C), with an optimum at 15 °C. Contrary to the literature (JÄGER and WERNER, 2002) it is no cold germinator, because its optimum lies above 10 °C. Due to its broad amplitude of germination temperature the species is one of the first to germinate in the year (DITOMMASO, 2004). *Ambrosia artemisiifolia* is probably a light-induced species, because the fruit – achenes enclosed by the involucre – rarely germinate if buried deeper than 4 cm (MARTINEZ et al. 2002), since without the light stimulus they can develop a secondary dormancy (BASKIN and BASKIN, 1980; PICKETT and BASKIN, 1973; SQUIERS, 1989). Inundation (MARTINEZ et al., 2002) and elevated CO_2-concentration (GARBUTT et al., 1990) have no effect on germination. Low concentrations of NaCl reduce germination success or inhibit germination completely, this effect is reversible according to DITOMMASO (2004).

The seeds of *A. artemisiifolia* need a period of cold to ripen completely: a treatment at –4 °C to –10 °C for app. 15 weeks results according to BASKIN and BASKIN (1987) in a germination rate of 75 % maximum in light. Our own experiments confirm that freshly harvested seed do not germinate at optimum conditions, while available seeds (from previous years) germinated during the whole year. According to SQUIERS (1989) the (secondary) dormancy can be broken only by stratification. The course of germination was modelled by SHRESTHA et al. (1999). Our own observations and numerous statements in literature (IKEDA, 2003; MEDVE, 1984; SLUIS, 2002) show that the species is only able to germinate in open sites and is displaced over the course of succession after a few years.

2 Reaction to disturbance and stress

Ambrosia artemisiifolia tolerates damage like removal of the stem apex and leaves. The plants mostly bud from the basis or increase growth of existing lateral stems (IRWIN and AARSON, 1996). Removing the stem apex in vegetative form does not reduce the regenerative ability, but delays the initiation of flowering and enhances ramification. Mowing during flowering reduces the generation of inflorescences, while no regeneration occurs after flowering any more (see also ARMESTO and PICKETT, 1985; VINCENT and AHMIM, 1985). *Ambrosia artemisiifolia* shows only minor tolerance to trampling, because the main stems of mature individuals tend to break easily.

Increased NaCl-concentration results in a rapid loss of germination capacity of the seeds (DITOMMASO, 2004; own results). However, not germinated seeds are able to germinate in considerable amounts in freshwater (DITOMMASO, 2004; MARTINEZ et al., 2002). This may favour the establishing along roadsides. The sensibility to salt of the various ecotypes is apparently very variable, it seems usually to be at the highest in the juvenile phase (DITOMMASO, 2004).

Ambrosia artemisiifolia shows a high tolerance to lead and can accumulate mainly in its roots up to 1,600 mg/kg without lethal consequences. *Ambrosia artemisiifolia* can therefore be used to remove lead from soil (PICHTEL et al., 2000).

Ozone does not damage *A. artemisiifolia* significantly even at a concentration four times the natural (ZISKA, 2002). Therefore common ragweed has a relative advantage over competing species (which are often O_3-sensitive) at an elevated ozone concentration, which is often found in urban regions.

3 Reaction to herbicides

Ambrosia artemisiifolia has developed resistances to Linuron and Triazin and it is able to partly detoxify Imazethapyr (LEIF et al., 2000). It ceases to grow for a prolonged period after application of Imazethapyr but does not die; it is able to sprout from lateral auxiliary buds (BALLARD et al., 1996). Elevated moisture and temperature facilitate the uptake of the herbicide. Bentazon inhibits the uptake of Imazethapyr at low relative moisture level instead of enhancing it (HAGER et al., 1999). Our own orientating experiments with Roundup sprayed onto the plants showed an effect only at higher concentrations (2 % and 4 %). Through the long-term application of the same herbicides, especially in south eastern Central Europe, it is very likely that for example triazin-resistant plants have been selected, which are now spreading effectively.

4 Pathways and means of dispersal

Most entries in literature dealing with the pathways refer to American corn (for example WAGENITZ in HEGI, 1979; HARDTKE and IHL, 2000; VERLOOVE, 2003). American clover seed is also frequently mentioned (for example WAGENITZ in HEGI, 1979; GATTERER and NEZADAL, 2003), which may be related to former introductions. Today birdseed, especially that containing sunflower seeds, should be regarded as the main source for new unwanted introductions to Germany (SCHRADER, 2003). Therefore birdseed mixtures from retail were examined by random testing: 328 fruits of *A. artemisiifolia* were found in 13.8 kg of samples tested. The contamination differed between 0 and 34 seeds per kg, the mean value was 23.8 seeds per kg of birdseed. NAWRATH and ALBERTERNST (this volume) found a maximum value of 170 fruits per kg. No fruit of ragweed was found in seed mixtures for "Blüh-Streifen" ("flower-belts") for sugar beets.

Harbours and goods stations seem to be of no [more] importance in Germany as dispersal centres, because their *A. artemisiifolia*-populations are usually small and transient, if the species can be found at all. With changes in the way of transport the importance of harbours as dispersal centres might decrease even further; involuntarily introduced diaspores will reach farmland directly or at least the surroundings of agricultural deposits. If local founder populations finally have established, *A. artemisiifolia* is obviously able to disperse quickly and efficiently along linear structures, as can be observed, for example in Hungary, Slovenia and in southern Brandenburg. *A. artemisiifolia* was dispersed into the region of Geneva by combine harvesters, rented from the area surrounding Lyon (CH. SCHNEIDER/Geneva: n. p.). Transient deposits and subsequent reuse of ground excavation of contaminated sites can multiply the problem (PETER STURM/Laufen: n. p.). Therefore, the unwanted transport of diaspore-containing soil seems to be an especially effective way of dispersal.

Unlike often stated in literature rivers are only of minor importance as migration routes for this species in Germany. The few local populations observed along riversides got there by chance through deposit of litter or waste.

5 Current situation of distribution in Germany

5.1 Evaluation of recent regional floras, distribution maps and interviews with experts

An evaluation of regional floras published since 2000 (HAEUPLER and MUER, 2000; HARDTKE and IHL, 2000; MEIEROTT, 2001; OBERDORFER, 2001; JÄGER and WERNER, 2002; KORSCH et al., 2002; GATTERER and NEZADAL, 2003; GARVE, 2004; OTTO, 2004; ZAHLHEIMER, 2001) resulted in no evidence of occurrences near to or on farmland in Germany. The recent literature states nonetheless a (tentative) prediction that common ragweed could be expected to appear on farm land in the near future (ZWERGER and AMMON, 2002). The distribution map published at Floraweb by BfN provides a survey of the findings of *A. artemisiifolia* for Germany since 1950 (http://www.floraweb.de/). The map shows an accumulation of findings in Saxony, the Niederlausitz, the Berlin area, near Hamburg, the Ruhr Basin, the Mannheim-Ludwigshafen area as well as Stuttgart. This map does obviously not reflect the current state of knowledge (ALBERTERNST et al., this volume), also shown by a comparison with a distribution map for Lower Saxony (E. GARVE/Hannover: n. p.). Despite numerous findings of the species in Lower Saxony its status is still classified as casual, because normally only a few individuals were found, which appear only for a transient period of time.

The analysis of floristic lists of seaports, inland harbours, goods stations and cities regarding the occurrences of *A. artemisiifolia* showed the following pattern: so far *A. artemisiifolia* was frequently found at harbours, but only as a casual: Düsseldorf, Homberg, Duisburg, Wesel, Neuss, Ürdingen, Emmerich (WAGENITZ in HEGI, 1979), Hamburg (among others JEHLÍK, 1981) and Bremen (MISSKAMPF and ZÜGHART, 2000). We found the species at the following inland harbours in the years of 2003 to 2005: Dömitz, Lauenburg, Regensburg (Osthafen, Westhafen). Furthermore it was observed at the harbours of Ludwigshafen (MAZOMEIT, 2003), Mannheim (ALBERTERNST et al., this volume) and Strasbourg (BRANDES, 2003). Despite intensive search the species could not be found at the following harbours in recent years: Boitzenburg, Braunschweig (annually controlled, solitary individuals in the years of 1969 and 2002), Dresden, Hannover (Nordhafen), Hildesheim, Magdeburg (ephemeral, found in 1992), Oldenburg, Riesa, Rinteln, Schnackenburg (2004), Schönebeck (old harbour), Schönebeck-Frohse, Uelzen, Vorsfelde/Wolfsburg, Wittenberg, Wittenberge (not observed between 2000 to 2005 despite former oil mill). Published findings of *A. artemisiifolia* at goods stations are rare in recent years: harbour railway territory in Braunschweig (ephemeral), old railway territory in the north of Basle (BIRRER et al., 2003); ephemeral near the railway crossing Marxen/rural district Harburg (FEDER, 2002).

Interviews with the responsible plant protection services of all 16 Federal States did not result in new knowledge concerning occurrences of *A. artemisiifolia* on farmland, with the exception of Brandenburg and Thuringia. Partly the species is already under surveillance due to its allergenic properties, but mostly little is known about the species.

Following analysis of all sources three foci in the current occurrences for Germany could be shown. Brandenburg: In Guben observed according to WAGENITZ (in HEGI, 1979) since 1928, but now no occurrences on farmland were known. Mannheim/Ludwigshafen area: "Completely naturalized" in Ludwigshafen since 1952 (HEINE, 1952). Today in this region mainly distributed along roadsides as well as development areas (B. ALBERTERNST, S. NAWRATH, n. p. and ALBERTERNST et al., this volume). For Baden-Wuerttemberg the current distribution map of *A. artemisiifolia* (FRITZSCH et al., 2005) shows a noticeable increase of findings compared to SEBALD et al. (1996), but only 4 stands are found on arable land (Dr. K. FRITZSCH/Stuttgart: n. p.). Southern Bavaria: In southern Bavaria the species is present on a sand dune near Daßfeld/Siegenburg (nature reserve) at least since 1975 (Dr. W. ZAHLHEIMER/Landshut: n. p.). The increase of this population can be credited to wrong methods of landscape care like prohibited depositing of fertile soil. Two years ago app. 10,000 plants were eliminated by weeding, while in 2005 only app. 1,000 plants had to be removed. Since 2003/4 *A. artemisiifolia* is observed in Burghausen (compound of the State horticultural exhibition), Laufen and Freilassing (partly ephemeral). A high success of reproduction could be observed on seasoned excavation material. A reuse of this material at traffic islands can lead to a dominant occurrence of this species. No occurrences on farmland in southern Bavaria are known so far (P. STURM/Laufen: n. p.).

5.2. Farmland in the surrounding area of Braunschweig

An intensive search on farmland in the area of the rural districts of Wolfenbüttel and Peine as well as in the urban area of Braunschweig did not lead to the finding of more than one stand. We also found no evidences for spreading along roads in Lower Saxony.

5.3. Riparian vegetation of rivers

Despite intensive search *A. artemisiifolia* was found only scarcely at river banks in Germany; according to SIEDENTOPF (2005) it shows no linkage to riparian habitats here. Apart from small random ephemeral populations, the summer fluctuations of the water level may be the main reason for hampering or inhibiting of the establishment below the main water level, because the species seems not to be tolerant to inundation. The situation is different for torrential rivers with an extended period of summer drought, for common ragweed grows often in dried up river beds, which still provide a comparatively good supply of water (own observations in Italy, in the Slovenian karst and along the river Ardèche).

5.4. Urban area of Magdeburg

The occurrence of *A. artemisiifolia* at Magdeburg included at least 25,000 plants in 2005. The largest population was found on the levelled debris of a former oil mill. This included app. 22,600 individuals on app. 507 m^2 (mean density app. 45 plants/m^2). The ragweed population declined since 2004 (D. WALTER/Magdeburg: n. p.). *Ambrosia artemisiifolia* grows near this area in form of a narrow, often interrupted band on the unsecured side of an asphalted lane. The plants here remain very small, probably due to the mechanic damage by trampling and passing over as well as the lack of tall-growing competition. These stands include at least 2,500 individuals on app. 166 m^2 (mean density app. 15 individuals/m^2).

5.5. Farmland in southern Brandenburg

Probably the largest stands of *A. artemisiifolia* in Germany are found in southern Brandenburg near Calau. The plant was found by us near Schorbus, Laubst (largest population), Altdöbern and Calau in October 2005. The pattern is similar to that observed in Hungary or Slovenia: *Ambrosia artemisiifolia* grows at the edges of corn fields, on fallow land and stubble fields, in the intercrop, near silage depots and on roadsides. The very uneven distribution appears to be characteristic. The whole population amounts to app. 44,000 individuals; a maximum height of 180 cm was measured. Affected farmers saw no reason for acting, because they estimated only a minor loss for the crop yield "as with other weeds".

6 Competition experiments with crop plants

Own observations in Hungary, Slovenia, Italy and France make a scenario for Germany probable, in which tuber crop fields are more likely infested than cereal fields. An orientating preliminary experiment at the botanical garden of Braunschweig was conducted to estimate crop yield loss in potato and sugar beet due to *A. artemisiifolia* at four different densities (0, 35, 70, 105) on 6-m^2-plots.

In densely growing crop plants like potato the yield loss caused by *A. artemisiifolia* reached 30 %. The ragweed remained small, the plants were barely ramified, but were able to survive below the shading potato plants. The damage was much higher in crop plants with lower height (for example beets). Here the yield loss can reach app. 70 %. The chances for establishment of *A. artemisiifolia* are considerably higher in beet fields; the plants become taller (up to max. 180 cm) and are more ramified. According to the information from several farmers the crop yield loss in corn is no larger than it would be through the infestation by other weed species.

7 Discussion

Ambrosia artemisiifolia is at least partly naturalized in Germany. The cost caused by illness triggered by ragweed was estimated by REINHARDT et al. (2003) as app. 32 million € p. a. for Germany. To this the economical damage is added, which is caused through the crop yield loss by the species on farmland. No ecological damage caused by *A. artemisiifolia* is known. Control measures against *A. artemisiifolia* should be taken because of its potential allergenic properties.

The growth performance in several places in 2005 show clearly, that the species can build considerable populations in Germany under the present conditions. Expected climate changes may even enhance its performance in Central Europe.

For a precautionary avoidance of greater harm, we propose the following control measures: (1.) Dense populations should be removed – if possible before flowering – by weeding (with gloves). The weeded plants should be burned in favour of security. (2.) Affected farmland should be treated with herbicides, even if a permanent control by herbicide was not obtained according to recent results. (3.) Roadsides with band-like populations of *Ambrosia* should be mowed several times a year. An additional planting of grass and clover (near agricultural roads) should be tested to reduce openings in the vegetation matrix. (4.) A removal of soil from roadsides is to be avoided, because this would activate the seed bank. (5.) Soil from contaminated sites should not be deposited without cover and in no case be reused, because this would lead to an unwanted reproduction. (6.) Agricultural vehicles should not be transferred from infested to non-infested farmland without thorough cleaning.

In addition, we propose the following preventive measures: (1.) Sunflower, cereal and other seeds from affected countries should be checked for seeds of *Ambrosia* as a matter of routine. (2.) Sunflower seed and sunflower-birdseed should only be traded after a cleaning of the seed (simple sieving). (3.) An introduction of certified *Ambrosia*-free birdseed (SCHRADER, 2003), but at least a regular screening of birdseed. (4.) A long-term monitoring of farmland, fallow land, roadsides, silos, deposits and debris dumps in affected regions. (5.) An analysis of the current results from pollen traps for a possible detection of *A. artemisiifolia* in this region. (6.) A sensitization and sufficient information of plant protection services, farmers, road maintenance staff and persons employed in landscape care with the intention to take necessary and balanced measures in individual cases.

9 Acknowledgements

For discussions and informations we thank Prof. Dr. KLAUS ADOLPHI (Cologne), Dr. BERND AUGUSTIN, DIETRICH BÜSCHER (Dortmund), Dr. CHRISTIANE EVERS (Braunschweig), Dr. DIETER FRANK (Halle), Dr. KATRIN FRITZSCH (Stuttgart), ECKHARD GARVE (Hannover), ANGELIKA HÄNISCH (Frankfurt/Oder), Dr. WERNER HILBIG (Petershausen), Dr. HORST JAGE (Kemberg), MICHAEL LITTEL (Kelheim), Dr. G. MEINERT (Stuttgart), UWE RAABE (Recklinghausen), Dr. INGEBORG SCHINNINGER (Vienna), H.-U. SCHMIDT (Berlin), CHRISTIAN SCHNEIDER (Geneva), PETER STURM (Laufen), JEAN-PAUL THEURILLAT (Geneva), DIETRICH WALTHER (Magdeburg), PD Dr. V. WEISS (Leipzig), Dr. ZUNKER (Stuttgart), Dr. W. ZAHLHEIMER (Landshut) as well as the employees of the plant protection services of all 16 Federal States, the employees of the Raiffeisen subsidiaries and the farmers of the affected farmland. We thank ANNETTE KAISER and THORSTEN MARSCHALL for the support during the conducted experiments and the Federal Biological Research Center for Agriculture and Forestry (BBA), Department for Plant Health for discussion of the project outline and for the financial support.

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Contact address: Prof. Dr. Dietmar Brandes, Technische Universität Braunschweig, Institute of Plant Biology, Working Group for Vegetation Ecology, 38092 Braunschweig. Germany, E-Mail: D.Brandes@tu-bs.de