L'ambroisie à feuilles d'armoise (*Ambrosia artemisiifolia* L.) en Russie : propagation, distribution, abondance, dangerosité et mesures de contrôle

Common ragweed (*Ambrosia artemisiifolia* L.) in Russia : spread, distribution, abundance, harmfulness and control measures

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Résumé

Le document suivant présente un inventaire rapide de l'invasion de l'ambroisie à feuilles d'armoise en Russie. La première observation d'*Ambrosia artemisiifolia* L. a été faite dans le sud de la Russie européenne en 1918. Dès la fin 1930, de nombreuses infestations étaient assez largement réparties au-delà du nord du Caucase. Depuis les années 1940, l'ambroisie est considérée comme la mauvaise herbe invasive la plus nocive de Russie. A la fin des années 1980, la zone d'infestation avait atteint plus de 60 000km^2. Néanmoins, à partir de 1990, la situation s'est stabilisée, suggérant que l'ambroisie avait occupé son aire de répartition potentielle. Des observations de terrain, conduites en Russie européenne en 2005-2007, suggérèrent que les limites nord de l'aire de distribution de l'ambroisie étaient déterminées par une température moyenne en septembre de 14-15°C et qu'une hygrométrie inférieure à 250 mm, entre avril et octobre, limitait son expansion vers l'est. De nombreuses méthodes furent mises en place pour supprimer cette mauvaise herbe. En culture, l'ambroisie peut être contrôlée efficacement par divers pesticides, par des méthodes culturales (les cultures hivernales pouvant supprimer sa croissance). Dans les milieux plus stables *A. artemisiifolia* peut être éliminée par un ensemencement d'herbes pérennes cultivées ou sauvages. Il y a plus de 30 ans, quelques espèces d'insectes phytophages furent introduites pour contrôler l'ambroisie à feuilles d'armoise, mais ne se sont pas établis ou leur impact sur la plante est négligeable.

Abstract

The present paper is a brief review of common ragweed invasion in Russia. *Ambrosia artemisiifolia* L. was first recorded in southern part of European Russia in 1918. In the late 1930's, numerous infestations were rather widely distributed over the North Caucasus. Since the 1940's common ragweed was considered the most noxious invasive weed in Russia. By the end of 1980's the heavily infested area increased up to 60,000 km^2. However, starting from 1990, the situation was practically stable suggesting that common ragweed had occupied its potential range. Field explorations conducted in European Russia in 2005 – 2007 suggested that the northern limits of common ragweed distribution range were determined by average September temperature of 14 - 15°C, while the total of April – October precipitations less than 250 mm was limiting its spread eastward. Various methods were used to control this weed. In agricultural fields, common ragweed was effectively controlled by various herbicides, by cultural control (particularly, winter crops could suppress the ragweed growth) and by appropriate agricultural practice (timely cultivation, black summer fallow, etc.). In more stable habitats (field borders, roadsides, ruderals, etc.) *A. artemisiifolia* could be suppressed by sowing of cultured or wild perennial grasses. More than 30 years ago, several phytophagous insect species were introduced to control common ragweed, but all of them either did not establish or have a negligible impact on the target plant.

Mots clés : mauvaise herbe invasive, ambroisie, *Ambrosia artemisiifolia* L., Russie.
Key-words : invasive weeds, ragweed, *Ambrosia artemisiifolia* L., Russia;

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During the last 60 years, common ragweed, *Ambrosia artemisiifolia* L., was rightly considered the most noxious invasive weed in Russia (60, 61, 26, 34, 31, 32). More recently, this invasive alien plant received sharply increasing attention in certain other European countries (19, 6, 7, 4, 5, 23, 22). The present paper is a brief review of common ragweed invasion in Russia, its current distribution, abundance, and control methods.

Spread of the weed

A. artemisiifolia was first found in Russia in 1918 (31, 26, 32) which is much later than in France (4), almost at the same time as in the Eastern Europe (19, 23), but earlier than in China (5). First specimens of common ragweed were collected in France in the XIXth century. The first occasional introductions were possibly connected with the increasing international trade via Black Sea ports (26) and rail roads (31), although in Ukraine *A. artemisiifolia* was even grown as a medical plant (31, 42). Then, the First World War, the Russian Civil War and the forced creation of "collective farms" facilitated the spread of the weed by a marked increase in the number of abandoned fields, which was also the case for some other European countries (23). At the late 1930's, numerous local infestations of common ragweed were widely spread over Stavropol' and Krasnodar territories. As early as in 1940, the first special conference on *Ambrosia* was conducted in Stavropol', where it was stated that "the harmfulness of common ragweed exceeds that of any other annual weed" (60). Soon after, *A. artemisiifolia* was first recorded in Rostov province.
In the 1950's – 1980's, the explosive spread of the weed occurred in Russia, while starting from 1990 the situation was practically stable (Fig. I) suggesting that from that time common ragweed has occupied its potential range. In Ukraine the total square of ragweed infestations now constitutes more than 10,000 km^2 and the expansion of the weed is reportedly still continuing (59).

Current distribution

At present almost 80% of the total square infested by common ragweed in Russia falls on Krasnodar territory (32, 58). Also Stavropol' territory, Rostov province and some republics of the Russian North Caucasus are highly infested, while in adjacent regions (Voronezh, Saratov, Volgograd and several other provinces of Russia) only small local infestations occur (Fig. II). Although individual *A. artemisiifolia* plants were rather often found (mostly along railways and highways) in various parts of Central and Northern Russia, practically none of these plants was able to produce mature seeds (32). Similar results were obtained in Baltic states (54). Southwards, the area infested by *A. artemisiifolia* in European Russia extends into Georgia and westwards, into Ukraine (42, 59). Primorsk and Khabarovsk territories (Russian Far East) is another, relatively small, isolated area of common ragweed invasion.
In 2005-2007, we have conducted country-wide scale field explorations in the southern part of European Russia (Fig. II). All studies were conducted between 15 July and 15 August, just before the beginning of mass flowering of common ragweed. Plots with more or less uniform vegetation separated from other plots by natural borders (field boundary, road, forest belt, etc.) were considered as sampling units. Area of a plot varied from hundreds of square meters (small wastelands) to 60 – 80 hectares (large agricultural fields). Duration of inspection varied from 5 to 30 minutes per plot, depending on the plot size. Usually, 15 - 25 plots per location were inspected along a randomly selected route. Route length was not less than 10 km and total duration of inspection was not less than 8 h per location (see 53, for other details of the method).
The results of this study agreed well with the earlier published data. In Krasnodar territory, the average ragweed population density was high in practically all locations studied. In all of these locations, both arable fields, field borders and other anthropogenic landscapes (roadsides, ruderals, etc.) were infested. The south-western parts of Stavropol' territory and of Rostov province were infested to the same extent (see "Abundance" for the averages). However, towards the northeast, the rate of infestation by common ragweed markedly decreased. In addition, the weed was found there only along roadsides and irrigation canals, near settlements but not in arable fields or field borders. As for several locations studied in the northern parts of Belgorod and Voronezh provinces, same as in Volgograd and Astrakhan' provinces, *A. artemisiifolia* was not found there during one day of intensive search per each location (Fig. II).

It has long been known (e.g. 1) that the potential geographic range of common ragweed, same as that of many other plant species, is primarily determined by two most important environmental factors: temperature and precipitations. The specific feature of *A. artemisiifolia* is that it is a typical "short-day plant", i.e. its flowering is initiated in autumn by the short light day (1, 8). Many authors analyzing the geographic distribution of common ragweed noted the northern limit at ca 50°N which is obviously determined by the temperature requirements (1, 32, 58, 42, 59, 30). However, temperature dynamics depends not only on latitude, but also on longitude. Thus, it makes sense to directly correlate *A. artemisiifolia* geographic range with climate (5, 64). Phenological observations showed that in Southern Russia (60, 61, 34, 31, 32), same as in Germany (3), and in the North America at latitudes of 40-50°N (1), the common ragweed flowering began in the first half of August, while seed maturation occurred in September and extends until frosts kill the plant. Thus, we used the average September temperature as the first parameter of climate. Note that this seems to be much more ecologically justified than minimal temperature of the coldest month (5) or mean July temperature (64) used in other recently published models.

As the second climate parameter, we used the sum of precipitations during the "warm period" (April – October). When our data on *A. artemisiifolia* distribution and abundance were plotted against these two climatic parameters (Fig. III), the figure made it clear that, at least in European Russia, the northern limits of common ragweed distribution range were determined by average September temperature of 14 - 15°C, while the total of April – October precipitations less than 200 - 250 mm was limiting its spread eastward.

The eastern limits of common ragweed geographical range almost coinciding with the boundary between steppe and dry steppe climatic zones were stable during at least last 10-20 years. The further spread of the weed in this direction is highly improbable. Although drought tolerant varieties are known for many agricultural crop plants (e.g. 33, 43, 55) drought resistance is still a rather stable species-specific feature. In its native range, *A. artemisiifolia* population cannot survive even a single extremely dry season (57). In addition, steppe and dry steppe zones of southern Russia also differ in agricultural use: practically the whole of the steppe zone is currently used for tilled crops rotation, while dry steppes are mostly used as pastures which are much less suitable for ragweed invasion. As could be expected, the easternmost stable populations of *A. artemisiifolia* usually located near irrigation canals, river banks, etc. Interestingly, in other habitats, *A. artemisiifolia* was often replaced by more drought resistant representatives of the same plant tribe: *Xanthium* spp. and *Iva xanthiifolia* (50).

As was noted above, the northern limits of common ragweed invasion (ca 50° N) are rather stable both in Europe (32, 58, 42, 59, 30) and in North America (1). This stability is fairly surprising, as the timing of flower initiation is a highly plastic developmental process (2) and rather rapid natural or artificial selection for earlier or later flowering was repeatedly demonstrated for various plant species (13, 17, 9). It was demonstrated that *A. artemisiifolia* plants grown from seeds collected in Canada and South Carolina differed in flowering time (14). Moreover, so called "early form" of common ragweed which starts to flower in the beginning of July (i.e. one month earlier than "normal form") was found in Krasnodar territory more than 50 years ago (60, 61) although a genetic basis for this difference was not demonstrated. On the other hand, multiyear attempts to grow *A. artemisiifolia* in Moscow province (ca 55°N) showed that the plants started flowering, but seeds never ripened (32). The most Northern regions of Russia where common ragweed seed maturation was recorded at least in certain extremely warm seasons are Samara and Novosibirsk provinces, located at 53-54°N (32). Field observations conducted near northern limits of common ragweed distribution range (Rossosh' and Liski regions of Voronezh province, 50 - 51°N) showed that there, in contrast to the eastern boundary, it occupied the most dry, insolated and well heated habitats such as sandy roadsides, railway embankments etc. (50).

Generally, our observations suggest that near the limits of its geographic range, *A. artemisiifolia* grows mostly close to settlements, along roads, irrigation canals, etc. while in agricultural fields (wheat, corn, barley and many other crops), and field margins, it is practically absent (Fig. II). Urban environments were shown to favor the ragweed establishment in USA (65). In Russia, settlements could also provide more warm habitats in the northern boundary and more humid soil in the eastern boundary of ragweed invasion.

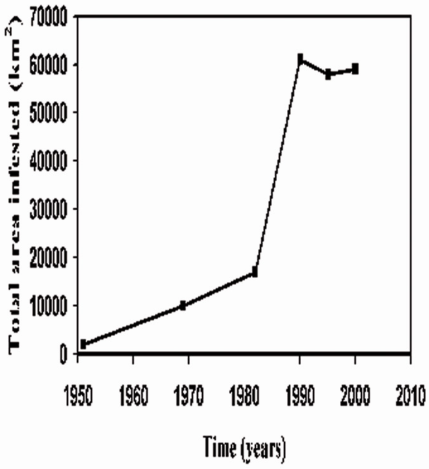

Figure I. Dynamic of the total area infested by *Ambrosia artemisiifolia* in Russia (data from Moskalenko, 2002).

Figure II. *Ambrosia artemisiifolia* geographic distribution and abundance in European Russia in 2005 – 2007: 1 – high density (both arable fields and other anthropogenic landscapes were infested); 2 – low density (arable fields and field borders were not infested); 3 – the weed was not found.

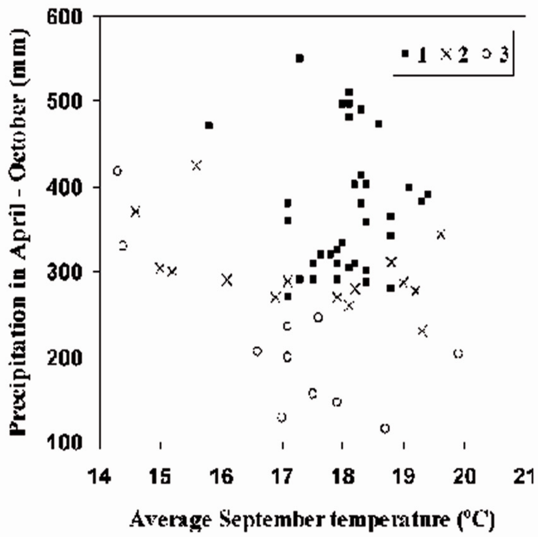

Figure III. Data on *Ambrosia artemisiifolia* geographic distribution and abundance in European Russia plotted against two main climatic factors: the average September temperature and the average total precipitation during April – September. See Fig. II for explanations of symbols.

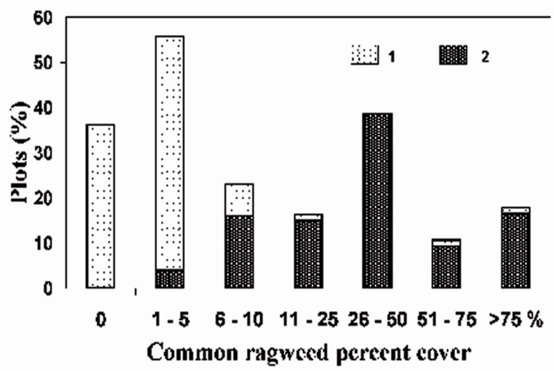

Figure IV. Distribution of plots with different *Ambrosia artemisiifolia* percent cover in locations with high average weed population density (those indicated by "1" in Figs. II and III). Types of plots: 1- arable fields; 2 - relatively stable habitats: field margins, roadsides, abandoned fields, ruderals, etc.

Abundance

In 1988-1989, we have conducted estimation of common ragweed population density in 675 agricultural fields (total square of ca 250 km^2) located near Stavropol', in one of the most heavily infested area. In each particular field, infestation rate varied depending on the cultured plant species (52). On the average, population density of *A. artemisiifolia* was very high: in July-August, its mean wet weight was about 100 g/m^2. Further studies, conducted in the same region in 1991 and in 1994 gave similar results (49).

Recent wide-scale estimation conducted in Southern Russia in 2005-2007 (Fig. II) showed somewhat lower average population density of *A. artemisiifolia.* Particularly, 25 of 69 arable fields inspected in the zone of a high ragweed population density were practically free from ragweed, which was most probably achieved by herbicides treatments or by recent ploughing. In most of other fields, the cover of *A. artemisiifolia* was less (usually, much less) than 5% (Fig. IV). However, in few fields common ragweed obviously dominated which was undoubtedly the repercussion of wrong agricultural practice: i.e., sunflower grown without herbicide application, winter wheat moved without subsequent turning of stubble, unweeded potato field, etc. As the square of inspected fields was highly variable (from 0.6 to 80 hectares), the results were averaged with weighted mean, which constituted the average cover of 1.7%. This is rather close to the recent estimation made by Os'kin (35) in Stavropol' territory: circa 3.8% of agricultural fields were heavily infested by ragweed.

Note that the inspected random sample (12 regions, 69 fields, 11.8 km^2 in total) represented a wide patchy area of more than 60,000 km^2 (Fig. I and II). Our data could be considered as nothing more than a very rough estimation of the average infestation rate, but even 1% cover means at least 500 km^2 densely grown with common ragweed. In relatively stable habitats (field margins, roadsides, abandoned fields, ruderals, etc.) the average cover of common ragweed was much higher than that in crop rotations, the weighted mean being 44% (Fig. IV). On the other hand, as stable biotopes were usually much smaller than agricultural fields (total square of 181 inspected stable biotopes was 0.2 km^2) their impact on overall infestation was relatively small: weighted mean for both types of habitats was 2.4%. However, these relatively small patches or lines, bordering most of agricultural fields and unsurfaced roads play very important role of "ragweed nurseries" spreading seeds over surrounding fields.

Harmfulness

In the Western Europe (6, 7, 3, 4), in USA (65) and in the Eastern Europe (19, 23), common ragweed have attracted public attention mostly as an allergic plant and also as a serious agricultural weed. In Russia, both aspects were long ago considered as extremely important (60, 61, 37). By the 1980's the average concentration of ragweed pollen in Krasnodar territory in August – September was 200 – 600 pollen grains / m^3 (37). According to the recent publications, in Krasnodar territory ca 2% of its population very seriously suffer from allergy to ragweed pollen (32), while Os'kin (35) stated that in the neighboring Stavropol' territory up to 20% of the population are to a different extent allergic to pollen of *A. artemisiifolia*. However, on the other hand, *A. artemisiifolia* could be also a source of useful biologically active substances (38, 39).

In agricultural fields, common ragweed successfully competes for resources with most of crops. Transpiration rate and absorption of minerals and microelements from soil in common ragweed is 2-3 times as high as those in cereal crops. Besides, *A. artemisiifolia* produces allelopathic effect on most of cultured plants. As for a threat to natural biodiversity, it is relatively small, as common ragweed invades almost exclusively disturbed, agricultural or ruderal habitats (34, 32, 31).

Control measures

Mechanical control

In arable fields, common ragweed may be rather efficiently controlled by appropriate agrotechnology. Particularly, preplant cultivation and turning of stubble followed by fall-ploughing could consecutively provoke germination of ragweed seeds and destroy seedlings (31, 32).

Chemical control

In agricultural practices, *A. artemisiifolia* could be successfully controlled by herbicides. Moskalenko (32) recommended to apply 2, 4-dinitrophenol and clopyralid to wheat and barley dichlormid and metolachlor to corn, MCPA (2-methyl-4-chlorophenoxyacetic acid) to sorghum, metolachlor and EPTC (S-ethyl dipropylthiocarbamate) to sunflower, phenmedipham to sugar beet, trifluralin and metribuzin to tomatoes and potatoes, and imazethapyr to alfalfa. In orchards, vineyards, and uncropped fields, it is advisable to apply glyphosate or imazapyr.

Cultural control

Although *A. artemisiifolia* manifests a very high competitive ability (31, 26 , 32), some annual crops, particularly, winter wheat and barley could markedly suppress its growth. Thus, alternation of winter crop and black fallow could markedly reduce the ragweed seed bank. Perennial fodder crops often caused even more strong negative effect on *A. artemisiifolia* populations (31, 32). In relatively stable habitats (abandoned fields, field borders, roadsides, ruderals, etc.) *A. artemisiifolia* could be also suppressed by sowing of perennial plants. For this purpose, mostly various grasses (*Agropyrum, Alopecurus, Bromopsis, Festuca* etc.) are used (31, 32), although Dzybov (10, 11) suggested a natural mixture of wild steppe grasses and herbs.

Biological control

In the 1960's – 1970's, several phytophagous insect species were introduced in the former USSR to control the common ragweed. Agents selection and preliminary studies were conducted by Kovalev (24, 26) in cooperation with American entomologists (18, 16, 15). The released biocontrol agents are listed below.

Zygogramma suturalis F. (Coleoptera: Chrysomelidae)

The striped ragweed leaf beetle is certainly the most known of the insects used to control the common ragweed. Its biology has been extensively studied (27, 29, 51, 62, 44, 45, 46, 47, 48, 63) and the history of its introduction into Russia was described in detail (26, 49). In short, *Z. suturalis* was introduced into the former USSR from the USA and Canada in 1978. About 1500 specimens were released in the vicinity of Stavropol'. The initial phase of this introduction was a population explosion with more than 30-fold yearly increase in number and extremely high population densities: up to 100,000,000 adults/km^2 and up to 5,000 adults/m^2 in aggregations (25, 26). In some cases, "solitary population wave", i.e. moving zone of ultra-high population density leaving behind an area of complete elimination of the weed was observed (25). Since 1982, numerous releases were made in the south of European Russia and Ukraine (27), but such a high efficiency was never recorded, possibly because the insects were released in regularly exploited agricultural lands, but not in special protected sites (52, 53).

Moreover, further observations have showed that in the place of the initial introduction *Z. suturalis* population density drastically decreased and it was not able to control the weed. Sampling conducted in 1988-1994 over 25,000 ha around the release site showed very low population density of the ragweed leaf beetle. Significant damage to ragweed has only been recorded on few fields and on several small patches, where the beetle reached the relative population density of more than 50 adults per kg of ragweed wet weight (52). Similar results were later obtained by other authors (40, 35, 12). Apparently, *Z. suturalis* turned to be not tolerant to crop rotation and other common agricultural practices (49). Random sampling conducted in 2005-2007 showed that *Z. suturalis* has spread over most of the area heavily infested by ragweed in Russia (Fig. II). However, its average population density was very low: ca 0.001 first generation adult/m^2 in arable fields and ca 0.1 adult/m^2 in relatively stable habitats. In only a few of the studied plots *Z. suturalis* population density up to 2–3 adults/m^2 was recorded. The impact on the targeted weed was negligible (50, 53).

Note that in the 1980's *Z. suturalis* was introduced against *A. artemisiifolia* in Croatia and China, but either not established or had no significant impact on the weed (20, see 21 for more references). However, having regard to the spectacular success achieved in the special protected experimental plot (25, 26) it is still possible that protected field nurseries could be a promising method of *Z. suturalis* mass rearing for suppression of common ragweed in surrounding areas.

Zygogramma disrupta Rogers (Coleoptera: Chrysomelidae)

This closely related species of the same genus was considered to be more fecund and better adapted to hot and dry climate. It was repeatedly released in the 1980's, but never established (27, 29, 21).

Brachytarsus (Trigonorrhinus) tomentosus Say (Coleoptera: Anthribidae).

This flower-feeding weevil was released in 1977 (26), but also did not establish (21).

Tarachidia candefacta Hubn. (Lepidoptera: Noctuidae)

Chronologically, this moth was the first herbivorous insect intentionally introduced in Europe for biological control of an invasive weed: it was released in Krasnodar territory of the former USSR in 1969 (28, 24). During many years, *T. candefacta* was only sporadically recorded in Russia and Ukraine. However, in the 1990's these records became regular (56). Moreover, in 2005 *T. candefacta* population density in Krasnodar territory and Rostov province of Russia locally reached to 3 eggs per plant or 1 larva / m^2 (41). The last authors suggested that this may be at least partly explained by global warming: in the studied area, the winters of 2002-2005 were unusually mild and wet.

Euarestia bella (Loew) (Diptera, Tephritidae)

This seed-feeding fly was repeatedly (in 1969, 1973, 1977, and 1988) released in the Russian North Caucasus but still was not recorded there (24, 26, 21).

Conclusion

In arable fields, common ragweed could be rather efficiently controlled by mechanical and / or chemical control. At present, agricultural fields (sunflower, corn, sugar beet, potato, various vegetables) same as stubbled wheat and barley fields densely grown with ragweed are rather rare in Russia and could be considered as the repercussions of wrong agricultural practice. However, in field borders and non-agricultural lands average population density of *A. artemisiifolia* is much higher because in such habitats weeds are most often uncontrolled. Several attempts of biological control with phytophagous insects were made, but all of them were not efficient.

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