Implications of life history for control and eradication

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Introduction

Weed control needs detailed knowledge about the biology of the target species to be efficient. In case of the invasive *Ambrosia artemisiifolia* L. (common ragweed) several studies about its biology were performed in the 20th century in North America (Gebben, 1965; Dickerson, 1968; Basset and Crompton, 1975). In the latest review about the biology of this species (Kazinczi *et al.,* 2008a) some data on population biology and habitat preferences of European populations were integrated to the pool of knowledge. Since that time the number of papers about the biology of common ragweed in European populations increased seriously.

Besides the trials within this project several new studies on *A. artemisiifolia* and other comparable invasive plants were published (see the review by Smith *et al*., 2013). We have to expect local adaptation to the new habitat (environment, co-occurring species, predators and parasites). Therefore the analysis of the most recent biological behaviour of common ragweed is essential to decide about the optimal local control measures. Scalone *et al*. (2013) already indicated that the European populations show specific adaptations to the northern climate by shifting the growth and flowering period towards July and June. During field work for the section "Biological fundamentals" and "Non-chemical and integrated control strategies" we also could find some individuals within few populations in eastern Austria that started flowering in mid-June already (Karrer *et. al*., 2011). Obviously the life cycle of common ragweed is shortened in the invasive European range.

Life cycle of Ambrosia artemisiifolia

The section "Biological fundamentals" of the HALT-AMBROSIA-project aimed at increasing the knowledge of the biological characters of common ragweed from European populations. Like any other summer annual weed the fate of the population depends very much on the seed production in the respective year so that the future generations have a realistic chance to establish and succeed. The lifespan of a single common ragweed plant (Fig. 1) begins with the barochorous release of seeds from the mother plant, followed by the phase of being part of the soil seed bank for variable times. High variation of seed morphs were found by Fumanal *et al*. (2007a, b) indicating pre-adaptation to be different distribution vectors. They found that the partition of light seeds is able to float on water for longer time and thus is prone to be spread easily along rivers.

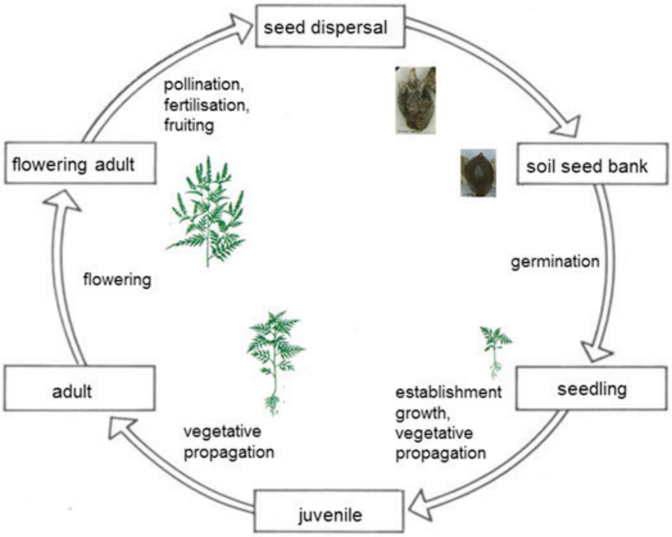

Fig. 1: Annual lifecycle (developmental stages) of *Ambrosia artemisiifolia*

Lifetime of seeds as element of the soil seed bank varies depending on the frequency of soil disturbance and dormancy. In arable fields with annual soil tillage the turnover rate of seeds is higher compared to that of abandoned fields or grassland. Consequently, the persistence of individual seeds in the soil seed bank of fields is short. In grassland, most of the seeds stay in the upper soil or on soil surface, and are integrated to the annual seed turnover, whereas the smaller partition of seeds will be integrated to deeper soil horizons by bioturbation and build the long-time persistent part of the soil seed bank.

Toole and Brown (1946) found a maximum longevity of (few) common ragweed seeds by 39 years. In their experiment the storage conditions were very good, not comparable to the very stressful conditions in the upper soil and soil surface. Seeds stored at soil surface conditions turned out to loose viability within 5 years. Our studies of the soil seed bank of common ragweed along roadsides (see section A article 3) showed losses of 20% on average when autumn and early spring samples of the sites where compared with respect to the number of common ragweed seeds in the upper soil layer (0-7 cm). Beres (2004) found that seeds exposed to field conditions (soil surface) throughout 5 years lost their viability by 100%. A screening for viability of common ragweed seeds with different age stored at dry conditions and room temperature (ca. 20°C) gave comparable results (Kazinczi in section A article 3). Considering the high variability in seed mass (Fumanal *et al.,* 2007b) one could expect that smaller seeds that show higher dormancy tend to be accumulated in the lower soil, whereas heavier seeds have better chances to stay aboveground. Fenner and Thompson (2005) state that small seeds are more likely to be buried and are more dormant. It is not known if the partition of small common ragweed seeds build up the more persistent seed bank whereas the seeds from upper soil/soil surface were bigger and less dormant but more successful by carrying more resources. Such was proved at least for other taxa (Zhang, 1993; Imbert, 1999).

Like other typical summer annual weeds common ragweed seeds show innate dormancy after seed set in autumn and need stratification of about 4 weeks at temperatures around 0°C (Baskin and Baskin, 1998) for germination. If the conditions after stratification are not suitable for germination (darkness, drought, temperature regime at low positive values, low O_2 or high CO_2 concentration in the soil) enforced (secondary) dormancy can be initiated (Baskin and Baskin, 1980). As long as the conditions do not change seeds persist in secondary dormancy until spontaneous death (latest after 39 years after Toole and Brown, 1949). Such data were published for North American populations of common ragweed. Only few data about seed biology are available from European populations (Fumanal *et al.,* 2007a; b; Beres, 2004). Adaptive evolution in the newly invaded range could have changed the preferred site conditions for the regulation of germination and growth. Therefore some experiments were started in 2012 to elucidate these important aspects of the life cycle. The burial experiment (section A article 3) will test the survival rates of common ragweed seeds buried at upper (5 cm) or lower (25 cm) soil depths. Survival rates of common ragweed seeds varied between 30 and 98% depending on the seed source. Before burial, seeds were collected and stored at various conditions, transported by postal services (airmail) at maybe less optimal temperatures. The older sample (3 years in age when buried) gave generally lower viability rates (30-80%) than the younger ones (1 year old, 70-98%).

Common ragweed individuals that germinate early in the season (March to April) grow slowly at the beginning forming a rosette-like stage with 4-6 leaves. With increasing temperatures vegetative growth is enhanced during June and July by significant stem elongation and +/- branching – depending on the resource availability (Leskovšec *et al.,* 2012 and Section B article 11) or population density (Patracchini *et al.,* 2011; Simard and Benoit, 2011). Consequently, the number of pollen as well as seeds produced per individual also depends largely on habitat features and population density.

Effects of control measures on common ragweed life cycle

If the soil seed bank of common ragweed is already established it can be reduced by crop rotation and direct control of germinated plants. On arable fields with regular ploughing a significant proportion of seeds always will be left in the soil seed bank. Switchback to summer crop cultivation will promote the common ragweed population to recover from the persistent part of the soil seed bank. Only total abandonment and succession towards forests over decades might deplete the soil seed bank by death from ageing. Depletion of soil seed bank by repeated stimulation to germinate (i.e. by soil tillage every month from spring onwards) could help to control common ragweed.

Seed production is positively correlated to biomass (Leskovšek *et al.,* 2012). Cutting aboveground biomass at early stages (May or June) is +/- compensated by rapid basal regrowth from axillary buds, often supplemented by accessory buds. Early regrowth tends to produce rather more male flowers whereas later regrowth in August or September invest more into female flowers/seeds. Regrowth from early cuts also increases the number of axillary buds positioned at lateral shoots below the cutting height. They promote common ragweed to increase even the number of lateral shoots below the cutting line that bear mostly female flowers. Based on the cutting experiments in pots (Milakovic *et al.,* 2014a) as well as in the field it can be stated that a first cut should be delayed as far as possible towards the start of female flowering. In the southern part of Central Europe (S-France, Switzerland, Austria, N-Italy, Hungary, Slovakia, Slovenia, Croatia, Serbia) such late first cut must be supplemented by at least one second cut about 3 weeks later to prohibit successful seed production from the regrowth (Karrer *et al.,* 2011; Pixner, 2012; Karrer and Pixner, 2012; Milakovic *et al.,* 2014b).

When cutting is one of the most frequent control measures against common ragweed in sensitive habitats (within villages, water resource areas, nature protection areas), application of herbicides is used often as an appropriate control tool against common ragweed in traditional farming. In graminoid crops common ragweed can be sprayed rather effectively, but herbicides have to be applied rather sophisticated if the farmers aim at very effective regulation. Several seedling cohorts (even in maize) produce enough seeds for future generations so that common ragweed continues to be present in the soil seed bank. Maybe the crop yield is not reduced but common ragweed stays in the system for long time. Furthermore, common ragweed cannot be fought chemically in some minor crops (oil pumpkin, red bean, soybean, and most sunflower breeds) because of the lack of registered herbicides in some countries (Austria, Hungary, Germany, etc).

In cereal stubbles late germinating common ragweed cohorts can even dominate. Simply spraying herbicides does not kill common ragweed by 100% at this late developmental stage (Bohren *et al.,* 2008b). But combined measures like mowing plus spraying the regrowth or simply ploughing can destroy common ragweed most efficiently (Kazinczi *et al.,* 2008b). Donald (2000) demonstrated that a combination of band applied herbicides in the crop rows and mowing twice between the crop rows was sufficient to control annual weeds like common ragweed without reducing the yield of the main crop in Australia.

The most sensitive phases of common ragweed's life cycle for appropriate application of the commonly used control measures are illustrated in Fig. 2. When optimizing the available tools with respect to timing and sequence, the effort for control can be kept low. Which kind of measure to apply, depends primarily on the habitat type infected and on the season.

Most important for hindering the invasion to not yet infected sites/countries is prevention of seed dispersal by human vectors. I.e., commodities (seed material, soil, relevant for trading and construction areas) should be kept clean as well as vehicles that move from infected to uninfected areas (most relevant in agricultural landscapes).

Once common ragweed seeds arrive on or in the soil the seed bank can be managed by depletion or long-time full abandonment. Stimulating seeds to germinate and subsequent kill is a way to decrease the presence of weeds aboveground as well as belowground (Swanton *et al.,* 2000; Murphy *et al.,* 2006). Pre-emergence herbicides would not help so much if subsequent soil disturbance provides new seeds from deeper soil horizon. Even better would be to provoke common ragweed to germinate and to kill afterwards by ploughing. During and short time after germination (seedling and juveniles up to the 4 leaf stage) is the best time for herbicide application in habitats where they are registered. Sophisticated mechanical weeding could also have high efficacy at this early stage of common ragweed development as the common ragweed seedlings and juveniles are prone to being killed by drought because of the lack of a well-developed tape root at that time of the year. The older common ragweed gets the less effective are mechanical treatments and herbicide application (Bohren *et al.,* 2008a; b; Section B).

Young adults are the best stage for hand-pulling: easy to detect and to identify, mechanically firm enough to be hold tight but the roots still not too deep. Therefore, pulling is generally the most effective control measure against common ragweed (Bohren *et al.,* 2008c) at least for small to medium sized populations (1-1000 individuals). Pulling before flowering is fine also for getting rid of the plant by use in simple humus composters. Pulling late in the year will produce individuals with ripened seeds that have to undergo a serious destruction of organic material by burning or fermentation.

Fostering competition by other plants (crops, intercrops, lawn species, tall grasses and herbs) is an admitted control option. Competition by shading green leaves or by litter can hamper already germination what can be documented easily on fallow land (Karrer *et al.,* 2011). Competition can enforce germinated common ragweed to develop quickly in height and therefore bearing only few buds for regrowth below cutting height (Milakovic *et al.,* 2014b). If germinated without competition in early spring common ragweed tends to grow only slowly in height forming almost a rosette of 4 to 6 leaves near to the ground. Consequently, such plants have very high regrowth potential from lower axillary buds after being cut. The number of available meristems for regrowth below the cutting height is also increased by the torsion of the main root and the shoot base in older common ragweed plants. This causes the indirect lowering of the shoot base with its regrowth meristems (Vitalos, unpubl.). Outcompeting regrowing lateral shoots of mown common ragweed by even faster regrowing competitors can help to keep the number of common ragweed flowers or seeds at low levels (Milakovic and Karrer, 2011). Fostering of competing vegetation after every mowing event is only possible on nutrient rich sites. Unfortunately, the substrate used to cover road shoulders since about 10 years is very unfavourable for any plant to grow. As a typical (CS)R-strategist (CSR theory: Competitors, Stress tolerators and Ruderals) common ragweed is able to establish even at such unfavourable site conditions (gravel as substrate) and it will take many years to establish a competitive vegetation cover.

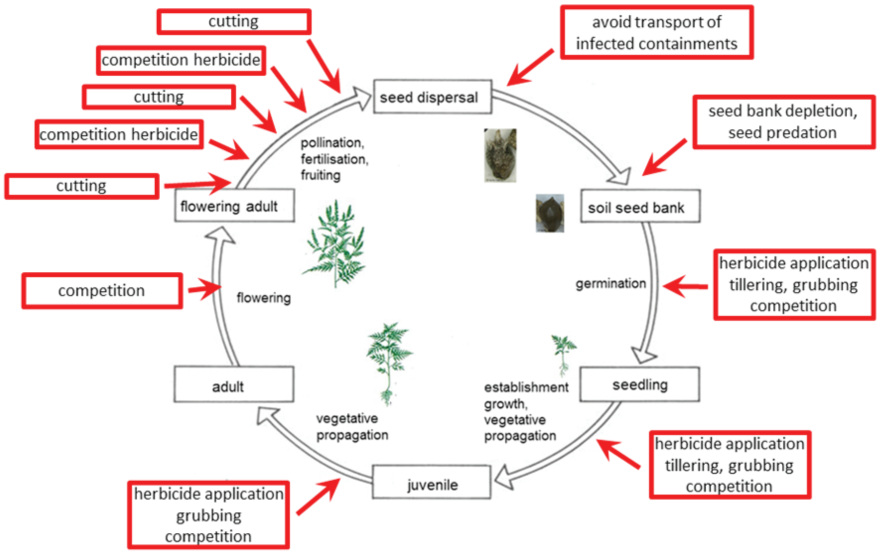

Fig. 2: Life cycle of common ragweed and the optimized timing for appropriate application of control measures.

Consequences and conclusions

The HALT-trials gave improved insight to the biology of seeds and seed production in European populations of common ragweed at different habitat types. But, we have to face new problems when common ragweed succeeds to adapt to lower temperatures for growth, to higher temperatures for stratification and to earlier initiation of flowering and seed set. Future research has to be on the qui vive when adaptive processes in common ragweed evolution call for continuous adaptation of control measures.

References

Baskin, J.M. and Baskin, C.C. (1980): Ecophysiology of secondary dormancy in seeds of *Ambrosia artemisiifolia*. Ecology 61(3): 475-480.

Baskin, C.C. and Baskin, J.M. (1998): Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. San Diego: Academic.

Basset, I.J. and Crompton, C.W. (1975): The biology of Canadian weeds 11. *Ambrosia artemisiifolia* L. and *A. psilostachya* DC. Can. J. Plant Sci. 55, 463-476.

Béres, I. (2004): Integrated weed management of common ragweed (*Ambrosia artemisiifolia* L.). (Az ürömlevelű parlagfű (*Ambrosia artemisiifolia* L.) elleni integrált gyomszabályozási stratégiák). Hung. Weed Res. and Technol. 5:3-14.

Bohren, C., Delabays, N., Mermillod, G., Baker, A., Vertenten, J. (2008a): Ambrosia artemisiifolia L: Optimieren des Schnittregimes. Agrarforschung 15(7): 308-313.

Bohren, C., Delabays, N., Mermillod, G. (2008b): *Ambrosia artemisiifolia* L.: Feldversuche mit Herbiziden. Agrarforschung 15 (5), 230-235.

Bohren, C., Mermillod, G., Delabays, N. (2008c): *Ambrosia artemisiifolia* L. - Control measures and their effects on its capacity of reproduction. Journal of Plant Diseases and Protection, Special Issue 21: 307-312.

Dickerson, C.T., (1968) Studies on the germination, growth, development and control of common ragweed (*Ambrosia artemisiifolia* L.) – PhD. Cornell Univ. Ann Arbour, Michigan.

Donald, W.W. (2000): Timing and frequency of between-row mowing and band-applied herbicide for annual weed control in soybean. Agronomy journal, 92(5): 1013-1019.

Fenner, M. and Thompson, K. (2005): The ecology of seeds. Cambridge. Cambridge University Press.

Fumanal, B., Chauvel, B., Bretagnolle, F. (2007a): Estimation of pollen and seed production of common ragweed in France. Ann Agric Environ Med 14: 233-236.

Fumanal, B., Chauvel, B., Sabatier, A., Bretagnolle, F. (2007b): Variability and Cryptic Heteromorphism of *Ambrosia artemisiifolia* Seeds: What Consequences for its Invasion in France? Annals of Botany 100 : 305-313.

Gebben, A.I. (1965): The ecology of common ragweed, *Ambrosia artemisiifolia*, L. in southeastern Michigan. Michigan, University of Michigan. Doctor of Philosophy: 234 pp.

Imbert, E. (1999): The effects of achene dimorphism on the dispersal in time and space in Crepis sancta (*Asteraceae*). Canadian Journal of Botany 77: 508–513.

Karrer, G. and Milakovic, I. (2011): Optimization of cutting regimes for control of ragweed along road-sides. - In: Bohren, C.; Bertossa, M.; Schoenenberger, N.; Rossinelli, M.; Conedera, M. (eds): 3rd International Symposium on Environmental Weeds and Invasive Plants. Abstracts. October 2 to 7, 2011. Monte Verità, Ascona, Switzerland. Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research WSL. p 113.

Karrer, G., Milakovic, M., Kropf, M., Hackl, G., Essl, F., Hauser, M., Mayer, M., Blöch, C., Leitsch-Vitalos, M., Dlugosch, A., Hackl, G., Follak, S., Fertsak, S., Schwab, M., Baumgarten, A., Gansberger, M., Moosbeckhofer, R., Reiter, E., Publig, E., Moser, D., Kleinbauer, I., Dullinger, S. (2011): Ausbreitungsbiologie und Management einer extrem allergenen, eingeschleppten Pflanze – Wege und Ursachen der Ausbreitung von Ragweed (Ambrosia artemisiifolia) sowie Möglichkeiten seiner Bekämpfung. Endbericht, BMLFUW, Wien. 315 pp. German version available from: https://www.dafne.at/dafne_plus_homepage/.

Karrer, G. and Pixner, T. (2012): The contribution of post-harvest ripened ragweed seeds after cut for control. In: GEIB Grupo Especialista en Invasiones Biológicas (Ed.) NEOBIOTA 2012, 7th European Conference on Biological Invasions Ponte-vedra (Spain) 12-14 September 2012, Halting Biological Invasions in Europe: from Data to Decisions, Abstracts, 229. Available from http://neobiota2012.blogspot.co.at/p/book-of-abstracts.html.

Kazinczi, G., Béres I., Novák R., Bíró K. (2008a): Common ragweed (*Ambrosia artemisiifolia* L.): A review with special regards to the results in Hungary: I. Taxonomy, origin and distribution, morphology, life cycle and reproduction strategy. Herbologia, 9(1): 55-91.

Kazinczi, G., Novák, R., Pathy, Z., Béres, I. (2008b): Common ragweed (*Ambrosia artemisiifolia* L.): A review with special regards to the results in Hungary. III. Resistant biotypes, control methods and authority arrangements. Herbologia 9(1): 119-144.

Leskovšek, R., Datta, A., Knezevic, S.Z., Simončič, A. (2012): Common ragweed (*Ambrosia artemisiifolia*) dry matter allocation and partitioning under different nitrogen and density levels. Weed Biol. Manag. 12, 98-108.

Milakovic, I., Karrer, G. (2011): Competitive suppression of common ragweed in early successional stages of revegetation. . [3rd International Symposium on Weeds and Invasive Plants, Ascona, Switzerland, October 2 -7] In: Bohren, C.,Bertossa, M., Schoeneberger, N., Rossinelli, M., Conedera, M. (Eds.), 3rd International Symposium on Weeds and Invasive Plants. Abstracts., p. 111

Milakovic, I., Fiedler, K. & Karrer, G. 2014a Fine tuning of mowing regime, a method for the management of the invasive *Ambrosia artemisiifolia* L. at different population densities. (in revision)

Milakovic, I., Fiedler, K. & Karrer, G. 2014b Management of roadside populations of invasive *Ambrosia artemisiifolia* by mowing (Weed Research, in press).

Murphy, S.D., Clements, D.R., Belaoussoff, S., Kevan, P.G., Swanton, C.J., 2006. Promotion of weed species diversity and reduction of weed seedbanks with conservation tillage and crop rotation. Weed Science, 54: 69-77.

Patracchini, C., Vidotto, F. Ferrero, A. 2011. Common Ragweed (*Ambrosia artemisiifolia*) Growth as Affected by Plant Density and Clipping. Weed Technology 25(2): 268-276.

Pixner, T. (2012): Die Reaktion von *Ambrosia artemisiifolia* L. auf unterschiedliche Schnittrhythmen. Dipl. Thesis, University of Natural Resources and Life Sciences Vienna. 129 pp.

Scalone, R., Kolseth, A.K., Stefanic, E., Andersson, L. (2013): Will photoperiod requirements serve as a barroier to establishment of *Ambrosia artemisiifolia* in Sweden. European Weed Research Society (ed.) Proceedings of the 16th Symposium of the EWRS, 24-27 June, 2013, Samsun, Turkey, 57.

Simard, M.-J. and Benoit, D.L. (2011): Effect of repetitive mowing on common ragweed (*Ambrosia artemisiifolia* L.) pollen and seed production. Ann Agric Environ Med 18(1): 55-62.

Smith, M., Cecchi, L., Skjøth, C.A., Karrer, G., Šikoparija, B. (2013): Common ragweed: A threat to environmental health in Europe. Environment International, 61: 115-126.

Swanton, C.J., Shrestha, A., Knezevic, S.Z., Roy, R.C., Ball-Coelho, B.R. (2000): Influence of tillage type on vertical weed seedbank distribution in a sandy soil. Canadian Journal of Plant Science, 80: 455-457.

Toole, H.E. and Brown, E. (1946): Final results of the Durvel buried seed experiment. J. Agric. Res. 72, 201-210.

Zhang, J. (1993): Seed dimorphism in relation to germination and growth of *Cakile edentula*. Canadian Journal of Botany 71: 1231–1235.