ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2018 Vol. 62, Št. 1: 67–76

The impact of mowing on the growth and blooming of common ragweed (*Ambrosia artemisiifolia*)

Vpliv košnje na rast in cvetenje pelinolistne žvrklje (*Ambrosia artemisiifolia*)

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Abstract: Common ragweed (*Ambrosia artemisiifolia*) is an invasive alien species originating in North America that has spread widely in Europe in last decades. Removal of common ragweed and prevention of its reproduction is mandatory for landowners in Slovenia, decreed by Slovenian legislation. One of the most commonly used removal methods is mowing, so we decided to conduct a research project on the impact of mowing on the growth and propagation of this species. We used the common ragweed plants that we collected in the spring at the road embankments and planted them in plastic box planters. At the beginning of the summer, we cut the plants at three different heights, which represented a mowing at three different heights. A group of plants was left untreated and represented a control group to compare with the test plants. We monitored their growth until the end of September, by measuring the height of plants, the development of male inflorescences, where allergenic pollen is produced, and seed development. We found out that the survival rate of the plants cut above the first pair of leaves were affected the most, while all the plants cut above the third pair and plants of the control group, survived. Plants of control group reached largest height and produced the highest dry mass as well. Contrary to expectations, differences in height and mass of test plants were negligible. Mowing has a major impact on the development of male inflorescences. Mowing above the 1st and 2nd pairs of leaves has reduced the overall length of male inflorescences to a third, while mowing above the 3rd pair almost halved the length of inflorescences. That resulted to a significant reduction in the amount of allergenic pollen. Altogether, most of the fruits (achenes) have grown on control plants. If we calculate the average number of fruits per plant, on average most fruits have developed on control plants and plants cut the lowest. We may conclude that a single mowing in a season does not reduce the production of seeds, which is an important information for maintainers of public areas as well as landowners.

Keywords: *Ambrosia artemisiifolia*, common ragweed, mowing, sexual reproduction

Izvleček: Pelinolistna žvrklja ali pelinolistna ambrozija (*Ambrosia artemisiifolia* L.) je v Evropi zelo razširjena tujerodna vrsta, ki izvira iz Severne Amerike. V Sloveniji nas k njenemu odstranjevanju zavezuje zakonodaja, ki lastnikom zemljišč zapoveduje odstranjevanje ambrozije in preprečevanje njenega razmnoževanja. Eden od najbolj uporabljanih načinov odstranjevanja je košnja, zato smo se odločili izdelati raziskavo o vplivu košnje na rast in razmnoževanje ambrozije. V poskusu smo uporabili rastline, ki smo jih spomladi nabrali ob cesti in jih posadili v cvetlična korita. Rastline smo na začetku poletja porezali na treh različnih višinah (nad 1. 2. in 3. parom listov), kar je predstavljalo košnjo na treh različnih višinah, z namenom opredeliti najprimernejšo višino košnje za učinkovito zatiranje ambrozije. Del rastlin smo pustili neporezanih in so predstavljale kontrolno skupino, s katero smo primerjali testne rastline. Do konca septembra smo spremljali njihovo rast, tako da smo merili višino rastlin, razvoj moških socvetij in razvoj semen. Ugotovili smo, da je propadlo največ rastlin, ki so bile porezane nad prvim parom listov, vse rastline, porezane nad tretjim parom pa so, prav tako kot kontrolne, preživele. Najvišje so zrasle kontrolne rastline, ki smo jim na koncu poskusa izmerili tudi največjo suho maso. V nasprotju s pričakovanji so bile razlike v višinah in masi testnih rastlin zanemarljivo majhne. Velik vpliv ima košnja na razvoj moških socvetij. Košnja nad 1. in 2. parom listov je skupno dolžino moških socvetij zmanjšala na tretjino, košnja nad 3. parom pa skoraj na polovico. To pomeni veliko zmanjšanje količine alergenega peloda. Skupno največ plodov se je razvilo na nepokošenih rastlinah. Če izračunamo povprečno število plodov na rastlino, se je v povprečju največ plodov razvilo na kontrolnih in najnižje pokošenih rastlinah. Enkratna košnja torej ne zmanjša tvorbe semen, kar je pomemben podatek za vzdrževalce javnih površin in lastnike zemljišč.

Ključne besede: *Ambrosia artemisiifolia*, pelinolistna žvrklja, ambrozija, košnja, spolno razmnoževanje

Introduction

Common ragweed (*Ambrosia artemisiifolia* L.) is an invasive alien species originating in North America. Genetic analysis of microsatellite markers in French populations have shown that it was introduced to Europe several times independently (Genton et al. 2005). First records for its presence in Europe are from the middle of 19th Century (Chauvel et al. 2006, Csontos et al. 2010), but its invasive spreading began a few decades ago. In Austria, the first naturalized population was recorded nearly 70 years after the first record of a casual population (Essl et al. 2009). The successful invasion is the result of high seed productivity (Fumanal et al. 2007), seed longevity (Darlington 1922) and effective spreading by the human assisted vectors, as transport of contaminated crops and bird seeds, dirty agricultural and mowing machines and transport of soil (Essl et al. 2009). Common ragweed is the most frequent in Eastern and Central Europe (Buttenschøn et al. 2008–09). First findings in Slovenia are from the middle of 20th Century (Jogan and Vreš 1998). In Europe, the first records were associated with railways (Essl et al. 2009), but later it became frequent also on ruderal sites, fields and bird-feeding sites (Buttenschøn et al. 2008–09, Essl et al. 2009, Strgulc Krajšek and Batič 2014).

Common ragweed is air pollinated annual plant, flowering in late summer. Due to strongly allergenic pollen it has very negative effects on human health (Kofol Seliger, 2001). If the population is dense, it also has negative impact on crop yields, especially maize, sugar beet and sunflowers (Buttenschøn et al. 2008–09).

The spread of *Ambrosia* in Slovenia is controlled by two legal instruments. The first is Commission Regulation (EU) No 574/2011 of 16 June 2011, concerned with undesirable contents of animal feed, including *Ambrosia* seeds (Anon. 2011). The second is the Slovene regulation "*Odredba o ukrepih za zatiranje* škodljivih *rastlin iz rodu Ambrosia*" (Decree on measures to suppress harmful plants of genus *Ambrosia*), that obliges every citizen to remove all *Ambrosia* plants from his property to prevent the plants from developing flowers and fruits (Anon. 2010).

The most effective method for the prevention of flowering and reproducing of common ragweed is uprooting the whole plants before the flowering period. When the populations are large, this method is time consuming and too expensive, therefore the most commonly used removal method is mowing (Buttenschøn et al. 2008–09). Common ragweed has well documented regenerative capability and several experiments shown that cutting by itself cannot control common ragweed (Karrer 2016).

We decided to research the impact of single mowing at three different heights, conducted before the flowering period, on the biomass production, flowering and seed development of *Ambrosia artemisiifolia*, with the aim to prepare a recommendation for the most appropriate cutting height.

Material and methods

We collected the samples of *Ambrosia artemisiifolia* on 16th of June 2017 in Gunclje, in Central Slovenia, in NW suburbs of Ljubljana. Information about the locality: Slovenia: Ljubljana, Gunclje, next to the road between Gunclje and Dvor, lane of grass between the road and pavement, 46° 6’ 13,26” N, 14° 26’ 41,89” E. Leg: Z. Krajšek, Š. Jakoš and S. Strgulc Krajšek, 16th of June 2017.

We gathered about 250 entire young plants, which were 3 to 10 cm tall. Until the planting we stored them in plastic containers. We planted them into elongated plastic box planters (size: 50 × 15 cm), half-filled with mixture of soil (Bio Plantella start, manufacturer Unichem, Vrhnika) and vermiculite in a proportion 2:1, on the same day. In each of 8 box planters we planted 25 ragweed plants. We planted all the remaining plants in the 9th box planter and were planned to be used as source of plants in case of some ragweed plants fail to survive until cutting. We put them on a shady outdoor place without roof so plants were exposed to the local weather. The soil in each box planter have been watered with 1 L of tap water. During the experiment we watered the plants regularly when we saw the soil was getting drier.

On 9th of July 2017 we measured the height of plants and counted pairs of leaves for the first time. Height of each plant has been measured from the soil level to the apical meristem and we counted those fully-developed pairs of leaves, where leaves have been already apart and positioned horizontally. Based on these measurements (Fig. 1) we divided the box planters in 4 groups, containing more or less similar size range and leaf development of plants and decided which box planters will be used for control and which for each experiment treatment:

- plants (N=48) in box planters number 1 and 2 were cut above the first pair of leaves (approx. 1.5–3 cm above the ground),
- plants (N=49) in box planters number 3 and 5 were cut above the second pair of leaves (approx. 2.5–5 cm above the ground),
- plants (N=50) in box planters number 6 and 7 were cut above the third pair of leaves (approx. 4–8 cm above the ground) and
- plants (N=50) in box planters number 4 and 8 were left untreated and were meant for the control group.

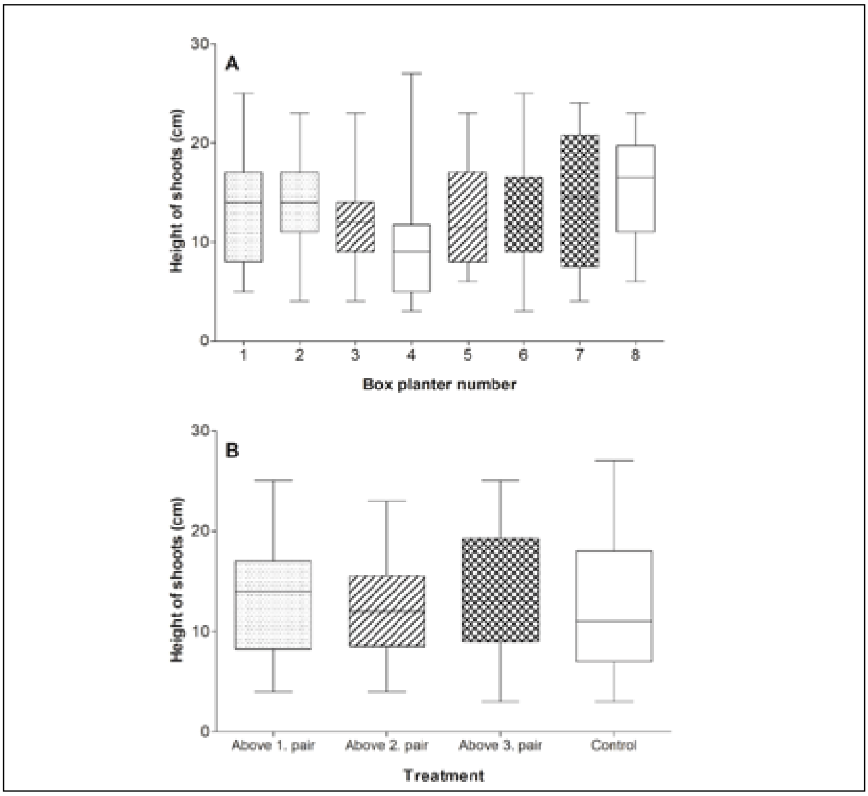

Figure 1: Prior the experiment, the height of shoots was measured in all 8 box planters (A). The box planters were combined in pairs, so the starting intervals of plants' heights before the experiment were similar (no significant difference using Tukey's Multiple Comparison Test) in all four treatments (B).

Slika 1: Pred začetkom poskusa smo izmerili višine rastlin v vseh 8 cvetličnih koritih (A). Korita smo razporedili v pare, tako da smo dobili 4 skupine, ki so imele pred začetkom poskusa čimbolj enak razpored višin rastlin (Tukeyev primerjalni test ni pokazal statistično značilnih razlik, B).

We have compared the distribution of plant sizes among all pairs of groups using Tukey's Multiple Comparison Test and the differences were never statistically significant. When measuring, we discovered that three plants died. We decided that we would not substitute them with new ones from reserve as the samples were still big enough. We began our experiment on 10th of July 2017. We left box planters on the same place as before.

About month and a half after the beginning of the experiment (on 23rd of August 2017) we measured height of all plants and counted the plants that have developed shoots with male flowers.

The number of living plants included in the experiment was counted twice, 45 days after cutting, and at the end of the experiment, 76 days after cutting.

The experiment has been finished a month later (on 23rd of September 2017). On that day we cut shoots (above ground part of the plant) of each plant just above the soil level and marked them with unique numbers. We (1) put each shoot on white paper and took a photograph, (2) measured each shoot from the bottom of the stem to the top of the longest shoot, (3) counted the number of branches with male inflorescences on each plant and measured their lengths, and (4) inserted each plant in separate newspaper sheet and let them dry in dryer for herbarium plants.

After drying we weighted each dry plant, collected all seeds from each of them separately and counted them. Plants without seeds have been thrown on compost. Later we combined all seeds that had developed on plants from the same plastic box planters and weighted them together.

On five plant samples we have counted the number of male capitula on 5 cm of the male raceme to calculate the approximate average number of capitula on 1 cm of the male raceme.

Data analyses were carried out in programs MS Excel and GraphPad Prism (Version 5.01, GraphPadPrism Software Inc. 1992–2007).

Results

The number of living plants and the survival rate of plants in different treatments is shown in Tab. 1. All the plants that failed to survive the cutting died in the period of the first 6 weeks after cutting. The lowest survival rate (69%) was observed in group, where plants were cut just above the 1st pair of leaves, in group where plants were cut above the 2nd pair, only 1 plant died, so the survival rate was 98%. In group where plants were cut above the 3rd pair of leaves and in control group all plants survived to the end of experiment.

Table 1: Survival rate of *Ambrosia artemisiifolia* in four different experiment groups.
Preglednica 1: Delež preživelih rastlin pelinolistne žvrklje v 4 različnih eksperimentalnih skupinah.

	Number of plants			
Treatment	**Cutting 9. 7. 2017**	**45th day 23. 8. 2017**	**76th day 23. 9. 2018**	**Survival rate [%]**
Control	50	50	50	100
Cut above 1st pair	48	33	33	69
Cut above 2nd pair	49	48	48	98
Cut above 3rd pair	50	50	50	100

The plant height and dry mass of aboveground parts of plants were measured at the end of experiment. The average heights of plants that were cut were significantly shorter than in the control group, regardless of the height of the cut (Fig. 2A). The plant heights were measured also in the middle of the experiment (on 45th day). Measured heights were almost the same as at the end of experiment, so plants nearly reached their final height already in August. The dry mass of aboveground parts in all three treatments at the end of experiment was significantly smaller than in the control group (Fig. 2B).

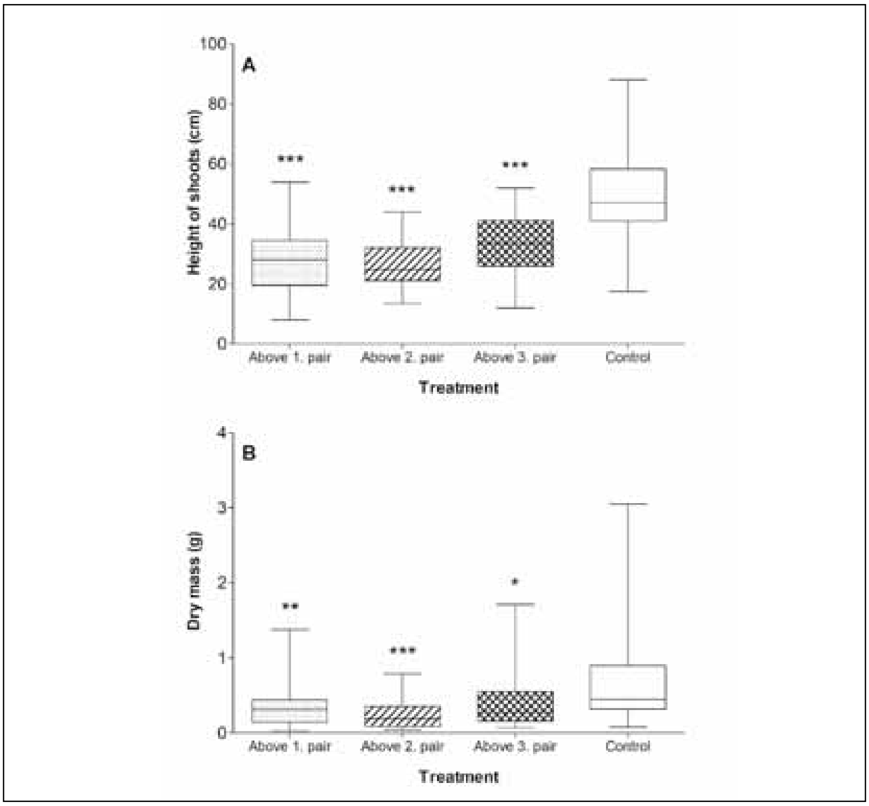

Figure 2: The average height of cut plants at the end of the experiment is significantly shorter than in the control group (Tukey's Multiple Comparison Test), regardless of the height of the cut (A). The average dry mass of aboveground parts of all cut plants was also significantly smaller than in the control group (Kruskal-Wallis Test and Dunn's Multiple Comparison Test, B).

Slika 2: Povprečne višine rastlin v vseh treh skupinah s porezanimi rastlinami so ob koncu eksperimenta statistično značilno nižje od rastlin v kontrolni skupini (Tukeyev primerjalni test, A). Prav tako je statistično značilno manjša suha masa njihovih nadzemnih delov (Kruskal-Wallisov test in Dunnov primerjalni test, B).

One month before the end of the experiment, all plants from the control group already developed male inflorescences. In the experimental groups, the number of flowering plants was lower (cut above 1st pair of leaves: 76%, cut above 2nd pair of leaves: 91% and cut above 3rd pair of leaves: 94%). Almost all the plants that have been cut developed 2 side shoots with male inflorescence. In the control group, most of the plants had only 1 or 3–4 shoots with male inflorescences. This is connected with plant morphology, as ragweed has opposite leaf arrangement and opposite axillary buds.

The average lengths of male inflorescences at the end of the experiment in all groups are significantly shorter than in the control group, regardless of the height of the cut (Fig. 3A). This confirms that, the cutting decreased the pollen production. The average total length of male inflorescences in the control group was 24 cm. The biggest decrease in the total length of male inflorescences (65% less than in the control group) was observed in the group where plants that were cut above the 2nd pair. The only significant difference between pairs of experiment groups was detected between the group cut above 2nd and 3rd pair, where the plants cut above 2nd pair developed less male inflorescences.

Cutting has almost no influence on the seed (fruit) production. Only the treatment, where plants have been cut above the 2nd pair of leaves, developed significantly less seeds per plant. Cutting above the 1st pair of leaves resulted in production of more seeds as cutting higher on the stem (Fig. 3B). We have also noticed big differences within all 4 groups. Some plants had only a few seeds while the others had more than 100 seeds (Fig. 3B). We have weighted seeds and calculated the average mass of 100 seeds in test groups. In all the test groups the seeds were similar in size. The biggest seeds were produced in the control group but the differences in the mass were not significant.

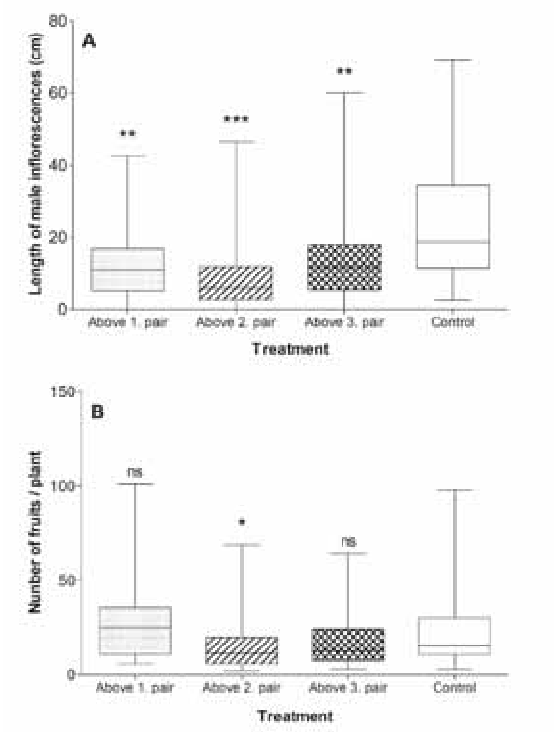

Figure 3: The total lengths of male inflorescences of 2nd order per plant at the end of the experiment in all groups are significantly shorter in comparison with in the control group (Kruskal-Wallis Test and Dunn's Multiple Comparison Test), regardless of the height of the cut (A). Cutting has almost no influence on the seed (fruit) production. The only treatment with significantly less seeds per plant was cut above the 2nd pair of leaves. Cutting above the 1st pair of leaves resulted in production of more seeds than cutting higher on the stem (Kruskal-Wallis Test and Dunn's Multiple Comparison Test, B).

Slika 3: Končna dolžina vseh moških socvetij 2. reda na koncu eksperimenta je bila pri vseh skupinah statistično značilno manjša kot pri kontrolni skupini (Kruskal-Wallisov test in Dunnov primerjalni test, A). Količina semen (plodov) se zaradi rezanja poganjkov ni bistveno zmanjšala. Statistično značilno manjšo količino semen smo prešteli le pri skupini, ki je bila porezana nad 2. parom listov. Rastline, ki so bile porezane nad 1. parom listov, so imele statistično značilno več semen, kot višje porezane rastline (Kruskal-Wallisov test in Dunnov primerjalni test, B).

Discussion

Cutting of *Ambrosia artemisiifolia* plants in the beginning of summer, before the flowering period could reduce the number of surviving plants, but only, when plants were cut very low, above the 1st pair of leaves. In this group 69% survival rate was observed. If plants were cut above 2nd or 3rd pair of leaves, no significant decrease in survival rate was observed. Basset and Crompton (1975) reported that common ragweed in Canada could survive mowing, cutting and trampling. The survival rate of plants cut at 5 cm above ground was 83%. In research conducted in Poland, where tested plants were cut above cotyledons node, the survival rate was 50%, and all plants survived the cutting on higher levels (Tokarska-Guzik et al. 2011).

Growth of *A. artemisiifolia* in early season is slow, internodes are short. In June, rapid upright growth with elongation of younger internodes and growth of shoot in apical meristem starts (Karner 2016). The same author reports, that the growth in height stops in the middle of September, which is different than the results of our experiment, where plants stopped to gain height already in August. In our experiment the average heights and dry mass of aboveground parts of cut plants were significantly lower than in the control group, but the differences among cut groups were not significant. Simard and Benoit (2011) got no significant differences in biomass between mown and intact plants regardless of the mowing time. Plants of *A. artemisiifolia* are very capable to regenerate after cutting, so cutting cannot control growing of common ragweed (Karner 2016).

In the end of August all control plants started to bloom. They developed male inflorescences on primary shoot at least. Over 90% plants that were cut above 2nd and 3rd pair also developed male inflorescences. Only the plants cut above 1st pair had significantly reduced percentage (76%) of plants with male inflorescences. Basset and Crompton (1975) report that common ragweed plants that were cut in July, developed several new stems and started to flower only 10 days later than adjacent uncut plants. Plants cut above cotyledons failed to produce buds of male inflorescences until 2 weeks after cutting (Tokarska-Guzik et al. 2011), but if they were cut higher the percentages of flowering plants were high (over 60%) (Tokarska-Guzik et al. 2011, Simard and Benoit 2011).

Karner (2016) reports that cutting in the time of the beginning of male flowering reduces in 8 times shorter male inflorescences. Simard and Benoit (2011) found out that plants cut twice 10 cm from the ground produced 89% less pollen than intact plants, as cut plants produced less pollen per unit inflorescence length. The same authors report that the average number of pollen grains per intact plant was approximately 4×10^8. Only 10 pollen grains per m^3 of air is enough for allergic reaction of the most sensitive people (Buttenschøn et al. 2008–09). It was estimated that 10–30% of Europeans are sensitive to ragweed's pollen (Kofol Seliger 2001). The reduction of pollen production is important, but millions of pollen grains are produced on mowed plant as well.

For the persistence of *A. artemisiifolia* populations and it's spreading, the production of viable seeds is essential. The total number of fruits developed on control plants was the highest in comparison to cut pants, so cutting reduces the amount of seeds. In the experiment conducted by Simard and Benoit (2011) cut plants developed 3–4 times less seeds than control plants. They have cut the plants twice. If the cutting is done only once, the timing is very important (Karner 2016). The best results with almost no vital seeds were achieved if the cutting was carried out in beginning of September (Bohren et al. 2005), but this mowing time is too late if we want to reduce the pollen production. We have calculated the number of seeds per plant in all test groups. The result, that the plants that were cut above 1st pair of leaves produced the highest amount of seeds, was surprising as all published results show the reduction of seed production in cut plants (Bohren et al. 2005, Simard and Benoit 2011, Karner 2016). The average number of seeds per plant was even higher than in the control group, but the difference was not significant. Results of some published experiments show, that mowing reduces not only the number, but also the viability of seeds (Bohren et al. 2005, Simard and Benoit 2011).

For the control of common ragweed, hand pulling before the flowering is still the most effective method. Mowing could reduce the number of surviving plants and the total amount of pollen and seeds, but absolutely not enough.

Single mowing is ineffective. Due to very high reproduction capacity of common ragweed plants (Karner 2016) and longevity of viable seeds that could germinate even after 40 years (Darlington 1922), the control of the species remains a challenge for landowners to fulfil the obligation prescribed under the Slovene legislation (Anon 2011). As the most effective method is removal of whole plants before flowering, it is very important to educate people to recognize the plant in early stage of development. Common ragweed is not growing only along roads, on abandoned land and on fields, but it could appear e. g. in the gardens (Kus Veenvliet et al. 2012), and vicinity of bird houses, as ragweed seeds are very often present in packages of sunflower seeds for bird feeding (Strgulc Krajšek and Novak 2013). It is crucial to prevent the development of pollen because of allergies, and to prevent the development of seeds, as their dispersal prolongs the removal problem for many years (Darlington 1922).

Conclusions

1. Only cutting above the 1st pair of leaves (approx. 1.5–3 cm above the ground) has reduced the number of ragweed plants. The observed survival rate was 69%.
2. The cutting reduces the average heights and the average dry mass ragweed plants, regardless of the height of the cut.
3. The cutting reduces the average total lengths of male inflorescences, regardless of the height of the cut.
4. Cutting has almost no influence on the seed (fruit) production. Only the treatment, where plants have been cut above the 2nd pair of leaves, developed significantly less seeds per plant.

Final conclusion: Mowing could reduce the number of surviving plants and the total amount of pollen and seeds, but absolutely not enough. Single mowing is ineffective.

Acknowledgements

This study was partially financially supported by the Slovenian Research Agency, grant no. P1-0212.

Povzetek

Pelinolistna žvrklja ali pelinolistna ambrozija (*Ambrosia artemisiifolia*) je v Evropi zelo razširjena tujerodna vrsta, ki izvira iz Severne Amerike. V Sloveniji nas k njenemu odstranjevanju zavezuje zakonodaja, ki lastnikom zemljišč zapoveduje odstranjevanje ambrozije in preprečevanje njenega razmnoževanja. Najučinkovitejši način odstranjevanja je ruvanje rastlin pred cvetenjem, a ta metoda je časovno potratna in draga, kadar gre za velike sestoje ambrozije. Ker je košnja pogosteje uporabljan način odstranjevanja, smo se odločili izdelati raziskavo o vplivu enkratne košnje na rast in razmnoževanje ambrozije.

Uporabili smo rastline ambrozije, ki smo jih spomladi nabrali ob cesti v predmestju Ljubljane in jih posadili v testna cvetlična korita. Rastline smo na začetku poletja razdelili v 4 skupine po 50 rastlin in jih porezali na treh različnih višinah, kar je predstavljalo košnjo na treh različnih višinah: nad 1., 2. in 3. parom listov. Del rastlin smo pustili neporezanih in so predstavljale kontrolno skupino. Do konca septembra smo spremljali njihovo rast, tako da smo merili višino rastlin, razvoj moških socvetij, v katerih nastaja alergeni pelod, in razvoj semen.

Ugotovili smo, da je propadlo največ rastlin, ki so bile porezane nad prvim parom listov, vse rastline, porezane nad tretjim parom in kontrolne rastline pa so preživele. Najvišje so zrasle kontrolne rastline, ki smo jim na koncu poskusa izmerili tudi največjo suho maso. V nasprotju s pričakovanji so bile razlike v višinah in masi testnih rastlin zanemarljivo majhne. Ugotovili smo tudi, da rastline že v začetku avgusta skoraj dosežejo svojo končno višino, kasneje se rast praktično ustavi in rastlina začne razvijati moška in ženska socvetja.

Že enkratna košnja pred cvetenjem ima velik vpliv na razvoj moških socvetij. Košnja nad 1. in 2. parom listov je skupno dolžino moških socvetij zmanjšala na tretjino, košnja nad 3. parom pa skoraj na polovico. To pomeni veliko zmanjšanje količine alergenega peloda. Skupno največ plodov

je zraslo na nepokošenih rastlinah. Ko pa smo izračunali povprečno število plodov na rastlino, se je pokazalo, da se je največ plodov razvilo na kontrolnih in najnižje pokošenih rastlinah. Enkratna košnja torej ne zmanjša tvorbe semen, kar je pomemben podatek za vzdrževalce javnih površin in lastnike zemljišč.

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