Identification of correct timing of mowing based on mowing in the most vulnerable phenological stages of ragweed

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This experiment produced efficacy data for mechanical measures (mowing) in correlation with ragweed (*Ambrosia artemisiifolia* L.) development. The influence of different mowing regimes on ragweed was investigated in this trial.

Material and methods

Pot trial was carried out to check the possibility to completely prevent the pollen and seed formation by mowing ragweed plants only twice a season. We tried to mimic the development of ragweed plants growing on the highway margins and frequency of mowing of highway vegetation performed by highway Maintenance Company.

For each treatment there were 5 pots (10 L) with 5 common ragweed plants. Mowing was performed at 3 cm above soil surface.

Experimental treatments:

3 growth stages of first mowing: 2 leaves – 1. node, 4 leaves - 2. node, 8 leaves – 3. Node.

A. Mowing regime for second mowing: no additional mowing, after 4 weeks, after 6 weeks, after 8 weeks, after 12 weeks.

B. Mowing regime for second and third mowing: after 4 weeks – after 3 weeks, after 4 weeks – after 6 weeks, after 6 weeks – after 3 weeks, after 6 weeks – after 6 weeks, after 8 weeks – after 3 weeks, after 8 weeks – after 6 weeks, after 12 weeks – after 3 weeks, after 12 weeks – after 6 weeks

Ragweed plants were grown in plastic pots (10 l). 5 plants of ragweed were grown in each pot. Plants were mowed at different developing stages (2 leaves – 1. node, 4 leaves - 2. node, 8 leaves – 3. node) using scissors and we cut them at height of 3 cm above the soil level. Mowing was performed once, twice or three times a season in different time intervals (4, 6, 8 or 12 weeks).

In total there were 40 combinations of intervals between mowing and growing stages of plants at period of first mowing. Percentage of plants producing flowers, percentage of plants developing fertile seeds, amount of seeds produced per plant (pot) and fresh plant mass per pot at the end of October was measured.

Results

- One or two mowing of ragweed plants is not sufficient to completely prevent pollen and seed production.

-Our results indicate that pollen and seed production can be largely (-90 %) prevented with two optimal cuts at proper development stage

- The reduction of produced seed is higher if the first mowing is performed at higher growth stage of plants (end of June or later).

- Ragweed plants produced less seed if time intervals between successive mowing are longer, especially in case if first mowing is performed at 2 leaves growth stage.

- If highway maintenance service decides to perform just two mowing a season, than first mowing should not be performed earlier than 3 nods growth stage and second mowing not earlier than 12 weeks after the first one.

- The most efficient system for pollen and seed production prevention is to perform first mowing at 3 node growth stage, repeat mowing after 8 weeks, and then the third one after 12 weeks.

Regrowth of common ragweed after mowing at different growing stages (II)

This experiment produced efficacy data for mechanical measures (mowing) in correlation with common ragweed development and the height of mowing. Besides the mowing, influence of the competition between common ragweed and other weed species was investigated in this trial.

Experimental treatments

1. Two mowing heights (3 cm and 6 cm above the soil surface)
2. Three growing stages (heights) of common ragweed at first mowing (20 cm, 40 cm, 60 cm)
3. Two time intervals between cuts (after 5 and 10 weeks)
4. Competition between common ragweed and other plants (no competition, competition with *Lolium* and *Chenopodium*)

Material and methods

For each treatment there will be 5 pots (10 L) with 5 common ragweed plants (and 5 weed species in case of competition). This pot trial was also performed to mimic the conditions of ragweed development on the margins of highway. The trial setup was the same like in trial one. 5 ragweed plants were competing with 5 lamb's quarters plants (*Chenopodium album*), or with 5 ryegrass plants (*Lolium perenne)*. Seeds of all plant species were sown together and thinning of seedlings in the cotyledon stage was performed.

Both ragweed and competitor plants were mowed by scissors at different ragweed plant heights (20, 40 and 60 cm high plants) at level of 3 cm above ground. At the end of season (end of October) plants were weighed, number of seeds produced per plant was determined and the portion of plants that developed seeds was calculated. Percentage of plants that producing flowers, Percentage of plants developing fertile seeds, amount of seeds produced per plant (pot) and fresh plant mass per pot were measured at the end of October.

Results

-The greatest dry matter reduction after cutting was determined, when ragweed was grown in the mixture with ryegrass

- The regeneration capacity of ragweed exposed to competition to other weeds after mowing is significantly lower when compared development to environment without competition with other plants

-Cutting height (3 and 6 cm) influenced ragweed dry matter and seed production only when ragweed in monoculture was grown in the pots; it increased at lower mowing height

-Dry matter and seed production of ragweed significantly decreased with ragweed first cut at later growth stages and increased period between two cuts

-Our results indicate that pollen and seed production can be completely prevented with two optimal cuts at proper development stage (40-60 cm and 10 week time interval).

Identification of correct timing of mowing based on mowing in the most vulnerable phenological stages of ragweed.

Mechanical control: Mowing

1a. Improving efficiency of mechanical ragweed control of urban areas based on mowing in the most vulnerable phonological stages of the plant

1b. Identification the optimal time of mowing that most effectively decreases the biomass, number of male inflorescences, pollen release and seed production of ragweed.

2. Material and methods

2.1. Ragweed mowing experiment was carried out in the experimental field of the Plant Protection Institute of Hungarian Academy of Sciences at Nagykovácsi (47º 32′ N, 18º 56′ E). The experiment was set up on a land, which was abandoned for three years with the only disturbance of autumn ploughing and seed bed preparation in April. Prior to set up the mowing experiment seed bed preparation was done in the middle of April; secondary tillage was carried out with harrow and cultivator. After emergence of ragweed plants, on 5 May 10x10 m plots were stacked out. Plots were separated with 1 m wide land stripes of boundaries. The stripes were kept weed free by regular cultivator treatments. Number of ragweed plants was counted on randomly selected 10x1 m^2 areas.

2.2. Experimental treatments included: in 2011 none-mowed control, early mowed treatment BBCH 51(inflorescences, flower buds visible), late mowed BBCH 59 (first flower petals visible) twice mowed treatment BBCH 51 and 59. In course of the mowing the plants were cut at the height of 5-7 cm in 2011 by traditional scythes and in 2012 to improve efficiency of mowing (decreased cutting height) to 1-3 cm Husqvarna, 128 R loanmower was used.

In 2012 and 2013 treatment included none-mowed control, early mowed treatment BBCH 51, late mowed BBCH 59, twice mowed treatment: first mowing BBCH 51 and the second one was made when re-growth terminal racemes reached BBCH 59 and in 2013 mowing 3 times BBCH 51, 59and 59treatments. The cutting height of the plants was 2-3 cm in 2012 and 2013 due to changing the traditional scythes into Husqvarna loan mower.

During the study plots in 4 replicates were randomly designed. Plants were sampled at weekly intervals 5 randomly selected plants were cut off at soil surface level from each plot (20 plants/treatment altogether). Plants were transferred into the laboratory, where the above ground fresh biomass and the plant height were measured, further male inflorescences and female flowers were counted.

For pollen production studies two plants on each plot were selected (4x2 plants/ treatment) to collect pollen. Transparent polyethylene bags for pollen collection were placed on the plants at BBCH 60 (first flower petals open sporadically) (Hess et al., 1997). Each plant was covered with a plastic bag that gave sufficient room for the growth. The non-mowed and early mowed plants were covered by 120x40 cm polyethylene bags. Plants of the late mowed, twice mowed treatments were covered with 80×40 cm polyethylene bags. Plants of mowing three times treatment were covered with 50 × 40 cm polyethylene bags. For ventilation purposes he bottom corners of the bags were opened on a 5 mm wide and 15 mm long surfaces, which served as ventilation holes just like the 10 randomly pricked 1.0-1.5 mm holes on each bag. The bigger holes served to fix the bags with a pulled trough string to the wire frame. The opening of the polyethylene bags were fixed to the wire frame and closed on the main stems of the ragweed plants under the lowest side shoots with the aid of an adhesive rubber. The polyethylene bags were replaced by new ones weekly, when the pollen content of the bags were washed off in 250 ml of 0.02 % Tween 20 detergent solution. The pollen containing solution was stirred by a glass rod than 5×1 ml samples were collected into Eppendorf tubes. Eppendorf tubes were labelled and stored in refrigerator until pollen counting. After thorough shaking from each Eppendorf tube 2.5µl samples were taken and individually transferred into a glass hemacytometer (MOM Budapest). Pollen grains were counted on 160 × magnification by means of a light microscope. Based on the numbers of 5 counts the number of pollen grains in 250 ml water was calculated.

Pollen production study was carried out in 2011 and 2012, because counting the pollen grains is a labour-consuming activity. We spent 5 months with counting the pollen grains during the first two years of the study.

Statistical analyses. Data were analyzed by ANOVA using STATISTCA, StatSoft, Inc., 2007 program package. The effect of the mowing treatments on the plant above ground fresh biomass, plant height, number of male inflorescences and number of female flowers during the whole season was evaluated by Tukey HSD test.

Results 2011

In the first year of the study the height of the mowing was 5-7 cm. Using Husqvarna, 128 R loan mower it was not possible to decrease the cutting height.

Fig. 1. Due to the 5-7 cm cutting height ragweed plants produced intensive side shoot formation. The higher the cut stem more internodes' are situated on it. The side shoots develop from the buds of the internodes.

The ANOVA revealed significant effect of mowing treatments on the plant above ground fresh biomass, plant height, number of female flowers, number of male inflorescences in 2011. *F* values are: 273, 687, 107, 1643, respectively (n=640). The *P* values are <0.000. Mowing treatments significantly influenced the number of released pollen grains as well *F*=72, n=32 *P*<0.000.

Fig. 2 Mowing induces intensive ramification.

The Tukey HSD test revealed the significant difference between the above ground biomass, plant height and the number of male flowers of non-mowed control plants and those of the early mowed plants (Table 1.). However, the number of female flowers and number of pollen grains did not decrease significantly due to early mowing. Due to late and twice mowing there was no significant difference between mowing treatments at the above ground fresh biomass, plant height, number of female flowers and number of male inflorescences. However, the number of pollen grains decreased in a greater extent due to double mowing compared to late mowing. The decreasing effect of twice mowed treatment reached 80 percent at the measured plant parameters (Figs. 3-6).

Non-mowed control plants released 59 million pollen grains during pollination. Although, the pollen reducing effect of the best mowing twice treatment was only 85 % mowing treatments shipped the beginning of pollen releasing period. The flowering of male inflorescences started on non-mowed control plants started on 25 August and lasted for six weeks. Early mowing postponed pollination by three weeks. However, due to late and twice mowing the pollen production started 6 weeks later and it lasted for 4 weeks. Early and late mowing not only postponed the beginning of pollination, but the intensity of pollen production also decreased significantly (Fig. 7, 8).

Table 1. The effect of mowing treatments on the above ground biomass, plant height, number of female flowers, male inflorescences, number of released pollen grains of ragweed plants and the percent reduction due to mowing treatments. Juliannamajor, Budapest 2011.

Treatment	Valid No	Mean± S. E.	Min	Max	% reduction
Above ground biomass (g)					
None-mowed	220	28.33±1.37 a	4.00	275	0.00
Early mowed	200	18.41±0.90 b	0.40	99	35.02
Late mowed	120	5.52±0.34 c	0.30	26	73.64
Twice mowed	140	7.47±0.38 c	0.60	34	80.64
Plant height (cm)					
None-mowed	220	100.60±1.13 a	47.00	146	0.00
Early mowed	200	47.36±1.10 b	4.70	103	53.03
Late mowed	120	25.45±0.68 c	0.70	47	74.80
Twice mowed	140	20.84±0.67 c	5.50	55	80.28
Number of female flowers					
None-mowed	220	636.76±12.90 a	0	6456	0.00
Early mowed	200	413.70±10.34 ab	0	1582	35.04
Late mowed	120	170.01±5.90 bc	0	687	73.30
Twice mowed	140	107.22±6.78 c	0	714	83.16
Number of male inflorescences					
None-mowed	220	2753.72±121.80 a	0	18580	0.00
Early mowed	200	1292.93±68.65 b	0	5860	53.05
Late mowed	120	328.36±16.64 c	0	1700	88.08
Twice mowed	140	181.41±19.67 c	0	595	93.12
Number of released pollen grains (millions)					
None-mowed	48	59.435±7.67a	39.32	109.47	0.00
Early mowed	32	43.460±1.13a	31.68	58.13	26.88
Late mowed	32	24.309±3.02b	14.12	35.88	51.10
Twice mowed	32	8.668±1.56c	2.91	17.59	85.42

Means with different letters are significantly different $p<0.05$ (Tukey HSD test)

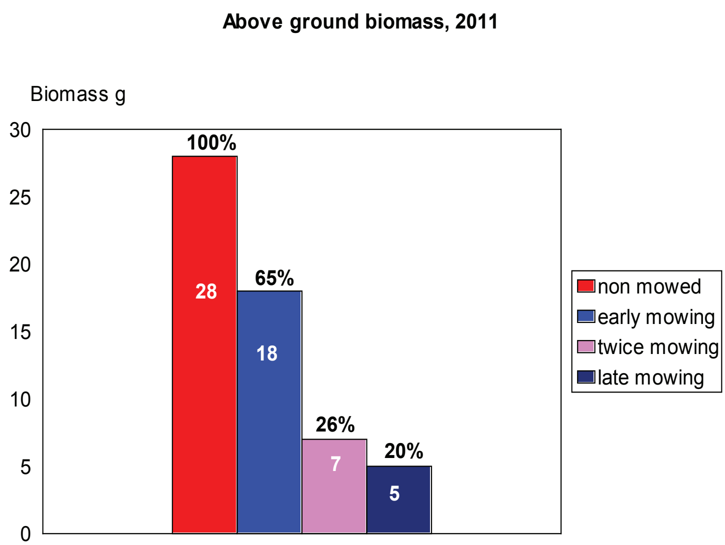

Fig. 3. The effect of mowing treatments on the development of above ground plant biomass. Budapest 2011.

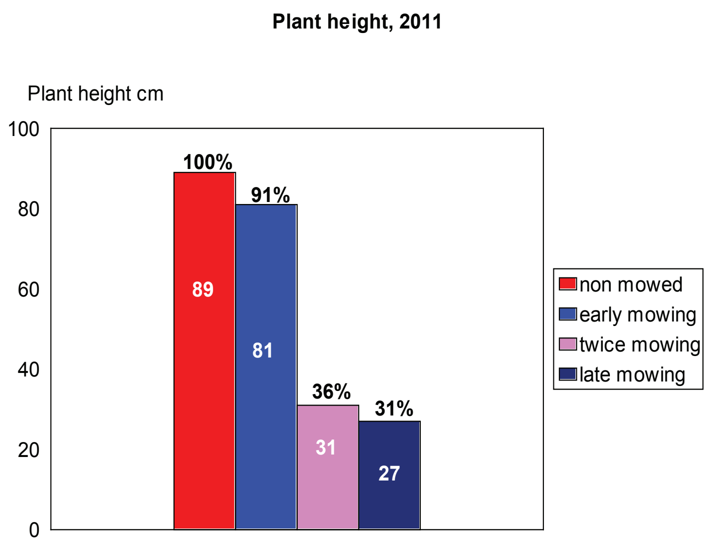

Fig. 4. The effect of mowing treatments on the plant height. Budapest, 2011.

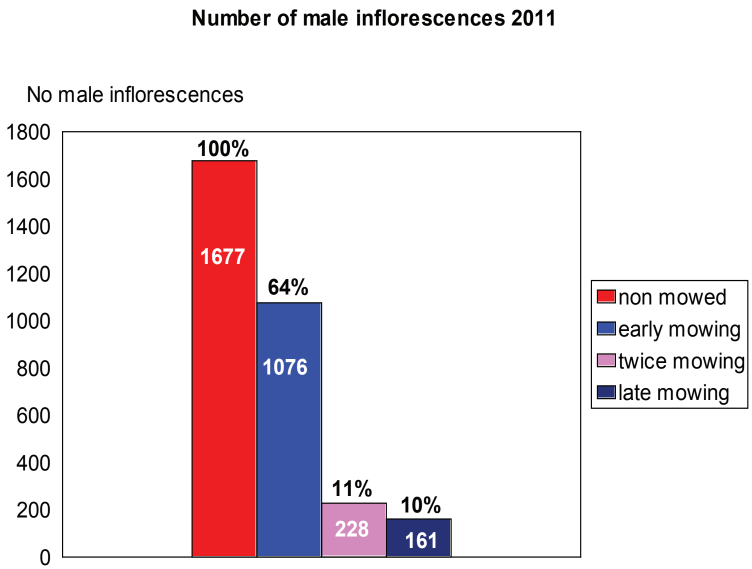

Fig. 5. The effect of mowing treatments on the number of male inflorescences. 2011.

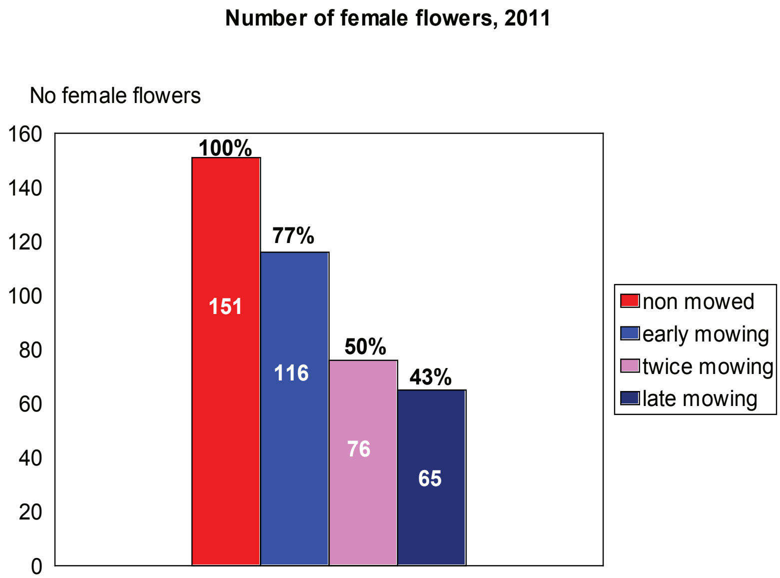

Fig. 6. The effect of mowing treatments on the number of female flowers. Budapest, 2011.

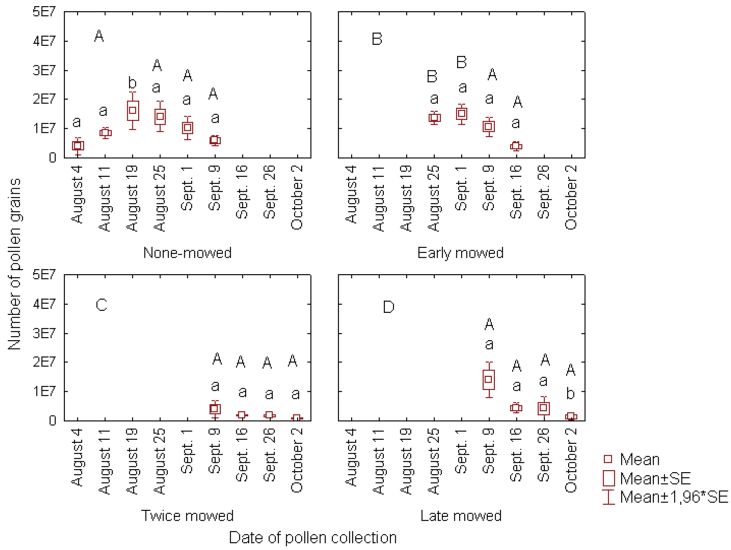

Fig. 7. The effect of mowing treatment on the number of released pollen grains and the length of the pollen production period. Budapest 2011.

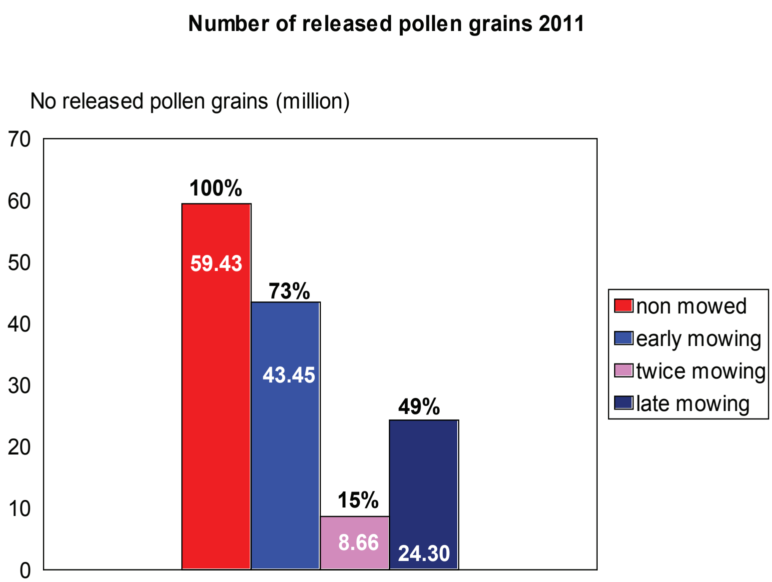

Fig. 8. Effect of mowing treatments on the number of the released pollen grains. Budapest, 2011.

Results 2012

In the second year of the study the traditional scythes was replaced by Husqvarna, 128 R loan mower . With the loan mower the cutting height of the plans could be reduced up to 2-3 cm.

Fig. 9 The early mowed plants in 2012

Due to the 1-3 cm mowing height, the mowing treatments significantly affected above ground plant biomass, plant height, number of female flowers, number of male inflorescences ANOVA. The *F* values are: 281, 163, 68, 129, respectively, n=1220 $P<0.000$. The mowing treatments significantly affected the number of released pollen grains as well $F=82$, n=40, $P<0.000$.

Fig. 10. The late mowed plants in 2012

Fig. 11. The twice mowed plants in 2012

Fig. 12. The three times mowed plants in 2012

Fig. 13. The non-mowed control plants

Table 2. The effect of mowing treatments on the above ground biomass, plant height, number of female flowers, male inflorescences, number of released pollen grains of ragweed plants and the percent reduction due to mowing treatments. Juliannamajor, Budapest 2012.

Treatment	Valid No	Mean± S. E.	Min	Max	% reduction
Above ground biomass (g)					
None-mowed	220	84.89±4.85a	2	303	0.00
Early mowed	240	15.51±0.93b	1	88	81.23
Late mowed	180	4.26±0.24c	0.2	25	94.08
Twice mowed	280	4.75±0.33c	0.2	37	94.41
Mowing 3 times	300	3.81±0.34c	0.2	65	96.52
Plant height (cm)					
None-mowed	220	82.77±1.64a	19	150	0.00
Early mowed	240	43.56±1.46b	5	93	43.38
Late mowed	180	22.66±0.72c	5	44	72.63
Twice mowed	280	19.05±0.57cd	4	56	76.45
Mowing 3 times	300	17.24±0.58d	3	65	70.92
Number of female flowers					
Non-mowed	220	663.16±75.51a	18	2550	0.00
Early mowed	240	171.11±19.49b	20	1430	74.20
Late mowed	180	68.14±6.37bc	6	480	89.75
Twice mowed	280	33.82±3.38c	2	288	95.03
Mowing 3 times	300	13.35±1.41c	2	194	97.44
Number of male inflorescences					
None-mowed	220	4638±406.91a	26	36.443	0.00
Early mowed	240	874±80. 18b	25	6877	81.16
Late mowed	180	186±18.09bc	18	1321	96.00
Twice mowed	280	55±4.97 c	14	530	98.82
Mowing 3 times	300	32±4.62 c	3	626	99.32
Number of released pollen grains (millions)					
None-mowed	8	155.295±134.492a	103.860	196.720	0.00
Early mowed	8	44.452±3.870 b	24.860	62.640	71.38
Late mowed	8	35.342±4.711 bc	61.340	22.700	73.25
Twice mowed	8	8.905±1.382 cd	17.020	4.840	94.27
Mowing 3 times	8	2.272±378 d	4.020	680	98.54

Means with different letters are significantly different *p*<0.05 (Tukey HSD test)

Due to mowing treatments the above ground biomass, plant height, number of female flowers, number of male inflorescences and number of released pollen grains significantly decreased (Table 2.). There was significant difference between early and late mowed treatments. However, there was no significant difference between twice and three times mowed plants (Figs. 14-19).

Plant weight, 2012

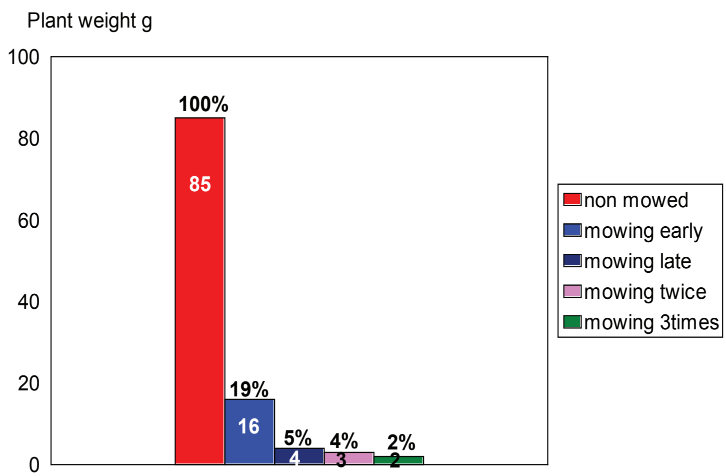

Fig. 14. The effect of mowing treatments on the development of above ground plant biomass. Budapest 2012.

Plant height, 2012

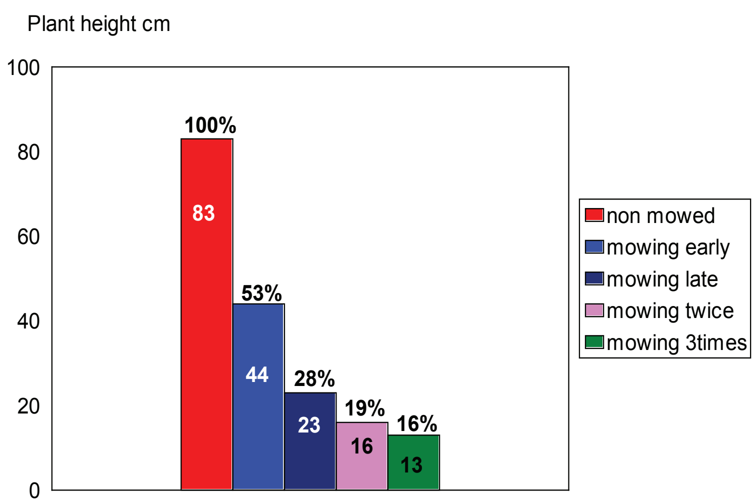

Fig. 15. The effect of mowing treatments on the plant height. Budapest, 2012.

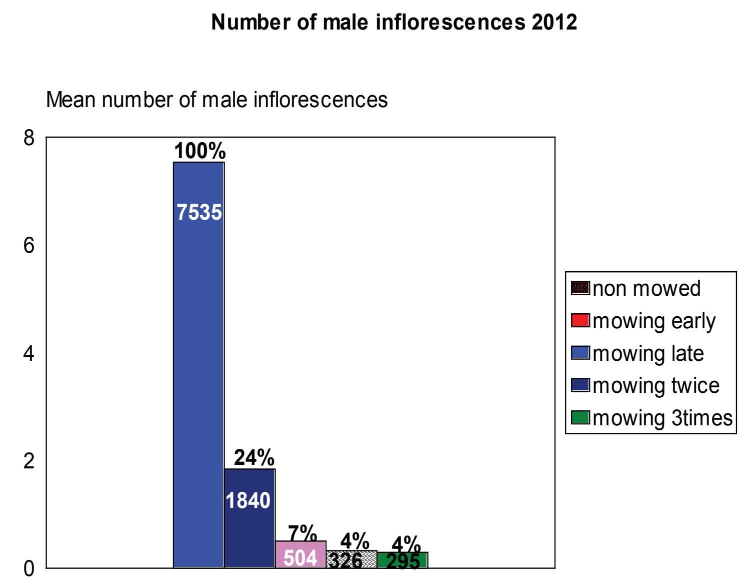

Fig 16. The effect of mowing treatments on the number of male inflorescences. 2012.

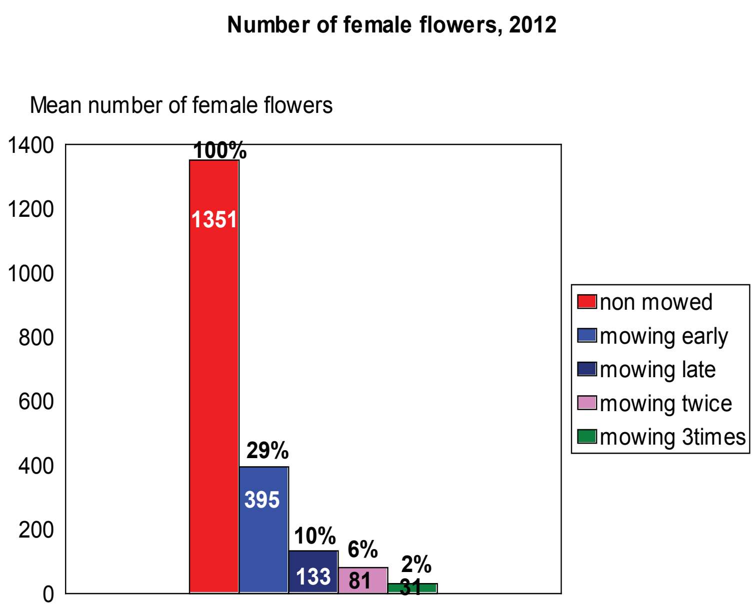

Fig. 17. The effect of mowing treatments on the number of female flowers. Budapest, 2012

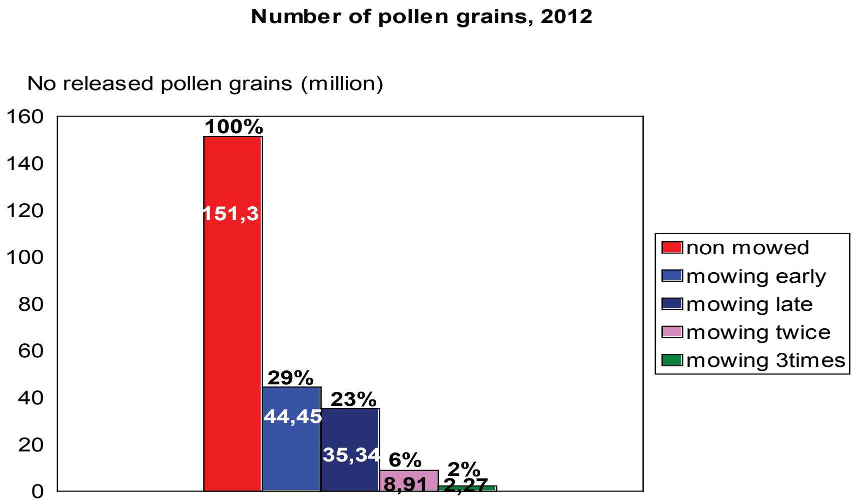

Fig. 18. The effect of mowing treatments on the number of released pollen grains. Budapest, 2012

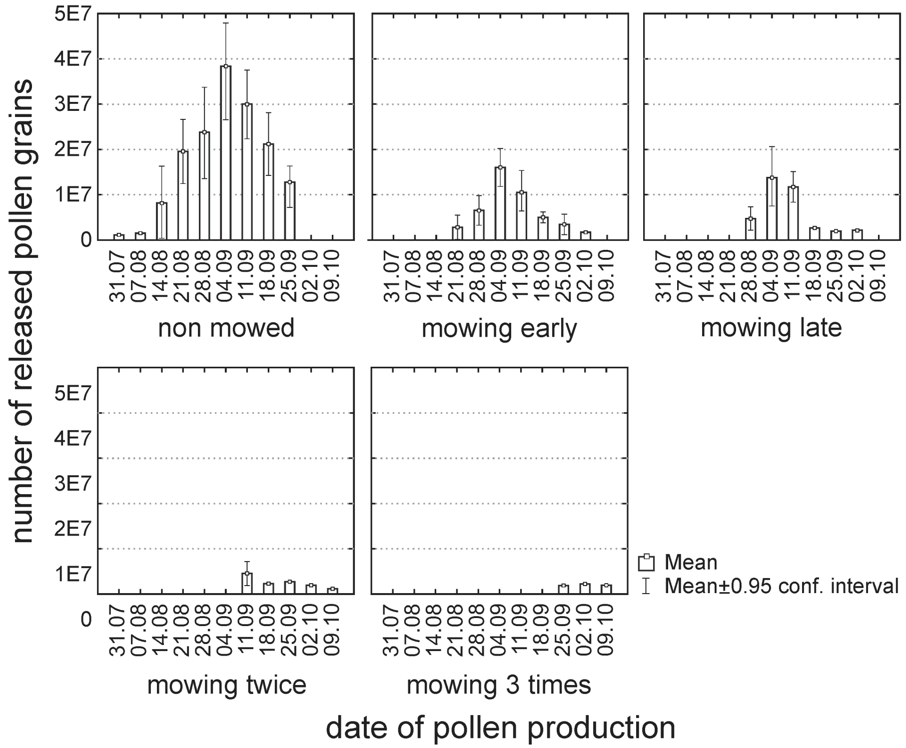

Fig.19. The effect of mowing treatment on the number of released pollen grains and the length of the pollen production period. Budapest 2012.

Results 2013

The mowing treatments significantly affected above ground plant biomass, plant height, number of female flowers, number of male inflorescences ANOVA. The *F* values are: 238, 742, 267, 68, respectively, n=1460 $P<0.000$.

Table 3. The effect of mowing treatments on the above ground biomass, plant height, number of female flowers, male inflorescences, ragweed plants and the percent reduction due to mowing treatments. Juliannamajor, Budapest 2013.

Treatment	Valid No	Mean± S. E.	% reduction
Above ground biomass (g)			
None-mowed	300	44.48±1.71a	0.00
Early mowed	300	19.12±0.71b	57.02
Late mowed	260	13.31±0.67c	70.08
Twice mowed	300	11.72±0.56c	73.66
Mowing 3 times	300	7.92±0.49d	82.20
Plant height (cm)			
None-mowed	300	90.84±1.19a	0.00
Early mowed	300	55.44±1.08b	38.07
Late mowed	260	36.93±0.99c	59.35
Twice mowed	300	30.72±0.80d	67.19
Mowing 3 times	300	23.35±0.87e	74.30
Number of female flowers			
Non-mowed	300	445.43±36.15a	0.00
Early mowed	300	187.97±12.39b	57.08
Late mowed	260	268.93±19.37c	39.96
Twice mowed	300	107.58±10.55d	75.96
Mowing 3 times	300	22.32±3.50e	95.06
Number of male inflorescences			
None-mowed	300	2099.45±91.12a	0.00
Early mowed	300	783.19±40.25b	62.70
Late mowed	260	594.90±41.74b	71.71
Twice mowed	300	207.88±20.16c	90.10
Mowing 3 times	300	72.91±11.97c	96.53

Means with different letters are significantly different $p<0.05$ (Tukey HSD test)

Due to mowing treatments the above ground biomass, plant height, number of female flowers, number of male inflorescences significantly decreased compared to none mowed control (Table 3.). Apart from the number of male inflorescences there was significant difference between early and late mowed treatments. In 2013 there was significant difference between twice and three times mowed plants except the number of male inflorescences (Figs. 20-21).

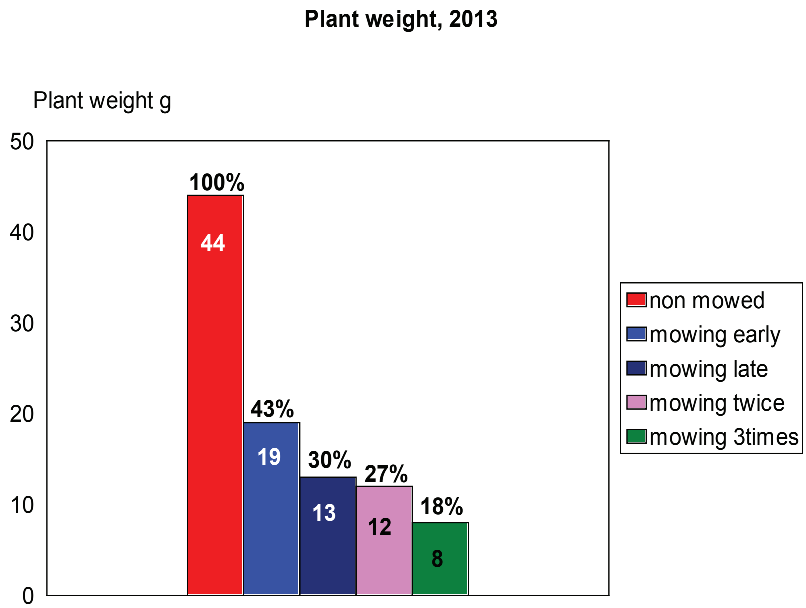

Fig. 20. The effect of mowing treatments on the development of above ground plant biomass. Budapest 2012

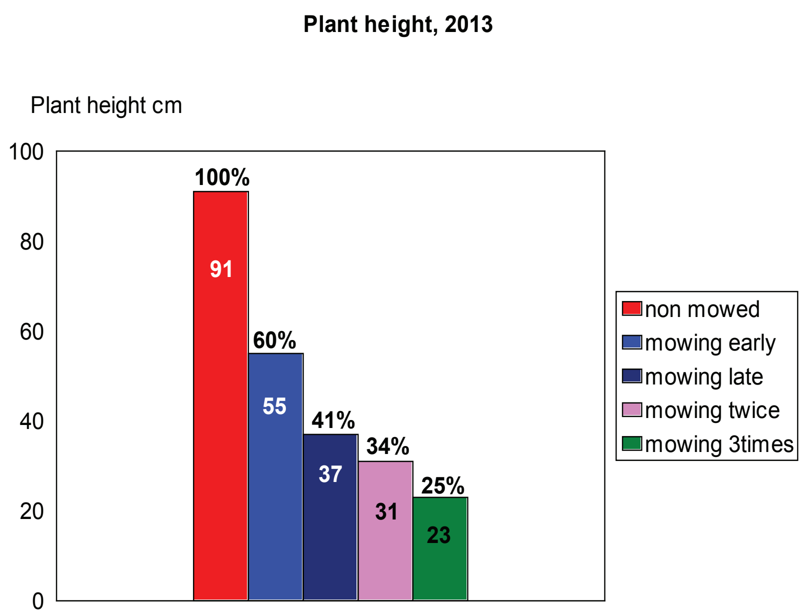

Fig. 21. The effect of mowing treatments on the plant height. Budapest, 2013.

Conclusions

We managed to decrease the cutting height up to 1-3cm by using the Husqvarna lawn mower. The low cutting height resulted in increased male inflorescence and seed decreasing efficiency. Number of female flowers, male inflorescences and pollen grains decreased more than 70 % even due to one early mowing. Late mowed treatment decreased the flowers by 90 %, but pollen grains only 77 %. Twice mowed treatment resulted in 94 % reduction of the reproductive parts. Mowing three times resulted in reduced seed, male inflorescence and pollen production between 97.7-98.5 %.

The seed production decreasing effect has great importance. Up to now results of the mowing experiments showed efficient pollen decreasing effect, however, mowing was not considered to be an efficient method to decrease seed production. The seed decreasing effect of the present study proves that mowing before flowering low (1-3 cm) cutting height results in proper seed production reduction.

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