ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 71 23 Number 6, 2023

VERIFICATION OF THE SELECTIVE EFFICACY AND EFFECT OF THE APPLICATION OF THE PRE-EMERGENCE HERBICIDE STOMP (PENDIMETHALIN) ON SHOOT GROWTH IN YOUNG ORNAMENTAL WOODY PLANTS USING PRIVET AND EUROPEAN BLADDERNUT AS AN EXAMPLE

Pavel Bulíř[1], Lenka Miksová[1]

[1] The Department of Planting Design, Faculty of Horticulture, Mendel University in Brno, Valtická 337, 691 44 Lednice, Czech Republic

Link to this article: https://doi.org/10.11118/actaun.2023.023
Received: 8. 3. 2022, Accepted: 6. 12. 2023

Abstract

The research was carried out on newly planted bare-root plants at an early stage of their cultivation. The scope of the growth responses of woody plants was verified in relation to the recommended herbicide rate, namely for herbicide solution application rates of 0.825% and 1.025%. The new increment of the longest shoot and the mortality rate were evaluated. The selective efficacy on weeds was observed. Data collection took place at 2, 4, 8, 12 and 24 weeks after application. The experiment followed the manufacturer's recommendations for application. It was conducted on an experimental area of loamy sand soil in 2019 and it was not affected by extreme weather conditions. The application of the herbicide to privet (*Ligustrum vulgare*) showed a small inhibitory effect, reducing the average increment of the longest plant shoot by 4.7% and 8.3%, respectively, by the end of the study period compared to the control. By contrast, in the case of the European Bladdernut (*Staphylea pinnata*), the application was found to have an adverse effect. The role of the application rate was secondary. The average increment of the longest shoot was reduced by 45.68% and 50.13%, respectively, and the mortality rate of the treated woody plants reached 10% at the end of the study period. The highest inhibitory effect of the herbicide on the ornamental woody plants that had been treated was observed in the first 2 and 4 weeks after treatment, respectively. The application of the herbicide proved ineffective against horseweed (*Conyza canadensis*) and groundsel (*Senecio vulgaris*).

Keywords: herbicide tolerance, ornamental woody species, growth inhibition, weed control

INTRODUCTION

In the nursery production of ornamental woody species, as well as in planting and maintaining ornamental plants used in landscape architecture, we often deal with heavy weed infestation of soils. Weed eradication and weed population control are very effective when pre-emergence herbicides are applied to target crops of ornamental woody species, especially at the beginning of the growing season. Due to competition for habitat, light, water and nutrients, the presence and development of weeds over time naturally limits the growth and development of target ornamental plants and increases their mortality rate, especially for young and newly planted plants. Weeds also host many diseases and pests, or contribute to their development (Nienhaus, Butin and Böhmer, 1998). In composite plantings, weeds also naturally adversely affect the aesthetic perception and quality of an area. The presence of weeds logically affects the quality and size of nursery-grown plants and, in turn, their price (Berchielli-Robertson, Gilliam and Fare, 1990). In this context, Fretz (1972) states that competition from hairy crabgrass (*Digitaria sanguinalis L.*) causes a growth reduction of up to 60% in some woody plants. Similarly, weeds affect the labour and economic requirements associated with growing ornamental plants in a permanent habitat. Crop management often favours efficient and cost-effective solutions, which tend to be associated with the chemical suppression of weed growth (Carey and South, 2005; Saha, 2017).

There are many publications that study the use of pre-emergence herbicides, including pendimethalin, in ornamental plant nurseries and plantings. In particular, their efficacy against a specified group of weeds is compared with each other (Altland, Gilliam and Wehtje, 2003; Zheljazkov *et al.* 2007; Harpster, Sellmer and Kuhns, 2012). Also, very weak concentrations of total non-selective herbicides – so-called semi-selective herbicides – are recommended for use in ornamentals plants and nurseries to complement pre-emergence herbicides (Hancock, 2016). Other scientific papers summarise weed management in the context of cultivation practices and the option of using pre-emergence herbicides in the specific cultivation environment of container nursery production (Stewart, Marble, Pearson *et al.*, 2017). Researchers are also looking at the effect of environmental conditions when applying these herbicides, the duration of their efficacy (Altland, 2019) and the extent of phytotoxicity and degradation in the soil environment (Kočárek, Artikov, Voříšek *et al.*, 2016). Other papers focus on monitoring a wide range of taxa tolerant to the application of particular types of herbicides, or specifying the conditions for such application. For pendimethalin, these data have been summarised e.g. by Palmer, Vea and Sims, 2006 and Harpster, Sellmer and Kuhns, 2012. Currently, there is virtually no research in the Czech Republic addressing the verification of the efficacy and phytotoxicity of pre-emergence herbicides in a wide range of ornamental woody plants. In the more distant past, the topic was addressed by Nováková (1986).

At present, only a few products are registered in the Czech Republic in the segment of pre-emergence herbicides for ornamental nurseries (plants), which share a common active substance, pendimethalin (Ústřední, 2021). In ornamental horticulture practice, the registered herbicide with the trade name Stomp® 400 SC (pendimethalin, 400 g/l) is used predominantly. It is also used for planting ornamental woody and herbaceous plants outside nurseries. The instructions for use supplied with the herbicide do not give any further taxonomic specification of the ornamental woody plants with which it may be used. Given the very wide range of ornamental taxa, this can pose considerable uncertainty and risk to users in terms of potential damage or impact on growth. This is particularly important for young and newly transplanted plants. The use of the herbicide Stomp (pendimethalin) in the cultivation of ornamental woody plants in nursery practice and in landscape plantings in the Czech Republic often depends on the personal experience of the grower.

Therefore, this research aims to provide an initial validation of the most commonly used pre-emergence herbicide, Stomp® 400 SC, especially in relation to possible plant damage and shoot growth inhibition in newly planted young ornamental woody plants. At the same time, the manufacturer's claims of the herbicide's selective efficacy on the weed species present is also being verified.

To date, the effects of pendimethalin phytotoxicity on the growth of new shoots in treated ornamental woody plants has only been studied in a limited range of taxa (Derr and Salihu, 1996; Derr and Simmons, 2006; Pacanoski, Kolevska and Mahmeti, 2020). These studies point to possible adverse effects on the increments of new shoots at a certain time interval after treatment, as well as on damage to and an increased mortality rate of treated plants.

MATERIALS AND METHODS

The herbicide Stomp® 400 SC is registered as a spray selective herbicide for the control of both monocotyledonous and dicotyledonous annual weeds. It does not affect perennial weeds. It is primarily intended for pre-emergence application. However, it can also be applied early post-emergence, up to the growth stage of 1.5 developed leaves for monocotyledonous weeds and 1 pair of leaves for dicotyledonous weeds. Pendimethalin interferes with cell division and elongation in roots. Due to the inhibition of initial growth, affected plants die shortly after germination or emergence. Efficacy is conditional upon sufficient soil moisture or activation by rainfall. It is recommended that the herbicide be applied on a well-prepared soil surface, possibly with a shallow subsurface application. Detailed information is provided in the instructions for use of the herbicide (ÚKZÚZ, 2021).

The experimental field area is located on the outskirts of Hradec Králové at an altitude of 240 m above sea level in the T2 warm climate zone (Culek, 1996). At the site, the geological subsoil consists of sandy gravel. The soil type consists of transitional arenaceous Cambisol (Tomášek, 2000). The site has a warm and permeable loamy sand soil with 74% fine sand particles. The organic matter content is 1.5% and the pH is 6.7.

Visually attractive native ornamental woody species (Kavka, 1974) that are generally suitable for cultivation in the area were chosen for the experiment – the wild privet (*Ligustrum vulgare* ´Atrovirens´) and the European Bladdernut (*Staphylea pinnata*). The lowest and the highest herbicide rate as recommended by the manufacturer was tested on both woody plant species, which are planted in separate basic areas, 50 pieces each. The rates investigated were 3.3 l/ha, which corresponds to a spray mixture application rate of 0.825%, and 4.1 l/ha, which corresponds to a spray mixture application rate of 1.025%. For each woody plant species, two herbicide-untreated controls were planted simultaneously.

The woody plants were planted on 2nd April 2019 in field habitats within randomly arranged basic areas. For planting, bare-root yearling cuttings were used for privet, and two-year-old bare-root seedlings were used for European Bladdernut. Planting was done at a spacing of 500 × 150–200 mm. After planting, all plants were reduced by cutting to a uniform height of 30–50 mm above the root collar. The application of the different spray mixture variations on the selected basic areas was carried out on 15 April 2019. Two days before spray mixture application, the experimental area was irrigated with an additional 5 mm of water spray. At the time of application, the soil surface was moist, level and free of clods. Occasionally, the weed-free area contained emergent monocotyledonous and dicotyledonous annual weeds in stages up to the first observed pair of leaves. The area application of the spray mixture was performed using a Solo 425 backpack sprayer in cloudy weather.

The mortality rate and the length increment of new shoots were evaluated at all basic areas at 2, 4, 8, 12 and 24 weeks after spray mixture application. For each living plant, the total size of the longest shoot on the plant was recorded at the given point in time. The size was measured from where the plant was cut after planting to the growth apex in mm. Dead specimens of woody plants were recorded. Additionally, any visual symptoms of herbicide damage to the woody plants were also recorded at the same time. The taxonomic spectrum of vital weeds present was recorded.

The experimental area was not mechanically cultivated (hoed) during the evaluation period. In addition, no growing vital weeds were manually removed. Supplementary spray irrigation was performed only during rain-free periods longer than 10 days at a rate of 10 mm/week. No additional fertiliser application or other pesticide treatment was done.

The experiment took place in 2019, when the average annual temperature at the site was 10.7 °C and the total annual rainfall was 564.4 mm. In the key months at the beginning of the growing season, the total rainfall was 40.6 mm in March, 42.4 mm in April, 96.7 mm in May and 12.2 mm in June (In-Počasí, 2021; ČHMÚ, 2021).

The minimum and maximum values, arithmetic mean, and standard deviation (SD) were determined for the shoot increments measured. The data obtained were tested for homogeneity of variance using Fisher's LSD (Least Significant Difference) test for $\alpha = 0.05$. In addition, analysis of variance (ANOVA) with interactions was used for the increments measured, and a correlation analysis was performed. Absolute and relative frequencies were determined for the mortality rate parameter.

RESULTS AND DISCUSSION

In the experiment, significant differences were found depending on the time since herbicide treatment and the woody plant species. Tab. I and Tab. II shows the differences in the average length of shoot increments between plants treated with herbicide at the two rate variants and the control populations. In all measurements, the average length of the increment increased with increasing time after herbicide treatment. In the case of privet (*Ligustrum vulgare* 'Atrovirens'), the highest average increments were always recorded for the control population, which also showed a clear growth similarity. The smallest increments were recorded in the woody plant population that was treated with the herbicide at the higher application rate (1.025%). In contrast, for the European Bladdernut (*Staphylea pinnata*), the increments of plants in the control populations were significantly greater than those of herbicide-treated plants. However, no clear effect was observed between the selected herbicide rates. At 2 and 12 weeks after application, the mean values for woody plant increments were slightly greater for the higher herbicide rates used. The opposite was true for woody plant growth at the other measurement intervals. With the exception of the last measurement, in which a growth difference of approximately 10 mm was recorded in favour of the lower herbicide application rate, these differences were less than 1 mm. The similarity of the populations under evaluation was also demonstrated by Fisher's LSD test, which found no significant differences between the herbicide-treated groups of the European Bladdernut. At the same time, a strong correlation coefficient between the parameters of increment length and herbicide concentration was found, ranging from -0.47 at 2 weeks after application to -0.91 at 4 weeks after application. At 24 weeks after application, the correlation coefficient value was -0.79. In contrast, for privet, the correlation coefficient ranged from -0.31 at 24 weeks after application to -0.45 at 8 weeks after application, indicating an overall weaker relationship between increment length and herbicide application. The lowest value of the correlation coefficient, which was recorded at 24 weeks after application, points to a gradual decline in the effect of the herbicide and in the difference in increment length between treated and control plants.

It can therefore be concluded that, in the case of the European Bladdernut, the effect of the herbicide application itself was stronger than the effect of the

I: *Average increment length of the longest shoot of Ligustrum vulgare 'Atrovirens' depending on herbicide application rate and time interval from application (mm)*

Weeks after application	*Ligustrum vulgare* 'Atrovirens'							
	application rate (%)							
	1.025		0		0.825		0	
	increment	SD	increment	SD	increment	SD	increment	SD
2	5.1	4.5	10.2	5.6	8.0	5.4	10.6	5.0
4	35.1	8.6	42.3	7.0	37.6	7.1	43.5	7.7
8	75.8	15.7	96.4	17.5	84.0	13.8	95.4	18.9
12	123.6	21.0	145.3	21.2	134.6	22.5	146.7	24.5
24	426.3	46.9	465.1	50.4	453.3	55.1	475.7	44.0
LSD*	131.0		151.3		142.4		154.4	
**	a		c		b		c	

* Fisher's LSD test at α = 0.05
** For each taxon separately, the same letter indicates that there are no significant differences between the groups

application rate. For privet, herbicide application clearly had a lesser effect on reducing increment length.

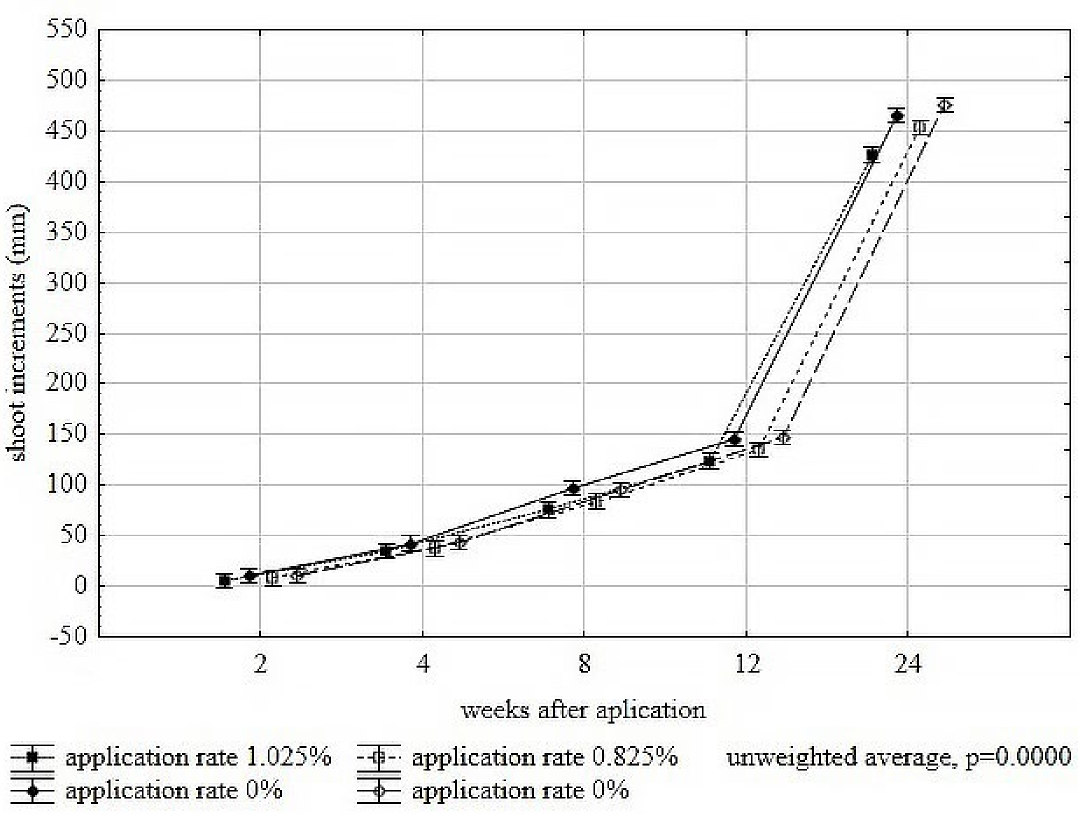
A closer analysis of the results shown in Tab. I and Tab. II also clearly shows that the greatest growth differences between treated and untreated plants were recorded at 2 weeks after application. For privet (Tab. I), the average increment of the longest shoot was 5.1 mm in plants treated with the 1.025% mixture, which is 50% less compared to the control population. For the lower application rate, the average increment was 8.0 mm, corresponding to a difference of approximately 25% in favour of the control plants. At 24 weeks after application, the differences were no longer so significant. In all versions of the experiment, woody plant increments exceeded 426 mm. The highest increment value was found in the second control (475.7 mm), while the lowest was found in plants after the application of the herbicide at the higher application rate (426.3 mm). Compared to the control population, the average increment was 4.7% smaller for the 1.025% application rate and 8.3% smaller for the 0.825% application rate. The situation and the relative evenness of the results for the different options over time is shown in Fig. 1.

In contrast, significant growth differences were found in the European Bladdernut (Tab. II) throughout the duration of the experiment. Two weeks after herbicide application, the treated plants experienced an almost complete stagnation of growth. The average increment was 0.4 mm for the higher application rate and only 0.2 mm for the lower application rate. The shoot increment in the control plant populations was also small (2.6 and 2.3 mm, respectively), but it was still clearly

II: *Average increment length of the longest shoot of Staphylea pinnata depending on herbicide application rate and time interval from application (mm)*

Weeks after application	*Staphylea pinnata*							
	application rate (%)							
	1.025		0		0.825		0	
	increment	SD	increment	SD	increment	SD	increment	SD
2	0.4	1.4	2.6	2.5	0.2	1.0	2.3	2.5
4	4.2	4.3	30.4	6.6	4.4	3.2	30.8	7.2
8	22.4	7.5	49.5	10.5	23.3	5.5	50.6	11.6
12	51.9	14.9	116.3	20.1	51.2	12.9	115.4	22.5
24	159.1	45.2	319.1	55.6	168.3	47.9	309.8	73.7
LSD*	43.0		102.4		46.1		101.8	
**	a		c		b		c	

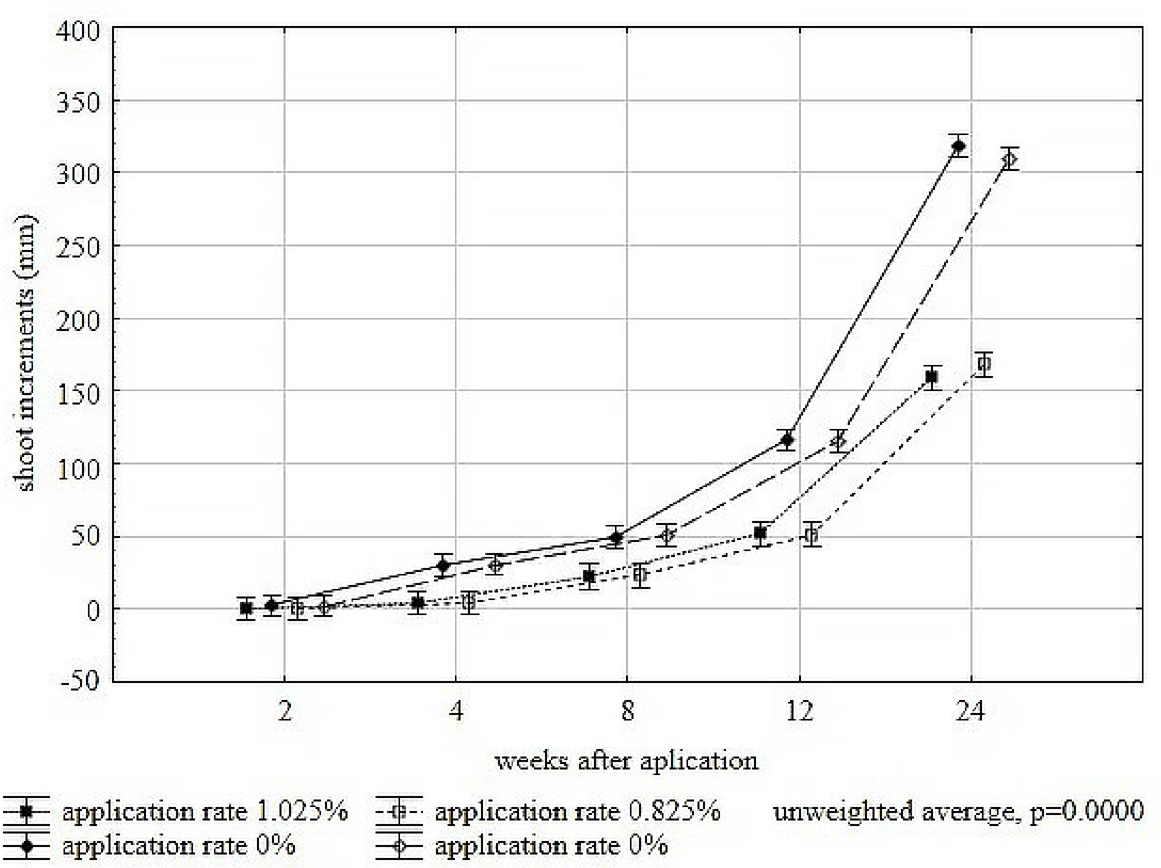
* Fisher's LSD test at α = 0.05
** For each taxon separately, the same letter indicates that there are no significant differences between the groups



1: *Trends in average increment length of the longest shoot depending on application rate and time interval from application, the wild privet (Ligustrum vulgare 'Atrovirens')*

greater compared to the treated plants. For both application rate variants, growth stagnation was observed in treated plants as long as the 4th week after herbicide application. The overall significantly slower growth of the treated plants throughout the evaluation of the experiment is shown in Fig. 2. With increasing time from herbicide application, growth differences between treated and untreated plants declined, but they persisted until the end of the evaluation. European Bladdernut plants that were treated with the herbicide at the lower application rate reached an average increment length of 168.3 mm at 24 weeks after application. For the control plant population, this was 309.8 mm. Therefore, a difference of 45.68% in favour of untreated plants was observed. At the higher application rate (1.025%), the treated plants reached an average increment length of only 159.1 mm. In this case, the control plants were as much as 50.13% larger.

Overall, as seen in Tab. I and Tab. II, shoot growth in privet was more balanced over time. For both woody plant species, the largest standard deviation (SD) values were recorded at 2 weeks after herbicide application, and at the beginning of cultivation they were clearly related to an increased number of plants with zero growth. A clear difference (in cultivation terms) between the different woody plant species is evident at the end of the evaluation period – for privet, the deviation from the average increment length did not exceed 12.16% at 24 weeks after application. In contrast, for the European Bladdernut, this was 28.4% for the herbicide-treated versions of the experiment at the same time interval. This finding points to greater differences in the increments of individual European Bladdernut plants in the tested variants, i.e. to greater growth unevenness in practical cultivation. The observed growth variability is very likely related to an overall poor response to herbicide application. This was also confirmed in the field by visual signs of damage (the presence of deformed or curled apical leaves, the occurrence of light chlorosis), which were observed in about 20% of herbicide-treated plants. The different response of the two woody plant species under evaluation to the application of the pre-emergence herbicide may not only indicate the proven higher sensitivity of the European Bladdernut, but it may also be related to their different growth dynamics. By comparing only two species, it cannot be objectively determined whether faster-growing woody plants are generally better able to cope with herbicide treatment. The results of the experiment show that the time interval from herbicide application is a significant factor. Therefore, it



2: *Trends in average increment length of the longest shoot depending on application rate and time interval from application, the European Bladdernut (Staphylea pinnata)*

can be assumed that the growth of the European Bladdernut will also converge with the values for untreated plants over the long term. However, the manner of response to herbicide treatment and the rate of decline in any adverse effects have a significant impact on the efficiency and economics of the cultivation of ornamental woody plants in nurseries and the fulfilment of the desired functions of woody plants in their permanent habitats.

A practical comparison of the total shoot growth for the two species at the end of the evaluation, i.e. at 24 weeks after application, is provided for each version of the experiment in Fig. 3. It clearly shows the different resulting effects of herbicide application on the woody plant species under evaluation as discussed above. It is also clear that the growth dynamics are naturally lower for the European Bladdernut, which is probably determined genetically.

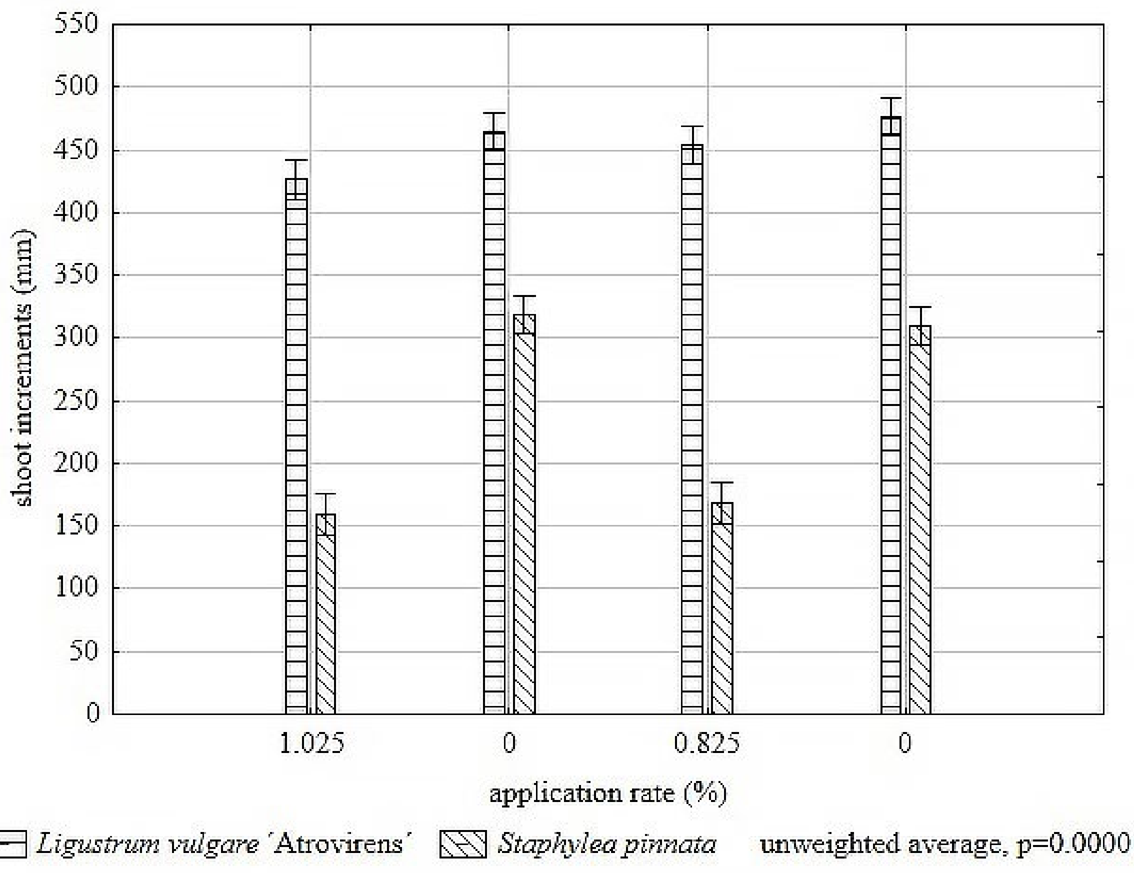
In addition to the average increment length of the longest shoot, plant behaviour is described in more detail by the observed minimum and maximum increment lengths at the selected weekly intervals after herbicide treatment, which are presented in Tab. III. The data show that at 2 weeks after treatment, all versions of the experiment had plants that showed no increments in all other plants that were significantly growth-inhibited. In the case of the European Bladdernut, zero-increment plants were still present in the treated versions of the experiment at 4 weeks after herbicide application, despite the fact that the weather conditions (average air temperatures, precipitation totals) were favourable for growth at the site (ČHMÚ, 2021; In-Počasí, 2021). The above phenomenon coincides precisely with the time of the highest herbicide efficacy on weeds (Altland, 2019) and, by extension, the time of its potentially highest inhibitory or damaging effect on the woody plants treated. Also, there are other research papers that involve the study of the active substance pendimethalin (Derr and Simmons, 2006) and that point to different levels of herbicide tolerance in other woody plant species and their potential herbicide damage. The weather patterns during the period of approximately 1 month before and after herbicide application were essentially normal for that time of year. Also, the nature of the habitat and its preparation for cultivation were in line with the recommendations for application provided on the product label (Ústřední, 2021). It can therefore be assumed that the effect of weather and other cultivation factors on the treated plants was rather insignificant in the given period. In the literature that has been reviewed, the causal relationship between pendimethalin and herbicide damage to treated woody plants is only described in connection with significantly increased total rainfall that occurred shortly after the application of herbicide treatment (Pacanoski, Kolevska and Mahmeti, 2020).

In the present experiment, above-average rainfall only occurred in the second half of May, i.e. 5–6 weeks after herbicide application. An unusual combination of low total rainfall and warmer air temperatures was experienced in June, i.e. 8–11 weeks after the treatment. At the same time, a clear acceleration in plant growth was experienced in all versions of the experiment 8–12 weeks after treatment, and the growth further increased at longer time intervals after treatment. Again, this fact corresponds well with the commonly given degradation time of this herbicide in the soil environment, which is around 8 weeks (Kočárek, Artikov, Voříšek *et al.,* 2016). The loss of herbicide efficacy against weeds has also been reported to occur at the same time frame by other research papers (Altland, 2019; Reeder, Gilliam, Wehtje *et al.*, 1994).

Tab. III also shows the situation at the end of the evaluation (at 24 weeks after the intervention), where the variance of the values measured for privet confirms the relative evenness in woody plant growth across both treated and untreated versions. In the same time period, a persistent inhibitory effect of herbicides and a significantly more variable growth of individual plants was observed in the European Bladdernut.

The authors are not aware of any comparable records describing the growth response in the herbicide-treated woody species monitored. For privet, tolerance to the active substance pendimethalin has been reported – albeit with no detailed links to post-treatment growth characteristics – for example by Harpster, Sellmer and Kuhns (2012). For the European Bladdernut, no indicative data are available, which may be due to data being either lacking or unrepresentative.

In the context of verifying the effect of herbicide application on the growth of selected woody plants, it is also important to mention the mortality factor. With the exception of one control version for the European Bladdernut, an uneven occurrence



3: *Average increment length of the longest shoot for each herbicide application rate, observed at 24 weeks after application*

III: *Minimum and maximum values measured for the increment of the longest shoot depending on the herbicide application rate and the time interval from application (mm) and the recorded plant mortality rate*

Weeks after application (WAT)	Application rate (%)	*Ligustrum vulgare* 'Atrovirens'			*Staphylea pinnata*		
		increment length (mm)		mortality rate (pcs)	increment length (mm)		mortality rate (pcs)
		min	max		min	max	
2	1.025	0	15	0	0	05	0
	0	0	25	0	0	05	0
	0.825	0	20	0	0	05	1
	0	0	20	1	0	05	0
4	1.025	15	50	4	0	15	0
	0	30	60	1	10	40	1
	0.825	25	60	2	0	15	0
	0	20	60	0	10	40	0
8	1.025	40	110	0	10	45	11
	0	65	140	0	30	75	1
	0.825	50	120	0	10	35	8
	0	50	140	0	30	75	0
12	1.025	80	165	0	30	95	0
	0	85	200	0	70	150	0
	0.825	80	190	0	30	80	0
	0	85	210	0	60	155	0
24	1.025	320	530	0	90	270	0
	0	280	570	0	150	420	0
	0.825	310	570	0	85	280	0
	0	370	620	0	150	430	0

of dead plants was observed in all other versions of the experiment in the period until the 8th week after herbicide application. In the later period, there were no more deaths. The situation during the experiment is clearly documented in Tab. III. In all versions, random deaths of privet plants were observed within 4 weeks after treatment. A total of 8 plants died, which makes up 4% of the total number of individuals planted. For plantings of young bare-root plants, the above percentage of non-specific deaths was in principle normal. Based on the nature of the development of the other (living) plants in the experiment and their growth as described above, no obvious connection with herbicide application was found. Even when visually inspected, no other plants showed any characteristic symptoms of herbicide damage throughout the duration of the experiment. The deaths were probably caused by the action of pathogenic soil fungi. In contrast, the overall mortality rate was noticeably higher in the European Bladdernut, and it was characteristically concentrated mainly in the period of 4–8 weeks after herbicide treatment. The overall mortality rate was 11% of the individuals planted, with 10% of the dead individuals in the herbicide-treated versions. At the same time, a higher mortality rate was also observed for the higher application rate (1.025%). In this case, the observed mortality rate is no doubt largely related to the woody plant species' lower tolerance to herbicide treatment. Other abiotic and biotic influences are rather secondary. The later plant deaths can be explained by the long growth stagnation or even complete absence of growth observed in many individuals in the first 4 weeks after treatment. It is associated with the energy depletion of reserve substances and, at the same time, the inhibitory effect of the herbicide, which prevents cell division and especially root growth as it does in weed plants. The clear and long-lasting growth inhibition in other plants of the same species and the visual symptoms of herbicide damage that were observed during the experiment are fully consistent with the above assumption.

In terms of selective efficacy against weeds, a simple visual comparison with the herbicide-untreated control populations as part of the experiment confirmed the manufacturer's stated (ÚKZÚZ, 2021) excellent efficacy against the following grasses: green foxtail (*Setaria* *viridis*), cockspur (*Echinochloa crus-galli*), annual meadow grass (*Poa annua*) and hairy crabgrass (Digitaria sanguinalis), and at the same time against dicotyledonous annual weeds: red dead-nettle (*Lamium purpureum*), shepherd's purse (*Capsella bursa-pastoris*), small nettle (*Urtica urens*), pigweeds (*Amaranthus* spp.), perennial quinoa (*Chenopodium* spp.), chickweed (*Stellaria media*), common purslane (*Portulaca oleracea*) and birdeye speedwell (*Veronica persica*). In addition, good efficacy against other weeds not explicitly listed by the manufacturer was also confirmed, such as: downy brome (*Bromus tectorum*), common mallow (*Malva neglecta*) and creeping woodsorrel (*Oxalis corniculata*). These weed species only began to appear randomly in the herbicide-treated areas 6 weeks after herbicide treatment, and their growth was partially visually inhibited, and their root system reduced. In the herbicide-untreated versions of the experiment, they grew without limitation throughout the duration of the experiment. A clear increase in the quantity of weeds present in the herbicide-treated versions of the experiment occurred at 8–10 weeks after application, which corresponds with the usual decay time of the active substance (Kočárek, Artikov, Voříšek *et al.*, 2016). At the same time, most of the weeds growing at that time no longer showed any degenerative symptoms or visually inhibited growth. Only limited efficacy of herbicide application was observed for quick weed (*Galinsoga* spp.), pineappleweed (*Matricaria discoidea*) and field pennycress (*Thlaspi arvense*), which grew in the treated areas in gradually increasing quantities from the 4th to 5th weeks after treatment. Their growth was clearly slower than in the control areas. The following weed species grew throughout the duration of the experiment without showing any symptoms of visual growth inhibition or degenerative changes, in both herbicide-treated and herbicide-untreated areas: groundsel (*Senecio vulgaris*) and horseweed (*Conyza canadensis*). In the experiment, the effect of weed plants on shoot growth of the woody plants under evaluation was only secondary, as evidenced by the low to no mortality rate and the significantly faster growth dynamics of the woody plants under evaluation in the period after herbicide treatment. Based on a simple visual comparison, it can be concluded that the woody plants growing in the untreated control areas had fewer lateral shoots at the end of the experiment.

CONCLUSION

Influencing the growth of, and possibly the degree of potential damage to, young ornamental woody plants is essential both in terms of their nursery production and in terms of caring for new plantings in cities and the landscape. From the results of the present experiment, it is clear that the use of the pre-emergence herbicide Stomp® 400 SC (pendimethalin, 400 g/l) – provided that the manufacturer's recommended procedures and application rates are followed – has a different effect on shoot growth in the selected ornamental woody plants and, in addition, this effect changes in the period after application. In the case of ornamental plants, this issue is not sufficiently verified and specified for users in the Czech Republic. It can be concluded that, in privet, herbicide application in the experiment clearly had little effect on the reduction of shoot increment length, and the initial inhibitory effect of the active substance pendimethalin also declined more quickly. Compared to the control, the average increment of the longest shoot was 4.7% and 8.3% smaller for the lower and higher application rates, respectively, at the end of the experiment (24 weeks after application). However, the European Bladdernut proved to have increased susceptibility to herbicide damage. The effect of the application itself was more pronounced than the effect of the application rates. Also, there were significant growth differences between plants (unevenness) throughout the duration of the experiment. At the end of the experiment, the difference in the average length of the longest shoot between herbicide-treated and herbicide-untreated plants was 45.68% and 50.13% for the lower and higher application rates, respectively. Poor tolerance to the herbicide was also confirmed by visual signs of herbicide damage which were observed in about 20% of the treated plants, and the increased mortality rate of the same, which stood at 10%.

The highest inhibitory effect of the herbicide on the ornamental woody plants that had been treated was observed in the first 2 and 4 weeks after treatment, respectively. In contrast, a clear decline in herbicide treatment efficacy occurred 8 to 10 weeks after application, when a clear increase in the presence of vital weeds was observed in the treated areas. In addition, plant increments also accelerated in the period of 8 to 12 weeks in all versions of the experiment. Therefore, this confirmed the commonly given degradation time of the herbicide in the soil environment, which is around 8 weeks.

In terms of selective efficacy against weeds other than those mentioned by the manufacturer, the herbicide was found to be very effective against downy brome (*Bromus tectorum*), common mallow (*Malva neglecta*) and creeping woodsorrel (*Oxalis corniculata*). In contrast, the herbicide is ineffective against the following common weeds: horseweed (Conyza canadensis) and groundsel (Senecio vulgaris).

It is clear from the results of the experiment that it took place under suitable conditions and, for its duration, was not significantly influenced by any modifying factors, especially the distribution of temperatures and precipitation. This confirmed the important role of herbicide tolerance of individual woody plant species and the need to study it further under different conditions. Understanding the growth response of ornamental woody plants to herbicide treatment and understanding the rate of decline under any adverse conditions have a significant impact on the efficiency and economics of their cultivation in nurseries and in the management of residential greenery. It also influences the fulfilment of the desired functions of woody plants in their permanent habitats.

The use of pre-emergence herbicides in ornamental and environmental horticulture in combination with other cultivation practices can help to address the need for a more sophisticated and effective control of undesirable weed plants, even in the Czech Republic where such use has been rather marginal to date. This appears to be particularly important for young plants and plants in early stages of cultivation.

Acknowledgements

This contribution was supported by project No. DH23P03OVV053 - Important and unresolved topics of Landscape Architecture, program to support applied research and experimental development of National and Cultural Identity for the years 2023 to 2027 of the Ministry of Culture Czech Republic (NAKI III).

REFERENCE

ALTLAND, J. E. 2019. Efficacy of preemergence herbicides over time. *Journal of Environmental Horticulture*, 37(2): 55–62. https://doi.org/10.24266/0738-2898-37.2.55

ALTLAND, J. E., GILLIAM, C. H. and WEHTJE, G. 2003. Weed Control in Field Nurseries. HortTechnology 13 (1): 9–14. https://doi.org/10.21273/HORTTECH.13.1.0009

BERCHIELLI-ROBERTSON, D. L., GILLIAM, C. H. and FARE, D. C. 1990. Competitive effect of weeds in the growth of container grown plants. *HortScience*, 25(1): 77–79. https://doi.org/10.21273/HORTSCI.25.1.77

CAREY, W. A. and SOUTH, D. B. 2005. Weed Control in Bareroot Hardwood Nurseries. In: *National proceedings: Forest and Concervation Nursery Associations 2004*. Charleston, 12–15 July 2004. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, pp. 34–38.

CULEK, M. (ed.). 1996. *Biogeographical division of the Czech Republic* [in Czech: *Biogeografické členění České republiky*]. Praha: Enigma.

ČESKÝ HYDROMETEOROLOGICKÝ ÚSTAV. 2021. Monthly data: Hradec Králové - Svobodné Dvory (2019) [in Czech: Měsíční data: Hradec Králové – Svobodné Dvory (2019)]. *ČHMÚ* [online]. Available at: http://www.chmi.cz/historicka-data/pocasi/mesicni-data/mesicni-data-dle-z.-123-1998-Sb# [Accessed: 2021, November 22].

DERR, J. F. and SALIHU, S. 1996. Preemergence Herbicide Effects on Nursery Crop Root and Shoot Growth. *Journal of Environmental Horticulture*, 14(4): 210–213. https://doi.org/10.24266/0738-2898-14.4.210

DERR, J. F. and SIMMONS, L. D. 2006. Pendimethalin Influence on Azalea Shoot and Root Growth. *Journal of Environmental Horticulture,* 24(4): 221–225. https://doi.org/10.24266/0738-2898-24.4.221

DEYL, M. 1956. *Weeds of fields and gardens* [in Czech: *Plevele polí a zahrad*]. Praha: Československá akademie věd.

FRETZ, T. A. 1972. Weed competition in container grown Japanese holly. *HortScience,* 7: 485–486.

HANCOCK, D. J. 2016. Semi-selective herbicide use in nursery weed control. *Acta Horticulturae*, 1140: 15–18.

HARPSTER, T., SELLMER, J. and KUHNS, L. J. 2012. Controlling Weeds in Nursery and Landscape plantings. *PennState Extension* [online]. Available at: http://extension.psu.edu/controlling-weeds-in-nursery-and-landscape-plantings [Accessed: 2021, December 3].

IN-POČASÍ. 2021. Weather station Hradec Králové - Svobodné Dvory (2019) [in Czech: Meteostanice Hradec Králové - Svobodné Dvory (2019)]. *In-Počasí* [online]. Available at: http://www.in-pocasi.cz/archiv/hradec_kralove_svobodne_dvory/?&typ [accessed: 2021, November 22].

KAVKA, B. 1974. Evaluation of the main types of shrubs in terms of their use in Garden and Landscape architecture [in Czech: Zhodnocení hlavních druhů křovin z hlediska jejich využití v zahradní a krajinářské architektuře]. *Acta Pruhoniciana*, 29: 98–99, 170–171.

KOČÁREK, M., ARTIKOV, H., VOŘÍŠEK, K. *et al.* 2016. Pendimethalin Degradation in Soil and Its Interaction with Soil Microorganisms. *Soil & Water Res.*, 11(4): 213–219.

NIENHAUS, F., BUTIN, H. and BÖHMER, B. 1998. A*tlas of diseases and pests of ornamental woody species* [in Czech: *Atlas chorob a škůdců okrasných dřevin*]. Praha: Brázda.

NOVÁKOVÁ, V. 1986. *Herbicides for ornamental plants and woody species* [in Czech: *Herbicidy pro okrasné rostliny a dřeviny*]. Průhonice: Výzkumný a šlechtitelský ústav okrasného zahradnictví.

PACANOSKI, Z., KOLEVSKA, D. D. and MAHMETI, A. 2020. Tolerance of black locust (Robinia pseudoacacia L.) seedlings to PRE applied herbicides. *Agriculture and Forestry*, 66(2): 157–165.

PALMER, C., VEA, E. and SIMS, K. 2006. Ornamental Horticulture Program Pendimethalin Crop Safety [online]. Available at: http:// cuisinedocbox.com/Vegan/76757006-Ir-4-ornamental-horticulture-program-pendimethalin-crop-safety-authors-cristi-palmer-ely-vea-and-karen-sims-date-june-20-2006 [accessed: 2021, December 3].

REEDER, J. A., GILLIAM, C. H., WEHTJE, G. R. *et al.* 1994. Evaluation of selected herbicides on field-grown woody ornamentals. *Journal of Environmental Horticulture,* 12 (4): 236–240.

SAHA, D., MARBLE, C., BOYD, N. S. *et al.* 2017. Impacts of preemergence herbicide formulation on cost and weed control efficacy for container nursery crop producers. *Acta Horticulturae*, 1174: 319–324.

SLAVÍK, B. (ed.). 1988–2004. *Flora of the Czech Republic* [in Czech: *Květena České republiky*]. Praha: Academia.

STEWART, C. J., MARBLE, S. C., PEARSON, B. J. *et al*. 2017. Impact of Container Nursery Production Practices on Weed Growth and Herbicide Performance. *HortScience*, 52 (11): 1593–1600. https://doi.org/10.21273/HORTSCI12241-17

TICKNOR, R. L. 1965. Effect of Herbicides on Nursery Plants Studied. *Oregon Ornamental and Nursery Digest,* 9(3): 3–4.

TOMÁŠEK, M. 2000. *Soils of the Czech Republic* [in Czech: *Půdy České republiky*]. Praha: Český geologický ústav.

ÚSTŘEDNÍ KONTROLNÍ A ZKUŠEBNÍ ÚSTAV ZEMĚDĚLSKÝ (ÚKZÚZ). 2021. Register of Plant Protection Products [in Czech: Registr přípravků na ochranu rostlin]. *eAGRI* [online]. Available at: http://eagri.cz/public/app/eagriapp/POR/Vyhledavani.aspx [Accessed: 2021, November 20].

ZHELJAZKOV, V. D., PATTERSON, K., PARSONS, K. J. *et al.* 2007. Tolerance of bare-root ornamental perennials to selected herbicides. *Canadian Journal of Plant Science*, 87: 439–442.

Contact information

Pavel Bulíř: pavel.bulir@mendelu.cz (corresponding author)