UDC 632.51:633.31
632.954.02
Acta Agriculturae Serbica, 29 (57), 43–48, 2024
doi: 10.5937/AASer2357043T
Publisher: Faculty of Agronomy Čačak
www.afc.kg.ac.rs

Comparative analysis of alfalfa cultivation with and without herbicide use to gain insights into the potential for sustainable system development

Dalibor Tomić[1*], Vladeta Stevović[1], Nebojša Bogdanović[2], Miloš Marjanović[1], Nenad Pavlović[1], Đorđe Lazarević[3], Mirjana Petrović[3], Vladimir Zornić[3]

[1]*University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, 32000 Čačak, Serbia*
[2]*AGRO DM, D.O.O., Beogradski put 5, 11400 Mladenovac, Serbia*
[3]Institute for Forage Crops, 37251 Globoder, Kruševac, Serbia

*Corresponding author: dalibort@kg.ac.rs

Received 7 February 2024; Accepted 21 February 2024

A B S T R A C T

A major problem when establishing alfalfa crops can be the presence of weeds. In intensive systems, weeds are controlled with herbicides, which inevitably contaminate water, soil, air, and food. The work aimed to carry out a comparative analysis between the intensive system of alfalfa cultivation with herbicide use and the cultivation method without herbicide use in order to be able to make recommendations for the development of sustainable management systems in agriculture. A field trial was conducted at the experimental field of the Institute for Animal Husbandry, Zemun, Serbia, using a randomized block design with three replications and three treatments: control treatment (without herbicide application), treatment with bentazon and treatment with imazamox. The forage yield and hay yield in the first cut were significantly reduced in the treatments with herbicide application. The application of herbicides led to a significant reduction in weed biomass. The herbicides had different effects on individual weed species and their proportion in the total weed biomass. The application of herbicides gave no significant reduction in the number of weed species present. The number of weed species decreased over time due to the competitiveness of alfalfa. Under conditions of appropriate agrotechnics, the alfalfa crop can be established without using herbicides, which could be a good practice for sustainable farming systems. In this case, increased weed emergence can be expected in the first cut, which should be used carefully, and a reduction in weed levels can be expected with each subsequent cut.

Keywords: alfalfa, forage yield, hay yield, herbicides, weed species

И З В О Д

Велики проблем при заснивању луцеришта може бити присуство корова. Корови се у интензивним системима сузбијају применом хербицида, који неизбежно доводе до загађења воде, земљишта, ваздуха и хране. Циљ рада је био упоредна анализа интензивног система гајења луцерке уз примену хербицида и начина гајења без примене хербицида како би се дале препоруке за развој одрживих система управљања у пољопривреди. Пољски оглед је постављен на огледном пољу Института за сточарство, Земун, Србија по случајном блок систему у три понављања и три третмана: контролна варијанта без примене хербицида, третман бентазоном и третман имазамоксом. Принос зелене крме и принос сена у првом откосу су значајно смањени на третманима са применом хербицида. Примена хербицида је утицала на значајно смањење биомасе корова. Хербициди су имали различит утицај на поједине коровске врсте и њихов удео у укупној маси корова. Примена хербицида није имала већег утицаја на смањење броја присутних коровских врста. Број коровских врста се временом смањивао као резултат конкурентских способности луцерке. Усев луцерке је у условима адекватне агротехнике могуће засновати без примене хербицида, што би могла да буде добра пракса у одрживим системима управљања. У том случају се може очекивати повећано присуство корова у првом откосу, који треба користити опрезно, а у сваком следећем откосу се може очекивати смањење удела корова.

Кључне речи: корови, луцерка, принос крме, принос сена, хербициди

1. Introduction

Weeds can severely impair the development of alfalfa (*Medicago sativa* L.). Particular damage can occur if sowing is delayed and late spring weed species develop intensively, which can suppress young alfalfa plants. If sowing is done in time, early spring weed species that grow alongside young alfalfa plants can cause major damage (Vrbničanin and Janjić, 2006). Rassini et al. (1995) pointed out that under the influence of weeds, alfalfa yield can be reduced by 60% and dry biomass yield by up to 75%. In addition, many weeds can be noxious and toxic, and can pose a risk if found in hay or silage. Some weeds contain nitrates, HCN, HCl, alkaloids, and glycosides and can cause various diseases and even death of animals that consume them (Puschner, 2005). Unpleasant odor and low nutritional value reduce the palatability of forage and the quality of animal products (Ilić and Nikolić, 2016). Renz (2015) concluded that forage quality decreases with increasing weed biomass, to varying degrees depending on the presence of weed species. Some weeds have leaves or flowers with spines and thorns that can cause injury to domestic animals (Fava et al., 2000).

Modern forms of alfalfa cultivation are based on herbicide treatments. The choice of herbicides and the timing of their application depend on the composition of the weed flora and the phenophase of the crops and weeds. Today, preparations based on bentazone, imazethapyr, imazamox, 2,4 D, and their combinations PAFS (2022) are most commonly used to control broadleaf weeds after emergence in the first year.

The frequent and inappropriate use of herbicides has caused problems in terms of environmental pollution (Ramos-Ulate et al., 2022). The intensive use of herbicides, which have a similar mechanism of action, has led to the emergence of resistant forms of weeds and thus to the continuous improvement and development of new herbicides (Khanh et al., 2005). Moreover, herbicide use contributes to higher greenhouse gas emissions from the soil (Shi et al., 2020).

In order to develop sustainable management systems in agriculture, attempts have recently been made to avoid the use of herbicides and instead apply preventive measures for weed control (Shi et al., 2020; Baidoo and Shandan, 2023; Tomić et al., 2023; Pantović et al., 2023).

The aim of the work was to carry out a comparative analysis between an intensive alfalfa cultivation system with herbicide use and a method without herbicide use in order to make recommendations for the development of sustainable management systems in agriculture.

2. Materials and methods

A field trial was set up in 2017 at the experimental field of the Institute of Animal Husbandry, Soko Salaš, Zemun, Serbia (44º49'10'' N, 20º18'25'' E, 102 m above sea level). The experiment was carried out on a carbonate chernozem soil pH_{KCl} 7.15, which contained 2.74 % organic matter, 5.13 % $CaCO_3$, 0.256 % N, 98 mg extractable P 100 g^{-1} soil and 45 mg K 100 g^{-1} soil. Wheat was grown as the previous crop. The soil was prepared by plowing in autumn to a depth of 25 cm and before sowing by spreading and harrowing to a depth of 10 cm. Pre-sowing fertilization was carried out with the complex fertilizer N16P16K16 at a rate of 300 kg ha^{-1}. Sowing was carried out on March 25 at a rate of 20 kg ha^{-1} seed. The alfalfa variety 'Niagara' was used (Institute of Field and Vegetable Crops, Novi Sad).

The trial was set up in a randomized block design with three replications. There were three treatments: the control treatment (without herbicide use), the bentazon herbicide treatment and the imazamox herbicide treatment. The herbicide treatments were applied once in the second half of May when the plants were at the 10–15 leaf stage. Bentazon was applied as Savazon 480 at a rate of 2 L ha^{-1} and imazamox as Soyasan at a rate of 1.2 L ha^{-1}. After herbicide treatment, all variants were treated with the insecticide Decis 2.5 EC and supplemented with the foliar fertilizer N13P8K24 and NU-Film 17.

Weed species were determined before herbicide treatment. After mowing in the alfalfa budding phase, the total biomass was measured on an area of 1 m^2. Alfalfa and weeds were then separated by species and the samples were dried at 65°C. The hay yield (t ha^{-1}) and the proportion of weed species in the dry biomass of the sample were calculated based on the dry weight of the samples. The above analyses were repeated in the second section.

The average annual air temperature for 2017 and the ten-year period in the specified area was 13.2 and 13.0°C, respectively, and the average annual precipitation was 485 and 580 mm, respectively. The largest amounts of precipitation fell in May (Table 1).

The results obtained were subjected to a variance analysis using STATISTICA 8 (StatSoft Inc., 2007). The differences between the mean values were analyzed using the LSD test.

Table 1.
Monthly precipitation distribution (P) and average monthly temperatures (T) for the experimental 2017 and the ten year period 2007–2017) (Republic Hydrometeorological Service of Serbia)

Month		1	2	3	4	5	6	7	8	9	10	11	12
2017	P (mm)	18.8	21.0	26.6	45.6	82.1	35.8	37.7	26.6	58.2	51.6	33.1	47.8
	T (°C)	-4.4	4.8	10.5	12.3	17.8	23.9	25.0	25.2	18.0	13.1	7.7	4.4
2007–2017	P (mm)	52.8	40.5	60.2	38.0	87.3	73.2	49.0	40.9	53.7	54.0	42.3	41.5
	T (°C)	1.6	3.7	8.0	13.7	17.9	21.8	24.0	23.7	18.5	12.1	8.0	2.6

3. Results and discussions

In the first cut, the highest forage and dry matter yield of alfalfa was recorded in the control treatment without herbicide application (Table 2). However, the proportion of weeds in the total dry matter yield was significantly higher ($P \leq 0.05$) in the control treatment than in the treatments with herbicides, totaling 28.5% (Figure 1). Forage and dry matter yields were significantly higher in the bentazone treatment than in the imazamox treatment, which produced the lowest yields. The proportion of weeds in the total yield at first cut was not significantly different between the bentazon and imazamox treatments. The results indicated that both herbicides significantly reduced the weed biomass in the total biomass, but they also diminished alfalfa yield, as shown by the results of Beck et al. (2020). The dry matter yield decreased by 36.6% when treated with bentazone and by 54% when treated with imazamox compared to the control. The proportion of weeds in the total dry matter yield was reduced by more than 50% through the use of herbicides. Similar results were reported by Lee et al. (2022). Mamnoje and Mejghani (2020) found that the application of bentazon significantly reduced the plant density and dry matter yield of weeds, but also the dry matter yield of alfalfa.

In contrast to the first cut, there were no significant differences between the treatments in terms of forage yield and dry matter yield in the second cut. The proportion of weeds in the second cut was significantly higher in the control than in both treatments with herbicides. In addition, weed proportion was significantly higher in the treatment with bentazon than in the treatment with imazamox. The results showed that the herbicides used had no negative influence on the alfalfa stand in the second cut. However, the proportion of weeds in the second cut was significantly reduced in both treatments compared to the control. The lowest proportion of weeds in the second cut was found in the treatment with imazamox.

Table 2.
Forage and dry matter yields of alfalfa

Treatment	Forage yield (t ha^{-1})		Dry matter yield (t ha^{-1})	
	I cut	II cut	I cut	II cut
Control	79.60 a	15.60 a	22.45 a	6.30 a
Bentazon	46.13 b	15.26 a	14.23 b	6.63 a
Imazamox	28.33 c	19.33 a	10.33 c	7.57 a
Average	**51.35**	**16.73**	**15.67**	**6.83**

Values characterized by different lower case letters within the columns differ significantly (P≤0.05) according to the LSD test

In the composition of the weed flora in the alfalfa crop immediately before the treatments, the presence of 17 weed species was determined. Among the annual broad-leaved weeds, the following were found: *Polygonum aviculare* L., *Chenopodium album* L., *Amaranthus retroflexus* L., *Veronica persica* Poir., *Capsella bursa pastoris* Medik., *Abutilon theophrasti* Medik. and *Chenopodium hybridum* L. The most abundant were *Polygonum aviculare* L., *Chenopodium album* L. and *Amaranthus retroflexus* L. Among the annual narrow-leaved weeds, the following were represented: *Setaria glauca* Beauv. and *Echinochloa crus-galli* L. Perennial broad-leaved weeds were represented by: *Tharaxacum officinale* Web., *Convolvulus arvensis* L., *Rumex crispus* L., *Plantago lanceolata* L. and *Calystegiasepium* R.Br., and perennial narrow-leaved weeds by *Sorghum halepense* L., *Agropyrum repens* L. and *Cynodon dactylon* Pers. Vasić and Živković (2023) indicated a similar composition of weed flora in alfalfa.

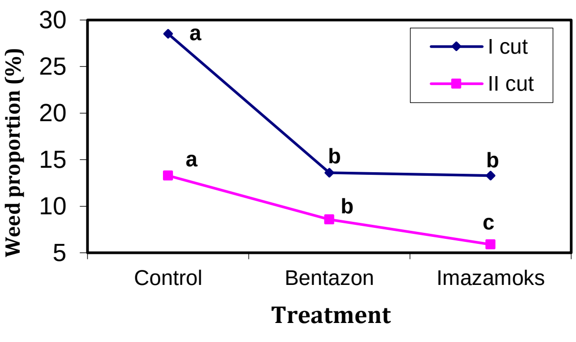

Figure 1. Weed proportion in dry matter yield

The occurrence of 214 weed species was recorded in the alfalfa fields of the western Balkans (Čuturilo and Nikolić, 1986). Milić et al. (2016) reported that, in the year of alfalfa establishment, the most important broad-leaved weeds included *Amaranthus retroflexus* L., *Chenopodium album* L., *Sinapis arvensis* L., *Cirsium arvense* L., *Atriplex patula* L., *Polygonum lapathifolium* L., *Rumex spp*. and *Ambrosia artemisiifolia* L. Among the grass weeds, *Sorghum halepense* L., *Cynodon dactylon* Pers., *Agropyrum repens* L., *Setaria spp*. and *Echinochloa crus-galli* L. were the most common. The most common weeds on old alfalfa are *Capsella bursa-pastoris* L., *Plantago spp*., *Taraxacum officinale* Web. and *Stellaria media* L. Similar results can be derived from other studies. One of the biggest problems with alfalfa cultivation is the occurrence of dodder (*Cuscuta spp*.) (Konstantinović et al., 2004; Milić et al., 2016), which was not present in this trial.

In the first cut in the control treatment, the presence of 7 species was detected (Table 3), of which two species were absolutely dominant: *Chenopodium album* L. (74.7%) and *Polygonum aviculare* L. (21.0%). *Sorghum halepense* L. and *Setaria glauca* Beauv. were present to a much lesser extent (2.3% and 1.7%, respectively).

The species *Capsella bursa pastoris* Medik., *Abutilon theophrasti* Medik. and *Veronica persica* Poir. were also present. In comparison to the observations before the herbicide treatment, the following species were not present in the first cut: *Amaranthus retroflexus* L., *Rumex crispus* L., *Plantago lanceolata* L., *Calystegia sepium* R.Br., *Agropyrum repens* L. and *Cynodon dactylon* Pers., indicating that alfalfa with its faster growth did not allow the further development of the mentioned species. Alfalfa crop is a complex plant community whose members have different needs. The cultivated crop itself has a certain interaction with the weed vegetation (Živanović, 1975). When the crop is established, alfalfa is less competitive with weed species due to its slower growth, lower lushness, cover, and incompletely developed stem density (Kojić and Šinzar, 1985). Similar results with red clover were reported by Tomić et al. (2018).

In the second cut of the control treatment, there were 5 weed species (Table 4). As in the first cut, *Polygonum aviculare* L. (54.5%) and *Chenopodium album* L. (32.8%) dominated. *Sorghum halepense* L. and *Setaria glauca* Beauv. represented 6.6% and 5.1% of the weed biomass, respectively, and *Amaranthus retroflexus* L. accounted for less than 1 %. The occurrence of the species *Capsella bursa pastoris*Medik., *Chenopodium hybridum* L., *Abutilon theophrasti* Medik., *Veronica persica* Poir. and *Echinochloa crus-galli* L. was not observed in the second cut compared to the first cut. The lower number of species in the second cut than in the first is also a consequence of the even more pronounced competitive ability of alfalfa (Tomić et al., 2018). The agrophytocenosis of alfalfa is characterized by the anthropogenic influence of mowing alfalfa fields, with each cut also being a seasonal aspect of the agrophytocenosis (Živanović, 1975). Changes in weed communities during the aging of alfalfa have frequently been observed (Konstantinović et al., 2005). In this trial, some plants of *Polygonum aviculare* L. remained uncut due to the slightly higher cutting height recommended for the first cut of alfalfa, as well as due to pronounced emergence. For these reasons, the herbicides used could not fully treat this species and its percentage remained high in both cuts.

Table 3.
Proportion of weed species in the total weed biomass of the first cut

Family	Weed species	Weed proportion (%)		
		Control	Bentazon	Imazamox
Asteraceae	*Tharaxacum officinale* Web.	-	-	1.93
Brassicaceae	*Capsella bursa pastoris* Medik.	0.09	-	-
Chenopodiaceae	*Chenopodium album* L.	74.66	20.32	48.82
	Chenopodium hybridum L.	-	-	36.85
Convolvulaceae	*Convolvulus arvensis* L.	-	0.08	1.06
Malvaceae	*Abutilon theophrasti Medik.*	0.09	-	1.51
Plantaginaceae	*Veronica persica* Poir.	0.06	0.16	-
Poaceae	*Echinochloa crus-galli* L.	-	36.89	-
	Setaria glauca Beauv.	1.75	19.07	1.13
	Sorghum halepense L.	2.35	5.84	1.28
Polygonaceae	*Polygonum aviculare* L.	21.0	17.64	9.35
In total		100	100	100

In the first cut in the treatment with bentazon, the presence of 7 species was detected. The most common were *Echinochloa crus-galli* L. (36.9%), *Chenopodium album* L. (20.3%), *Setaria glauca* Beauv. (19.1%), *Polygonum aviculare* L. (17.6%) and *Sorghum halepense* L. (5.8%). In addition, the presence of *Convolvulus arvensis* L. and *Veronica persica* Poir. was detected. Compared to the control, the presence of *Capsella bursa pastoris* Medic. and *Abutilon theophrasti* Medik. was not detected, indicating that bentazon was fully effective in controlling these species. However, the proportions of *Echinochloa crus-galli* L., *Setaria glauca* Beauv., *Polygonum aviculare* L., *Sorghum halepense* L. and *Veronica persica* Poir. were higher in bentazon treatment. This indicates that the impact of bentazon on these species was lower.

In the second cut in the treatment with bentazon, 5 weed species were detected. *Chenopodium album* L. (45.5%), *Polygonum aviculare* L. (33.3%) and *Setaria glauca* Beauv. (18.9%) were the most common. *Taraxacum officinale* Web. and *Convolvulus arvensis* L. were found to a much lesser extent. Compared to the control treatment, *Amaranthus retroflexus* L. and *Sorghum halepense* L. were not found in the second cut in the bentazon treatment.

In the first cut in the variant with imazamox, 8 species were detected and the dominant species were *Chenopodium album* L. (48.8%), *Chenopodium hybridum* L. (36.8%) and *Polygonum aviculare* L. (9.3%). Other species represented less than 2% each of the weed biomass. Compared to the control, no occurrence was found for *Capsella bursa pastoris* Medic. and *Veronica persica* Poir., which indicated their greater sensitivity to imazamox. Conversely, the proportion of *Abutilon theophrasti* Medic. was slightly higher, which suggested a slightly lower efficacy of imazamox against this species.

In the second cut in the treatment with imazamox, the presence of three species was observed, of which *Polygonum aviculare* L. (87.1 %) dominated. The presence of *Chenopodium album* L. (12.1 %) and *Setaria glauca* Beauv. (<1%) was also observed. Compared to the control treatment, the presence of *Amaranthus retroflexus* L. and *Sorghum halepense* L. was not detected in the imazamox treatment in the second cut, as in the first cut. It can be assumed that more time was needed to develop a higher effect of both herbicides on these species. According to the results of Noroozi et al. (2022), imazamox showed better results in weed control in a young alfalfa crop compared to bentazon.

Table 4.
Proportion of weed species in the total weed biomass of the second cut

Family	Weed species	Weed proportion (%)		
		Control	Bentazon	Imazamox
Amaranthaceae	*Amaranthus retroflexus* L.	0.98	-	-
Asteraceae	*Tharaxacum officinale* Web.	-	2.02	-
Chenopodiaceae	*Chenopodium album* L.	32.85	45.46	12.15
Convolvulaceae	*Convolvulus arvensis* L.	-	0.34	-
Poaceae	*Shorghum chalepense* L.	6.64	-	-
	Setaria glauca Beauv.	5.08	18.92	0.78
Polygonaceae	*Polygonum aviculare* L.	54.45	33.26	87.07
In total		100	100	100

4. Conclusions

In the first cut, the forage and hay yield were significantly reduced in the treatments with herbicide application compared to the control treatment. The reason for this was the reduction in weed biomass, but also the diminishing effect of the herbicides on the alfalfa crop. A significant part of the yield in the control treatment consisted of weed biomass. In treatments with herbicides, the proportion of weeds was significantly lower. However, in the second cut, there were no significant differences in forage and hay yield between the treatments, but the proportion of weeds in the total biomass was also significantly lower in the herbicide treatments than in the control treatment. The lower number of species in the control treatment in the first cut compared to the first observation and in the second cut compared to the first cut was the result of the expressed competitive ability of alfalfa. Despite the significant reduction in weed biomass, the use of herbicides did not lead to a major reduction in the number of weed species. However, a significant influence on the dominance of certain species was observed.

The results showed that alfalfa cultivation can be successfully carried out without the use of herbicides under the conditions of appropriate agrotechnics involving the application of preventive measures against weeds, especially timely sowing. In this case, increased weed biomass is to be expected at the first cut, which in this case accounted for almost a third of the total forage yield. Caution should therefore be exercised when using biomass to feed domestic animals. However, thanks to the highly competitive nature of alfalfa, a significant reduction in weed levels can be expected with each subsequent mowing. In this way, it can contribute significantly to the protection of the environment and the health of humans and domestic animals, and therefore it can be a good practice in sustainable farming systems if appropriate precautions are taken.

Acknowledgment

The research presented in this article is part of Projects Ref. No. 451-03-66/2024-03/200088 and 451-03-66/2024-03/200217 were funded by the Ministry of Science, Technological Development and Innovation, Republic of Serbia.

References

Baidoo, M., Shilpakar, C. (2023). Management practices to offset the declining trend of alfalfa hay production. *International Journal of Veterinary Sciences Research*, 9 (2), 018-026. https://dx.doi.org/10.17352/ijvsr.000133

Beck, L, Marsalis, M., Lauriault, L., Serena, M. (2020). Efficacy of Various Herbicides for the Control of Perennial *Plantago spp.* and Effects on Alfalfa Damage and Yield. *Agronomy*, 10 (11), 1710. https://doi.org/10.3390/agronomy10111710

Čuturilo, S., Nikolić, B. (1986). Korovi u lucerki i njihovo suzbijanje. Monografija. Nolit, Beograd, 170.

Fava, E., Rossi, F., Speranzini, G., Nigrelli, A., Rossignoli, G., Gelmetti, D., Von, B.O. (2000). Enzootic ulcer in the back of the tongue in cattle after ingestion of hay containing flower clusters of yellow bristle-grass. *Deutsche Tierarztliche Wochenschrift*, 107 (9), 351-400.

Ilić, O., Nikolić, LJ. (2016). Floristic composition and weed biomass in an organic alfalfa crop. *Journal of Agricultural Sciences*, 61 (2), 137-150. https://doi.org/10.2298/JAS1602137I

Khanh, T. D., Chung, M. I., Xuan, T. D., Tawata, S. (2005). The Exploitation of Crop Allelopathy in Sustainable Agricultural Production. *Journal of Agronomy and Crop Science*, 191, 172-184. https://doi.org/10.1111/j.1439-037X.2005.00172.x

Kojić, M., Šinzar, B. (1985). Korovi. Monografija. Naučna knjiga Beograd, 325.

Konstantinović, B., Meseldžija, M. (2005). Weeds in alfalfa and clover and their control. *A herbalist*, 33 (5), 595-599. http://scindeks.ceon.rs/article.aspx?artid=0354-61600505595K

Konstantinović, B., Meseldžija, M., Konstantinović B. (2004). The importance of perennial weeds and parasitic flowers in the alfalfa crop and the possibility of control. *Acta Agriculturae Serbica*, 9, 413-419.

Lee, H.B., Kim, H.J., Lee, W.K., Lee, Y.S., Jung, S.J., Park, S.H. (2022). Effect of Postemergence Herbicides on Dry Matter Yield and Weed Control in Spring Seeding Alfalfa (*Medicago sativa* L.). *Journal of the Korean Society of Grassland and Forage Science*, 42 (1), 10-16. https://doi.org/10.5333/KGFS.2022.42.1.10

Mamnoie, E., Meighani, F. (2020). Effect of repeated spraying and efficacy of some herbicides on weed control and yield of alfalfa (*Medicago sativa*). *Iranian Journal of Weed Science*, 16 (1), 135-145. https://doi.org/10.22092/ijws.2020.122586.1269

Milić, D., Katanski, S., Karagić, Đ., Vasiljević, S. (2016). Alfalfa – the queen of forage plants, a guide for successful production, Institute of Field and Vegetable Crops, Novi Sad, 23 pages.

Noroozi, M., Dadashi, M.R., Meighani, F., Ajam Norouzi, H. (2022). Efficacy of different herbicides on weed control, growth indices and forage yield in alfalfa (*Medicago sativa* L.). *Annali di Botanica*, 12, 43–50. https://doi.org/10.13133/2239-3129/17623

PAFS (2022). Pesticides in agriculture and forestry in Serbia. Society for the Protection of Plants of Serbia. Twenty-first amended and supplemented edition, 700 pages.

Pantović Golijan, J., Sečanski, M., Gordanić, S., Todosijević Šarčević, LJ. (2023). Weed biological control with fungi-based bioherbicides. *Acta Agriculturae Serbica*, 28 (55), 23-37. https://doi.org/10.5937/AASer2355023G

Puschner, B. (2005). Problem weeds in hay and forages for livestock. Proceedings, California Alfalfa and Forage Symposium, December, 2005, Visalia, CA, USA, 12-14.

Ramos-Ulate, M.C., Pérez-Álvarez, S., Guerrero-Morales, S., Palacios-Monarrez, A. (2022). Biofertilization and nanotechnology in alfalfa (*Medicago sativa* L.) as alternatives for a sustainable crop. *Characterization and Application of Nanomaterials*, 5 (2), 111-118. https://doi.org/10.24294/can.v5i2.1769

Rassini, J.B., Freitas, A.R., De-Prado, R. (1995). Effects of weed interference on alfalfa crop yield. *Revista Brasileira de Zootecnia*, 24 (4), 502-509.

Renz, M. (2015). Effect of annual grass weeds on alfalfa establishment, yield and forage quality. Proceedings of the Wisconsin Crop Management Conference, January 2015, Wisconsin, USA, 129-130.

Shi, L, Guo, Y, Ning, J, Lou, S, Hou, F. (2020). Herbicide applications increase greenhouse gas emissions of alfalfa pasture in the inland arid region of northwest China. *Peer Journal*, 8, e9231. https://doi.org/10.7717/peerj.9231

StatSoft Inc. (2007) STATISTICA for Windows (data analysis software system), version 8.0., Tulsa, OK, USA.

Tomić, D., Stevović, V., Đurović, D., Bokan, N., Popović, B., Knežević, J. (2018). Forage yield of a grass-clover mixture on an acid soil in the third year after soil liming. *Journal of Central European Agriculture*, 19 (2), 482–489.

https://dx.doi.org/10.5513/JCEA01/19.2.2149
Tomić, D., Stevović, V., Đurović, D., Marjanović, M., Madić, M., Pavlović, N., Lazarević, Đ., Petrović, M., Radovanović, M. (2023). Perennial forage legumes as an element of sustainable systems. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 51 (3), 13240. https://dx.doi.org/10.15835/nbha51313240
Vasić, T., Živković, S. (2023). Efficacy of herbicides in controlling weeds in alfalfa. *Acta herbologica*, 12, 57-64. https://doi.org/10.5937/actaherb2301057V
Vrbničanin, S., Janjić, V. (2003). The influence of abiotic factors on the composition of weed vegetation of small grains. *Herbology*, 4 (1), 27-38.
Živanović, Ž. (1975). Contribution to the study of vegetation dynamics in the life cycle of the agrophytocenosis cycle of alfalfa in South Banat, Proceedings of XI Counseling on the fight against weeds, Novi Sad.