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INFLUENCE OF DIFFERENT METHODS OF WEED CONTROL ON THE VINEYARD WEED SYNUSIA IN PODGORICA SUBREGION

ABSTRACT

The study of the impact of different methods of weed control in vineyard was carried out in 2015 in the Podgorica sub region. Six different variants of weed control were tested: control, mechanical control, glyphosate (one treatment), glyphosate (two treatments), flazasulfuron and flazasulfuron+glyphosate. A total of 13 weed species from nine families were identified. The *Asteraceae* family was the most widespread with four species (31%), followed by *Poaceae* with two (15%), while all other families participated with one weed species each (8%).

The dominant weed species in the experimental vineyard were *Ambrosia artemisiifolia, Amaranthus retroflexus, Chenopodium album, Sorghum halepense, Heliotropium europaeum* and *Xanthium strumarium*. Annual thermophilic, heliophilic weeds dominated the weed synusia of the vineyard (77%), while perennial species participated with 23%. All applied methods of weed control showed a satisfactory level of efficiency, reducing the number of weed plants and the weed mass per unit area. The best effect in weed control between rows of the vineyard was demonstrated by the variants glyphosate, applied twice (92.7%), flazasulfuron, applied once (92.0%) and glyphosate+flazasulfuron (91.7%). The combination of glyphosate+flazasulfuron (100%) showed the highest efficiency in controlling weeds between the vines in a row.

Keywords: vines, weeds, weed control, Podgorica vineyards

INTRODUCTION

Weeds represent a very complex and diverse group of plants that grow against human's will together with cultivated plants, and are mainly the result of

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agricultural activities (Čekić and Kovačević, 2015; Hulina, 2005). Weeds are characterized by certain biological and ecological characteristics, which are the result of long-term adaptation to elevated anthropogenic effects (Stefanović *et al.*, 2011). Their vitality and resilience come from the ability to adapt to different conditions and influences, high level of plasticity, wide ecological adaptability, production of huge amount of seeds, cosmopolitanism, etc. (Kojić & Šinžar, 1985). Weeds are a regular companion of the vine, and their abundance and biomass depend primarily on climatic and soil conditions, but also on the soil cultivation techniques applied during vineyard maintenance (Gago *et al.*, 2007; Bešlić, 2019).

Weed plants cause multiple damages to the vine, primarily by depriving it of water and nutrients (Fredrikson, 2011). In addition, they significantly complicate soil cultivation, disrupt the water-air regime of the soil, and increase air humidity, which creates more favourable conditions for the development of fungal diseases. They are also hosts of numerous disease-causing agents and pests (Korać, 2011; Štefanac, 1988; Cvrković, 2009; Filippin *et al.*, 2009; Agustí-Brisach *et al.*, 2011; Cvrković *et al.*, 2011; Atanasova, 2015). Certain weed species significantly affect the reduction of vine vigour and wine quality (Saayman & Huyssteen, 1983; Karoglan - Kontić *et al.*, 1999; Hulina 1998; Dujmović-Purgar & Hulina, 2004). Finally, to a lesser or greater extent, they also reduce grape yield, and increase the price of grape production (Savić, 2006).

Due to all mentioned above, the control of weeds within and between row spaces must be carried out continuously, primarily by regular autumn, spring and summer tillage, destroying weeds on the surrounding surfaces, preventing flowering and seed formation, using natural or synthetic mulch and by using herbicides (Mirošević & Karoglan-Kontić, 2008; Fredrikson, 2011).

For a long period of time, multiple cultivations of the soil (deep and surface layers) were the main method of weed control in vineyards. However, this measure of physical weed control often favours the survival of certain annual weed species, and significantly contributes to the spread of perennial, especially rhizome weed species (Mirošević & Karoglan-Kontić, 2008; Gago *et al.*, 2007; Fredrikson, 2011). Due to the unsatisfactory efficiency of the mechanical method of weed control, the increased lack of manpower, as well as the increased costs of purchasing, using and maintaining mechanization for tillage, herbicides have been more used in viticulture in recent years. The effectiveness of chemical weed control has been confirmed in a large number of studies, which is why herbicides are so widely used in grape production. Nowadays, in conventional viticulture, herbicides are mostly used to control weeds between the vines in the row, while weed control within row is performed with the combined use of agrotechnical and chemical measures (Konstantinović, 1999; Ostojić, 1999; Marković, 2012). Unlike agrotechnical measures that have a one-time effect and destroy weeds at the time of application, the use of herbicides provides more effective weed control over a longer period of time (Dolijanović *et al.*, 2017).

The floristic composition of the weed community significantly depends on the agro-ecological conditions prevailing in the wine-growing regions, and therefore the application of herbicides in each locality is strictly specific. For the proper selection of herbicides, one of the most important prerequisites is knowledge of the weed flora in a given vineyard, because the selection of preparations for their control is made based on the weed species present. Only in this way is it possible to make a correct choice of the type and amount of herbicide, the method and time of application, which will enable the achievement of maximum effects in controlling weeds and elimination of possible negative consequences to the greatest extent for the cultivated plant, the environment, domestic animals and humans (Jovović *et al*., 2013).

The weed flora and vegetation of vineyards in the territory of Montenegro has been relatively modestly researched. Most of the research so far is restricted to the influence of the methods of cultivation and soil maintenance in vineyards (Ulićević *et al*., 1991) on weed suppression and vine productivity, while a very small number of works dealt with issues related to weed flora and vegetation. For these reasons, this research was designed with the aim of establishing the dominant weed species in the vineyard of the Biotechnical Faculty in Podgorica and detecting the most effective ways to control them. In addition, the aim of this work was to study the effectiveness of the new Chikara herbicide, which has not been used in Montenegro so far.

MATERIAL AND METHODS

The study of the effectiveness of different methods of weed control on the weediness of Vranac cultivar was carried out in 2015. The research was carried out in the experimental vineyard of the Biotechnical Faculty in Podgorica, planted in 2005 with a planting distance of 2.4 x 1 m (42°26′54″N, 19°12′19″E). The cultivation form is a two-rods horizontal cordon with a stem of approximately 80 cm height. Data on applied herbicides, amount and time of application are given in table 1.

Evaluation of weediness was carried out twenty days after the last treatment with herbicides, using the method of quantitative-qualitative determination, in permanent squares with an area of 1m^2. Determination of weediness was done in the within row space and in the space between rows. By analysing the samples, the species and number of weed plants were determined and the effectiveness of the studied herbicides (EH) was calculated for the number of weeds and their biomass (fresh and air-dried) according to the following formula:

$$\text{HE (\%)} = \frac{\text{NWC - NWH}}{\text{NWC}} \text{ x } 100$$

HE – efficiency of herbicides (%)
NWC – number of weeds in control variant
NWH – number of weeds in variant with herbicides applied

The average annual air temperature was 17.2°C in Podgorica in 2015, while the average vegetation temperature was 23.2ºC. During the year, 1176.0 mm of rain fell, i.e. 438 mm during the vegetation period (Monstat, 2016).

Table 1. Data on applied methods of weed control

Variant		Active substance	Preparation	Content of active substance	Preparation amount per hectare	Time of application
K		Control variant (no weed control)				
MO		Variant with mechanical weed control				Several times during the growing season
Variants with herbicides applied	H_1	Glyphosate	Glifosav 480 SL	480 g l^{-1}	4 l ha^{-1}	End of April
	H_2	Glyphosate	Glifosav 480 SL	480 g l^{-1}	4 l ha^{-1}	End of April
		Glyphosate	Glifosav 480 SL	480 g l^{-1}	4 l ha^{-1}	End of June
	H_3	Flazasulfuron	Chikara 25 WG	250 g kg^{-1}	0,2 kg ha^{-1}	Before weed germination
	H_4	Flazasulfuron	Chikara 25 WG	250 g kg^{-1}	0,2 kg ha^{-1}	Before weed germination
		Glyphosate	Glifosav 480 SL	480 g l^{-1}	4 l ha^{-1}	End of April

The soil of the experimental field is carbonate-free in the surface layer 0-30 cm, in the layer 30-60 cm $CaCO_3$ is found in traces (1.62%), while in the layer 60-90 cm $CaCO_3$ is present in larger quantities (4.39%). Based on the pH value in KCl, the soil has an acidic to slightly acidic reaction. It is well supplied with humus (2.26%) and easily accessible potassium (28.19 mg/100g of soil), and poor with easily accessible phosphorus (5.32 mg/100g of soil).

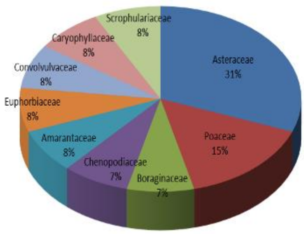
Statistical data analysis was done using the analysis of variance (ANOVA), and the evaluation of differences between mean values was performed using the LSD test.

RESULTS AND DISCUSSION

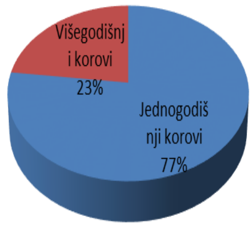
In the vineyard weed community a total of 13 weed species from 9 families were recorded in 2015 (graph 1). The majority of weed species - four, i.e. 31% belong to the *Asteraceae* family, two weed species (15%) belong to the *Poaceae* family, while the other families participated in the total weediness of the vineyard with one weed species each (8%).

The analysis of the represented weed species established the dominance of annual thermophilic, heliophilic weeds (77%), while perennial weeds were represented by 23% (graph 2).

The dominant group is represented by 6 species: *Ambrosia artemisiifolia, Amaranthus retroflexus, Chenopodium album, Sorghum halepense, Heliotropium europaeum* and *Xanthium strumarium*. In addition to them, other weed species such as: *Convolvulus arvensis*, *Euphorbia maculata*, *Digitaria sanguinalis*, *Sonchus asper*, *Sonchus asper* subsp. *glaucescens*, *Stellaria media* and *Veronica chamaedrys* were detected. Bagi and Bodnar (2012) came with similar results. The most common weed species in their research were: *Ambrosia artemisiifolia*, *Amaranthus retroflexus*, *Chenopidium album*, *Convolvulus arvensis*, *Digitaria sanguinalis*, *Stellaria media*, *Sorghum halepense* and *Xanthium strumarium*.



Graph 1. Representation of weed species



Graph 2. Representation of annual and perennial weeds in the vineyard

The results presented in table 2, show that in the control variant in within row space, the dominant weed species are *Chenopodium album* 22% (49 units/m^2), *Ambrosia artemisiifolia* and *Amaranthus retroflexus* with a share of 18% each (40 units/m^2), *Sorghum halepense* 13% (29 units/m^2), *Heliotropium europaeum* 11% (24 units/m^2), and *Xanthium strumarium* 10% (21 units/m^2). Other weed species were represented by 8% (17 units/m^2). The lowest weediness was measured in the H4 variant, where only two weed species were registered, *Chenopodium album* with the participation of 15 units/m^2 (94%) and *Ambrosia artemisiifolia* with single unit (6%).

Table 2. The number of weed species in the inter-row space of the vineyard

Variant	Weed species														Total
	Sorghum halepense		*Heliotropium europaeum*		*Ambrosia artemisiifolia*		*Chenopodium album*		*Xanthium strumarium*		*Amaranthus retroflexus*		Other weed species		
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No
K	29	13	24	11	40	18	49	22	21	10	40	18	17	8	209.7
MO	8	8	9	8	23	22	17	16	11	10	26	25	12	22	107
H1	3	6	4	9	9	19	9	20	11	24	6	13	4	9	41.6
H2	2	12	4	23	3	18	3	18	4	23	0	0	1	6	16
H3	3	18	1	6	4	23	1	6	7	41	1	6	0	0	16.7
H4	0	0	0	0	1	6	15	94	0	0	0	0	0	0	17.3

	LSD 0.05	*LSD 0.01*
Dominant weeds	*25.787*	*36.151*
Total	*23.256*	*32.603*

Rotim (2016) states that in the Herzegovinian and South Dalmatian vineyards, among the perennial weeds, *Sorghum halepense* and *Convolvulus arvensis* are the most abundant, and among the annual weeds, *Amaranthus retroflexus*, *Stellaria media* and *Chenopodium album*, which is partly in agreement with our results. Janjić (1985) mentions the high efficiency of Glyphosav in controlling the weed species *Amaranthus retroflexus*.

The highest total number of weeds in the inter-row space (table 2) was recorded in the control - 209.7 units/m^2 (52%), followed by the variant with mechanical weed control 107 units/m^2 (26%), while the lowest weediness recorded in the variant with two-time application of Glyphosav (H2) - 16 units/m^2 (4%). Statistical data analysis revealed a significantly higher number of weed individual plants in the control and variants with mechanical control compared to all variants with the application of herbicides. A significant difference in weediness was also determined by comparing the variants H2, H3 and H4 with the variant H1, which had 41.6 units/m^2 (10%).

Table 3. The number and percentage of weeds between and within the rows

Variant	Weed species														Total
	Sorghum halepense		*Heliotropium europaeum*		*Ambrosia artemisiifolia*		*Chenopodium album*		*Xanthium strumarium*		*Amaranthus retroflexus*		Other weed species		
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No
K	29	34	10	11	8	9	18	21	5	6	11	13	5	6	86.7
MO	16	41	5	13	4	10	6	15	2	5	3	8	3	8	38.3
H1	5	23	2	9	3	14	4	18	2	9	3	14	3	14	21.3
H2	2	28	0	0	2	29	0	0	2	29	0	0	1	14	8.6
H3	6	43	5	36	0	0	0	0	3	21	0	0	0	0	14.3
H4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	LSD 0.05	*LSD 0.01*
Dominant weeds	*17.903*	*25.099*
Total	*18.554*	*26.012*

From the data provided in table 3. it can be concluded that the dominant weed species on the control variant, between the rows, were *Sorghum halepense* with 29 units/m^2 (34%), *Chenopodium album* with 18 units/m^2 (21%), *Amaranthus retroflexus* with 11 units/m^2 (13%), *Heliotropium europaeum* with 10 units/m^2 (11%) and *Ambrosia artemisiifolia* with 8 units/m^2 (9%). *Xanthium strumarium* and other weed species participated in the total weediness of the control with five plants each (6%). The highest prevalence of weeds between the vines in the row was also the highest in the control variant - 86.7 units/m^2 (51%). Higher weediness was also noted in the variants MO 38.3 units/m^2 (23%) and H1 21.3 units/m^2 (13%). The difference in the number of weeds in the control variant and all other weed control methods was statistically very significant. The differences in the number of weeds between the variant with double application of Glyphosav (H2) - 8.6 units/m^2 (5%) and the variant Chikara+Glifosav (H4) - 0 units/m^2, compared to the variant with mechanical control, were rated as very significant. All other differences in the total number of weeds between rows were without statistical significance.

Data on the fresh and dry biomass of weeds in the inter-row space and the space between the vines in the row are presented in Table 4. The highest fresh biomass of weeds in the inter-row space was measured on the control (1304.7 g) and mechanically treated variants (914.3 g), while the lowest values for this parameter were measured in variants H4, H3 and H2 (88.3, 92.3 and 95.7 g, respectively). Compared to the other variants, these three variants had a statistically very significant reduction in the fresh biomass of weeds. The dry biomass of weeds in the inter row space was also the highest in the control (466.7 g), while the lowest was measured in the variants H3, H2 and H4 (41, 43 and 46 g, respectively). Statistical data analysis showed a very significant increase in the dry biomass of weeds in the control compared to all other studied methods of weed control. A significant increase in weediness was also noted in the variant with mechanical control (220 g) compared to the variants H3, H2 and H4.

Table 4. Fresh and dry biomass of weeds between and within rows

Variant	Between rows		Within rows	
	Fresh (g)	Dry (g)	Fresh (g)	Dry (g)
K	1304.7	466.7	636.7	236.0
MO	914.3	220.0	467.0	167.7
H1	370.0	141.0	182.0	69.0
H2	95.7	43.0	58.3	24.0
H3	92.3	41.0	52.0	24.0
H4	88.3	46.0	0.0	0.0

	Fresh biomass		*Dry biomass*	
	LSD 0.05	*LSD 0.01*	*LSD 0.05*	*LSD 0.01*
Between rows	*100.63*	*141.07*	*99.162*	*139.02*
Within rows	*148.93*	*208.79*	*34.003*	*47.670*

The lowest fresh biomass of weeds between the vines in the row (table 4) was measured in the herbicide treatments H4, H3 and H2 (0, 52 and 58.3 g, respectively), while the highest was in the control (636.7 g) and the variant with mechanical treatment (467.0 g). By comparing the differences in the fresh biomass of the weeds in the control and variants with mechanical processing with the variants with the application of herbicides, statistically very significant differences were noted. A very significant increase in the dry biomass of weeds between rows was determined by comparing the control variant (236.0 g) and all other methods of weed control, as well as by comparing the variant with mechanical treatment (167.7 g) and the variants on which weeds were controlled using herbicides.

The efficiency of the studied methods of weed control is presented in table 5. From the results shown, variants H2, H3 and H4 (92.7%, 92% and 91.7%, respectively) showed a very high efficiency in controlling weeds in the inter-row space, the variant H1 had high efficiency (80.0 %), while the effectiveness of weed control using mechanical measures (MO) was very low (49.3%). Statistical data analysis revealed a very significant increase in efficiency on variants H2, H3 and H4 compared to the variant on which Glyphosav (H1) was applied once and the variant with mechanical control (MO).

The variant with the combined application of the Chikara+Glyfosav herbicide - H4 (100%) and the variant where the herbicide Glyfosav was applied twice - H2 (90%) showed the highest effectiveness in controlling weeds between the vines in the row. The differences in effectiveness between these two tretments and all other weed control methods were marked as statistically highly significant. The lowest efficiency was on plots with the application of mechanical measures (55%). Compared to the studied herbicides, this method of weed control exhibited statisticaly significantly lower performance.

Table 5. Effectiveness of the studied methods of weed control in reducing the number of weed individual plants

Variant	Between rows (%)	Within rows (%)
MO	49.3	55.0
H1	80.0	74.3
H2	92.7	90.0
H3	92.0	71.3
H4	91.7	100.0

	LSD 0.05	*LSD 0.01*
Between rows	*6.9282*	*9.7128*
Within rows	*9.7349*	*13.648*

Along with the reduction in the number of individual weed species, all applied herbicides had a very significant effect on the reduction of fresh biomass of weeds in the inter-row space compared to mechanical treatment (table 6). A very significant increase in efficiency was also determined by comparing variants H4, H3 and H2 (94%, 93% and 92.7%, respectively) with variant H1 (72%). Herbicides H3, H2 and H4 (90%, 89%, and 87.7%, respectively) showed the best performance in reducing the dry biomass of weeds in the inter-row space. Treatments with a single application of Glyphosav and mechanical weed control showed a rather unsatisfactory effect in this respect.

The treatment with the application of the herbicide combination Chikara+Glifosav (100%) showed the greatest efficiency in the reduction of fresh weed biomass between the vines in the row (tab. 6). The H2 variant, on which Glyphosav was applied twice (87.3%) and the H3 variant (85.7%), showed high efficiency, while the weakest effect had the H1 variant, on which the Glyphosav herbicide was applied once (72.0%), as well as the variant with mechanical weed control (26.7%). All studied methods of weed control showed a significantly higher efficiency in the reduction of fresh biomass of weeds compared to the variant with the application of mechanical weed control. Treatments H4, H2 and H3 showed significantly higher efficiency compared to variant H1.

Table 6. The effectiveness of the studied methods of weed control in the reduction of weed biomass

Variant	Between rows		Within rows	
	Fresh (%)	Dry (%)	Fresh (%)	Dry (%)
MO	29.0	47.3	26.7	28.3
H1	72.0	64.0	72.0	70.3
H2	92.7	89.0	87.3	91.3
H3	93.0	90.0	85.7	87.3
H4	94.0	87.7	100.0	100.0

	Fresh biomass		*Dry biomass*	
	LSD 0.05	*LSD 0.01*	*LSD 0.05*	*LSD 0.01*
Between row	*7.3470*	*10.300*	*19.752*	*27.691*
Within rows	*7.8558*	*11.013*	*7.7658*	*10.887*

In the reduction of dry biomass of weeds between the vines in the row, the best results were shown by the variant H4 (100%), while the variant with a double application of the herbicide Glyphosav (91.3%) and a single application of the herbicide Chikara (87.3%) showed a very satisfactory effect. The variant with mechanical weed control showed very poor efficiency (28.3%). Statistical data analysis showed a very significant reduction in the dry biomass of weeds on all studied varieties compared to mechanical control.

CONCLUSIONS

Based on the conducted studies, the following conclusions can be drawn:

1. A total of 13 weed species systematized into nine families were found in the sample vineyard.
2. The dominant group of weed species consists of: *Ambrosia artemisiifolia*, *Amaranthus retroflexus*, *Chenopodium album*, *Sorghum halepense*, *Heliotropium europaeum* and *Xanthium strumarium.*
3. Annual thermophilic, heliophilic weeds dominate the weed synusia of the vineyard (77%), while perennial weeds accounted for 23% of the total weeds.
4. The highest total number of weed plants both within and between row spaces was recorded in the control variant (209.7 units/m^2; 86.7 units/m^2), while the lowest presence of weed plants in the inter-row space was in the variant with two applications of Glyphosav - H2 (16 units/m^2), and in the space between the vines in the row in the variant with the combined application of the Chikara+Glyfosav herbicide, where the presence of weed plants was not recorded.

5. Fresh and dry biomass of weeds both within and between rows was the highest in the control variant and the variant with mechanical control.
6. The best effect on weeds within the rows of the vineyard was demonstrated by the herbicide Glyphosav with two applications (92.7%), and the combination of herbicide Chikara + Glyphosav (100%) was the most effective between the vine rows. The least effective in controlling weeds was the variant with mechanical control (49.3% in the inter-row space, i.e. 55% between the plants in the row).
7. The efficiency coefficient based on the total fresh and dry biomass of weeds within and between row spaces was the highest with the Chikara+Glifosav herbicide combination, while the lowest was recorded with the variant with mechanical control.

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