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CHEMICAL WEED CONTROL IN FRUIT-BEARING TABLE GRAPE VINEYARDS (*VITIS VINIFERA* L.)

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Abstract

Weeds are competitive with cultivated plants, as for vines as well. They make harvesting, manual and mechanized operations, etc. difficult. The purpose of the present study, conducted in the area of the Varben village, Bulgaria, was to investigate the efficacy of herbicides and herbicide combinations on weed density and on productivity and yield elements in a vineyard, cultivar "Bolgar". Variants of the experiment were: 1. Untreated control; 2. Economic control; 3. Two-time application of Ecopart Turbo (26.5 g/l pyraflufen-ethyl) - 0.08 L ha^{-1}, without removing the young shoots from the stem; 4. Two-time targeted application of Ecopart Turbo - 0.08 L ha^{-1}, with removing of the young shoots from the stem; 5. Double application of Roundup Classic Pro (360 g/l glyphosate) - 0.40 L ha^{-1} + Ecopart Turbo - 0.03 L ha^{-1}. The highest yield in the economic control - 11.89 t ha^{-1} was reported, which represents a 54% higher yield than that of the untreated control. In the variants with herbicides, the highest yield - 11.69 t ha^{-1} in treatment 5 (Roundup Classic Pro - 0.40 L ha^{-1} + Ecopart Turbo - 0.03 L ha^{-1}) was recorded.

***Key words**: grapes, weeds, herbicides, yields.*

INTRODUCTION

By 1980, Bulgaria was in the top three in the export of table grapes after Italy and the USA. According to recent market research, the leading countries in the production of table grapes such as Afghanistan, Algeria, Bulgaria, Hungary, France, Italy and Romania have had a negative market share in the production and sale of table grapes in recent years (Seccia et al., 2015).

The production and sale of table grapes is linked to obtaining a product with a good and attractive appearance, but at the same time combined with good taste characteristics, which are determined by the balance of sugars and titratable acids. Grape production in 2023 was 147,804 tons, 9% less than the previous year.

The Southeast region produced 42% of the grapes, and the South Central region 36% (www.mzh.government.bg).

Main issue in grape productions is the uncontrolled weed flora.

Grape growers regulate competition for water and nutrients between the vines and inter-row vegetation by tilling, mulching and/or herbicide application (Winter et al., 2018).

Vior and Cârciu (2011) conduct a study which provides an information on the composition of weed flora in vineyards located in Romania. The majority of weeds consisted of monocotyledonous perennials - *Agropyron repens* and *Cynodon dactylon* in particular.

A number of researchers are conducting trials for chemical weed control around the globe.

A research conducted by Stoyanova et al. (2024) evaluates the influence of three soil herbicides (Stomp New 330 EK, Dual Gold 960EK and Alcans Sync Tech) both on the root system and the growth of grafted rooted vines. Indicators such as diameter of the internode and the length of the internodes of the shoots, length and mass of the ripe shoots and the standard planting material yield reveal that the usage of those herbicides do no cause any negative effects, compared with the untreated control.

Similar experiment was performed in the Institute of Viticulture and Enology, Pleven. Grapevine from variety Misket Kaylashki, grafted on rootstock Berlandieri x Riparia SO_4 was treated by the herbicides Venzar 80 WP, Goal 2, Devrinol 4 F, Dual Gold 960 EC, Lumax 538 SC and Stomp 33 EC at different rates. As an outcome any of the herbicides was found to cause detrimental effect on the grapevine root system and mature wood formation (Prodanova-Marinova et al., 2014).

In a study, Prodanova-Marinova (2024) assessed the effects of treating grapevine Cabernet Sauvignon variety ILV 1/11 clone, grafted on Berlandieri x Riparia selection with herbicide mixture of Targa Super 5 EK at 0.300 l/da and Pledge 50 VP at a rate of 0.040 kg/da. The tank-mix was found to control all the weeds in the plot without affecting negatively the development of the grapevine.

With regard to the profitability of herbicide application in the process of grafted rooted vines production a research was carried out by Prodanova-Marinova (2017). Treatments of the rooted cuttings of grape variety Merlot consisted of Dual Gold 960 SC (3 L ha^{-1}), Gardoprim plus Gold (4 L ha^{-1}), Wing P (4 L ha^{-1}) and untreated control. The results of the study ascertained that herbicide application with Wing P increases significantly the net income and decline the prime cost of the standard grafted vine by 15,3%.

Analysis of the impact of Gardoprim plus Gold and Lumax 536 SC applied at different rates during the first months after planting Cabernet Sauvignon grapevine was recently done. No bud's germination suppression was found. Moreover, the study reveals that the shoot length at the end of the vegetation and the mass of the mature annual growth increased in the treated variants (Prodanova-Marinova et al., 2019).

Besides the abovementioned the herbicidal treatments may have a negative influence on the vines. Zaller et al. (2018) claim that herbicides applied in vineyards may disrupt both grapevine's nutrition and soil organisms. A significant recession of root mycorrhization, nutrient composition in grapevine roots, leaves, grape juice and xylem sap after applying flazasulfuron, glufosinate and glyphosate within-row was observed.

Bigot et al. (2007) report that flumioxazin used as pre-emergent herbicide in vineyards reduce the production of the net photosynthesis. Other authors claim that affecting the grapevine roots by flumioxazin may bring about serious consequences such as water status and nitrogenous metabolites disturbance. Those physiological changes may be detrimental for the vineyard (Saladin et al., 2003).

The aim of this study is to investigate the efficacy of some herbicides and herbicide combinations on weed density, as well as on the elements of productivity and yield in a fruit-bearing vineyard of the "Bolgar" variety.

MATERIALS AND METHODS

The experiment was carried out in the period 2020-2021 in a table grape vineyard (5 years old), in the land of the Varben village, Brezovo municipality, Plovdiv region, Bulgaria (42°25'01.1"N 24°57'39.1"E).

In both experimental years, no significant deviations were observed in terms of temperature compared to the average for the region. The total precipitation in 2020, for the period April-October, was 340 mm, and in 2021, for the same period, 360 mm.

The experiment was set up using the block method, in three replications, with random placement of the variants. The size of one replication was 15 m^2 (3 inter-rows x 5 vines x 1.3 between them - 19.5 m * 0.75 area). Five treatments (T) were evaluated as follows:

1. Untreated control (K_1); 2. Economic control (K_2); 3. Two-time application of Ecopart Turbo (26.5 g/l pyraflufen-ethyl) - 0.08 L ha^{-1}, without removing the young shoots from the stem; 4. Two-time targeted application of Ecopart Turbo - 0.08 L ha^{-1}, with removing of the young shoots from the stem; 5. Double application of Roundup Classic Pro (360 g/l glyphosate) - 0.40 L ha^{-1} + Ecopart Turbo - 0.03 L ha^{-1}.

For the purpose of the study, the variety "Bolgar" was used, grafted on SO4 rootstock (Berlandieri x Riparia, selection Oppenheim 4) with a planting distance of 2.80 x 1.30 m, representing 2750 plants per hectare. The formation of the vines is medium-stemmed, with a stem height of 0.80 m, with a pruning system of 4 fruiting canes, located on two parallel supporting bodies with 10-12 buds, and 2 scions of 2 buds, left at the base.

The herbicides were applied in BBCH 68 vine development phase (after the end of flowering), respectively 25.05.2020 and 27.05.2021, for the first treatments, and for the second treatment 25.06.2020 and 27.06.2021, phase BBCH 73. The application was performed by using a backpack sprayer. The volume of the working solution was 300 L ha^{-1}.

Weed counting was performed three times (for all variants): 1. Immediately before the trial was established. 2. Thirty days after that (coinciding

the application of the second rates of herbicides. 3. Thirty days after the application of the second rates of herbicides. Weed counts were performed using the quantitative method in permanent plots - number of weeds per 1 m^2. The following indicators were evaluatedt:
- The efficacy of the herbicides and herbicide combinations on the weed species composition and density;
- Grape yield (t ha^{-1})
- Influence of the tested variants on the and the grape quality - Sugar content, % (determined with the "Dujardin" mustometer by measuring the relative weight of the must, and depending on the temperature, the sugar content was determined) and Total acid content, g/dm^3 (determined as 10 cm^3 of grape must is titrated with 0.1 N NaOH solution. The titration is carried out in the presence of bromothymol blue indicator to pH 7.0).

The statistical analysis of some of the collected data (Table grape yields; Sugar and Total acids contents) was performed by by Duncan's Multiple Range test ($p < 0.05$).

RESULTS AND DISCUSSIONS

During the years of the study (2020 and 2021), a total of 14 weed species were registered, of which 12 were annual and 2 were perennial.
The annual weeds were represented by late spring species, of which 10 are dicotyledonous: *Abutilon theophrasti* L., *Xanthium strumarium* L., *Chenopodium album* L., *Conyza Canadensis* L., *Amaranthus retroflexus* L., *Persicaria lapathifolia* L., *Amarantus blitodes* W., *Datura stramonium* L., *Portulaca olerracea* L., *Solanum nigrum* L., and two monocotyledonous species: *Setaria viridis* L. and *Digitaria sanquinalis* L. Perennial weeds were represented by *Cynodon dactylon* Pers and *Convolvulus arvensis* L.
The percent of the weed infestation on average for the studied period is presented in Figure 1.

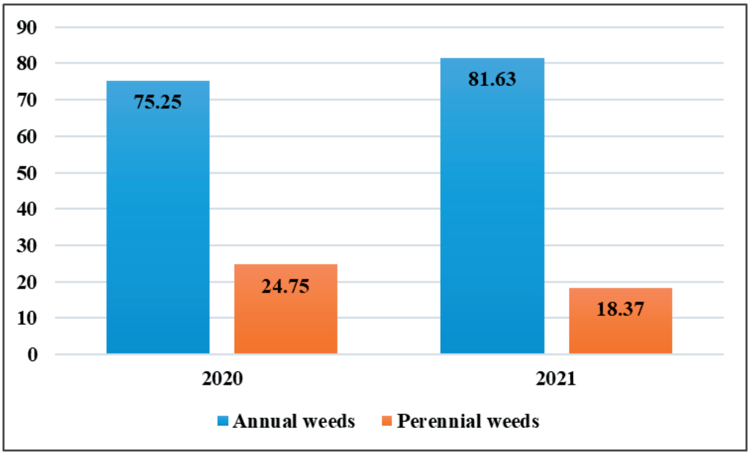

Figure 1. Total weed density per 1 m^2 before treatments, as % distribution

Analysis of the data for the two experimental years shows an almost equal ratio of annual to perennial species, with an almost constant species composition of weeds. Annual species predominate, with their density in the individual variants varying from 22 to 34 species per m^2 for 2020 and from 27 to 43 species per m^2 for 2021. This group of weed plants forms 75.25% and 81.63% of the weed association in the vineyard, respectively. The density of perennial weeds is in the range of 3 to 6 specimens per m^2 and 3 to 5 specimens per m^2 or 24.75 and 18.37% of the total weed density for 2020 and 2021. In quantitative terms, 2021 surpasses 2020, with the reported growth being 14.27%, mainly due to a high infestation with annual species.
The data on the influence of the different treatments on the weeds density for the two experimental years are shown in Table 1. The following interpretations can be made from the presented results. In the two years of the study, the highest efficiency, compared to the untreated control (Variant 1), was reported in Variant 5, respectively 53.10% for 2020 and 45.15% for

2021. The reason for this is the combined application of two active substances (from Ecopart Turbo - pyraflufen-ethyl and Roundup Classic Pro - glyphosate). The presence of herbicides with different modes of action - a foliar contact herbicide with primary action against broadleaf weeds and a systemic total herbicide, impose this system as the most effective. It is confirmed by the findings of Barbieri et al. (2022) that stated herbicidal tank mixing can optimize and widen the weed control spectrum. The efficacy of the application system was enhanced with successive re-treatment (30 days after the first application) - 63.98% for 2020 and 60.86% for 2021. Variant 2 (Economic control) ranked second with 40.30% and 30.01%, respectively, with high efficacy at the first reporting (54.38%) and lower (49.73%) at the second reporting, for 2020 and 2021 respectively. Hand hoeing is the oldest method of weed control in perennial crops, and the results obtained confirm the high effect of its application. Options 4 and 3 follow. With the highest weed density, as expected, was the untreated control.

Table 1. Efficacy of the treatments against the weeds, %.

Treatment	Biological group of weeds	2020				
		1st report	2nd report	% - K_1	3rd report	% - K_1
T 1 (K_1)	Perennial – rhizome	5	6	100%	7	100%
	Perennial – root sprouting	3	5	100%	6	100%
	Annual – late spring	30	64	100%	72	100%
	Total	**38**	**74**	100%	**84**	100%
T 2	Perennial – rhizome	6	5	12.28%	6	14.93%
	Perennial – root sprouting	5	6	-14.00%	4	29.82%
	Annual – late spring	31	34	47.09%	29	60.00%
	Total	**42**	**44**	40.30%	**39**	54.38%
T 3	Perennial – rhizome	7	8	-35.09%	8	-14.93%
	Perennial – root sprouting	3	3	40.00%	3	47.37%
	Annual – late spring	34	39	38.74%	35	51.11%
	Total	**43**	**50**	33.15%	**46**	45.62%
T 4	Perennial – rhizome	4	5	12.28%	6	14.93%
	Perennial – root sprouting	3	4	20.00%	5	12.28%
	Annual – late spring	24	39	38.11%	33	54.31%
	Total	**31**	**48**	34.91%	**44**	48.34%
T 5	Perennial – rhizome	6	2	59.65%	1	80.60%
	Perennial – root sprouting	5	3	40.00%	3	47.37%
	Annual – late spring	22	30	53.54%	26	63.75%
	Total	**33**	**35**	53.10%	**30**	63.98%
Treatment	**Biological group of weeds**	**2021**				
		1st report	**2nd report**	**% - K_1**	**3rd report**	**% - K_1**
T 1 (K_1)	Perennial – rhizome	4	4	100%	5	100%
	Perennial – root sprouting	3	5	100%	6	100%
	Annual – late spring	36	68	100%	82	100%
	Total	**42**	**77**	100%	**94**	100%
T 2	Perennial – rhizome	4	4	9.76%	4	16.33%
	Perennial – root sprouting	5	6	-19.23%	4	33.87%
	Annual – late spring	39	44	35.00%	39	52.91%
	Total	**48**	**54**	30.01%	**47**	49.73%
T 3	Perennial – rhizome	5	5	-31.71%	5	-10.20%
	Perennial – root sprouting	3	3	40.38%	3	50.00%
	Annual – late spring	43	45	34.56%	41	50.49%
	Total	**51**	**53**	31.44%	**49**	47.27%
T 4	Perennial – rhizome	3	4	9.76%	4	16.33%
	Perennial – root sprouting	3	4	21.15%	5	16.13%
	Annual – late spring	30	48	29.56%	42	48.67%
	Total	**36**	**56**	27.94%	**52**	44.81%
T 5	Perennial – rhizome	4	2	60.98%	1	77.55%
	Perennial – root sprouting	5	3	40.38%	3	50.00%
	Annual – late spring	27	38	44.56%	32	60.68%
	Total	**36**	**42**	45.15%	**37**	60.86%

In the grapevine production, climate change can affect yields (Ghiglieno et al., 2023). Herbicide application may play a vital role in bringing about the good development of grapevines. There is some evidence that weeds may affect grape yield up to 32% depending on their species and density (Pala, 2020). This is primarily because weeds compete the cultivated plants for nutrients and water and cause significant yield decrease (Travlos et al., 2018). In order to manage weeds successfully, it is vital to be aware of the variety of weed species present (Rassele et al., 2022).

The unfavourable climatic conditions may influence the grape quality and yield (Stanus et al., 2024). In the current trial, the analysis of variance showed that the variation in the yields of the table grape variety "Bolgar" were determined both by the herbicides and herbicide combinations, and by meteorological conditions (Table 2).

The highest average grape yield for the Economic control (Variant 2) was recorded - 11.89 t ha^{-1} that reaches 54% increase in comparison to the untreated control (7.70 t ha^{-1}). From the treatments where herbicides were applied, the highest yield from the treatment with the double application of Roundup Classic Pro + Ecopart Turbo (Variant 5) was found - 11.69 t ha^{-1}, that reaches 52% increase in comparison to the untreated control.

For the other two treatments the average table grape yield was 10.94 and 11.09 t ha^{-1} respectively for Variant 3 (Two-time application of Ecopart Turbo, without removing the young shoots from the stem) and Variant 4 (Two-time targeted application of Ecopart Turbo, with removing of the young shoots from the stem).

Table 2. Grape yields, t ha^{-1}

Variants	2020		2021		Average for the period	
	t ha^{-1}	% of yield increase compared to K_1	t ha^{-1}	% of yield increase compared to K_1	t ha^{-1}	% of yield increase compared to K_1
T 1. K_1	7.54 c	100%	7.85 c	100%	7.70	100%
T 2.	11.74 a	156%	12.04 a	160%	11.89	154%
T 3.	10.84 b	144%	11.04 b	146%	10.94	142%
T 4.	10.99 b	146%	11.19 b	148%	11.09	144%
T 5.	11.59 a	154%	11.79 ab	156%	11.69	152%

Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$).

From the analyses of the grape juice was found that in consumer maturity, the sugar content in all variants of the experiment were in normal values characteristic of the "Bolgar" variety. During the two years of the study, intensive sugar accumulation was found in all variants, with the average values for the period of harvest of the production ranging from 17.70% to 18.40% (Figure 2). The sugar content was slightly lower for the variants where herbicides were applied.

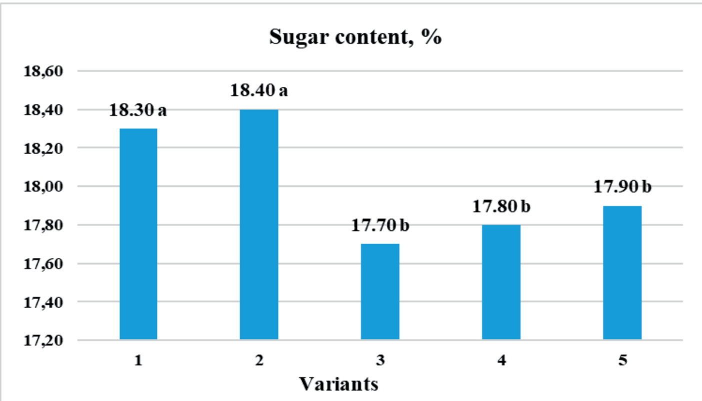

Figure 2. Sugar content in the grapes of "Bolgar" variety (%), average for the period 2020-2021
Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$)

The amount of titratable acids in the grape juice is within the limits characteristic of the variety (Figure 3). The average values for the two years of the study are in the range of 3.62 to 4.34 g/dm^3. The lowest titratable acids were reported for treatments 3 and 4.

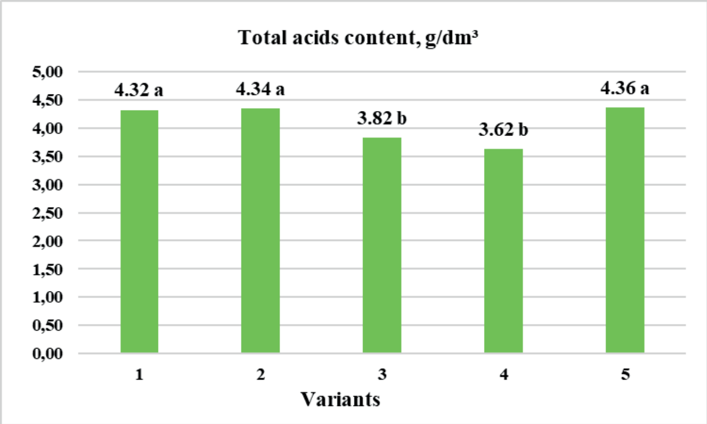

Figure 3. Total acid content in the grapes of "Bolgar" variety (g/dm³), average for the period 2020-2021
Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$)

During the study damages on the grapes in all variants in which Ecopard Turbo was applied were registered. The damages were observed on all green parts of the grapevine plant - leaves, stalks, shoots, but the most significant were the damages on the grapes. On the growing young shoots, on the forming vines, the damages were associated with longitudinal splitting, accompanied by a change in color. The death of plants with such damages was not observed. On the remaining green parts, the damages were expressed in the manifestation of small necrotic spots, with a characteristic slightly concave shape and black color. Subsequently, these disorders of the vine tissues caused, in places, partial distortions of their vegetative parts. On the grapes of the white table grape variety "Bolgar", this led to an unsightly appearance, as a result of which a large part of them were rejected and unqualified (Pictures 1 and 2).


Pictures 1 and 2. Toxicity caused by Ecopard Turbo evaporation

CONCLUSIONS

From the three studied variants involving the herbicide Ecopart Turbo, the one with the highest weed control efficacy was variant 5 (Double application of Roundup Classic Pro - 0.40 L ha^{-1} + Ecopart Turbo - 0.03 L ha^{-1}.) at vines development stage BBCH 68, for the first treatment, and for the second treatment - phase BBCH 73 (thirty days later).

The alone two-time application of Ecopart Turbo (variants 3 and 4) showed an unsatisfactory weed control efficacy against the present weed species in the experimental areas. The efficacy, on average for the two years of the experiment, was 16.4-16.77% lower when compared to the efficacy reported for variant 5.

The highest yield was reported in variant 2. The average yield for the two years of the experiment was 11.89 t ha^{-1}, representing 54% higher than the yield obtained in the untreated control.

For the variants with herbicidal applications, the highest yield of 11.69 t ha^{-1}, or 52% higher than the control, in variant 5 was recorded.

The lower yields for the variants with herbicidal applications are explained by the negative effect of the commercial product of Ecopart Turbo on the vines and the grape production, and the lower weed control efficacy as well.

The sugars and titratable acids were slightly influenced by the treatments in the study.

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