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Comparative testing of herbicides in newly planted vineyard

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Abstract

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The impact of the herbicides 312.5 a. i. L^{-1} s-metolachlor + 187.5 a. i. L^{-1} terbuthylazine (Gardoprim plus Gold), and a. i. L^{-1} s-metolachlor + 125 a. i. L^{-1} terbuthylazine + 337.5 a. i. L^{-1} mesotrione (Lumax 538 SC 375) applied at different doses on the weed vegetation and grapevines (*Vitis vinifera*) during the first months after planting of a Cabernet Sauvignon vineyard had been investigated at the Institute of Viticulture and Enology, Pleven, Bulgaria. Selectivity, high efficacy against weeds and sufficient soil persistence are the required conditions for achieving the maximum effect of the application of the selected herbicides. Along with the determination of the efficacy of some soil active products under the specific climatic conditions, the objective of this study was to investigate their impact on the vine growth and development in the year of planting. The study was carried out in the period 2014-2015. The tested herbicides did not inhibit buds' germination and did not cause a reduction in the number of shoots per vine. The shoot length at the end of the vegetation, as well as the mass of the mature annual growth, formed by the vines in the treated variants, exceeded those of the control. Lumax 538 SC, applied at a dose of 322 g a. i. ha^{-1}, provided the best control over the annual weeds in the plantation; the treated vines had the most intense growth and formed a mature growth with the greatest length and mass.

Keywords: doses; herbicides; mature growth; shoots; *Vitis vinifera*; young vines

Introduction

The efficient weed control has been an important condition for the creation of a new vineyard. The first 6-8 weeks from the onset of the vegetation have been of particular significance. The competition for the absorption of the major biotic factors greatly delayed the normal vine growth. It had been found that the species *Convolvulus arvensis* L., *Sinapis arvensis* L., *Amaranthus retroflexus* L., *Cynodon dactylon* (L.) Pers., *Chenopodium album* L.*, Cirsium arvense* L.*, Malva neglecta* L.*, Taraxacum officinale* L., etc. had been transpiring much more intensely than vine. Further to more water, weeds absorbed more nutrients from the soil (Boychev, 1980; Lopes et al., 2004). The high rate of weeds usually resulted in less developed shoots, smaller cluster weight, and lower yield per decar (Moulis, 1992). Young vines, infested with *Conyza canadensis* plants had fewer leaves and accumulated approximately 20% less dry mass compared to the weeded out plantations (Alcorta et al., 2011). The mass incidence of various annual and especially perennial species might hinder the mechanized soil tillage; serve as an environment for the development of the causative agents of some economically important diseases and pests; increase the risk of frost and frost damages (Fetvadzhieva et al., 1981; Cousens & Croft, 2000; Agustí-Brisach et al., 2011). Associations of row weeds and mainly representatives of the late spring weeds were formed in the young vineyards. In some cases, perennial rhizome and root weeds might also be observed – *Cynodon dactylon* (L.), *Sorghum halepense* (L.) Pers., *Agropyron repens* (L.), *Convolvulus arvensis* L, *Sonchus arvensis* L., etc. (Kolev, 1963; Beuret & Neury, 1987; Moreira, 1994; Encheva, 2003; Tonev et al., 2007).

Trifluralin, oryzalin, oxyfluorfen etc. could be applied for weed control, which, although with good effect, were not sufficiently efficient against perennial weeds (Lange et al., 1970; Spasov et al., 1999; Tonev, 2000). Pendimethalin, napropamide, s-metolachlor had shown a high herbicidal effect (without damaging the vines) immediately after planting (Bordelon, 2011).

It has been recommended the chemical weed control to be applied to the intra-row stripe and the distance between the rows to be treated mechanically. Phytotoxicity caused by herbicides to young vines has been common and has serious consequences, so it is necessary the active substances to be selected according to the age of the plantation and the nature of the weed vegetation. The soil herbicides had effective action in vineyards below 4 years of age. Examples are butralin, isoxaben, napropamide, orisalin and propyzamide. Herbicides with foliar action are: setodixim, quizalofop ethyl, cycloxidine, haloxyfop R. Aminotriazole and glyphosate are toxic to young vines and could be applied only preventively by repeated treatment of the areas during the previous year (Groupe de travail regional Midi-Pirenes, 2002; Chambre Regionale d agriculture Langedoc Roussillon, 2014; Chambre d agriculture Charente-Maritime, 2017).

Selectivity, high efficacy against weeds and sufficient soil persistence are the required conditions for achieving the maximum effect of the application of the selected herbicides. Along with the determination of the efficacy of some soil active products under the specific climatic conditions, the objective of this study was to investigate their impact on the vine growth and development in the year of planting.

Materials and Methods

Plant material

Vines of Cabernet Sauvignon variety grafted to Berlandieri x Riparia Selection Openheim 4 (SO4) rootstock were used in the experimental work. The propagation material was produced for this purpose at the IVE, Pleven in 2013 and 2014. By the time of planting it was stored in a specialized room under controlled conditions.

Herbicides – Table 1

Setting of the trial

Vines were planted in stages in the spring of 2014 and 2015 (the first ten days of May). Protective piles of soil with a thickness of 5-6 cm were formed above each one (Abrasheva et al., 2008). The distance between the rows was 3 m, while the intra-row distance was 1.2 m. The trial was set by the long plots method in 5 replicates. Each replicate had a plot size of 5 m^2 and included 4 vines (20 vines per variant).

Application details

The herbicides were introduced into the intra-row stripe once, immediately after the planting of the vines and the formation of the protective piles, with a backpack sprayer, at a rate of working solution of 40 l ha^{-1}, a conical nozzle pressure Pmax 300 kPa. In the years prior to planting (2013 and 2014), the areas were pretreated with glyphosate (Nasa 300 SL, 360 g a. $i.L^{-1}$, Agria) at a dose of 360 g a. i. ha^{-1}. For the eradication of Johnson grass (*Sorghum halepense)* germinated from seeds and partially preserved rhizomes during the vegetation, spraying with the recommended for use in young vineyards cycloxidine (Stratos ultra, 100 a. $i.L^{-1}$, Basf) at a dose of 20 g a. i. $ha^{-}1$ between the thirties and the sixtieth day after the vine planting was carried out. The distances between the rows were treated mechanically 4 times during the year.

Analysis

The herbicides impact and the applied doses on weeds were assessed by the quantitative method, taking into ac-

Table 1. Herbicides, their doses and time of application

	Herbicides applied (formulated product)	Time of appl.	Active substance (g a. i. L^{-1})	Doses (g a. i. ha^{-1})
1	Gardoprim plus Gold (Syngenta)	preem	312.5 a. $i.L^{-1}$ s-metolachlor + 187.5 a. $i.L^{-1}$ terbuthylazine	200
	Stratos ultra (Basf)	postem	100 a. $i.L^{-1}$	20
2	Gardoprim plus Gold (Syngenta)	preem	312.5 a. $i.L^{-1}$ s-metolachlor + 187.5 a. $i.L^{-1}$ terbuthylazine	300
	Stratos ultra (Basf)	postem	100 a. $i.L^{-1}$	20
3	Lumax 536 SC (Syngenta)	preem	375 a. $i.L^{-1}$ s-metolachlor + 125 a. $i.L^{-1}$ terbuthylazine + 337.5 a. $i.L^{-1}$ mesotrione	215
	Stratos ultra (Basf)	postem	100 a. $i.L^{-1}$	20
4	Lumax 536 SC (Syngenta)	preem	375 a. $i.L^{-1}$ s-metolachlor + 125 a. $i.L^{-1}$ terbuthylazine + 337.5 a. $i.L^{-1}$ mesotrione	322
	Stratos ultra (Basf)	postem	100 a. $i.L^{-1}$	20

count the dynamics of the weed density (pc/m^2) in the permanently marked parcels in the individual replicates of 1 m^2 every thirty days (Tonev et al., 2002; Zhelyazkov et al., 2017). The data were compared with untreated cultivated control (K).

The effect of two factors – "herbicide" and "dose" on the vine growth and development, as well as the interaction between them, has been studied. The variants were as follows:

– Factor A (herbicide): Al – Gardoprim plus Gold and A2 – Lumax 536 SC;

– Factor B (dose): B1 – low dose and B2 – high dose;

– K – Untreated cultivated control.

Their impact on the vines was determined by recording buds' germination in dynamics (%); shoot growth dynamics (cm); the length of the mature annual growth on the average per vine (cm) and the mass of the mature annual growth on the average per vine (g). The data showing the herbicides selectivity to the young vines were processed by two-factor analysis of variance. The assessment of the significance and the power of impact of the factors were calculated by Plochinski's method (Lakin, 1990).

Soil and climate characterization of the region

The soil type where the plantation was located was leached chernozem, formed on clay loess. By mechanical composition it was heavy sandy loam with prevalence of the bulk dust fraction (0.05 to 0.01 mm), on the average 42%, followed by the fraction of the core (particles smaller than 0.001 mm), 30%. These quantities were gradually decreasing along the depth of the profile. The volume of pores taken by air (when wetted to LSWC) throughout the depth of the profile had remained quite high – 27-31% of the soil volume. That characterized the leached chernozem in the region as soil having good water-physical properties, fully satisfying the vine biological needs. This type of soil was defined as the most suitable for cultivation of varieties intended for the production of red table wines (Kurtev et al., 1979). Carbonates were missing at depths up to 60 cm, and below that depth their content reached 24.18%. The active calcium in the carbonate horizons varied from 5.96 to 6.67%. Thus the soil reaction was determined accordingly – neutral in the carbonless horizons, low to medium alkaline in the carbonates. The presented description of the soil type was based on studies carried out in the region by Krastanov and Dilkova (1963).

Data on precipitation and temperature changes were obtained from METOS WEATHER data 000003 CA station, located on the territory of the Production Experimental Base of IVE – Pleven. The period from April to the end of September 2014 was characterized by significant rainfall (total 406 mm), the maximum being in April (131 mm) and in July (122 mm) – Fig. 1. For the same period in 2015, almost twice less precipitation was measured – 206 mm. The drought was particularly severe in July (27.4 mm) and in May (30.4 mm) – critical for the plantation. That, along with the higher average monthly temperatures recorded in 2015 for all months except April, made it as less favorable for the young vines growth.

Results and Discussion

The weed species observed in the plots planted in 2014 and 2015 were typical representatives of the row weeds association. The presence of two perennial species had been reported – *Convolvulus arvensis* L. and *Sorghum halepense* (L.) Pers. In 2014 the annual species were *Amaranthus blitoides* L., *Amaranthus retroflexus* L., *Chenopodium album* L., *Falopia convolvulus* A. Leve, *Heliotropium europaeum* L., *Portulaca oleracea* L., *Reseda lutea* L., *Sinapis arvensis* L.,

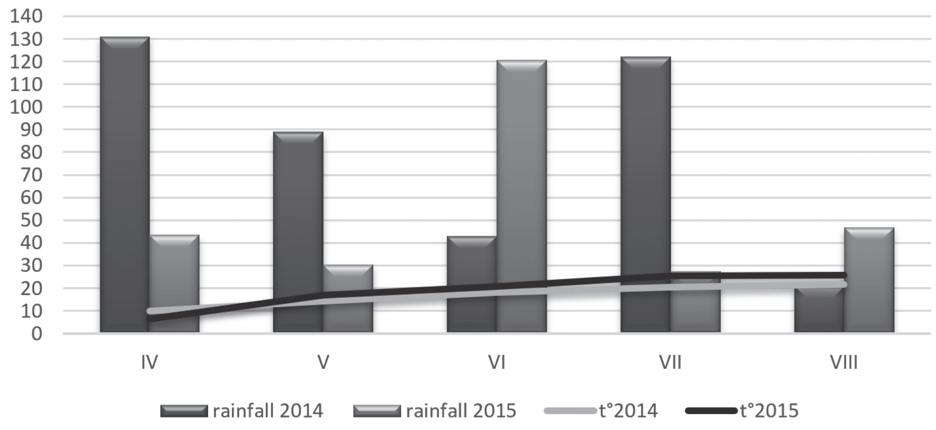

Fig. 1. Weather characterization for the period April – September 2014 and 2015

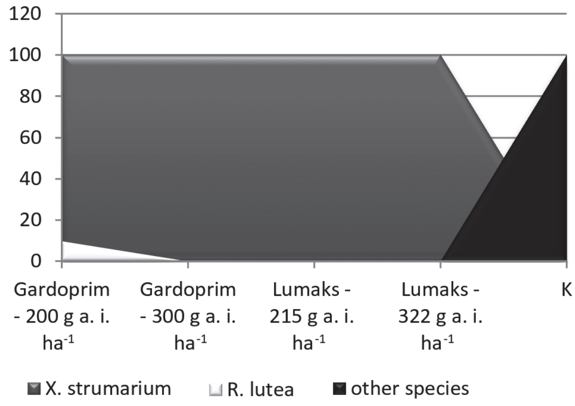

Fig. 2. Distribution of the annual weeds 90 days after the herbicide treatment on the average for the period 2014-2015

Solanum nigrum L. and *Xanthium strumarium* L. In the plot planted in 2015, the diversity of the annual species was less due to the two-fold preventive application of Nasa in 2013 and 2014. *Heliotropium europaeum* L., *Reseda lutea* L., *Setaria viridis* L. and *Xanthium strumarium* L. were observed.

The perennial species of *C. arvensis* and *S. halepense* were little affected by the applied soil herbicides. At high doses the tested combinations of active substances suppressed the germination of their seeds that resulted in a lower density of these species. By soil application none of the tested herbicides exhibited a satisfactory impact on *X. strumarium*. Some decrease in the density of this species was observed in the plots treated with Lumax 538 SC that was caused by the action of mesotrione. After the introduction of Gardoprim plus Gold (300 g a. i. ha^{-1}) and Lumax 538 SC (215 and 322 g a. i. ha^{-1}), *X. strumarium* represented 100% of the annual species found in the parcels from the thirtieth to the ninetieth day of the herbicidal action (Fig. 2). In the variant of Gardoprim plus Gold at a dose of 200 g a. i. ha^{-1}, it was also recorded the presence of *R. lutea.*

The three-fold accounting of the changes in the structure and density of the weed association indicated significantly long action of Gardoprim plus Gold and Lumax 538 SC – up to 90-days post-treatment. The reduction in total weed density on day 60 was due to the efficient action of Stratos ultra (herbicide against Johnson grass) (Fig. 3 and 4). In 2014 and 2015, higher doses of Gardoprim plus

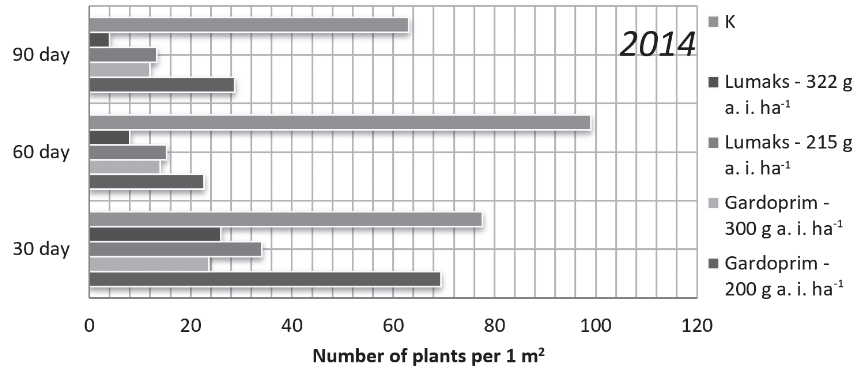

Fig. 3. Weed density in dynamics – 2014

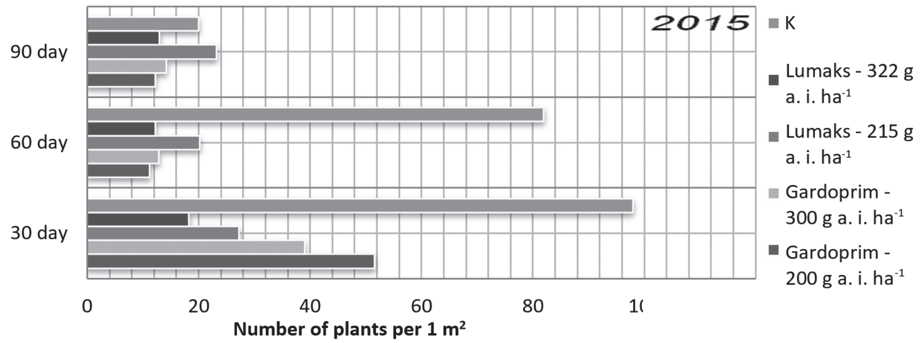

Fig. 4. Weed density in dynamics – 2015

Table 2. Vine germination dynamics

V	30th day				40th day				50th day				60th day				70th day			
	Germinated vines (%)		Average number of shoots per vine		Germinated vines (%)		Average number of shoots per vine		Germinated vines (%)		Average number of shoots per vine		Germinated vines (%)		Average number of shoots per vine		Germinated vines (%)		Average number of shoots per vine	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
G200	65.0	95.0	1.0	1.5	80.0	100.0	1.8	1.6	100.0	100.0	1.9	1.6	100.0	95.0	2.0	1.4	100.0*	95.0 n.s.	2.0	1.4
G300	86.0	95.0	1.1	1.5	91.0	100.0	2.1	1.5	91.0	100.0	2.1	1.5	96.0	85.0	2.1	1.4	96.0 n.s.	85.0 n.s.	2.1	1.4
L215	95.0	100.0	1.1	1.5	100.0	100.0	1.7	1.6	100.0	95.0	1.9	1.7	100.0	95.0	1.9	1.5	100.0*	95.0 n.s.	1.9	1.5
L322	91.0	90.0	1.2	1.4	96.0	100.0	2.0	1.7	100.0	100.0	2.2	1.7	100.0	95.0	2.4	1.5	100.0*	95.0 n.s.	2.4	1.5
K	60.0	90.0	1.0	1.7	85.0	100.0	1.6	1.9	90.0	100.0	1.7	1.9	95.0	95.0	1.6	1.5	85.0	95.0	1.6	1.5

G200 – Gardoprim plus Gold at a dose of 200 g a. i. ha^{-1}; G300 – Gardoprim plus Gold at a dose of 300 g a. i. ha^{-1}; L215 – Lumax 538 SC at a dose of 215 g a. i. ha^{-1}; L322 – Lumax 538 SC at a dose of 322 g a. i. ha^{-1}

***, **, * – significant at $p \leq 0.001$, $p \leq 0.01$ and $p \leq 0,05$; n.s. – non-significant

Gold and Lumax 538 SC were more effective. The smallest weed density and the most significant herbicidal effect, respectively, during the whole study period was reported for Lumax 538 SC at a dose of 322 g a. i. ha^{-1}. The results confirm the data on the efficacy of the tested herbicides obtained in our other studies conducted in the same soil type (Prodanova-Marinova, 2012; Prodanova-Marinova, 2015; Prodanova-Marinova, 2016). A similar effect on *Amaranthus retroflexus* L., *Setaria viridis* L. and *Solanum nigrum* L. is reported by Sarpe et al. (2007)¸ Andr et al. (2014), and others authors.

In addition to the good herbicidal activity against the weeds, the tested products also exhibited selectivity towards young vines. Gardoprim plus Gold and Lumax 538 SC did not inhibit bud germination. For all counts in 2014, the ratio of the germinated vines in the treated variants was greater compared to the control (Table 2). Similarly, the average number of shoots per vine also exceeded that of the untreated plot (K). Only the herbicide dose (factor B) had proven effect on the germination for that year, with a power of impact 43.39% (Table 3). The unexplained influence due to random factors was almost the same – 43.82%. The maximum ratio of germinated vines in 2015 was found on the fortieth day after the planting and the treatment (Table 2). It varied in the individual recordings of the treated variants and the control – some shoots died and were replaced by substitution buds, but the changes were due to the weather factors rather than the herbicidal action of the tested products. The analysis of variance showed that neither the herbicide nor the dose of its application had significant impact on the vines germination during that year. The average number of shoots per vine was changing due to the same reasons. It was the highest on the fiftieth day post-treatment, while in the next ten days it decreased non-significantly and became stable.

Thirty days after the application of the herbicides in 2014 the average shoot length in the treated variants varied from 18.0 cm (Gardoprim plus Gold at a dose of 300 g a. i. ha^{-1}) to 21.2 (Lumax 538 SC at a dose of 215 g a. i. ha^{-1}) – Fig. 5.

Table 3. Vine germination – impact of the factors

Source of variance	Significance		Impact of the factors (%)	
	2014	2015	2014	2015
Herbicide (A)	n.s.	n.s.	0.31	2.27
Dose (B)	*	n.s.	43.39	4.55
Interaction of the factors (A+B)	n.s.	n.s.	0.62	4.55
Error	–	–	43.82	73.86

***, **, * – significant at p≤0,001, p≤0,01 and p≤0,05; n.s. – non-significant

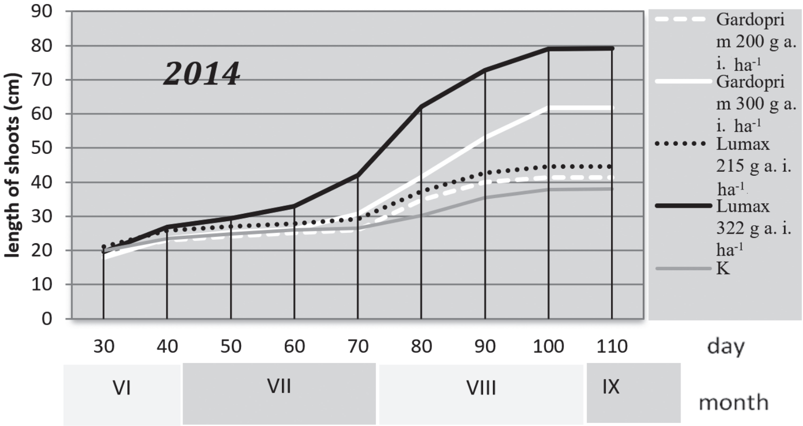

Fig. 5. Dynamics of shoot growth in 2014

Table 4. Shoot length – impact of the factors

Source of variance	Significance		Impact of the factors (%)	
	2014	2015	2014	2015
Herbicide (A)	n.s.	n.s.	2.98	0.12
Dose (B)	**	n.s.	51.56	11.00
Interaction of the factors (A+B)	n.s.	n.s.	3.61	1.28
Error	–	–	23.04	61.25

***, **, * – significant at $p \leq 0.01$, $p \leq 0.01$ and $p \leq 0.05$; n.s. – non-significant

The minimal length reduction compared to the control (K = 20.0 cm) recorded with Gardoprim plus Gold at doses of 200 g a. i. ha^{-1} and 300 g a. i. ha^{-1} and Lumax 538 SC at a dose of 322 g a. i. ha^{-1} was overcome already around the 40th day and by the end of the vegetation season all treated variants had significantly longer shoots than those of the control. The largest length of the shoots was accounted with Lumax 538 SC – 322 g a. i. ha^{-1} (79.2 cm) and Gardoprim plus Gold – 300 g a. i. ha^{-1} (61.8 cm). The length with Lumax 538 SC – 322 g a. i. ha^{-1} exceeded twice the recorded value of the control. The dose of the herbicides had the most significant effect (51.56%) on the growth that year (Table 4). The effect of the factor was significant $p \leq 0.01$. The differences compared to the control were well provided at higher doses for both herbicides.

During the year 2015, less favorable from weather viewpoint, thirty days after the herbicides application, the average length of the shoots in the treated variants varied from 15.8 cm (Gardoprim plus Gold – 200 g a. i. ha^{-1}) to 19 cm (Lumax 538 SC – 322 g a. i. ha^{-1}) – fig. 6. At the end of the vegetation period, all treated variants had relatively equal shoots in length. The last variations in the rates of this indicator were found on the seventieth day after the planting and the treatment, indicating that growth had stopped already at the end of July and of the untreated control even earlier.

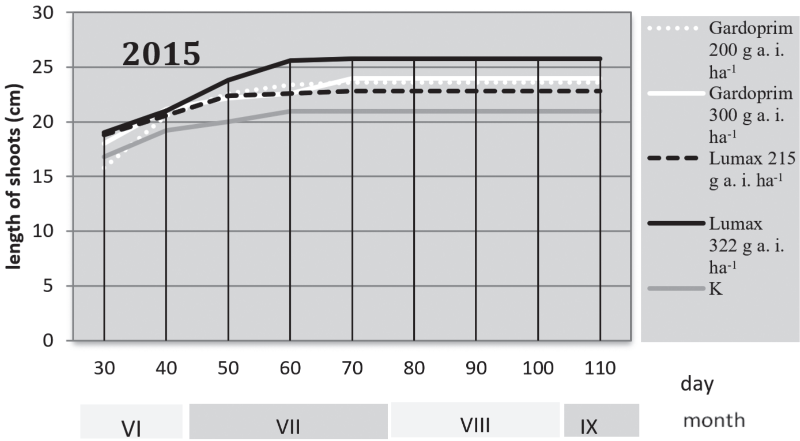

Fig. 6. Dynamics of shoot growth in 2015

Table 5. Length and mass of the mature annual growth on the average per vine

V	Length (cm)		Mass (g)	
	2014	2015	2014	2015
G200	48.0***	14.2*	8.5**	1.7 n.s.
G300	60.8***	17.8***	15.5***	2.5**
L215	48.8***	18.8***	9.9***	3.5***
L322	61.4***	19.6***	18.3***	3.5***
K	20.2	11.2	4.4	1.3

G200 – Gardoprim plus Gold at a dose of 200 g a. i. ha^{-1}; G300 – Gardoprim plus Gold at a dose of 300 g a. i. ha^{-1}; L215 – Lumax 538 SC at a dose of 215 g a. i. ha^{-1}; L322 – Lumax 538 SC at a dose of 322 g a. i. ha^{-1}
***, **, * – significant at p≤0.01, p≤0.01 and p≤0.05; n.s. – non-significant

The data on the vine wood maturity at the end of the vegetation period revealed a correlation between the shoot length and the length and mass of the mature growth. In all treated variants, higher annual mature growth was accounted compared to the control. The result was the same over the two years as it was particularly pronounced in 2014 (Table 5). The greatest average length and mass of the mature part of the shoots was measured with Lumax 538 SC at a dose of 322 g a. i. ha^{-1}.

The analysis of variance of the data on both indicators established a strong impact of the dose of herbicides (factor B) on the annual mature growth. In 2014 and 2015, that factor significantly increased the length of mature vines. Its power of impact during the first year was 92.92% whereas in the second one it was 68.90% (Table 6). During the study period, neither factor A nor the interaction between A and B had a significant effect on the mature growth. The unexplained impact due to random factors for this indicator was the smallest (5.85 and 12.45%).

The effect of the dose (factor B) on the mass of the mature growth was more pronounced in 2014. Its power of impact was 89.46% (Table 7). In 2015, factor B again prevailed (50.70%). Secondly, with a significantly lower but proven impact (23.37%) was factor A (the type of herbicide). However, the complex action of both factors had remained non-significant.

Table 6. Length of the mature annual growth – impact of the factors

Source of variance	Significance		Impact of the factors (%)	
	2014	2015	2014	2015
Herbicide (A)	n.s.	n.s.	0.01	7.91
Dose (B)	***	***	92.92	68.90
Interaction of the factors (A+B)	n.s.	n.s.	0.01	6.23
Error	–	–	5.85	12.45

***, **, * – significant at p≤0.01, p≤0.01 and p≤0.05; n.s. – non-significant

Table 7. Mass of the mature annual growth – impact of the factors

Source of variance	Significance		Impact of the factors (%)	
	2014	2015	2014	2015
Herbicide (A)	n.s.	***	2.19	23.37
Dose (B)	***	***	89.46	50.70
Interaction of the factors (A+B)	n.s.	n.s.	1.66	13.92
Error	–	–	6.28	10.32

***, **, * – significant at p≤0.01, p≤0.01 and p≤0.05; n.s. – non-significant

Factor B (dose of herbicide application) had a predominant impact on vine germination, the shoot length at the end of the vegetation and the length and mass of the annual mature growth, especially strong in the year 2014. The factors "herbicide" (A) and "dose" (B) had no significant impact on the growth rate in 2015 and taking into consideration the reported results and their correlation to the weather features of this period, that was due to the climatic factors – low precipitation in May (30.4 mm) and July (27.4 mm) and the relatively low air humidity during these months (35.5% and 57.6% on the average) – Fig 1. The dominant effect of the factor "dose" for all indicators characterizing vine growth and development was largely related to the similarity of the main active substances (s-metolachlor and terbuthylazine) contained in both herbicides. The presence of mesotrione in the composition of Lumax 538 SC enhanced its effect, but not so much to account for the influence of the factor "herbicide" alone.

Conclusions

The herbicides Gardoprim plus Gold and Lumax 538 SC were highly efficient against the annual weeds (except *Xanthium strumarium* L.) and showed high persistence in the soil, thus providing a favorable environment for the young vines development.

Lumax 538 SC, applied at a dose of 322 g a. i. ha^{-1}, ensured the best control over the annual weeds in the plantation, the treated vines had the most intensive growth and mature growth with the greatest length and mass.

The tested herbicides did not inhibit bud germination and did not cause a reduction in the number of shoots per vine. The shoot length at the end of the vegetation season, as well as the mass of the mature annual growth from the treated variants, exceeded those of the control.

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