Could electricity be an alternative method of weed control in the vineyard?

Kann Strom eine alternative Methode in der Unkrautregulierung im Weinberg sein?

Carina P. Lang[1*], Oliver Kurz[1], Anja Löbmann[1], Benjamin Klauk[2], Jan Petersen[2], Matthias Petgen[1,3*]

[1]Dienstleistungszentrum Ländlicher Raum Rheinpfalz, Institute for Viticulture and Oenology, 67435 Neustadt

[2]Technische Hochschule Bingen, Faculty of Life Sciences and Engineering, Department of Agronomy and Plant Protection, 55411 Bingen am Rhein

[3]Ministry of Economics Affairs, Transport, Agriculture and Viticulture Rhineland Palatinate (MWVLW), 55116 Mainz

*carina.lang@dlr.rlp.de; Matthias.Petgen@mwvlw.rlp.de

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Abstract

Environmentally friendly and resource-saving cultivation, sustainability and regionality are important aspects of today's agriculture. Reducing the use of herbicides is considered one of the most important goals and at the same time one of the biggest challenges in today's agriculture. In viticulture, however, the alternative management options are also under discussion.

The aim of this study is to analyze and test the *Electroherb* method developed by the company ZASSO GmbH. In three-year field experiments, vegetation monitoring and digital image analysis will be used to investigate the degree of coverage before and after treatment, as well as the effectiveness of the process on various problem weeds. Special attention will be paid to the vegetation in the under-floor area of the vine. In addition to the current intensity and driving speed, the number of treatment sessions will be investigated. Preliminary results show that the morphology of the weeds plays a decisive role in the efficiency. Weather and water supply are also important influencing factors.

Keywords: *Elektroherb*-method, grapevine, vegetation monitoring, viticulture, weeds

Zusammenfassung

Eine umweltfreundliche und ressourcenschonende Bewirtschaftung der Flächen, Nachhaltigkeit und Regionalität sind wichtige Aspekte der heutigen Landwirtschaft. Die Verringerung des Herbizideinsatzes gilt als eines der wichtigsten Ziele und ist gleichzeitig einer der größten Herausforderungen in der heutigen Landwirtschaft. Im Weinbau stehen jedoch auch die alternativen Bewirtschaftungsmöglichkeiten unter Diskussion.

Ziel dieser Studie ist, das von der Firma ZASSO GmbH entwickelte *Electroherb*-Verfahren zu analysieren und zu testen. In dreijährigen Feldversuchen sollen mittels Vegetationsmonitoring und digitaler Bildanalyse der Deckungsgrad vor und nach der Behandlung, sowie der Wirkungsgrad des Verfahrens auf verschiedene Problemunkräuter untersucht werden. Ein besonderes Augenmerk liegt auf der Vegetation im Unterstockbereich der Weinrebe. Neben Stromstärke und Fahrgeschwindigkeiten werden vor allem die Anzahl der Behandlungstermine untersucht. Erste Ergebnisse zeigen, dass die Morphologie der Beikräuter eine entscheidende Rolle in der Wirkung der Technik übernimmt. Auch sind Wetter und Wasserversorgung wichtige Einflussfaktoren.

Stichwörter: Beikraut, *Electroherb*-Verfahren, Vegetationsmonitoring, Weinbau, Weinreben

Introduction

Society's demand for regional, sustainably and safely produced food is constantly increasing. Likewise, the associated demand for more environmental, nature and resource protection are one of the most important goals of today's agriculture. At the same time, however, farmers and winegrowers are increasingly coming up against the limits of mechanical and chemical weed control. The public debate surrounding the non-selective herbicide glyphosate and its impact on consumer protection and the environment is of great importance. In December 2022, including a transition period, the approval of this active ingredient expires (BMEL, 2021). The increasing herbicide resistance of weeds in general also plays a major role. This problem almost doubled in the last 20 years (HEAP, 2021). The National Action Plan for the Sustainable Use of Pesticides (NAP), adopted in 2013, envisages a significant reduction in pesticides in the coming years (BMEL, 2013).

The alternatives to chemical weed control are mostly based on mechanical methods. In viticulture, these would be e.g., roller hoe, disc plough, shallow coulter. However, there are also some disadvantages in cultivation. Especially the winegrowers feel these effects clearly. In addition to injuries to the vines and material wear, the limited use on slopes and steep slopes is a clear problem. The associated problems for the soil (erosion, leaching and loss of soil fertility) also have a negative impact on yield and wine quality (SCHWAB & KÖRNIGER, 2016). Furthermore, this promotes additional mobilization of nitrogen and thus increases leaching into groundwater. Appropriate measures and cultivation alternatives are necessary to solve these problems. However, the development and advancement of new or existing technologies should also be on focus. Electrophysical methods for weed control are not new; initial experiments were conducted as early as the 1890s (VIGNEAULT & BENOIT, 2001). Since 1970, this method has been used for soil disinfection and germination inhibition of weed seeds (SAHIN & YALINKILIC, 2017). The advantages are considered that this method does not leave chemical residues and reduces soil erosion. The disadvantages are considered to be the high costs, which can only be compensated by the size of the treated area (VIGNEAULT & BENOIT, 2001). However, there are few studies and outdated literature on this topic, which refer to completely different theories and applications in practice (reviewed in DIPROSE & BENSON, 1984; SAHIN & YALINKILIC, 2017). Moreover, any literature is available dealing with weed control in viticulture and in particular with the under-floor area of vines. The Zasso Company has taken up this technology and developed a patented method for weed control using electricity. The system was launched in Europe in 2016 (KOCH et al., 2020) and is currently undergoing scientific testing. The system will be tested in terms of environmental impact, as well as the impact on soil fauna and flora in different agricultural systems and crops. In this study, we investigated whether Zasso's *Electroherb* technology could be a potential alternative to chemical and mechanical weed control in vineyards. In a three-year field experiment, different variants are tested in the under-floor area of the vine. The variants differ in (a) their travel speed (slow 2 kmh^{-1} and vineyard-typical 4 kmh^{-1}), (b) their current intensity (expressed in high-voltage units), and (c) the number of treatments.

Material und Methods

Mode of action of the Electroherb-technology by ZASSO GmbH

The weed growth is destroyed by means of electricity. Electrodes under high voltage brush over the vegetation, through this contact the current can penetrate into the leaves of the plant, reaches the root and flows back to the device. The conductive pathways and thus the supply lines for water and nutrients as well as membrane-dependent metabolic processes are destroyed by high temperatures. The result is a non-selective wilting of the weed.

Plant growth conditions and experimental design

The field experiments will take place on three experimental plots (VS 1, VS 2 and VS 3) with different management practices (conventional / organic viticulture) over three years (2020-2022). The vineyard

experimental design is a completely randomized block design, with a total of 20 blocks; these are divided into five treatments with four biological replicates each.
The treatments differ in driving speed (slow 2 kmh^{-1} / viticultural 4 kmh^{-1}), treatment dates (1^{st} & 3^{rd} dates / 3^{rd} dates) as well as current intensity (number of high voltage units) (Tab. 1). As a control, the usual tillage for weed control is used; VS 1- herbicide (glyphosate), VS 2 - mechanical (disc plough), VS 3 - mechanic (disc plough and roller hoe).
Due to the very dry conditions in the experimental year 2020 and the resulting low weed pressure, only two treatment dates (1^{st} and 3^{rd} date) were necessary on the experimental plots VS 1 and VS 2. The treatments took place between April and July 2020. On VS 3, due to high weed pressure, an additional treatment (2^{nd} date in June) was conducted.

Table 1 Detailed overview of the experimental variants at all three experimental pots VS1, VS2, VS3

Tabelle 1 *Detaillierte Übersicht der Versuchsvarianten an den Standorten VS1, VS2, VS3*

Treatment	**Speed [kmh-1]**	**Number of treatments**	**Current [kW]**
ZASSO 1	2	3	18
ZASSO 2	4	3	18
ZASSO 3	4	2	18
ZASSO 4	4	2	24
Control (mechanical / chemical)			

Vegetation monitoring

The vegetation monitoring was carried out according to the BRAUN-BLANQUET method (BRAUN-BLANQUET, 1964; TREMP, 2005). For this purpose, a metal frame of defined size (40 x 40 cm) was placed between two previously marked vines and a photo was taken. Then, the abundance as well as the dominance of each species present was determined. Evaluations were conducted one week before treatment, at time T0, and one week after treatment, at time T1.

Digital image analysis

Digital image analysis of the existing vegetation was performed at all three experimental sites. For this purpose, the same images with estimation frames were used as for the Braun-Blanquet vegetation monitoring. The digital image analysis was done in two steps; first the image was cropped to the appropriate size using the freeware graphics software GIMP (GIMP 2.10, The GIMP Team, USA) and oversaturated to a value of "3" for better contrast. The resolution was set to 310 dpi. As a second step, this new image file was analyzed using WinDIAS software (WinDIAS 3.3, Delta T Services, UK). Based on the number of pixels, the software analyzes the green component, the yellow and brown component, and the grey and black components of the image. Thus, based on the two measurement times (T0 and T1), the percentage change in active biomass / weed (green fraction), litter content (yellow and brown fraction), and soil (grey and black fraction) can be analyzed and the coverage can be calculated. Furthermore, the efficiency of each experimental variant was calculated at the time T0 and T1 on each treatment date (Fig. 1).

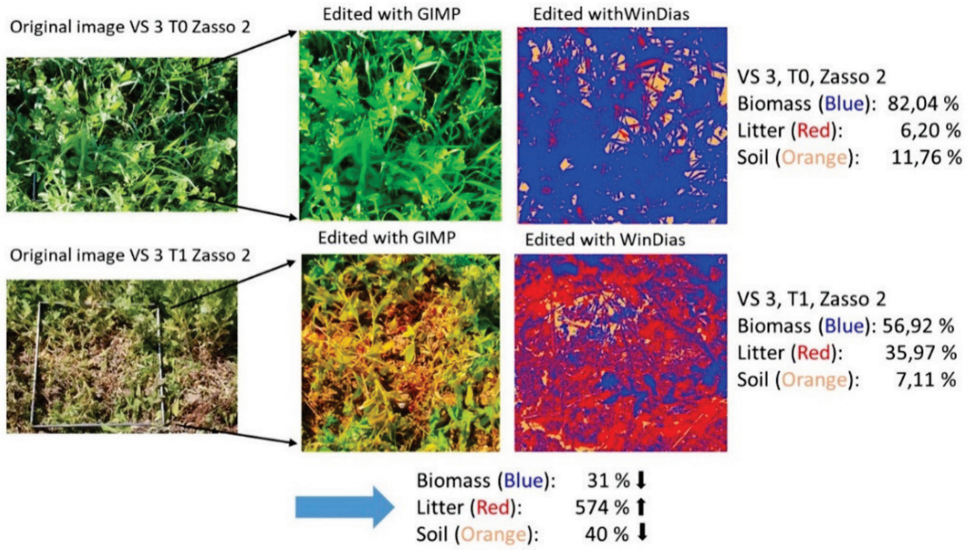

Figure 1 Digital image analysis using GIMP and WinDias on the example of VS 3, Zasso 2a (vineyard-typical driving speed (4 kmh^{-1}), 3 dates, 6 high voltage units, a= biological repetition) at the time T0 (top) and T1 (bottom). To the right are the percentages of the respective study factor (biomass, litter and soil).

Abbildung 1 *Digitale Bildanalyse mittels GIMP und WinDias am Beispiel des Versuchsstandorts 3, Versuchsvariante Zasso 2a (weinbautypische Fahrgeschwindigkeit (4 kmh^{-1}), 3 Termine, 6 Hochspannungseinheiten, a= biologische Wiederholung) zu den Zeitpunkten T0 (oben) und T1 (unten). Rechts daneben sind die Prozentalteile des jeweiligen Untersuchungsfaktors (Biomasse, Streu und Boden).*

Results and Discussion

First results of the vegetation monitoring show that the number of weed species decreases with increasing treatment frequency. This can be seen at all three experimental plots (Fig. 2). Furthermore, the treatment success increases with increasing treatment frequency. However, the efficacy of the different methods varies considerably (Tab. 2).
Generally, the first signs of wilting are visible after about 10 minutes, with a complete effect occurring in the following eight to 14 days, according to Zasso.

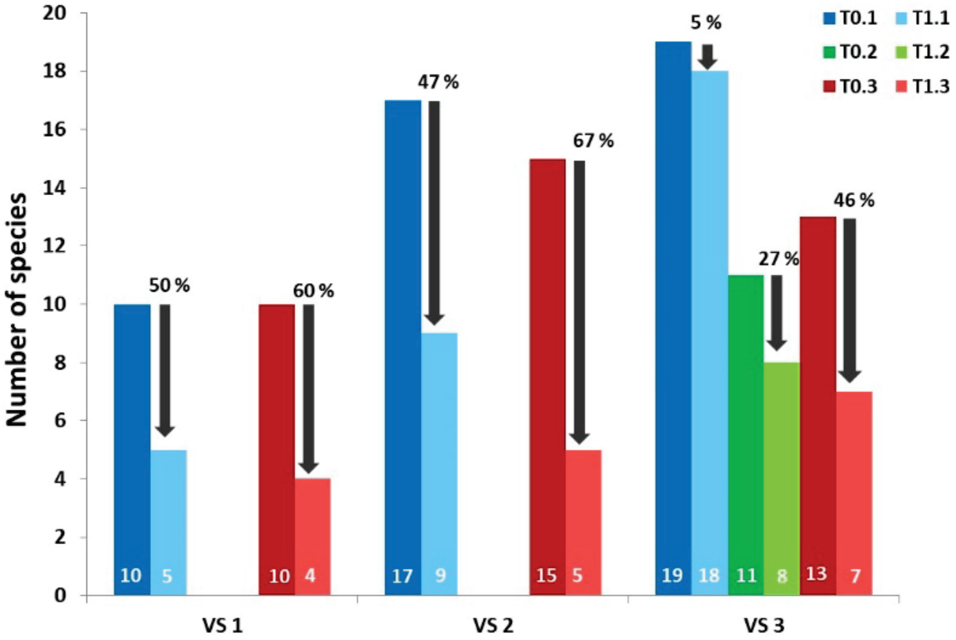

Figure 2: Change in species number at experimental plots VS1, VS2, and VS3 on all three treatment dates at the time T0 and T1, arrows show the percent change, (n=16).

Abbildung 2 *Veränderung der Artenzahl an den Versuchsstandorten VS1, VS2 und VS3 an allen drei Behandlungsterminen zu den Zeitpunkten T0 und T1, Pfeile zeigen die prozentuale Veränderung, (n=16).*

Vegetation monitoring further suggests that some weed species are easier to control with electricity than other species. The species that stand out as "problem weeds" are white goosefoot (*Chenopodium album*), couch grass (*Elymus repens*) and bindweed (*Convolvulus arvensis*) (Data not shown). Surprisingly, these species are difficult to control even with the operational options of chemical and mechanical weed control. One explanation for the difference in success between species could be the morphology and root anatomy of the plants. Fleshy roots or taproots that carry a lot of water and serve as a storage organ are a potential conductor of electricity. The size of the plant is also critical, as large plants require more energy for a lethal effect to occur by the method. Large plant species may also obscure smaller species so that they cannot be touched by the electrode and thus cannot be treated (VIGNEAULT & BENOIT, 2001). Furthermore, plant age plays a major role. According to VIGNEAULT & BENOIT (2001) and DIPROSE & BENSON (1984), plants with a higher lignin content (usually older plants) have a greater resistance to current. This also explains the greater treatment success with increasing treatment frequency. Plants sprouted at the second and third treatment dates are younger, smaller, and thus easier to control.

Table 2 Efficiencies of the treatments in terms of active biomass at all three experimental plots at all treatment dates, (n=16)

Tabelle 2 *Wirkungsgrade der Versuchsvarianten in Bezug auf die aktive Biomasse auf allen drei Versuchsstandorten zu allen Behandlungsterminen (n=16)*

Experimental plot	**Treatment**	**Treatment dates**		
		T0.1 vs. T1.1	**T0.2 vs. T1.2**	**T0.3 vs. T1.3**
VS 1	Chemical Control	64,2		16,5
	Zasso 1	85,6		84,1
	Zasso 2	65,1		88,8
	Zasso 3	86,1		90,4
	Zasso 4	72,5		93,6
VS 2	Mechanical Control	71,9		81,8
	Zasso 1	50,6		91,
	Zasso 2	39,9		81,5
	Zasso 3	49,3		86,5
	Zasso 4	47,7		74,4
VS 3	Mechanical Control	40,5	49,9	22,3
	Zasso 1	50,7	75,5	87,4
	Zasso 2	31,1	73,0	75,8
	Zasso 3	27,3		69,6
	Zasso 4	39,1		85,1

The data from the digital image analysis and the calculated coverage for VS3 with the active biomass factor also show that as treatment frequency increases, active biomass decreases, resulting in higher efficiencies and more dead weeds (Fig. 3). This is most evident with Zasso 1 and Zasso 4. Note that Zasso 1 has one more treatment, while Zasso 4 uses more high-voltage equipment, allowing more current to penetrate the plant and soil. The damage to the plant is greater for the same travel speed and thus the same exposure time, suggesting that more high-voltage equipment gives better treatment success. However, this needs to be verified again, the existing literature shows contrasting results (VIGNEAULT & BENOIT, 2001; SAHIN & YALINKILIC, 2017). Mechanical treatment (control) had the lowest treatment success.

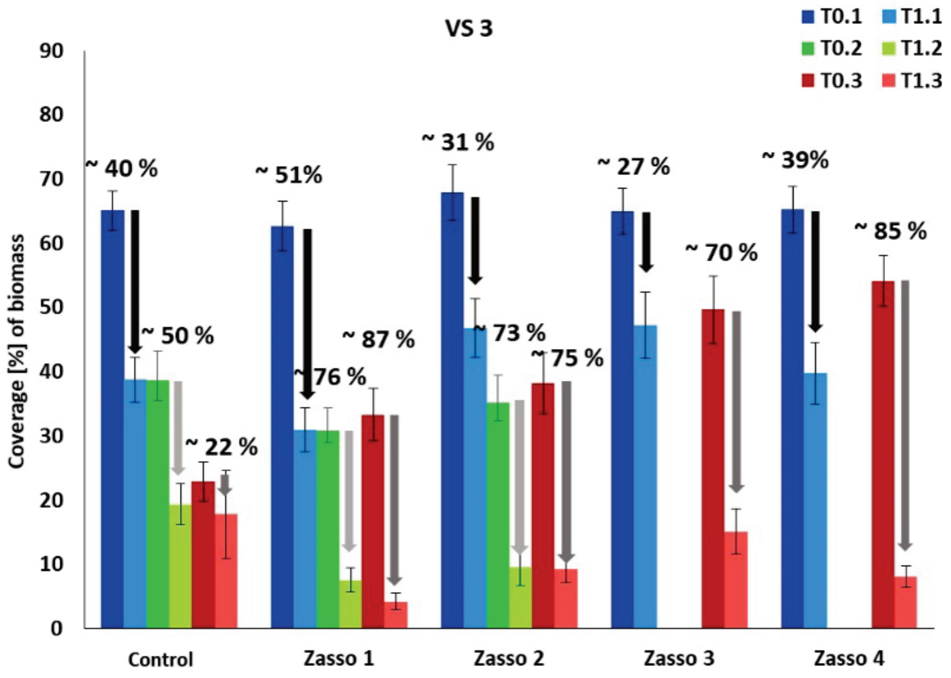

Figure 3 Degree of coverage [%] of active biomass on VS3 on all three treatment dates at the time T0 and T1, arrows show the percent change, (n=16)

Abbildung 3 *Bedeckungsgrad der aktiven Biomasse auf dem VS3 an allen drei Behandlungsterminen zu den Zeitpunkten T0 und T1. Pfeile zeigen die prozentuale Veränderung, (n=16)*

The weed infestation rate and the condition of the area have a significant influence on the effect of the method and must be taken into account (reviewed by VIGNEAULT & BENOIT, 2001). In the experimental year 2020 there was comparatively little rain, so there were few weeds on VS 1 & VS 2 and only two treatments were necessary.

In the experimental year 2021, experimental conditions were adjusted based on these results. Evaluated data were not yet available at the time of manuscript preparation.

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