Electrical weed control and its effect on soil organisms

Elektrische Unkrautbekämpfung und ihre Wirkung auf Bodenorganismen

Anja Löbmann[1], Benjamin Klauk[1], Carina Lang[2], Matthias Petgen[2], Jan Petersen[1*]

[1]Technische Hochschule Bingen, 55411 Bingen am Rhein

[2]Dienstleistungszentrum Ländlicher Raum Rheinpfalz, Institut für Weinbau und Oenologie, 67435 Neustadt

*petersen@th-bingen.de

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Abstract

The focus of the public demand for sustainable and resource-conserving agriculture is the reduction of herbicide use. However, successful weed control is essential to ensure crop yield and quality. Today's agriculture is confronted with the challenge of finding suitable crop management alternatives. In the present study, the Electroherb™ technology developed by the Zasso Group AG is investigated. The process is based on a non-selective, systemic electrical flow through the plants' vascular system causing severe cell destruction and ultimately wilting, as mode of action. However, aspects of the effect on non-target organisms must also be considered when evaluating this promising technology. The study investigates the effects of electro-physical weed control on soil organisms. Population densities of earthworms and epigeic arthropods are recorded. Parameters such as speed at application, soil moisture, energy intensity and application timing were investigated. No effects of the electrical treatment on earthworm abundance and biomass were detected. In addition, there was also no evidence of adverse effects on soil organisms. Electro-physical weed control could be an environmentally friendly, sustainable, soil-friendly and innovative way to control weed species, provided that the effects on soil organisms are acceptable when electrophysical voltage is applied.

Keywords: Alternatives in weed control, earthworms, epigeic arthropods

Zusammenfassung

Im Mittelpunkt der öffentlichen Forderung nach einer nachhaltigen und ressourcenschonenden Landwirtschaft steht die Reduzierung des Herbizideinsatzes. Eine erfolgreiche Unkrautbekämpfung ist jedoch unerlässlich, um den Ertrag und die Qualität des Ernteguts zu sichern. Die heutige Landwirtschaft steht vor der Herausforderung, geeignete Alternativen für den chemischen Pflanzenschutz zu finden. In der vorliegenden Studie wird die von der Zasso Group AG entwickelte Electroherb™-Technologie untersucht. Das Verfahren basiert auf einem nicht-selektiven, systemischen Stromfluss durch das Gefäßsystem der Pflanzen, der als Wirkungsweise eine starke Zellzerstörung und schließlich das Welken verursacht. Bei der Bewertung dieser vielversprechenden Technologie müssen jedoch auch die Aspekte der Wirkung auf Nicht-Zielorganismen berücksichtigt werden. In der Studie werden die Auswirkungen der elektrischen Unkrautbekämpfung auf Bodenorganismen untersucht. Es werden Populationsdichten von Regenwürmern und epigäischen Arthropoden erfasst. Parameter, wie die Geschwindigkeit bei der Anwendung, die Bodenfeuchtigkeit, die Energieintensität und der Zeitpunkt der Anwendung wurden untersucht. Es wurden keine Effekte der elektrischen Behandlung auf die Abundanz und Biomasse von Regenwürmern festgestellt. Darüber hinaus gab es auch keine Hinweise auf schädliche Auswirkungen auf Bodenorganismen. Die elektrische Unkrautbekämpfung könnte ein umweltfreundlicher, nachhaltiger, bodenschonender und innovativer Weg zur Unkrautbekämpfung sein, sofern die Auswirkungen auf das Bodenleben mit der Applikation von elektrophysikalischer Spannung im Einklang stehen.

Stichwörter: Alternativen in der Unkrautbekämpfung, epigäische Arthropoden, Regenwürmer

Introduction

Successful weed control is essential, as crop yield and quality can be significantly reduced by competition for light, nutrients and water. The number of available active substances is steadily decreasing due to restrictions imposed by recent pesticide registration regulations for weed control. Indeed, the use of mechanical methods is limited on many situations. Factors such as potential crop damage in vineyards, inclination, and high wear and tear on mechanical equipment complicate the use of mechanical weed control.

The Electroherb™ technology developed by the Zasso Group AG is based on the irreversible damage of the chlorophyll of the plant cells by contact with current-carrying applicators (KOCH et al., 2020). However, the evaluation of this promising technology must take into account the aspects of its effect on non-target organisms. Soil organisms are involved in numerous soil-forming processes and thus have a lasting effect on soil properties. Bioindicators are used to evaluate the effect of electrical voltage on soil organisms. Earthworms have the highest biomass, as measured by total soil fauna, at many arable fields and grassland sites and perform remarkable services for soil structure and organic matter turnover. They create large continuous soil pores, transport vegetation residues from the soil surface to deeper soil layers, and contribute to soil turnover (SYERS & SPRINGETT, 1983; KLADIVKO, 2001). Other groups of organisms, such as epigeic arthropods also have notable effects on the agroecosystem. In addition to their value for biodiversity, they have an important function as beneficial insects (LÜBKE-AL HUSSEIN & WETZEL, 1993).

The aim of this study was to investigate the influence of electrical treatments on the populations of soil organisms.

Material and methods

Investigations on earthworms

From 2020 to 2021, a field trial was conducted in the vineyards in Neustadt a.d. Weinstraße (49° 21′ N, 8° 9′ E) (clay loam), Germany. Two electrical treatments (2 km h^{-1} and 4 km h^{-1}) and a mechanical treatment (star hoe and disc harrow) were tested with four replicates. Each plot consisted of 2 rows with 10 vines each. Sampling was performed immediately before electrical treatment (early spring), four weeks later (spring), and six months later (autumn). Earthworms were sampled from the soil by using a combination of two different methods: hand sorting and extraction with mustard. The soil of a square of 50 cm × 50 cm up to a depth of 30 cm was removed by means of a spade or shovel. Then the soil was searched cautiously for earthworms. The same plot, from which the top soil has been removed for hand-sorting, is used for mustard extraction. A suspension of 60 g mustard powder and 10 L water was carefully and evenly applied into the plot in order to attract deep-burrowing earthworms to the surface. Firstly, the number of worms was counted and the species noted. Species identification in earthworms was according to KRÜCK (2018). The biomass was then determined by washing the individual worms, drying them quickly on a piece of paper and then determining the mass with a battery-operated laboratory balance.

Investigations on epigeic arthropods

Another field trial in Bingen (49°58′ N, 7°54′ E) (loamy sand), Germany, was conducted in 2020 and comprised four treatments with four replicates. The plot size was 15 x 15 m. The treatments were: control (no treatment), mechanical tillage (disc harrow), and two electrical treatments with 3 km h^{-1} and 6 km h^{-1} speed of the electric applicator, respectively. Five modified Barber traps (BARBER, 1931) per plot were arranged in a cube pattern. Glass jars were filled with saturated salt solution and soap. In total, 160 traps (four treatments x four replicates x five traps per plot x two sampling dates) were dug into the ground. The experiment was run for 2 weeks and 4 weeks after treatment. Subsequently, the soil organisms of the traps were counted and determined at the genus level.

Statistical analysis

All statistical analyses were carried out with version 3.5.1 of the R software package (R DEVELOPMENT CORE TEAM, 2018). First, all data were subjected to a test of normality and homogeneity of variance. Differences in earthworm numbers and earthworm biomass among the three treatments, as well as differences among the three sampling dates within a treatment, were analysed using analysis of variance (ANOVA). The same applied to the study of the epigeic arthropods.

Results and discussion

Number and biomass of earthworms

A total of six earthworm species were identified in the vineyards. These were four endogenous representatives living in the upper part of the mineral soil (*Aporrectodea caliginosa, Allolobophora chlorotica, Octolasium lacteum and Aporrectodea rosea*), one epigeic species (*Lumbricius rubellus*) living just below the soil surface in the organically enriched horizon above the mineral soil, and one anectic species digging vertically and also occurring in deeper soil layers (*Lumbricius terrestris*).

The numbers of individuals at the beginning of the trial did not differ significantly from each other in both trial years (Fig. 1). In 2020, 4 weeks after electrical treatment, it was found that the numbers of individuals changed only slightly. 6 months after electrical treatment, significantly increasing numbers were observed for all treatments. The reason for this could have been the weather conditions. Spring months were very warm and dry compared to the long-term average. Similarly, no significant differences could be found regarding the abundances of earthworms in 2021. This applies to the comparison of the treatments among each other as well as to the comparison of the abundances of the first sampling to the second sampling date within a treatment. Overall, the experiment shows high standard errors, which are probably due to different soil characteristics in the vineyards.

Besides, it must also be taken into account that the sampling started in the morning and ended in the afternoon. A study by KAUTZ et al. (2011) suggests that the time of day is a relevant factor influencing the expulsion rate, especially on days with high temperature amplitudes. Possibly, rising soil temperatures up to the afternoon may have influenced the abundance of earthworms.

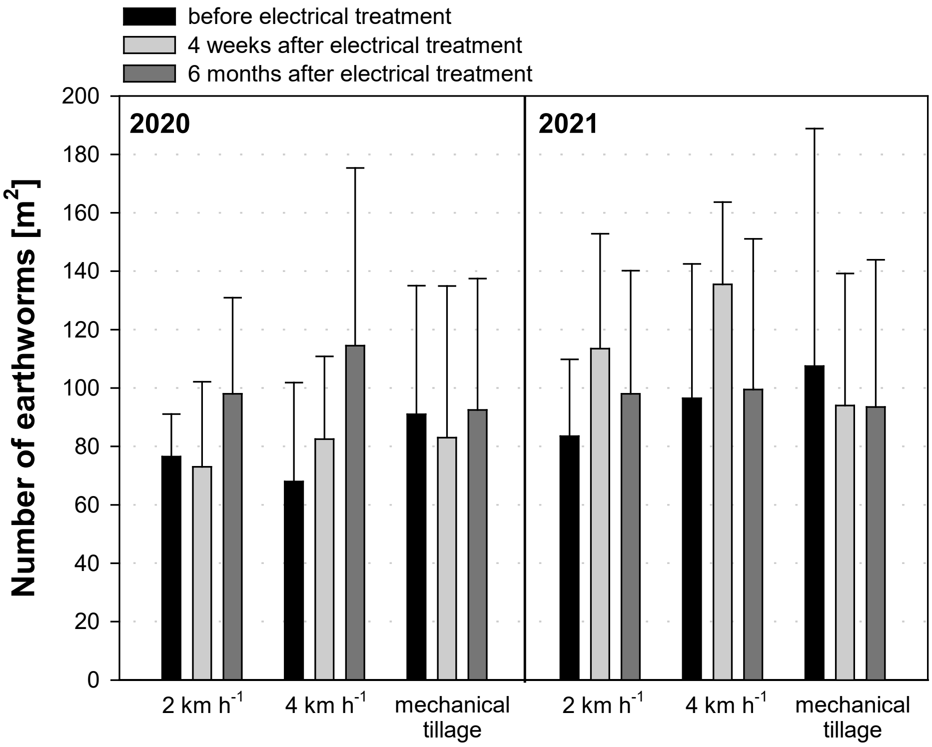

Figure 1 Mean number of earthworms per m^2 under the electrical treatments (with a speed of 2 km h^{-1} and 4 km h^{-1}) and the mechanical tillage in 2020 and 2021.

Abbildung 1 *Mittlere Anzahl der Regenwürmer pro m^2 für die elektrischen Behandlungen (mit einer Geschwindigkeit von 2 km h^{-1} und 4 km h^{-1}) und die mechanische Behandlung in den Jahren 2020 und 2021.*

The biomass of earthworms did not correlate with the number of earthworms (Tab. 1). Earthworm species vary strongly in length and diameter, and thus in biomass. Species, such as *L. terrestris* reach a much higher length and larger diameter than other earthworm species, so that individual species can significantly influence the total biomass. Therefore, the parameter biomass seems to be not a suitable indicator for assessing the effect of electrical power on the earthworm population.

From the results obtained so far, it can be concluded that the electrical treatment of above-ground flora does not have a lasting effect on the abundance and biomass of earthworms. It is assumed that the electric power is mainly absorbed by the dense flora growth and that the voltage in this application hardly touches the upper soil layers. It should also be noted that no lethally damaged individuals were found at any time.

Table 1 Mean biomass of earthworms (g per m²) and standard error (SE) for all treatments in 2020 and 2021

Tabelle 1 *Mittlere Biomasse der Regenwürmer (g pro m²) und Standardabweichung (SE) für alle Behandlungen 2020 und 2021*

	before electrical treatment	**4 weeks after electrical treatment**	**6 months after electrical treatment**
2020			
2 km h-1	126,9 (60,0)	108,6 (61,94)	101,7 (47,23)
4 km h-1	103,7 (75,14)	131,0 (53,26)	145,7 (76,94)
mechanical tillage	129,8 (99,2)	139,8 (116,47)	91,7 (66,75)
2021			
2 km h-1	131,5 (76,28)	165,5 (57,71)	110,08 (51,25)
4 km h-1	117,2 (45,47)	158,5 (62,41)	102,54 (63,47)
mechanical tillage	148,98 (108,17)	141,7 (55,04)	110,33 (60,11)

Evaluation of epigeic arthropods

The soil organisms captured in the traps were grouped into subgroups. They were *Opiliones, Araneae* (*Walckenaria, Erigone, Meioneta, Oedothorax*), *Coleoptera* (*Nebria, Carabus, Harpalus, Pterostichus* and *Poecilus*) and *Hymenoptera* (*Formicidae*). Non-target soil organisms that occurred were recorded, too, but were not considered in the evaluation. These included isopods, millipedes, centipedes, mites, earwigs, springtails, and cicadas.

When comparing the treatments, no significant differences were found for any subgroup of soil organisms ($p \leq 0.05$). Inevitably, no effect of the electrical power on soil organisms were observed in 2020 (Fig. 2). The increased mean number in *Formicidae* in the 'mechanical tillage' and '6 km h^{-1}' treatments at the sampling date '2 weeks after electrical treatment' were found in two individual plots. *Formicidae* are known to be organized in states, so the occurrence in the field trial could not be associated with the treatments.

Overall, the number of individuals '4 weeks after treatment' was lower than at the '2 weeks after treatment'. Since this was observed in all treatments, it is likely that other reasons, biotic or abiotic, are responsible for the decline in the number of individuals. It is conceivable that weather conditions could have had an influence. In the period between the electrical treatment and the first sampling date (2 weeks after electrical treatment), the average daily temperature was 19°C. During the following two weeks until the next sampling (4 weeks after electric treatment), the average daily temperature dropped to 15°C. Specifically for *Coleoptera*, explanatory factors for distribution and activity include soil physical and often associated microclimatic conditions such as soil moisture (HOLLAND et al., 2007).

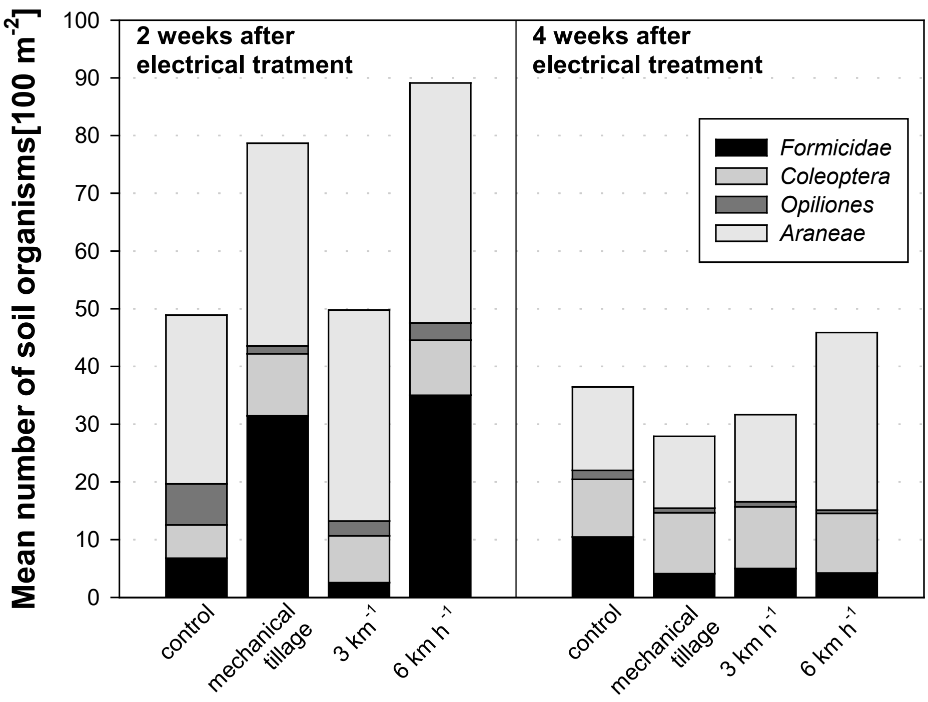

Figure 2 Mean number of soil organisms per 100 m2 two and four weeks after electrical treatment, respectively.

Abbildung 2 *Mittlere Anzahl der Bodenorganismen pro 100 m^2 zwei und vier Wochen nach der elektrischen Behandlung.*

Outlook

This study, which is integrated into the E-Herb RLP project, will be continued until the end of 2022. At present, no general statement can be made about the effect of electrical treatment on soil organisms. In addition, the efficacy of electrical treatment for weed control needs to be verified. Perhaps, the integration of electrical weed control could become a promising alternative or complement to chemical weed control in the long term.

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