Mechanical disturbance of *Cirsium arvense* - Results from a multi-year field study

Mechanische Kontrolle von Cirsium arvense - Ergebnisse eines mehrjährigen Feldversuchs

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Abstract

Perennial weeds like *Cirsium arvense* ensure their lifeform by their subterranean storage organs. Current control essentially relies on inversion tillage and herbicides (especially glyphosate). One alternative is the so-called “Kverneland Horizontal Root Cutter”. This machine fragments adventitious roots and cuts them off from belowground shoots and deep reaching root parts via horizontally arranged sheers, subsequently leading to a depletion of reserves.

We conducted an experiment between September 2019 and September 2021 on a field carrying *C. arvense* but no crop. Treatments differed in terms of use frequency and working depth of the “Root Cutter”. Six cuts per year (twelve in total) reduced the number of shoots by approximately 75% and the aerial expansion of thistle patches by approximately 90%. Lower cut frequencies decreased aerial expansion but failed to reduce number of shoots. HPLC root carbohydrate measurements revealed an exhaustion of reserves by root cutting. Total sugars and inulin reduction increased with cutting frequency. Based on the presented results the “Kverneland horizontal root cutter” can serve as a possible replacement for ploughing for the purpose of combating perennial weeds like *C. arvense*.

Keywords: creeping roots, glyphosate, mechanical weeding, perennial weeds, regenerative capacity

Zusammenfassung

Wurzelunkräuter wie *Cirsium arvense* sichern ihre Lebensform durch ihre unterirdischen Überdauerungsorgane. In der Landwirtschaft beruhen die Kontrollmethoden aktuell auf der wendenden Bodenbearbeitung und dem Einsatz von Herbiziden (vor allem Glyphosat). Eine Alternative hierzu bietet das Gerät „Kverneland Horizontal Root Cutter“. Dieses Gerät schneidet über horizontale Schare Adventivwurzeln und Sprosse ohne wendende Bearbeitung und trennt sie von Tiefwurzeln ab. In der Folge erschöpfen sich die Reservestoffe.

Von September 2019 und September 2021 etablierten wir einen Versuch auf einem Feld, auf dem *C. arvense* wuchs, aber keine Feldfrucht. Die Versuchsvarianten unterschieden sich in der Anwendungshäufigkeit und in der Arbeitstiefe des „Root cutters“. Sechs Cuts pro Jahr (zwölf insgesamt) reduzierten die Anzahl der Sprosse um ca. 75%, während die Befallsfläche der Distelnester um ca. 90 % reduziert wurde. Geringe Einsatzhäufigkeiten des Cutters reduzieren zwar die Befallsfläche, jedoch nicht die Anzahl Sprosse. HPLC Kohlenhydratmessungen der Wurzeln zeigten, dass Reservestoffe durch den Rootcutter erschöpft wurden. Die Gesamtzucker- und Inulin-Reduktion stieg mit der Einsatzhäufigkeit des Rootcutters. Der „Kverneland horizontal root cutter“ kann gemäß den hier präsentierten Ergebnissen das Pflügen bei der Bekämpfung von Wurzelunkräutern wie *C. arvense* ersetzen.

Stichwörter: Glyphosat, Kriechwurzeln, Mechanische Unkrautbekämpfung, Regenerationsfähigkeit, Wurzelunkräuter

Introduction

Chemical weed control with glyphosate as the primary choice to control perennial weeds such as *C. arvense* will be reduced or even, as currently discussed within the EU, completely banned (CLAUSING, 2019). Non-chemical measures to disturb perennial weeds in organic farming systems rely on ploughing the soil (MELANDER et al., 2012, HAKANSSON et al., 1998). Inversion tillage, however, is accompanied by soil erosion, a reduced soil biological activity, high energy consumption und a subsequently high output of CO2 (MOITZI, 2013; ARONSSON et al., 2015).

One alternative is the so-called "Kverneland Horizontal Root Cutter" (Fig. 1). This machine fragments adventitious roots and cuts them off from belowground shoots and deep rooting root parts via horizontally arranged sheers, subsequently leading to a depletion of reserves.

The aim of this experiment was to understand how an existing thistle infestation is influenced by the "Kverneland horizontal root cutter". Experimental factors were working depth and cutter use frequency. The impact of the different treatments on *C. arvense* was determined by the changes in shoot density and aerial expansion of the thistle patches before and after.

Materials and methods

We conducted a field experiment from September 2019 to September 2021 in Rostock, Germany (54°03'39.5"N 12°05'03.9"E). The experimental site was located at 45m above sea level, 15km away from the Baltic Sea (YAMAZAKI et al., 2017) on a sandy loam soil type. The mean annual temperature (1981-2010) was 9.2°C, the mean annual precipitation 646mm. In the experimental period (September 2019-September 2021) the mean monthly temperature was 9.7°C with mean monthly precipitation of 55.6mm. Before starting the experiment), the field lay fallow for two years (2018/2019). No field crop was cultivated during the experiment.

Figure 1 The "Kverneland horizontal root cutter" is a tractor pulled 5 sheered tillage machine. Each sheer has a diameter of 50cm and can run up to 30cm deep into the soil, cutting and fragmenting root and shoot parts in the process.

***Abbildung 1** Der „Kverneland horizontal root cutter" ist ein gezogenes Bearbeitungsgerät mit fünf Schaaren. Jedes Schaar hat einen Durchmesser von 50 cm und kann Arbeitstiefen von bis zu 30 cm erreichen um Wurzel und Sprossteile zu schneiden und zu fragmentieren.*

Contrary to classical experimental designs with field plots of the same size, we used individual thistle patches as plots. A randomized block design with two repetitions was set up. The total number of patches limited the total number of available plots. Since two replicates do not qualify to calculate means of treatment effects, Table 2 provides all data collected in the experiments. The experimental factors were the working depth of the cutter (10cm, 20cm, 30cm) and the cutter use frequency (2, 4 and 6 times per year). 10cm and 30cm were only tested two times per year. There were four periods of cutting per year (Tab. 1); two in spring and two in summer. This resulted in twelve plots including the untreated control plots. Cutting was carried out when newly emerged shoots reached their compensation point (low point in reserves; six to eight leaves). A treatment was conducted when 50% of the given shoots in each plot had acquired the six to eight leaf stage. In spring all shoots of the plot were considered while only newly emerged shoots were considered in summer. All treatments were conducted on the same dates. Being the soil too moist to cut after rainfalls, treatments were advanced or postponed till soil conditions were found to be sufficient for cutting (Tab. 1).

C. arvense were observed as total shoot density per patch, shoots/m^2 and aerial expansion at the beginning and the end of the experiment. Aerial expansion of the patches was determined via GPS (Pentax-GNSS, Getac-PocketPC). Shoot height was measured on a monthly basis. Root carbohydrate and biomass were measured in September 2021. In each patch, a minimum of five shoots, with each shoot having an approximate foliar radius of 10cm up to a root depth of 30cm, were sampled, a sampling method that had been already introduced for root sampling by WILSON and MICHIELS (2003). Root samples were analyzed for their carbohydrate content via a version of a HPLC-method (High-performance liquid chromatography) introduced by WEIß & ALT (2017) slightly modified for *C. arvense*. Root samples from both patches of one treatment were homogenized and each sample was analyzed twice.

Table 1 Dates and working depths of root cutting operations 2019 - 2021.

Tabelle 1 *Daten und Arbeitstiefen der Rootcuttereinsätze 2019 - 2021.*

Date/Working depth	**10cm**	**30cm**	**20cm**	**20cm**	**20cm**
09/25/2019	x	x	x	x	x
10/09/2019					x
10/23/2019				x	x
04/23/2020	x	x	x	x	x
05/07/2020					x
05/21/2020				x	x
09/24/2020	x	x	x	x	x
10/05/2020					x
10/20/2020				x	x
04/29/2021	x	x	x	x	x
05/11/2021					x
05/27/2021				x	x
abbreviation	10x4	30x4	20x4	20x8	20x12

Results and discussion

Individual thistle patches with different initial shoot densities and sizes treated as plots led to different initial infestation levels. Therefore, no absolute values but percentage changes for number of shoots, shoots/m^2 and hoot height (cm) are given (Tab. 2). A value of 100 represents the initial infestation level in September 2019.

Aerial expansion

In the control plots, *C. arvense* expanded at the highest rate (Tab. 2). Horizontal root spread of *C. arvense* is reported to be rapid under no disturbance or competition e.g., BAKKER (1960) reported a spread of 6m per season. An approximately tenfold increase as seen in our control patches therefore seemed reasonable.

Table 2 Illustration of parameters defining *C. arvense* infestation levels. Shoots/m², number of shoots, aerial expansion (m²), and shoot height (cm) represent the differences evaluated between September 2019 and September 2021 in % to initial values.

Tabelle 2 *Darstellung von C. arvense-Befall definierenden Parametern. Für shoots/m², number of shoots, aerial expansion (m²), und shoot height (cm) sind die evaluierten Unterschiede in % vom Ausgangwert von September-2019 im September-2021 dargestellt.*

Treatment	**Control**		**10 x4**		**30 x4**		**20 x4**		**20 x8**		**20 x12**	
Replicate (R)	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Shoots/m²	63	188	349	661	267	344	149	244	266	130	399	295
Shoot number	724	1847	961	1142	178	162	158	145	114	138	22	28
Expansion (m²)	1083	984	275	199	67	47	35	59	43	59	6	16
Shoot height (cm)	102	106	109	104	92	115	97	100	80	69	16	32

All cutting treatments except 10cm reduced the expansion values below the initial 100% base line. Thus, in order to reduce patch size, it was necessary to cut deep enough to disturb the actual root system. Treatment 20x12 showed the greatest reduction (94 and 84%-points) in patch size (Tab. 2).

Number of shoots, shoots/m²

The higher the cutting frequency, the lower were the total number of shoots (Tab. 2). The treatment 20x12 gave the greatest reduction of initial infestation levels (78 and 72%-points reduction). Treatments 20x8 and 20x4 resulted in lower numbers than the control but for both the number increased with respect to the initial infestation. 20x12 was more effective than 20x8 because 20x12 was the only treatment that did not grow past the flower bud stage before being cut again, which marks another point of low reserves (RODRIGUEZ et al., 2007). In our experiments six cuttings per year in treatment 20x12 reduced the initial level of shoots by more than 70%-points. TILEY (2010) stated that six-to-eight cultivations throughout the season controlled regrowth of C. arvensis on a fallow. Thus, we achieved similar results without inverting the soil. Cutting at 20cm depth was more efficient than 30cm (Tab. 2).

Shoots/m² increased in all cutted plots between September 2019 and September 2021 (Tab. 2), highest in the cutting depth 10cm. Cutting depth 20cm decreased the shoot density more than 30cm. Thus, fragmentation increased the shoot density per m². This results that cutting roots into smaller pieces significantly increases the number of adventitious shoots produced per unit length of root is proven by literature (HAMDOUN, 1972; NADEU & VANDEN BORN, 1989). Like in our experiment, initial shallower tillage depths also showed more resprouting than deeper tillage operations (HAKANSSON, 2003).

Carbohydrate content, shoot height, root/shoot weight

The highest root biomass occurred in the control treatment, while it was lower in all other treatments (Tab. 3). This result was expected as disturbing the root system results in new shoot growth by root buds which were inhibited by apical dominance of the aerial shoots prior to fragmentation (LEATHWICK & BOURDOT, 2012). Subsequently new root growth decelerated as reserves are needed for new shoot production (FAVRELIÈRE et al., 2020). Root weight values have the same order like number of shoots, indicating a relation between the reduction of root weight and number of shoots (Tab. 2). Cutting depths of 20cm and 30cm reduced the root biomass more than 10cm. Root biomass was negatively related with the number of cuts performed. The concentration of sugars in g/kg/DW was lowest in treatment 10x4. Cutting in 10cm depth resulted in more shoots; hence resprouting was higher than after deeper cuts (Tab. 2). However, the total amount of sugar (root biomass x concentration of sugars) was not lowest in 10x4 because of a higher root biomass. The cutting frequency decreased the total sugar amount, while cutting depths did not affect it. Shoot height or shoot dry weight were not different between the control and the cutting depth treatments but decreased with more cutting frequency (Tab. 2). A lower total amount of sugars was measured in the roots after a higher cutting frequency (Tab. 3). GUSTAVSSON (1997) and HAKANSSON (2003) showed that longer and bigger root fragments produce primary shoots with more biomass which also grow taller than shoots originating from shorter/smaller root fragments. In our experiment plants in 10x4, 20x4 and 30x4, produced shoot biomass and height like in the control (Tab. 2 and Tab. 3). We assume that they still had enough reserves left for shoot growth, whereas plants in treatments 20x8 and 20x12 had not. This theory is strengthened when looking at the two sugars inulin and fructose. Inulin is known to be the dominant reserve carbohydrate in underground organs of *C. arvense* (WILSON et al., 2006; RODRIGUEZ et al., 2007). NKURUNZIZA & STREIBIG (2011) proved for *C. arvense* that the hydrolysis of fructan (which inulin belongs to) resulted in free fructose molecules during the early growth of fructan storing organs. In our experiment the control treatment showed the highest concentration and total amount of inulin, together with equal fructose concentrations and higher total fructose amounts compared to the other treatments. Hence, treatments with the "Kverneland horizontal root cutter" in high frequencies (20x8, 20x12) significantly impacted the plants reserve carbohydrates via a reduced number of shoots and also lighter and shorter shoots.

Conclusion

When evaluated by shoot number and infested area our field study showed that the "Kverneland horizontal root cutter" reduced *C. arvense* when cuttings were performed at a frequency of six cuttings per year. Working depths must be deep enough to reach the root system, best at least 20cm deep. We conclude that the "Kverneland horizontal root cutter" could serve as a tool to combat perennial weeds like *C. arvense* without inverting the soil.

Table 3 Influence of "Kverneland horizontal root cutter" working depth and use frequency on amount and concentrations of total sugar, inulin and fructose in *C. arvense* roots. Values are averages of total biomass dry weight (g) of the treatments.

Tabelle 3 *Einfluss der Arbeitstiefe und Einsatzhäufigkeit des „Kverneland horizontal root cutter" auf die Gesamtmenge und die Konzentration von Gesamtzucker, Inulin und Fructose in C. arvense-Wurzeln. Die dargestellten Werte sind Mittelwerte.*

	Dry weight (g)		**Amount (g)**			**Concentration in g/kg/DW**		
Treatment	**Shoot**	**Root**	**Sugar**	**Inulin**	**Fructose**	**Sugar**	**Inulin**	**Fructose**
Control	459.7	17.5	3.9	3.13	0.15	221.4	179.17	8.34
10 x4	551.2	8.2	1.5	1.03	0.09	184.6	125.92	10.55
30 x4	447.9	6.8	1.54	0.78	0.12	226.73	114.69	17.9
20 x4	439.2	6.4	1.45	0.9	0.05	226.25	140.38	8.5
20 x8	306.4	4.4	0.93	0.63	0.04	209.25	143.1	9.57
20 x12	114	3.7	0.72	0.46	0.03	195.57	124.8	7.76

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