Efficacy of natural fatty acid based herbicides on mixed weed stands

Wirksamkeit von natürlichen, auf Fettsäuren basierten Herbiziden auf Unkrautbestände

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DOI 10.5073/jka.2018.458.048

Abstract

In the search for alternatives to synthetic herbicides we assessed the efficacy of 2 non-selective, natural products. The active substances were fatty acids: one herbicide containing pelargonic acid (C9) and the other containing caprylic (C8) and capric acids (C10). The aim of the study was to determine the dose required to achieve this range of efficacy (ED80) for weed stands with different canopy heights and densities. 2 trials were carried out. Weed stand height varied between 0.05 m (trial 2) and 0.25-0.35 m (trial 1). The herbicides were applied with a logsprayer on plots of 43.5 m². Dose-response curves were calculated using green weed coverage determined by image analyses as response variable. The ED80 increased with increasing weed canopy height: from 0.9 to 1.7 of the standard dose (n) for the caprylic and capric acid containing product and from 0.7 n to 1.7 n for the pelargonic acid containing product.

In conclusion, acceptable efficacies can be achieved if the herbicides are applied on young weed stages. For larger weeds the dose, spray volume and application technology need to be further adjusted. These herbicides could be used for the stale seedbed technique, crop pre-emergence or inter-row applications. Nevertheless, the relatively high price of these natural herbicides limits their broader use.

Keywords: Alternatives to synthetic herbicides, caprylic acid, capric acid, logsprayer, natural herbicides, pelargonic acid

Zusammenfassung

Auf der Suche nach Alternativen zu synthetisch-chemischen Herbiziden wurde die Wirksamkeit von 2 nicht selektiven «Naturherbiziden» geprüft. Der Wirkstoff von einem Produkt enthielt Pelargonsäure (C9), der andere enthielt Caprylsäure (C8) und Caprinsäure (C10). 2 Versuche wurden angelegt, um die Aufwandmenge für eine Wirkung von 80 % (ED80) auf Mischverunkrautungen mit unterschiedlicher Bestandeshöhe zu bestimmen. Die Unkrauthöhe betrug 0,05 m (Versuch 2) und 0,25-0,35 m (Versuch 1). Die «Naturherbizide» wurden mit einem Logsprayer ausgebracht. Die Parzellengröße betrug 43,5 m². Dosis-Wirkungskurven wurden basierend auf dem Merkmal grüner Unkrautbedeckungsgrad bestimmt, der anhand von Bildanalyse berechnet worden war. Der ED80 stieg mit zunehmender Unkrauthöhe: Von 0,9 auf 1,7 der Standardaufwandmenge (n) für das capyrl- und caprinsäurehaltige Produkt und von 0,7 n auf 1,7 n für das pelargonsäurehaltige.

Zusammenfassend kann gesagt werden, dass mit diesen «Naturherbiziden» eine ausreichende Wirkung gegen junge Unkräuter erzielt werden kann. Um eine ausreichende Wirkung gegen größere Unkräuter erzielen zu können, müsste die Aufwandmenge, die Wasseraufwandmenge und die Applikationstechnologie noch weiter optimiert werden. Diese Produkte eignen sich gut für eine Anwendung auf dem falschen Saatbeet, im Vorauflauf der Kultur oder im Bereich zwischen den Reihen bei Reihenkulturen. Die verbreitete Anwendung dieser „Naturherbizide" ist auf Grund ihres hohen Preises zurzeit nicht ökonomisch.

Stichwörter: Alternativen zu synthetisch-chemischen Herbiziden, Caprylsäure, Caprinsäure, Logsprayer, Naturherbizide, Pelargonsäure

Introduction

Synthetic-herbicides allow effective and cheap weed control (KRAEHMER and STUEBLER, 2012). However, their use is currently highly debated due to their downsides such as the development of resistance, water contamination, reduction of biodiversity and potential human toxicity (BOSCHETTO, 2013). In addition, many active substances have been lost or their use has been restricted due to the re-evaluation process (KARABELAS et al., 2009). In Switzerland for example the re-evaluation of glufosinate was completed in 2013 (ANONYMOUS, 2015). For arable crops the fallow treatment, for potatoes the desiccation application and for vegetables as for potatoes the pre-emergence treatment could not be registered further. In addition, the number of applications were restricted in many crops and the amount of active substance to be applied per pass was reduced (ANONYMOUS, 2013). In Germany, no glufosinate containing products are registered anymore (ANONYMOUS, 2017).

An alternative could be natural herbicides, often based on fatty acids. They are non-systemic, contact herbicides. VAUGHN and HOLSER (2007) specify further, that they affect the cuticle, which protects the leaf from evaporation and desiccation. These fatty acids solubilize the lipids. Sprayed foliage wilts and then dies. For that reason, these products can be used for the desiccant application e.g. in potatoes (COLEMAN and PENNER, 2008). For example, pelargonic acid showed good efficacy on young weed stages (reference to the study cited by WEBBER et al., 2014).

The persistence of these natural products is generally lower and as a consequence their impact on the environment is also lower (FUKUDA et al., 2004). Their rapid degradation is also a drawback as it affects their efficacy (DAYAN et al., 2012). Nevertheless, they could be an alternative to non-selective synthetic herbicides with foliar activity whose use has been restricted or might become more restricted. Efficacy data of such natural herbicides – especially dose-response curves for mixed weed stands of weeds common in Switzerland is not broadly available. Therefore, the goal of this study was to determine dose-response curves and the efficacy of 2 nonselective, foliar active, natural herbicides on mixed weed stands.

Materials and methods

Two trials were carried out in plastic tunnels at the research station of Agroscope in Wädenswil in Switzerland (47.2223 N, 8.6689 E) in 2016. Such plastic tunnels are typically used for vegetable production in Switzerland. The soil was a sandy loam (3.5% OM, 16% clay, 21% silt, 59.5% sand; pH 6.8). Both experiments were conducted in a randomized complete block design with 2 replicates (r1 and r2). Plot dimension was 1.5 m x 29 m.

To ensure a mixed weed stands common chickweed (*Stellaria media*), common speedwell (*Veronica persica)*, barnyard grass (*Echinochloa crus-galli*) and small-flowered quickweed (*Galinsoga parviflora)* (Appels Wilde Samen GmbH, Darmstadt, Germany) had been sown on July 13. Nevertheless, the dominant species in trial 1 was hairy galinsoga *(Galinsoga ciliata)* which had mainly established naturally. In trial 2, no weeds were sown before the trial; weed coverage consisted of 90% *S. media*, the remaining 10% were *G. parviflora* and *V. persica*. At the time of application, the weed stand height was 0.05 m (trial 2) and 0.25-0.35 m (trial 1).

Application was carried out with a 1.5-m-wide logarithmic sprayer; spray volume was 400 L/ha. Nozzle type was IDK12002 (operating pressure: 1.5 bar, flow rate: 0.6 L/min) (Lechler, Metzingen, Germany), nozzle spacing was 0.25 m, nozzle distance from target area was 0.25 m. Application speed was 3.6 kmh. Application took place 10 August (trial 1) and 19 September (trial 2) 2016.

Two natural herbicides containing fatty acids as active substances were tested: H1 containing pelargonic acid (EC, 680 g a.i. L^{-1}) and H2 containing caprylic and capric acids (EC, 470 g a.i. $L^{-1}$and 320 g a.i. L^{-1}, respectively). The target dose of H1 was 16 L ha^{-1}, and for H2 target range was 9 to 18 L ha^{-1}. On average 14.5 m of the plot was sprayed, the remaining plot served as untreated control *i.e.* the response at dose 0.

The response was determined by image analyses: images were taken every meter of each plot 6 (trial 1) and 2 days (trial 2) after treatment, using standard RGB cameras (trial 1: Panasonic Lumix DMC-LF1; trial 2: D90 with object lens AF-S Nikkor 16-85 from Nikon). Field of view was about 0.2 m^2. Excessive green coverage was determined using the program IMAGING Crop Response Analyser (http://www.imaging-crops.dk/) developed and described by RASMUSSEN et al. (2007). In trial 1, 2 images were taken each meter in the centre of the plot, for further analyses the average coverage derived from the images was used. In trial 2, 1 image was taken every meter.

A calibration experiment had shown previously that the applied dose of the logsprayer tended to be too high for the first 2 m, therefore the images taken within this range were not used for modelling.

The R 'drc' package was used for analysis (R CORE TEAM, 2016; RITZ et al., 2015). Dose response curves were determined using a log-logistic model with 4 parameters (RITZ and STREIBIG, 2005; RITZ, 2010):

$$y = C + \frac{D - C}{1 + \exp(b * (\log(x) - \log(ED50)))}$$

Where *D* denotes the upper and *C* the lower limit, *ED50* is the dose required to achieve half of the response, *b* represents the relative slope around the ED50. *X* is the dose in L ha^{-1} and y is the response in excessive green coverage (no coverage: 0, full coverage: 1). Analyses for each trial were done separately. For each herbicide per trial a full and reduced model was fitted: The full model estimated 4 parameters for each replicate and the reduced model estimated 4 parameters for both replicates. The model was reduced, if the F-test comparing the 2 models was not significant (p-value < 0.05). The dose required for an efficacy of 50, 70, 80, 90 and 95% was calculated using the ED-function in the 'drc' package. According to the manufacturer of these natural herbicides an efficacy of 80% is considered adequate for them to be successful in the market.

Results

For each individual plot a dose response curve was modelled (F-tests were significant). In trial 2 the natural herbicides were sprayed on a weed stand with a canopy height of 0.05 m, weed coverage ranged between 30 and 60% in the untreated control plots. With the doses recommended by the manufacturer; 16 L ha^{-1} for H1 and with the higher range recommended for H2 (9-18 L ha^{-1}); we achieved a strong response *i.e.* a high efficacy (Fig. 1): For H1 ED80 was 11.8 L ha^{-1} (r1) and 11.5 L ha^{-1} (r2) and for H2 ED80 was 17.6 L ha^{-1} (r1) and 14.7 L ha^{-1} (r2), correspondingly (Tab. 1). Less response *i.e.* lower efficacy was observed in trial 1, in which the natural herbicides were applied on a dense weed stand with a canopy height of 0.25 to 0.35 m (Fig. 2). For r1 the lower asymptote C was -20.7 for H1 and 0.2 for H2. For H1 r1 no EDs were calculated, because the parameter C was not biologically meaningful. For r1 H2 no EDs were calculated either, as even at high doses no complete weed control could be achieved (weed coverage 0.2). For H1 r2 the EDs have to be interpreted with caution as even at high doses, weed coverage was still 0.1 (C = 0.1). For H1 ED80 was 26.9 L ha^{-1} and for H2 31.2 L ha^{-1}. This was 2.3 and 1.9 times more compared to the trial 2 for H1 and H2, correspondingly.

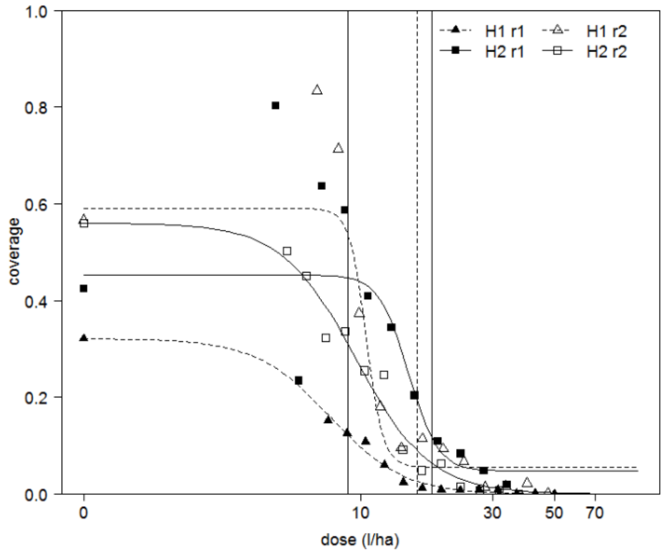

Fig. 1 Dose response curves for H1 (pelargonic acid) and for H2 (caprylic and capric acids) for trial 2 (weed canopy height 0.05 m). Vertical lines: target range for H2, vertical dotted line: target dose for H1, r1: replicate 1, r2: replicate 2.

Abb. 1 *Dosis-Wirkungskurven für H1 (Pelargonsäure) und für H2 (Caprylsäure und Caprinsäure) vom Versuch 2 (Unkrauthöhe 0,05 m). Vertikale Linien: Zielbereich von H2, vertikale gepunktete Linie: Zielaufwandmenge von H1, r1: Wiederholung 1, r2: Wiederholung 2.*

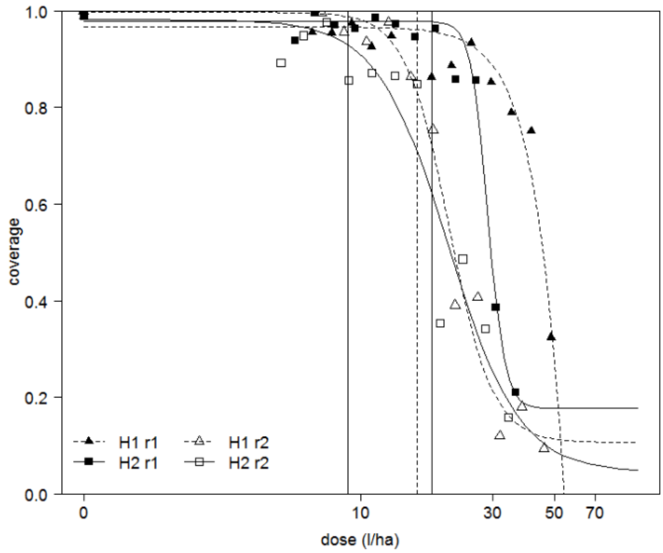

Fig. 2 Dose response curves for H1 (pelargonic acid) and for H2 (caprylic and capric acids) for trial 1 (weed canopy height 0.25m to 0.35m). Vertical lines: target range for H2, vertical dotted line: target dose for H1, r1: replicate 1, r2: replicate 2.

Abb. 2 *Dosis-Wirkungskurven für H1 (Pelargonsäure) und für H2 (Caprylsäure und Caprinsäure) vom Versuch 1 (Unkrauthöhe 0,25 m bis 0,35 m). Vertikale Linien: Zielbereich von H2, vertikale gepunktete Linie: Zielaufwandmenge von H1, r1: Wiederholung 1, r2: Wiederholung 2.*

Tab. 1 Calculated doses (ED) for H1 (pelargonic acid) and for H2 (caprylic and capric acids) from trial 1 and trial 2 for efficacies of 50, 70, 80, 90 and 95%.

Tab. 1 *Berechnete Aufwandmengen (ED) für H1 (Pelargonsäure) und für H2 (Caprylsäure und Caprinsäure) von Versuch 1 und 2 für Wirksamkeiten von 50, 70, 80, 90 und 95 %.*

		Trial 2 Weed height 0.05m ED (L ha^{-1})		**Trial 1 Weed height 0.25-0.35 m ED (L ha^{-1})**	
Herbicide	**Efficacy**	**rep 1**	**rep 2**	**rep 1[1)]**	**rep 2**
H1	50	7.7	10.5	-	20.9
	70	10.0	11.1	-	24.3
	80	11.8	11.5	-	26.9
	90	15.1	12.2	-	31.1
	95	19.0	12.9	-	35.7
H2	50	14.9	9.6	-	20.7
	70	16.5	12.5	-	26.6
	80	17.6	14.7	-	31.2
	90	19.4	18.9	-	39.6
	95	21.2	23.8	-	49.4

1) For trial 1 rep 1 no EDs were calculated.

Discussion

A high efficacy could be achieved with both tested natural herbicides, when they were applied on young weeds *i.e.* on a weed stand with a canopy height of 0.05 m. In contrast, no adequate weed control was achieved, when the natural herbicides were applied on a dense weed stand with a canopy height of 0.25 to 0.35 m (trial 1). At the time of application, the weed stand consisted of several leaf layers and only the top layers were burnt by the foliar active natural herbicides. Thus, we could not estimate meaningful ED80 for r1. In contrast, in the other replicate an efficacy of 80% (ED80) could be achieved at 1.7 times of the doses recommended for both products. Generally, to achieve a higher efficacy, the application should be repeated.

The application in trial 1 was carried out in the morning and there was still dew on the leaves. In addition, this might have negatively affected the efficacy. Due to their sole contact activity of these natural herbicides, they should be preferably applied on dry leaves (WEBBER et al., 2010). The trials were sprayed with 400 L ha^{-1}. Possibly the efficacy could be further improved, if the application technology was further optimized or the spray volume was increased. However, the latter would also increase the risk of run off from the target area, meanwhile the leaf layers at the bottom of the canopy would still remain largely unsprayed.

Due to their high efficacy on small and young weeds, these natural herbicides are suited for crop pre-emergence inter-row applications or on fallow land. They can be further applied on a stale seed bed, when adverse conditions impede mechanical weed control pass.

Apart from being effective, the products must be affordable for the farmers. The natural herbicide Finalsan® (188 g pelargonic acid L^{-1}, SL) is the best known natural herbicide in Switzerland. It is normally used in home gardens in ornamentals, lawns and turfs (target market). Therefore, the price is relatively high: The recommended dose is 166 L ha^{-1}, which amounts to 2’500 CHF ha^{-1} (2’185 EUR ha^{-1}) (ANONYMOUS, 2017a). In contrast the application’s cost of the non selective foliar active herbicide Basta®150 (150 g L^{-1} Glufosinate, SL, Bayer) costs for example at the recommended dose of 4.5 L ha^{-1} 135 CHF ha^{-1} (120 EUR ha^{-1}) (ANONYMOUS, 2017b). To become a true alternative to non selective, synthetic, contact herbicides, the price of these natural products needs to be similar to the price of the conventional herbicides.

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