Pelargonic acid for weed control in onions: factors affecting selectivity

Unkrautbekämpfung mit Pelargonsäure in Zwiebeln: Faktoren, die die Verträglichkeit bestimmen

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Abstract

In onions (*Allium cepa*) few herbicides are registered. Due to their erect leaf and plant structure, onions retain less herbicide after spraying than broadleaved weeds. Further, onion plants have a thicker plant cuticle. These differences allow a selective use of pelargonic acid in onions. The main aim of this study was to determine the selective dose at different crop growth stages.

Five field trials were carried out. Three pelargonic acid containing products (1 SL- and 2 EC-formulations) were applied with a logarithmic sprayer. Dose range was 0 to 56 kg active substance (a.s.) ha^{-1}. The growth stage varied between BBCH 10 and 16. Selectivity was rated visually.

The products were selective at 7.2 and 8.3 kg a.s. ha^{-1} (BBCH 10-11), 6.1 and 8.9 kg a.s. ha^{-1} (BBCH 11-12), 8.5 and 20.7 kg a.s. ha^{-1} (BBCH 13) and 6.3 and 9.0 kg a.s. ha^{-1} (BBCH 14-16) for the SL- and EC-products respectively. Selectivity depended on growth stage and weather conditions. Important for selectivity is an intact cuticle, a rain-free, light-intense period before application.

Pelargonic acid could become a component for sustainable weed control in onions. Due to its foliar activity, small weeds need to be targeted and several passes are required.

Keywords: Ammonium nonanoate, Liliaceae, logsprayer, nonanoic acid, pelargonic acid, selectivity trial

Zusammenfassung

In Zwiebeln (*Allium cepa*) sind nur wenige Herbizide bewilligt. Aufgrund ihrer aufrecht stehenden Blätter und aufrechten Pflanzenarchitektur bleibt an den Zwiebelpflanzen nach der Applikation weniger Herbizid haften als an breitblättrigen Unkräutern. Außerdem haben sie eine dickere Cuticula. Diese Unterschiede machen einen selektiven Einsatz von Pelargonsäure in Zwiebeln möglich. Das Hauptziel dieser Arbeit war, verträgliche Aufwandmengen für unterschiedliche Wachstumsstadien zu bestimmen.

In 5 Feldversuchen wurden 3 Pelargonsäure-haltige Produkte (1 SL- und 2 EC-Formulierungen) mit einem Logsprayer appliziert. Zwischen 0 und 56 kg Aktivsubstanz (a.s.) ha^{-1} wurden appliziert. Die Zwiebelstadien reichten von BBCH 10 bis 16. Die Verträglichkeit wurde visuell bonitiert.

Die Produkte waren verträglich mit jeweils 7.2 und 8.3 ka a.s. ha^{-1} (BBCH 10-11), 6.1 und 8.9 ka a.s. ha^{-1} (BBCH 11-12), 8.5 und 20.7 ka a.s. ha^{-1} (BBCH 13) sowie mit 6.3 und 9.0 kg a.s. ha^{-1} (BBCH 14-16) für die SL- bzw. die EC-Formulierungen. Die Verträglichkeit hing vom Kulturstadium und den Wetterbedingungen ab. Wichtig für einen selektiven Einsatz in Zwiebeln ist eine intakte Wachsschicht, was eine regenfreie, lichtintensive Periode vor der Applikation bedingt.

Pelargonsäure könnte eine wirksame Komponente für eine nachhaltige Unkrautbekämpfung in Zwiebeln werden. Aufgrund der reinen Blattwirkung müssen kleine Unkräuter behandelt werden und es sind mehrere Applikationen notwendig.

Stichwörter: Ammoniumnonanoat, Liliaceae, Logsprayer, Nonansäure, Pelargonsäure, Verträglichkeitsversuch

Introduction

Onion (*Allium cepa*) is an important vegetable crop worldwide. Onions are sown in rows, are weak competitors and cover the soil barely even at advanced crop stages. Therefore, effective weed control is of main importance in this crop (VOGEL, 1991; THEILER et al., 2004). In addition, onions react sensitive to foliar active herbicides targeting broadleaved weeds. This makes chemical weed control very challenging. To avoid crop damage, the crop plants have to be as erect as possible and their plant cuticle needs to be intact and robust (KREISELMAIER et al., 2019).

Generally, only few active substances (a.s.) are available for use in onions. For example in Switzerland, aclonifen, bromoxynil, clopyralid, diquat, pendimethalin, prosulfocarb, pyridate and several grass herbicides are registered for use in onions (BLW, 2019).

Pelargonic acid or nonanoic acid has a sole contact action, is not considered as a selective active substance and is rapidly degraded in soil (DT50 < 2 days) (STRABLEGG-LEITNER, 2017). It can be formulated as salt e. g. as ammonium nonanoate (SL-formulation) or as acid (EC-formulation). Against broadleaved weeds it is effective on young plant stages. Its activity against monocotyledonous weeds is limited (WEBBER and SHREFLER, 2006; CRMARIC et al., 2019). Onions have an erect plant and leaf architecture and their plant cuticle is well developed, if weather and growth conditions are favorable (BOUMA, 2008). Both characteristics allow a selective use of the unselective pelargonic acid in onions. In the US the pelargonic acid containing product Scythe for example is labeled for use in onions. However, the labeled use is restricted to general weed control for seedbed or site preparation, PRE-emergence application, directed and shielded or spot application and as a harvest aid and for desiccation (ANONYMOUS, undated). JOHNSON and DAVIS (2014), and JOHNSON and LUO (2018) tested pelargonic acid and ammonium nonanoate in field trials without shielding the transplanted winter onion plants. Selectivity and efficacy were assessed in the same trials. Both products were selective at the tested doses. However, the effect on onion yield was inconsistent due to difficulties in timing application regarding weed size and weather conditions in the winter season (JOHNSON and DAVIS, 2014; JOHNSON and LUO, 2018).

We were interested in the selective dose of 3 different pelargonic acid containing products (1 SL- and 2 EC-formulations) at different growth stages of onions cropped under standard Swiss conditions treated under varying weather conditions.

Materials and Methods

Two field trials were carried out in 2018 and 3 in 2019 in Northern Switzerland. In each year, trials were carried out in different growth stages of the crop (Tab. 1).

Tab. 1 Description and details of the 5 field trials carried out in onions. Cloudiness: 0/8 blue sky, 8/8 cloudy (no blue sky at all).

Tab. 1 *Übersicht über die 5 in Zwiebeln durchgeführten Feldversuche. Cloudiness: 0/8 blauer Himmer, 8/8 bewölkt (kein Blau am Himmel sichtbar).*

trial	---------------------------- application details ----------------------------						visual ratings
	growth stage (BBCH)	date	year	temperature [°C]	cloudiness [x/8]	rel. humidity [%]	date
1	10-11	25 May	2018	26	0/8	31	28 May
2	11	4 June	2019	31	0/8	43	5 June, 19 June
3	11-12	27 March	2019	7	0/8	57	28 March, 3 April
4	13	25 May	2018	26	0/8	31	28 May
5	14-16	27 March	2019	11	0/8	47	28 March, 3 April

H1 (EC, 680 gl^{-1} pelargonic acid), H2 (SL, 187 g l^{-1} pelargonic acid formulated as salt (ammonium nonoat)), and H3 (formulation not declared most likely an EC, 699 gl^{-1}) were applied with a logsprayer (nozzle spacing: 0.25 m, nozzle type: IDK 120 02 Lechler; pressure: 1.7 bar, velocity: 3.6 kmh^{-1}, boom height: 0.25 m). Thereafter we refer to ammonium nonanoate also as pelargonic acid. Spray amount was 400 l ha^{-1}. H3 was tested only in 2019. Trial 1 and 4 were treated at the same day in 2018, trial 3 and 5 at the same day in 2019. Plot dimensions were 1.5 m by 15 m. One plot corresponded to one application with the logsprayer. So in each plot a continuous range from a high amount to no herbicide applied was implemented. In 2018, initial concentration was 80 l ha^{-1} H1 (54.4 kg a.s. ha^{-1}) and 300 l ha^{-1} H2 (56.1 kg a.s. ha^{-1}). In 2019, initial concentration of H2 was reduced to 200 l ha^{-1} (37.4 kg a.s. ha^{-1}). The initial concentration for the other 2 products were 80 l ha^{-1} H1 (54.4 kg a.s. ha^{-1}) and 80 l ha^{-1} H3 (55.9 kg a.s. ha^{-1}) in 2019. Two replicates per trial were installed in 2018 and 3 replicates per trial in 2019. Visual selectivity ratings were carried out 3 days after application in 2018 and 1 and 7 days after application in trial 3 and 5, and 1 and 15 days after application in trial 2 in 2019. The rating approach was conservative i.e. when visible damages (distinct necrosis) were observed, the dose was not considered selective, even though the crop plants could recover from these effects. Based on the ratings in the field, the selective dose was calculated. Weather data was obtained from the closest weather stations (agrometeo, station Laufen Uhwiesen and station Lupfig) (Tab. 2).

Tab. 2 Description of the weather the week before the applications took place. For interpretability of the tables, the growth stage at application is shown again.

Tab. 2. *Übersicht über das Wetter der Woche vor den Applikationen. Für die Lesbarkeit der Tabellen ist das BBCH-Stadium am Tag der Applikation ebenfalls aufgeführt.*

trial	-------------------- weather conditions 1 week before application -----------------------				
	growth stage (BBCH)	temperature [°C]	relative humidity [%]	consecutive days without rain [d]	global radiation [W m^{-2} d^{-1}]
1	10-11	16	77	> 7	205
2	11	16	76	5	261
3	11-12	7	63	4	147
4	13	16	77	> 7	205
5	14-16	7	63	4	147

Statistical analysis was carried out in R studio (R version 3.5.3, 2019-03-11). A standard ANOVA was carried out for each experiment and rating day separately. Tukey HSD test was used, if ANOVA revealed significant treatment differences. Model assumptions were checked by diagnostic plots. For selectivity considerations, the minimum selective dose was determined. This is the dose, which was safe for the crop across all observations.

Results

For all tested products and growth stages, a selective dose could be determined (Tab. 3). Only once (1 from 8 ratings) a significant difference between the products could be observed (H2 < H1 & H3). Means over all trial means (first rating) were 6.85, 11.78 and 10.70 kg pelargonic acid ha^{-1} for H2, H1 and H3, respectively. H1 and H3 were more selective than H2.

Tab. 3 Average selective dose (active substance in kg a.s. ha^{-1}) 1 day after application (trial 2, 3 and 5) and 3 days after application (trial 1 and 4) for the 3 pelargonic acid containing products. P-Value: Non significant (n.s.), p-value < 0,05 (*).

Tab. 3 *Mittelwerte der verträglichen Aufwandmenge (Aktivsubstanz in kg a.s. ha^{-1}) 1 (Versuch 2, 3 und 5) und 3 Tage (Versuch 1 und 4) nach Applikation für die 3 pelargonsäurehaltigen Produkte. P-Wert: Non signifikant (n.s.), p-Wert < 0.05 (*).*

trial	BBCH	year	selective dose [kg a.s. ha^{-1}]			
			H1	H2	H3	p-value
1	10-11	2018	8.30	7.22	-	n.s.
2	11	2019	16.07	-	13.99	n.s.
3	11-12	2019	8.95	6.08	8.80	*
4	13	2018	20.01	8.46	-	n.s.
5	14-16	2019	8.59	6.31	9.31	n.s.

No clear tendency between selectivity and crop growth stage could be found in the trials. In the growth stages "10-11", "11-12" and "14-16" (trial 1, 3 and 5) about 8 kg pelargonic acid ha^{-1} were selective (averaged over the factor herbicide). For the former, weather conditions before and at application were favorable, but the growth stage was rather early. For the latter 2, weather conditions were rather cold with lower average radiation (Tab. 1 and 2). Considerable higher amounts of pelargonic acid were safe for the crop at the growth stages "11" (14.82 kg a.s. ha^{-1}) and "13" (14.24 kg a.s. ha^{-1}) (trial 2, 4). Weather conditions before and at application were favorable for both field trials with these crop stages. For the former, temperature was very high during application and average radiation before application was generally higher.

Ratings 1 day after application represented generally the highest observable damage; 7 and 15 days after application the crop plants had recovered considerably in trial 2, 3 and 5 (Fig. 1).

For H2, H1 and H3, the minimum selective dose across all observations (first rating) was 4.39, 6.67 and 8.27 kg a.s. ha^{-1} respectively – which corresponds to 23.50, 9.81 and 11.83 l ha^{-1} product.

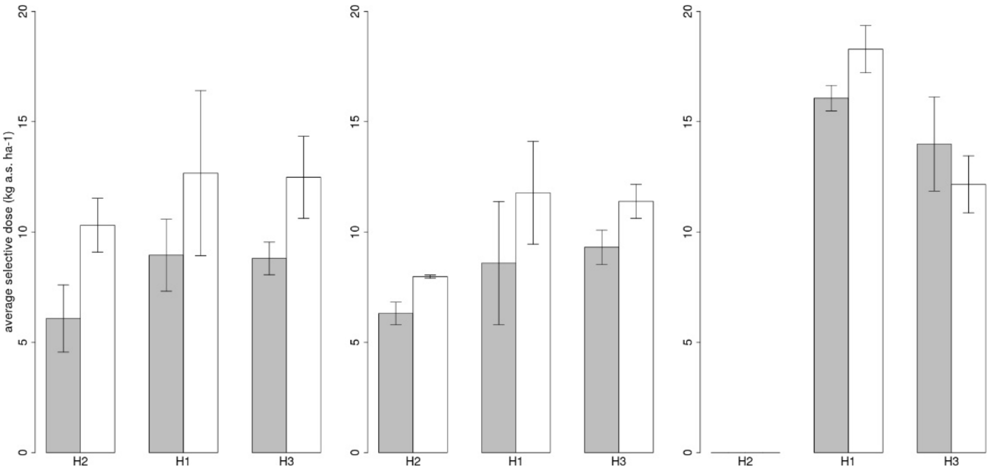

Fig. 1 Average selective dose (a.s. kg ha^{-1}) and standard deviation in trial 3 (BBCH 11-12) [left], trial 5 (BBCH 14-16) [middle] and trial 2 (BBCH 11) [right] for H2, H1 and H3. In trial 2, H2 was not tested. Grey bars: first rating 1 day after application (1 DAA) and white bars 7 DAA for trial 3 & 5 and 15 DAA for trial 2.

***Abb. 1** Durchschnittliche verträgliche Aufwandmenge (a.s. kg ha^{-1}) mit Standardabweichung für den Versuch 3 (BBCH 11-12) [links], den Versuch 5 (BBCH 14-16) [Mitte] und den Versuch 2 (BBCH 11) [rechts] für H2, H1 und H3. H2 wurde im Versuch 2 nicht geprüft. Graue Säulen stellen die erste Bonitur 1 Tag nach Applikation (1 DAA) und die weissen Säulen 7 DAA für den Versuch 3 & 5 und 15 DAA für den Versuch 2 dar.*

Discussion

In trial 1 and 3 to 5, winter onions were treated. Whereas in trial 2 summer onions were sprayed. The winter onions were grown for spring onion production (sold with the green leaves), thus very little crop damage was acceptable. In contrast, summer onions tend to be more susceptible to herbicides than winter onions due to their young leaves and their plant cuticle tends to be less robust.

The average selective doses determined in our field trials, correspond to the lower doses tested by JOHNSON and DAVIS (2014), and JOHNSON and LUO (2018). In their field trials, no thinning was observed and foliar necrosis was transient. Currently none of the tested products is registered for use in onions in Switzerland. H2 is registered as pesticide in ornamentals in Switzerland. H1 is registered for use in Switzerland in orchards, vineyards, potatoes (desiccation), ornamentals and vegetable fallows with 8-16 l ha^{-1} (BLW, 2019). The determined selective dose in onions for H1 in this study was around 10 l ha^{-1}. In previous experiments we could show that, with this dose an efficacy of about 70% could be reached on young weeds (< 5 cm) (CRMARIC et al., 2018; unpublished data). Therefore, small weeds need to be targeted and several passes might be required to successfully control weeds in onions with pelargonic acid. This corresponds to the current weed control strategy in onions, which consists already of several applications with low doses targeting germinating weeds (BBCH 10) with synthetic foliar active herbicides such as bromoxynil (KREISELMEIER et al., 2019).

The effect of weather conditions around application and the effect of growth stage were difficult to tackle. In leaflets and newsletters from extension services, the application of foliar active herbicides is described as risky on very young growth stages (<BBCH 11) and on older crop stages (>BBCH 14-15), except for the hook stage (LABER, 2014; ANONYMOUS, 2015; common experience onion growers). After a rainy period, they recommend to wait several, sunny days before applying foliar active herbicides targeting broadleaved weeds (LABER, 2014). In addition, stressed crop stands should not be treated. Based on our experience, the same rules apply for the selective application of pelargonic acid in onions. However, more trials have to be carried out to refine these rules and then to validate them.

Society in Western Europe is very skeptical about synthetic pesticides. For example, in Switzerland 2 public initiatives are on the way, which aim at strongly limiting the use of (synthetic) pesticides (ANONYMOUS, 2019). Natural product-based herbicides such as pelargonic acid have a positive environmental profile and are better perceived by the public (STRABLEGG-LEITNER, 2017). Currently, no pelargonic acid containing product is registered for use in onions in Switzerland (BLW, 2019). Nevertheless, such products could become an important component of sustainable weed management in onions and other selected crops in the future.

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