Autumn mowing and pelargonic acid can suppress *Elymus repens* abundance especially when combined with increased crop competition

Die Kombination aus Schröpfen, dem Einsatz von Pelargonsäure und einer erhöhten Konkurrenz der Kulturpflanzen kann das Vorkommen von Elymus repens unterdrücken

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Abstract

Couch grass (*Elymus repens*) is a creeping perennial weed that can cause great yield losses in a wide range of crops. Established stands are usually controlled by glyphosate, selective herbicides, or intensive tillage. Many herbicides, including glyphosate, are, however, currently at risk of being banned. Couch grass can be controlled with below-ground tillage treatments to a depth of 10-15 cm, followed with mouldboard ploughing at a depth of 20-25 cm. Mowing is sometimes used, but often with unsatisfactory results. We wanted to test if there was a better effect of combining a bio-herbicide with autumn mowing and if increased crop competition could further enhance efficacy. One field experiment was carried out in Norway with combinations of bio-herbicide, mowing and competition (cross-sowing of spring cereals) in 2019-2021 and one in Finland with mowing and bio-herbicide in 2019-2020. Pelargonic acid (Beloukha, 680 g a.i. L^{-1}, dose rate 16 L ha^{-1}) was used as bio-herbicide. Couch abundance in autumn, in early and late spring and finally before spring cereal harvest were assessed. In general, each of the treatments caused up to 25-50% short-term reduction in ground cover. The best effect against couch grass was achieved by the combination of all three treatments, with nearly 70% reduction in dry matter in the subsequent summer sampling. However, no treatment combination could reach the same level of efficacy that could be expected with glyphosate.

Keywords: bio-herbicide, couch grass, mechanical weed control, perennial weeds

Zusammenfassung

Das Auftreten der Gemeine Quecke (*Elymus repens*) in Kulturpflanzen kann zu hohen Einbußen der Ertragsmenge führen. Verbreitete Bekämpfungspraktiken des ausdauernden Wurzelunkrautes im konventionellen Anbau sind der Einsatz des Wirkstoffes Glyphosat, selektiver Herbizide und eine intensive wendende Bodenbearbeitung. Die Zulassungen vieler chemisch-synthetischer Herbizide, darunter auch der Wirkstoff Glyphosat, stehen jedoch in der aktuellen politischen und gesellschaftlichen Diskussion.

Die Gemeine Quecke kann durch flache Bodenbearbeitungsgänge in einer Tiefe von 10-15 cm und anschließender wendender Bodenbearbeitung (20-25 cm Tiefe) kontrolliert werden. Das Schröpfen der Pflanzen führt bisher zu einer unbefriedigenden Kontrolle.

Die vorliegende Studie ist der Frage nachgegangen, ob eine Maßnahmenkombination bestehend aus dem Einsatz eines Bioherbizides, dem Schröpfen der Pflanzen im Herbst und der Aussaat des nachfolgenden

Sommergetreides im Verfahren der Kreuzsaat geeignet ist, um die Gemeine Quecke wirkungsvoll zu kontrollieren.

Zu diesem Zweck wurden zweijährige Feldversuche (2019-2021) in Norwegen und einjährige Versuche (2019-2020) in Finnland etabliert. Es wurde die Wirkung des Bioherbizides Pelargonsäure (Beloukha, 680 g a.i. L^{-1}, Aufwandmenge 16 L ha^{-1}) untersucht. Das Vorkommen der Gemeine Quecke wurde zu vier Terminen (Herbst, frühes und spätes Frühjahr, vor der Ernte) als Deckungsgrad ermittelt und die Effizienz (%) der Kontrollmaßnahmen relativ zur unbehandelten Kontrolle ermittelt.

Die einzelnen Kontrollmaßnahmen bewirkten eine kurzfristige Verringerung des Deckungsgrades der Gemeinen Quecke um 25-50 %. Die wirkungsvollste Kontrolle der Gemeine Quecke wurde durch die Kombination aller drei Maßnahmen (Pelargonsäure + Schröpfen + Kreuzsaat) erzielt, die Maßnahmenkombination führte zu einer Verringerung der Trockenmasse der Gemeinen Quecke um ca. 70 % (Bonitur vor der Ernte).

Die Maßnahmen zur Kontrolle der Gemeinen Quecke konnten allerdings einzeln angewendet und auch in Kombination nicht die Wirkung erzielen, die mit dem Einsatz des Wirkstoffes Glyphosat zu erwarten gewesen wäre.

Stichwörter: Bioherbizide, Quecke, Mechanische Unkrautkontrolle, Wurzelunkräuter

Introduction

Creeping perennial weeds can cause great yield losses in a wide range of crops. Today such weeds are usually controlled by glyphosate, selective herbicides or intensive tillage including deep ploughing. Many herbicides, including glyphosate, are, however, currently at risk of being banned. Intensive tillage has however also disadvantages related to sustainability - it can e.g. lead to increased risk for nutrient leaching and erosion in bare soil periods (ULÉN et al,. 2010; MYRBECK et al., 2012; ARONSSON et al., 2015). Integrated weed management strategies have the potential to increase the sustainability and resilience of cropping systems by creating synergistic effects between chemical and non-chemical direct control measures and crop competition, but it is a challenge to reach the same control efficacy that glyphosate offers (FOGLIATTO et al., 2020). In organic farming mechanical treatments after crop harvest are common to control couch grass (*Elymus repens* (L.). Gould) (RINGSELLE et al., 2020). Typically, couch rhizomes are targeted with below-ground tillage treatments to a depth of 10-15 cm, followed by mouldboard ploughing to a depth of 20-25 cm. Mowing is sometimes used, but often with unsatisfactory results (RINGSELLE et al., 2015). Crop competition can improve the effect of mowing (KOLBERG et al., 2018). We wanted to test if there was a synergistic effect of combining a bio-herbicide with an autumn mowing treatment since it could potentially damage couch closer to the growth point and force it to re-shoot from its rhizomes, thus providing an efficient couch control without soil disturbance in the autumn. In addition, we hypothesized that the addition of crop competition could further reduce couch grass.

Material and methods

Two field experiments were carried out on areas relatively evenly infested by couch grass– one in Norway which included combinations of bio-herbicide, mowing and cross-sowing, repeated on the same plots over two years in 2019-2021, and the other in Finland with mowing, cover crops and bio-herbicide in 2019-2020.

In Norway, a strip-plot design was established with four treatments in autumn and two competition treatments in the growing season with six replicates at a silty clay loam in Ås (59°39'N, 10°45'E). The autumn treatments were 1) untreated, 2) mowing with 5-6 cm stubble height 3) bio-herbicide and 4) combination of mowing and the bio-herbicide. Plot size of the autumn treatments was 5.5 m x 8 m. Mowing was done manually with a handheld cutter in 2019 and a tractor-mounted chopper in 2020. The bio-herbicide used shortly after mowing was pelargonic acid (product Beloukha, EC formulation, 680 g L^{-1}

pelargonic acid (PA), dose rate 16 L ha^{-1}, water with temperature c. 20°C and 200 L ha^{-1}) applied with a backpack sprayer at good weather conditions on 14.10.2019 (mean and max. daily air temperature +7.1 and +11.1°C, respectively) and 11.09.2020 (mean and max. daily air temperature +9.6 and +14.9°C, respectively) but in 2019 it was cold and a lot of rain the following days. Ploughing was performed in spring on the entire field. The competition treatments were established after spring ploughing and seed bed preparation with (i) normal sowing rate of spring cereals (2020: spring barley, 2021: spring wheat) and (ii) cross-sowing with near 50% extra sowing rate given perpendicular to the normal sowing and thereby splitting the autumn treatments in two (sub-plot 5.5 m x 4 m) (Tab. 1). Sowing was done with row spacing of 12.5 cm. Efficacy of treatments was assessed by estimating ground cover of couch grass, other main weed species and crop in autumn, in early and late spring/early summer and finally before spring cereal harvest. At final assessment shoot density of perennial weed species and dry mass of above-ground parts of couch grass, other weeds and cereal crop were also assessed (4 squares of 0.25 m^2 per plot).

Table 1 Information and dates of main operations in the experimental sites

Tabelle 1 *Informationen und Zeitpunkte der Anbaumaßnahmen auf den Versuchsfeldern*

Site	**Ås, Norway**		**Jokioinen, Finland**
Growing season	**2019-2020**	**2020-2021**	**2019-2020**
Precrop	Spring oats	-	Grasslands
Start assessment 2019	27.08 (ground cover), 23-26.09 (density, biomass)	-	10.09 (ground cover)
Mowing	14.10 (a.m.)	08.09	10.09 (a.m.)
Pelargonic acid (PA)	14.10 (p.m.)	11.09	10.09 (p.m.)
Cover crops (increased competition FIN)	-	-	Italian ryegras + oilseed radish sown 16.09
PA, spring	-	-	On border area: 05.05
Tillage	Spring ploughing	Spring plouging	No (direct drilling)
Crop and cultivar	Spring barley	Spring wheat	Spring wheat
Sowing date	19.04	27.04	26.05
Normal sowing rate	360 viable seeds m^{-2}	580 viable seeds m^{-2}	600 viable seeds m^{-2}
Cross-sowing cereals (increased competition NO)	170 viable seeds m^{-2}	250 viable seeds m^{-2}	-
Combine harvesting	26.08	25.08	-
Ground cover (NO) /efficacy estimation (FIN)	08.04, 18.05, 11.08	05.10, 25.04, 28.05, 03.08	16.09.2019, on border area: 08.05.2020
Counting and biomass	-	03-13.08	

In Finland the field experiment was carried out in a second-year grassland on sandy clay in Jokioinen (60° 48' N, 23° 28' E) and the protocol for autumn treatments was similar to Norway, except that mowing was carried out with a tractor-mounted chopper perpendicular to the other treatments. PA was sprayed on 10.09.2019 in good conditions (+23 °C, 65% RH). The plot size was 2 m x 10 m but split in 2 m x 5 m sub-plots with mowing or no-mowing before the PA treatment. The cover crops, Italian ryegrass (*Lolium multiflorum* L.) and oilseed radish (*Raphanus sativus* L.), were sown to introduce the competition element in the treatments. These catch crops failed to emerge in autumn due to late sowing on 16.09.2019. One additional PA treatment was included in spring on 05.05.2020 (+15 °C, 37% RH) before direct-sowing spring wheat. The subsequent effect of treatments in crop stand could not be assessed in 2020 because spring wheat, direct-sown 26.05.2020, failed to emergence in dry conditions. Thus, only visual observations on herbicide effects after application were conducted. The burn-down effect of PA, assessed as withering and shortening at % scale, was visually observed seven days after application in autumn 2019 and three days after spring treatment in 2020.

For each trial, ANOVA was performed using procedure 'proc mixed' (SAS INSTITUTE INC., 2002-2012) with strip-plot design. Repeated measure was included in the analyses for ground cover in Norway. For perennial weeds, assessments of ground cover, shoot density or biomass of the species in autumn 2019 were used as covariate. Transformations were used, if necessary, to fulfil ANOVA assumptions. If main effects and interactions were significant (P≤0.05), Tukey-tests were performed.

Results

In Norway the ground cover and biomass of couch grass was affected by mowing, PA and cross-sowing. The effect of the autumn treatments was more evident in the same autumn or before cereal seedbed preparation than later. The PA treatment gave 25-50% reduction in the same autumn or the subsequent spring before sowing (Tab. 2). In early summer (May) the couch grass ground cover was considerably reduced, most probably by the spring ploughing, while it regrew during summer to a considerable amount at harvest of the cereals. At harvest, only the aboveground couch biomass in 2021 was significantly reduced by the PA applied the year(s) before, while the same magnitude of reduction was obtained in 2020 on ground cover. Autumn mowing gave effects of the same magnitude as the PA treatments with 28-81% reduction in couch ground cover in autumn and early spring, and 9-25% reduction before harvest. There was no interaction between mowing and PA, which means that the effects were more additive when combined.

Table 2 Effect of pelargonic acid (PA) on ground cover during experimental period and density and above ground biomass (dry matter, DM) at final assessment of *Elymus repens* from 2020 to 2021 in Ås, Norway. Percentage of change relative to no treatment, is given and marked with * if significant

***Tabelle 2** Effekte des Einsatzes von Pelargonsäure (PA) auf den Deckungsgrad der Gemeinen Quecke in der Kulturzeit sowie auf die Dichte und oberirdische Biomasse (Trockenmasse, TM) der Gemeinen Quecke zur Endbonitur in 2020-2021. Die relative Effektänderung im Vergleich zur unbehandelten Kontrolle ist angegeben und wird bei signifikanter Effektänderung durch * markiert*

	% ground cover 2020				**% ground cover 2021**			**No. of shoots m^{-2}**	**DM, g m^{-2}**
Date	08.04	18.05	11.08	05.10	25.04	28.05	03.08	03-13.08.2021	
No PA	4.3	0.4	25.7	13.9	10.8	1.9	18.6	130	75
PA	3.2	0.9	21.9	7	5.6	1.6	19.4	141	60
% change	-25	96	-15	-50*	-49*	-16	4	8	-19*

Cross-sowing gave around 20% increase in ground cover of cereals before harvest in Norway and resulted in an 11-26% reduction in ground cover of couch grass and 35% reduction in couch above-ground biomass before cereal harvest. The number of shoots of couch grass at final assessment was not affected by the treatments mowing and PA, but only by cross-sowing with a 19% reduction. For above-ground biomass there was a significant interaction between the three types of treatments and the maximum reduction (68%) were obtained with all three treatments.

In addition to couch grass in Norway, cross-sowing also reduced ground cover and biomass of perennial sow-thistle (*Sonchus arvensis* L.) and annual weeds. *Vicia cracca* L., another abundant perennial weed species, was not influenced by any of the treatments.

In Finland, one of the main observations was that PA was poorly dissolved in water. Consequently, the herbicide spray from nozzles followed logarithmic scale with increasing concentration towards the end when the tank was draining. In all, the average control efficacy against couch grass one week after application was 31% and there was no additive effect of mowing. PA was more effective against clover plants than couch and other grass species in the grassland. Application in early spring 2020 resulted in control effect of 52% on couch grass. The burn-down effect was higher in younger plants but in general only a transient hindrance to the growth of couch grass. Therefore, crop competition should start as soon as possible to prevent early growth of couch and other weeds.

To conclude, a combined effect of all three treatments provided with the best subsequent effect against couch next summer. However, the control effect of any treatments was not at the level that could be expected with glyphosate.

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