Sektion 7: Unkrautmanagement ohne Herbizide

Section 7: Weed management without herbicides

Comparison of different cover crop mulches and extracts on inhibition of crop and weed growth

Vergleich verschiedener Zwischenfrucht-Extrakte und Mulch hinsichtlich der Wachstumshemmung von Kulturpflanzen und Unkräutern

Dominic Johannes Sturm*, Roland Gerhards

Department of Weed Science, Institute of Phytomedicine,
University of Hohenheim, Otto-Sander-Str. 5, 70599 Stuttgart, Germany
*Corresponding author, dominic_sturm@uni-hohenheim.de

DOI 10.5073/jka.2016.452.056

Abstract

Weed suppression of cover crops is a result of competition for light, space, water and nutrients and the release of allelochemicals in the soil. Two laboratory and greenhouse experiments were conducted to analyse biochemical effects of extracts and mulches of *Fagopyrum tataricum* (L.) Gaertn., *Raphanus sativus var. oleiformis* Pers. and a cover crop mixture on germination and plant growth of the crop plants maize (*Zea mays* L.) and sugar beet (*Beta vulgaris ssp. vulgaris var. altissima* Döll.) and the weeds *Chenopodium album* L., *Matricaria chamomilla* L. and *Stellaria media* (L.) Vill.. In the first experiment, aqueous cover crop extracts were applied on crop and weed seeds in germination assays. Germination rate, mean germination time and root length of crops and weeds were measured. In experiment 2, the influence of cover crop mulch on germination rate and dry weight of the test plants was determined after a period of 21 days. Significant reductions of the root length for all test plants were observed in experiment 1. Additionally, mean germination time was extended for crops and weeds by all cover crops. Germination rate and dry matter of crops and weeds were decreased significantly in experiment 2 compared to the untreated control. Root length, germination rate and mean germination time in germination tests in experiment 1 were found to be correlated with biomass of crops and weeds in experiment 2. This work reveals the important role of biochemical effects on weed suppression by cover crops.

Keywords: Allelopathy, cover crops, germination tests, mulch, weed suppression

Zusammenfassung

Die Unterdrückung von Unkräutern durch Zwischenfrüchte kann auf die hohe Konkurrenzkraft um Licht, Raum, Wasser und Nährstoffe, sowie die Abgabe von Allelochemikalien in die Umwelt zurückgeführt werden. Zwei Labor- und Gewächshaus-Versuche wurden durchgeführt, um biochemische Effekte von wässrigen Extrakten und Mulch aus *Fagopyrum tataricum* (L.) Gaertn., *Raphanus sativus var. oleiformis* Pers. und einer Zwischenfrucht-Mischung auf die Keimung und das Wachstum von Mais (*Zea mays* L.), Zuckerrübe (*Beta vulgaris ssp. vulgaris var. altissima* Döll.) und Unkräutern (*Chenopodium album* L., *Matricaria chamomilla* L., *Stellaria media* (L.) Vill.) zu untersuchen. Im ersten Experiment wurden wässrige Zwischenfrucht-Extrakte in Keimtests auf Kulturpflanzen und Unkräuter appliziert. Die Keimfähigkeit, durchschnittliche Keimdauer und Wurzellänge von Kulturpflanzen und Unkräutern wurden untersucht. In Experiment 2 wurde der Einfluss von Zwischenfrucht-Mulch auf Keimrate und Trockenmasse der Versuchspflanzen untersucht. Die Wurzellänge aller Versuchspflanzen konnte in Experiment 1 signifikant reduziert werden. Zudem wurde die durchschnittliche Keimdauer für Kulturpflanzen und Unkräuter signifikant erhöht. In Experiment 2 wurden Keimfähigkeit und Trockenmasse durch die Aussaat in Zwischenfrucht-Mulch im Vergleich zur Kontrolle signifikant verringert. Wurzellänge, Keimfähigkeit und durchschnittliche Keimdauer aus den Keimtests in Experiment 1 konnten mit der Biomasse der Kulturpflanzen und Unkräuter aus Experiment 2 korreliert werden. Diese Studie weist auf die bedeutende Rolle der biochemischen Effekte von Zwischenfrüchten zur Unkrautunterdrückung hin.

Stichwörter: Allelopathie, Keimtest, Mulch, Unkrautunterdrückung, Zwischenfrüchte

Introduction

Cultivation of cover crops enhances the sustainability in agricultural systems because of its contributions to soil fertility and crop performance (TEASDALE, 1996). Even more, benefits include reduced soil erosion and leaching of nitrate, improved composition of soil organic matter and weed control (KRUIDHOF et al., 2009). The weed suppressing ability of cover crops can be attributed to their fast emergence, early development and high competitiveness for light, water, space and nutrients (RUEDA-AYALA et al., 2015). After vegetation, winter annual cover crop residues can affect weed germination and establishment by altering the seed environment through changes in light availability (TEASDALE, 1996), soil temperature (TEASDALE and MOHLER, 1993; KRUIDHOF et al., 2009), soil moisture (TEASDALE and MOHLER, 1993) and other types of interference as allelopathy (JABRAN et al., 2015). Allelopathy is defined as any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influences the growth and development of agricultural and biological systems (REIGOSA et al., 2006). Phytotoxic compounds are introduced in the environment during active plant growth, via leachates or root exudation, or by decomposition of biomass as cover crop mulch (BERTIN et al., 2003; WEIR et al., 2004). Various cover crop species own different inhibitory potentials due to differences in morphology, physiology as well as quality and quantity of allelochemicals. Observed weed suppression of cover crops within the field were combined effects of allelopathy, competition and mulching effects. Therefore, the knowledge about the contribution of different underlying mechanisms to weed suppression is lacking, so far. The objectives of this study were to analyse if (i) different cover crop mulches and extracts affect germination, mean germination time, root length and biomass of crops and weeds; if (ii) the suppressing effects vary in between crops and weeds and if (iii) biochemical effects can be separated from mulching effects in regard to weed suppression ability of cover crops.

Materials and Methods

All experiments were conducted in 2015 with two single cover crops (*Fagopyrum tataricum* (L.) Gaertn., *Raphanus sativus* var. *oleiformis* Pers.) and a cover crop mixture (Tab. 1). The effect of cover crop treatment was tested on two crops (*Zea mays* L., *Beta vulgaris*.) and three weeds *(Chenopodium album* L., *Matricaria chamomilla* L., *Stellaria media* (L.) Vill.). The cover crops were seeded separately in six 5 L pots each, containing a soil mixture of 50% compost, 25% loam and 25% sand using recommended sowing rates (Tab. 1). All cover crops were harvested after a period of 10 weeks. Untreated control soil for experiment 2 without cover crops was prepared. All pots were irrigated daily and fertilized with 2 g N-P-K (14-7-17) every two weeks.

Experiment 1

Germination tests with aqueous cover crop extracts were conducted to evaluate their biochemical effects on crops and weeds. Fresh cover crop material was chopped and grinded into powder using liquid nitrogen. Deionized water was added to reach a concentration of 0.125 g fresh plant matter per ml H_2O. After agitation (24 h, 200 rpm) at room temperature (RT), extracts were centrifuged (4500 rpm, 10 min, RT) and poured into a Büchner funnel lined with nylon filter (1,2 µm). Deionized water was used as untreated control (0 mg ml^{-1}). 6 seeds of crop plants and 30 seeds of weeds were placed separately on filter paper in petri dishes (60 mm) and 3 ml of extract were applied. The petri dishes were sealed (Parafilm M®) and stored in a climate chamber at 12 h/12 h day/night length with temperatures of 20 °C/15 °C for a period of 10 days.

Experiment 2

Above-ground biomass of cover crops was chopped and mixed with their previous growth medium. Mulch-soil mixtures were filled in pots (12 cm^3) and 10 seeds of crops and 200 seeds of weeds were seeded separately. The pots were covered with 2 mm of the respective mulch-soil mixture and were irrigated daily.

Data collection

In experiment 1, germination rate and root length were measured after a period of 10 days. Additionally, mean germination time (MGT) was calculated after ELLIS and ROBERTS (1980). In the greenhouse experiment, germination rate was recorded and above-ground biomass of crops and weeds was harvested after a period of 21 days. Harvested biomass was washed and dried at 80 °C in a drying chamber for 48 h.

Tab. 2 Amount of seeds and sowing rate of evaluated cover crops in experiments 1 and 2.

Tab. 1 *Prozentuale Anteile und Saatstärke der untersuchten Zwischenfrüchte aus den Versuchen 1 und 2.*

Cover crop	Amount of seeds [%]	Sowing rate [kg ha^{-1}]
***Fagopyrum tataricum* (L.) Gaertn.**	100	60
***Raphanus sativus* var. *oleiformis* Pers.**	100	25
Mixture	-	45
Pisum sativum L.	32	-
Secale cereale L.	30	-
Sorghum bicolor (L.) Moench x *Sorghum halepense* (L.) Pers.	10	-
Vicia pannonica Crantz	7	-
Phacelia tanacetifolia Benth.	5	-
Trifolium incarnatum L.	4	-
Linum usitatissimum L.	4	-
Trifolium resupinatum L.	2	-
Trifolium hybridum L.	2	-
Camelina sativa L.	1	-
Guizotia abyssinica (L.f.) Cass.	1	-
Raphanus sativus var. *niger* J.Kern	1	-
Helianthus annuus L.	1	-

Statistical analysis

Data was analysed by using R version 3.1.2. All data were subjected to standard analysis of variance (ANOVA). Tukey-HSD was applied to identify treatment differences in the experiments at a significance level of $p \leq 0.05$.

Results

In experiment 1, all cover crop extracts inhibited germination and root length of crops and weeds significantly compared to the untreated control (Fig. 1). The application of cover crop extracts of *F. tataricum*, *R. sativus* and the mixture resulted in inhibitory effects on germination rate of crops (82, 87, 84%) and weeds (60, 64, 74%), respectively. Moreover, a significantly delayed germination of crop and weed seeds was observed for *F. tataricum* and *R. sativus* extracts. Over all treatments, MGT was extended from 30 to 85% for weeds and crops compared to the untreated control. Root length was reduced up to 60% and 68% for crops and weeds over all treatments, thereby *R. sativus* extracts showed the strongest inhibitory effects (75%) on weeds.

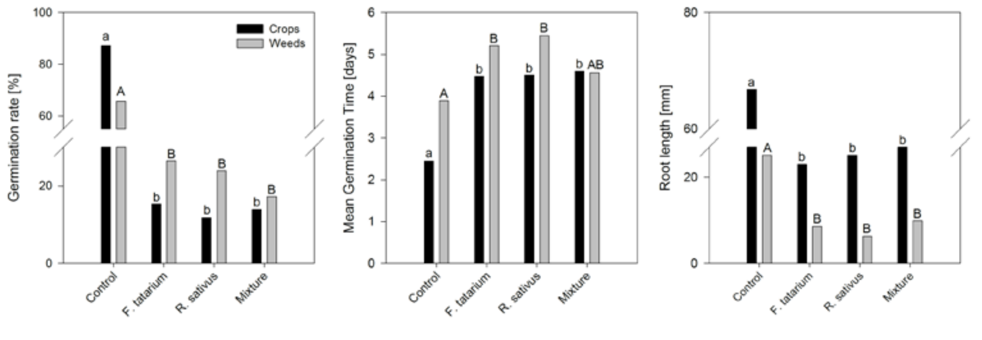

Fig. 1 Germination rate [%], mean germination time [days] and root length [mm] of crop plants and weeds after the application of different cover crop extracts (125 mg ml^{-1}) in germination assays. Means with identical letters within the table do not differ significantly (Tukey-*HSD-test*, p≤0.05).

***Abb. 1** Keimrate, durchschnittliche Keimdauer und Wurzellänge von Kulturpflanze und Unkräutern nach der Applikation verschiedener Zwischenfrucht-Extrakte (125 mg ml^{-1}) in Keimtests. Gleiche Buchstaben weisen auf keine signifikanten Unterschiede bei p≤0,05 (Tukey-HSD-Test) hin.*

The sowing of crops and weeds in mulch-soil mixtures in experiment 2 resulted in reductions of germination rate and above-ground biomass (Fig. 2). Germination rate of *Z. mays* and *S. media* was suppressed significantly (58%) by all cover crops compared to untreated control. However, no statistically significant differences over all treatments were observed for *B. vulgaris*, *C. album* and *M. chamomilla*. The mulch-soil mixtures of all cover crops led to significantly reduced biomass of *Z. mays*, *M. chamomilla* and *S. media*. Significant growth suppressions up to 31% for *B. vulgaris* and 53% for *C. album* were observed for soil-mulch mixtures of *R. sativus* and *F. tataricum* only.

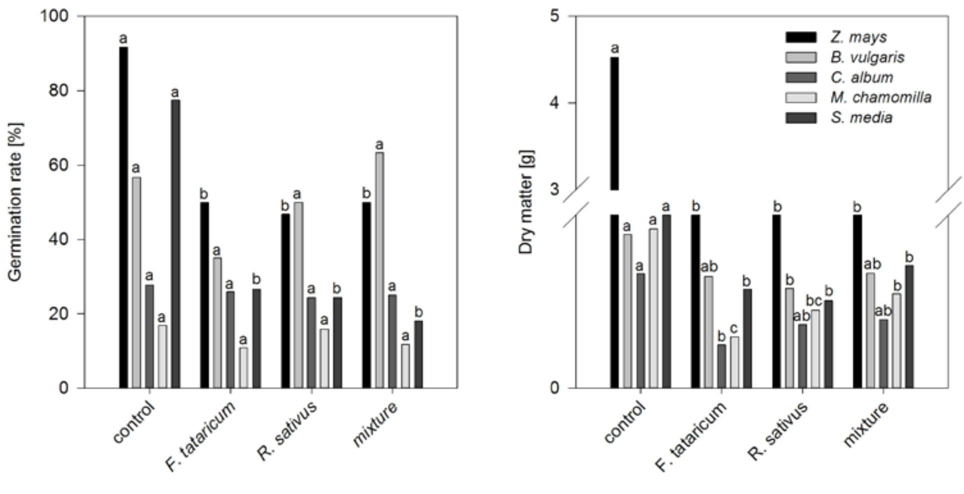

Fig. 2 Germination rate and dry matter of crops and weeds after growth in different soil-mulch-mixtures after 21 days. Means with identical letters within the table do not differ significantly (Tukey-*HSD-test*, p≤0.05).

***Abb. 2** Keimrate und Trockenmasse von Kulturpflanzen und Unkräutern nach 21 Tagen Wachstum in verschiedenen Mulch-Boden-Gemischen. Gleiche Buchstaben weisen auf keine signifikanten Unterschiede bei p≤0,05 (Tukey-HSD-Test) hin.*

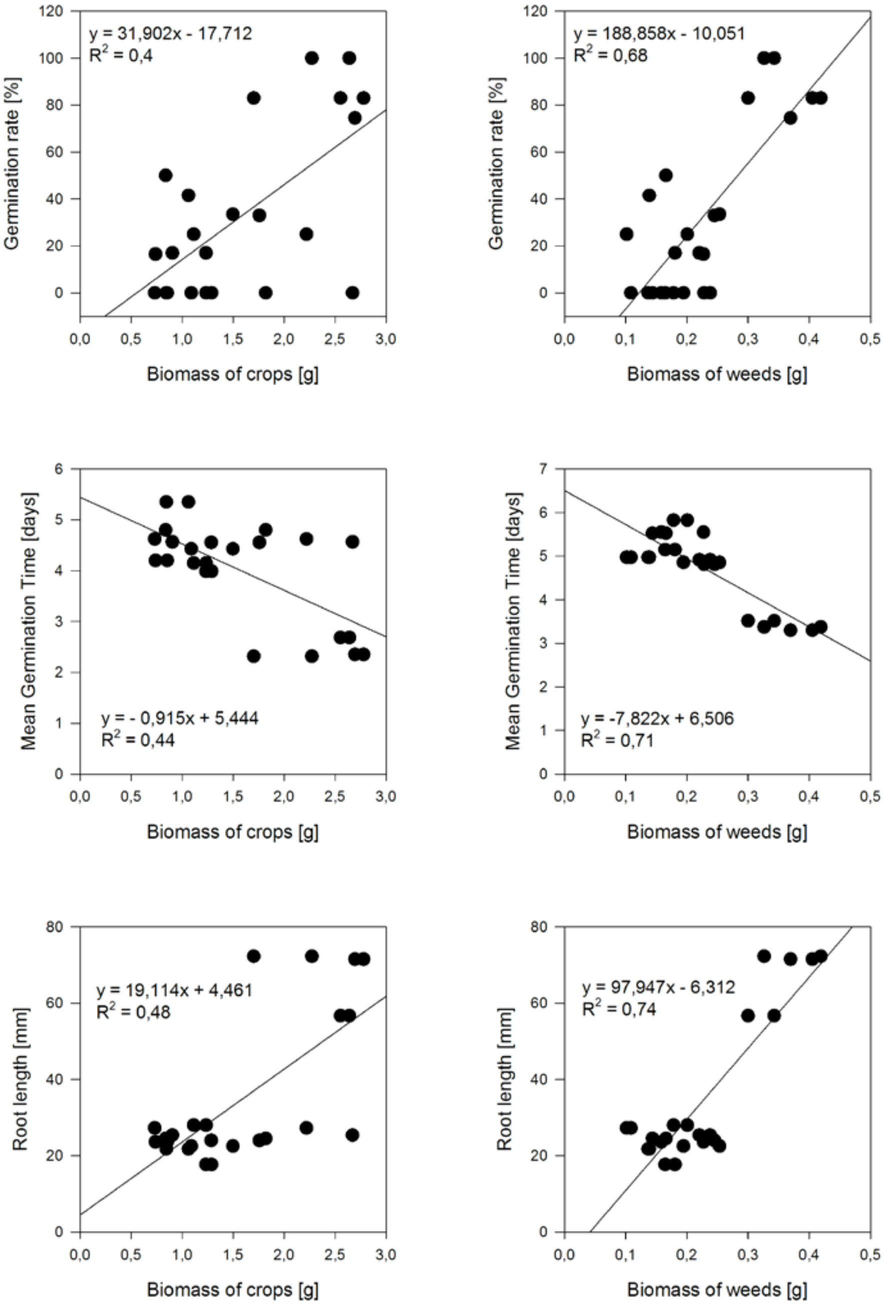

Fig. 3 Correlation between root length [mm], germination rate [%] and mean germination rate [days] in germination tests with biomass [g] in greenhouse experiments of crops and weeds.

Abb. 3 *Korrelation zwischen der Wurzellänge [mm], Keimfähigkeit [%] und durchschnittlichen Keimdauer [Tagen] aus den Keimtests mit der Biomasse [g] aus den Gewächshausversuchen von Kulturpflanzen und Unkräutern.*

Root length [mm], germination rate [%] and MGT [days] of crops and weeds in germination tests were expressed as a function of biomass [g] of crops and weeds in greenhouse experiments (Fig. 3). The comparison of the correlations results in a higher coefficient of determination for weeds in root length (R^2=0.74), germination rate (R^2=0.68) and MGT (R^2=0.71) compared to the crops.

Discussion

Over all experiments, significant inhibitions of germination rate, root length and dry matter of crops and weeds were measured. The effects were different between treatments, crops and weeds. High growth suppressing effects were found for *R. sativus* compared to the untreated control. HARAMOTO and GALLANDT (2004) reviewed the high allelopathic potential of *Brassicaceae* and indicated that the inhibition of germination and seedling growth could be attributed to the formation of isothiocyanates by hydrolysis of glucosinolates. Furthermore, an increase in germination time of 50% by the presence of methyl isothiocyanates was found for *Digitaria sanguinalis* L. in laboratory experiments (TEASDALE and TAYLORSON, 1986). The observed inhibitory effects of tartary buckwheat (*F. tataricum*) extracts and mulch could be attributed to the presence of allelopathic or phytotoxic compounds such as alkaloids, fatty acids, flavonoids and phenolic acids. Of these substances, the flavonoid rutin (quercetin-3-O-rutinoside) is believed to have the highest allelopathic activity (FALQUET et al., 2015).

Beside phytotoxic or allelopathic effects, KRUIDHOF et al. (2009) described chemical, biological and physical changes in soil and soil cover due to mulch. This can be temporary immobilization of nutrients, shifts in soil microbial populations or changes of physical soil properties, which might have influenced germination and plant growth in experiment 2 negatively. The linear relationship between root length in germination tests and crop and weed biomass in the greenhouse experiments (Fig. 3) reveal the high impact of biochemical effects on growth suppression. The smaller correlation of different crops compared to the analysed weeds can be attributed to a higher susceptibility of smaller weed seeds to extracts and residue-mediated stress (PETERSEN et al., 2001) including allelopathy. However, seeds of maize and *S. media* represented the most sensitive test plants compared to *C. album* and the small-seeded *M. chamomilla*. In addition to seed size, seed morphology and biochemical composition of the seeds can influence seed response to biotic and abiotic stresses (HARAMOTO and GALLANDT, 2004).

This study emphasizes the need of research specifically aimed at cover crops for suppressing individual weed species. Adequate cover crops or cover crop mixtures with optimum proportions of allelopathic and competitive traits could be selected for providing high weed control efficacy within the field.

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