Effects of cover crop in pure stands and in mixtures on weed control and performance of maize (*Zea mays*)

*Einfluss von Zwischenfruchtmischungen und -einzelsaaten auf Unkrautkontrolle in Mais (*Zea mays*) und dessen Ertrag*

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DOI 10.5073/jka.2020.464.065

Abstract

Pure stands of cover crops (CC) and species mixtures raise increasing consideration in agricultural production systems due to the manifold services they provide to farmers. Their contribution to weed control is one of the most obvious services. However, especially allelochemicals can affect both weeds and crop plants. We examined the carry-over effects of CC stands, pure and in mixtures, on the subsequent maize crop in terms of crop establishment speed and weed pressure in 2018. Within a field trial, 10 different CC species, as well as particular mixtures of four species with either enhanced allelopathic potential, biomass production or emergence speed as well as a mixture with all 10 species were examined. The emergence pattern of the maize crop was more heterogeneous between the pure CC stands than across the mixtures. However, the time of emergence was slightly delayed in the latter in comparison to the pure CC stands. The single CC oat, mustard and flax were able to accelerate crop emergence significantly. Rye and vetch were the most effective treatments in the reduction of weed density and coverage in June 2018. However, total maize biomass did not differ considerably between the treatments. Although designed for different purposes the mixtures performed quite uniform in regard to weed control. Additional criteria besides weed control ability should therefore be considered to create appropriate multifunctional CC mixtures.

Keywords: Cover crops, diversity, integrated weed control, maize

Abstract

Zwischenfruchtreinsaaten und Mischungen werden in landwirtschaftlichen Produktionssystemen aufgrund ihrer vielfältigen Dienstleistungen, die sie für die Landwirte erbringen, zunehmend eingesetzt. Ihr Beitrag zur Unkrautbekämpfung ist eine der offensichtlichsten Dienstleistungen. Allelopathische Substanzen der Zwischenfrüchte (ZF) können jedoch nicht nur Unkräuter, sondern auch Kulturpflanzen negativ beeinflussen. Wir haben die Auswirkungen von reinen ZF-Beständen und -Mischungen auf die nachfolgende Maiskultur im Hinblick auf die Auflaufgeschwindigkeit der Kulturpflanzen und den Unkrautdruck im Jahr 2018 untersucht. Im Rahmen eines Feldversuchs wurden 10 verschiedene ZF-Arten sowie spezielle Mischungen von vier Arten mit erhöhtem (i) allelopathischem Potenzial, (ii) Biomasseproduktion oder (iii) Auflaufgeschwindigkeit sowie (iv) eine Mischung mit allen 10 Arten untersucht. Das Auflaufverhalten des Mais war zwischen den ZF-Reinbeständen heterogener als zwischen den Mischungen. Allerdings war das Auflaufverhalten von Mais in den Mischungsvarianten im Vergleich zu den reinen ZF-Beständen etwas verzögert. Die ZF Hafer, Senf und Lein in Reinsaat konnten das Auflaufen der Kulturpflanze deutlich beschleunigen. Roggen und Wicke reduzierten im Juni 2018 die Anzahl der Unkräuter und die Unkrautdeckung sehr effektiv. Die Gesamtbiomasse des Mais unterschied sich jedoch nicht wesentlich zwischen den Behandlungen. Obwohl die Mischungen für verschiedene Zwecke konzipiert waren, zeigten sie in Bezug auf die Unkrautbekämpfung eine recht einheitliche Wirkung. Neben der Fähigkeit zur Unkrautbekämpfung sollten zusätzliche Kriterien in Betracht gezogen werden, um geeignete vielseitige ZF-Mischungen herzustellen.

Keywords: Biodiversität, Integrierte Unkrautkontrolle, Mais, Zwischenfrüchte

Introduction

Utilizing cover crops in the crop rotation is an important tool for integrated weed management. Lately cover crop mixtures are deliberately composed to enhance positive services such as N-fixation, erosion reduction and weed control and to comply with EU regulations (EU regulation No 1307/2013).

Cover crops are able to suppress weeds through several mechanisms and over a quite long time-span. In autumn, they provide weed control via competition for light, space, nutrients and water (BLANCO-CANQUI et al., 2015) and by exudating allelopathic substances into the environment (GFELLER et al., 2018). In spring, before sowing the main crop, the remaining plants are usually terminated chemically or mechanically. Plant residues can be incorporated into the soil or remain on the soil surface (CREAMER et al., 1996). In case of the latter, they constitute a physical barrier that new weeds need to penetrate (TEADALE and MOHLER, 1993). Additionally, also plant residues are able to release the remaining allelochemicals (TABAGLIO et al., 2013). After sowing the next main crop, these phytotoxic substances can still affect the weeds.

However, this might also negatively impact crop performance. Carry-over effects, like residual activities of herbicides, might inhibit crop emergence or affect the crop development. This potent nature of allelochemicals makes them ambivalent in terms of crop production.

The aim of this study was to determine if carry-over effects of single sown cover crops and mixtures are present after termination by measuring (i) the performance of the following maize crop and (ii) the resulting weed pressure.

Materials and Methods

The experiment was established on the research station "Ihinger Hof" of the University of Hohenheim (Latitude / Longitude: 48.744273° / 8.928766°). The long-term mean of temperature in this area is 8.4 °C with a mean precipitation of 738 mm. The cover crop treatments (Tab. 1) were sown on 28th August 2017 with a rotary hoe and sowing machine combination. Beside the CC, no additional weed control was applied. The control treatment was a weedy fallow with no cover crops. The experiment consisted of two adjacent field trials, both with a completely randomized block design with four repetitions and a plot size of 27 m^2 (3 m x 9 m). One field trial contained the single sown cover crops and the other trial the cover crop mixtures. Cover crops were either terminated by frost during winter or by mulching in spring and the soil was tilled afterwards with a rotary harrow on 2nd of May 2018. The maize crop was sown the same day with a seeding density of 92,300 seeds*ha^{-1} and a row distance of 0.75 m. Plots were not treated with crop protection measures (including additional weed control measures) and received mineral nitrogen fertilizer with a rate of 170 kg*ha^{-1} on the 9th May 2018.

Tab. 1 Cover crop treatments with their corresponding seeding densities and mixture compositions. Percentage of single cover crops in the mixture represent proportions (seed weight) of the respective single sown cover crops.

Tab. 1 *Zwischenfruchtbehandlungen mit ihren jeweiligen Saatstärken und Zusammensetzung der einzelnen Mischungen. Prozentangaben der einzelnen Zwischenfrüchte in den Mischungen entsprechen den jeweiligen Anteilen an den entsprechenden Reinsaaten.*

Cover crop treatment	Latin name	Mixture composition	Seeding density [kg*ha^{-1}]
Control	-	-	-
Mustard	*Sinapis alba L.*	-	25
Oilseed radish	*Raphanus sativus L.*	-	25
Phacelia	*Phacelia tanacetifolia* BENTH	-	14
Rye	*Secale cereale L.*	-	100
Vetch	*Vicia sativa L.*	-	120
Oat	*Avena strigosa* SCHREB.	-	100
Ramtil	*Guizotia abyssinica (L.F.)* CASS.	-	10
Buckwheat	*Fagopyrum esculentum* MOENCH	-	85
Red fescue	*Festuca rubra L.*	-	35
Flax	*Linum usitatissimum L.*	-	35
Allelo-Mixture		Oilseed radish (12%), rye (30%), buckwheat (35%), flax (23%)	71
Biomass-Mixture		Mustard (25%), phacelia (15%), rye (30%), buckwheat (30%)	64
Cover-Mixture		Mustard (30%), phacelia (20%), vetch (30%), buckwheat (20%)	63
NKIT-Mixture		Oat (25%), ramtil (30%), red fescue (15%), flax (30%)	44
Complete-Mixture		Mustard, Oilseed radish, phacelia, rye, vetch, oat, ramtil, buckwheat, red fescue, flax (all 10%)	55

Crop emergence was measured daily for three weeks after sowing of maize. To calculate crop emergence the emerged coleoptiles of the maize seeds were counted two times per plot on a row length of one meter. The mean of both values per plot was used for later analysis. An emergence rate of 7-8 maize plants per meter represents full emergence of the crop. Crop cover was estimated three times per plot on 15th of June 2018 with an estimation frame of 0.1 m^2. Crop biomass was assessed on 27th of June 2018 by harvesting one square meter above ground biomass of the maize plants of each plot.

Weed densities and cover were estimated three times per plot with an estimation frame of 0.1 m^2 on 15th of June 2018.

Data was analysed with the statistical software R (Version 3.4.4, R core team 2018). Weed densities, weed cover and crop cover were analyzed with the standard analysis of variance (ANOVA) and means were compared with a Tukey test ($p \leq 0.05$).

Results

Maize grown after the cover crop treatments flax, mustard and oat showed a faster emergence than the no cover crop control and the other cover crop treatments (Fig. 1). Maize emergence in all cover crop mixture treatments was delayed until 20 days after sowing, but full emergence was reached after 3-4 more days. Maize emergence after single sown cover crops started 9 days after sowing.

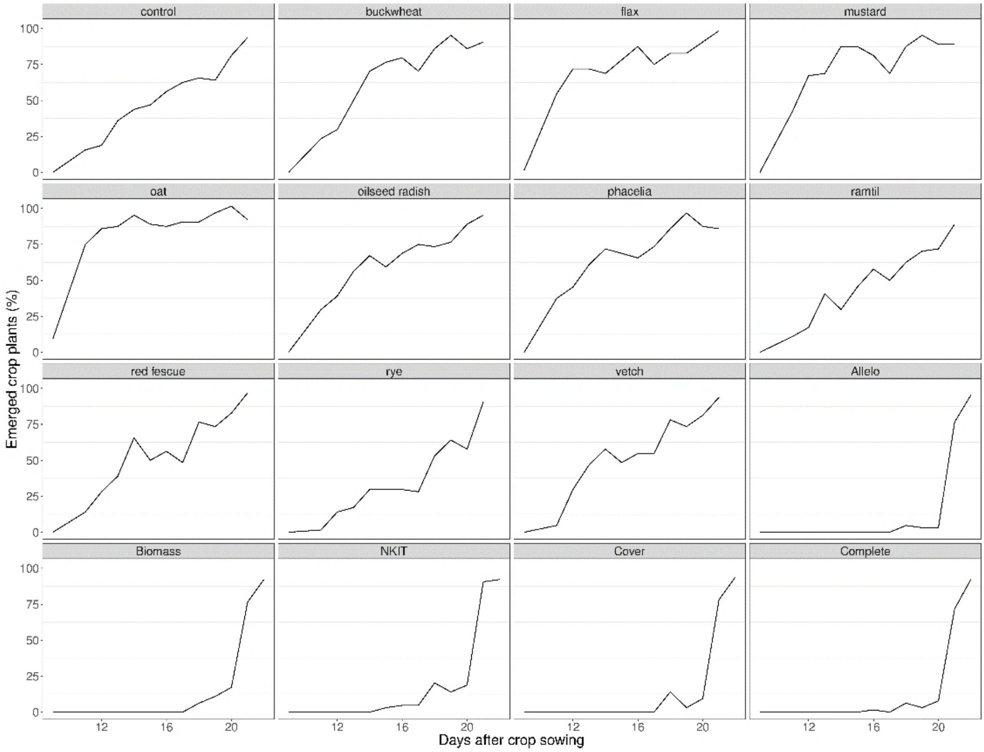

Fig. 1 Emergence of maize crop plants (%) sown after the respective cover crop treatments from 9 days after crop sowing (DAS) to 22 DAS. For cover crop mixture composition see Table 1.

Abb. 1 *Auflauf der Maispflanzen (%) nach Aussaat in die jeweiligen Zwischenfruchtbehandlungen von 9 Tagen nach Aussaat bis 22 Tagen nach Aussaat. Die Zusammensetzung der Zwischenfruchtmischungen ist in Tabelle 1 gegeben.*

Soil cover of maize was significantly higher after growing oat (71.9%). All other cover crop treatments did not differ from the control (Tab. 2). Total maize biomass (data not shown) between all treatments was not significantly different from the control in June. Weed densities and weed cover were smallest after growing rye or vetch, while the treatments NKIT and mustard showed an increase in these parameters compared to the control. The weed community in the two trials was dominated by *Chenopodium album*, *Stellaria media*, *Matricaria chamomilla* and volunteer wheat.

Tab. 2 Weed density (plants*m^{-2}) and weed soil cover (%) as well as crop soil cover (%) 45 days after sowing (corresponds to BBCH 30/31 of the maize plants). Differing letters within each column represent significant differences according to Tukey-test (p≤0.05). Small letters denote differences among the single sown cover crops and capital letters among the cover crop mixtures.

Tab. 2 *Unkrautdichte (Pflanzen*m^{-2}) und -bodenbedeckung (%), sowie Kulturpflanzendeckung (%) 45 Tage nach Aussaat des Mais (entspricht BBCH Stadium 30/31). Sich unterscheidende Buchstaben innerhalb einer Spalte zeigen signifikante Unterschiede auf Grundlage des t-Test (p≤0,05) zwischen den Behandlungen an. Großbuchstaben zeigen Unterschiede zwischen den Zwischenfruchtmischungen an und kleine Buchstaben zwischen den Reinsaaten.*

Cover crop treatment	Weeds		Crop
	Density (plants*m-2)	Soil cover (%)	Soil cover (%)
Control	90.0 abAB	41.0 abcAB	40.0 bcA
Mustard	113.8 a	47.6 a	48.1 bc
Oilseed radish	88.8 ab	43.8 ab	36.9 c
Phacelia	92.5 ab	41.3 abc	55.0 b
Rye	50.0 c	19.9 c	37.5 c
Vetch	70.0 bc	24.0 bc	38.8 c
Oat	88.8 ab	47.8 a	71.9 a
Ramtil	92.5 ab	39.3 abc	34.4 c
Buckwheat	70.0 bc	36.4 abc	36.9 c
Red fescue	76.3 abc	44.4 ab	38.1 c
Flax	73.5 bc	36.7 abc	47.5 bc
Allelo-Mixture	91.3 AB	29.1 B	38.8 A
Biomass-Mixture	80.0 AB	30.5 AB	38.8 A
Cover-Mixture	73.8 AB	28.6 B	31.9 A
NKIT-Mixture	118.8 A	46.7 A	41.3 A
Complete-Mixture	93.8 AB	38.0 AB	40.0 A

Discussion

Among the single sown cover crops especially oat showed long-term positive effects on maize by accelerating emergence and facilitating growth, which was indicated by a higher soil cover of the crop. However, weeds were not negatively affected by oat. Other oat species like *Avena fatua* and *Avena sativa* are known to produce the allelochemical Scopoletin along with other potential allelochemicals (FAY and DUKE, 1977, BELZ, 2007). If xenobiotics are taken up by plants in low concentrations they can invoke growth stimulation (hormesis) (BELZ, 2007). This effect was also observed for oat by NARVAL (2002) and might explain the positive effects on the maize plant emergence and development. Flax and mustard also exhibited stimulating effects on the crop emergence, but later no positive effects on weeds or crop plants were determined. Rye also belongs to the family of Poaceae and is known to produce benzoxazinoids. The degradation products of benzoxazinoids can exert quite long-lasting phytotoxic effects (BELZ, 2007). This might explain the slow emergence and low soil cover of the crop plants and the significant reduction of weed density and weed soil cover. The effects of allelochemicals are highly dependent on weather conditions, agronomic measures and amount of biomass, that actually contains allelochemicals (BELZ, 2007).

The cover crop mixtures showed no significant differences compared to the control in terms of weed control and crop facilitation. Emergence of the maize crop was even delayed in comparison to the single sown cover crops. This effect might be attributed to a more compacted soil, that was probably present at the location of the mixture trial, in opposition to the soil structure in the single sown cover crop trial. However, maize plants were able to compensate the delay in emergence until June. Cover crop mixtures provided no facilitation for the maize plants and showed no effects on the weeds. As cover crop mixtures are not solely composed to provide weed control, other aspects like N-fixation (HARTWIG and AMMON, 2002) or control of pests (FOURIE et al., 2016) might positively influence the following crop.

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