Crop yield following barley, ryegrass ley, or a ryegrass-clover mixture in crop rotations

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Abstract

How type and duration of leys affect carryover nitrogen to following crops is still poorly quantified. We established ten crop rotations to compare effects of: (1) leys during 18 or 30 months; (2) legumes, either as clover in leys or as grain legume; and (3) improved soil cover by catch crops. We assess effects on the yield and N nutrition of the crops, as well as on the N efficiency of the entire crop rotation. At this mid-stage of the experiment, we compare the effects of a perennial ryegrass-red clover mixture, a pure ryegrass ley, a barley-catch crop and a barley-fallow sequence on the yield of following spring wheat and pea crops. The leys and the barley were established in autumn 2020. In early spring 2022, stands were terminated to plant either wheat or peas. Wheat yield following grass-clover ley was on average 46% larger than following barley or pure grass. Pure grass did not benefit wheat yield compared to barley. After a single catch crop period, the effect of improved soil cover was trending beneficial for both peas and wheat, but differences were not significant. We conclude from these preliminary results that grass-clover is a clearly superior preceding crop for spring wheat compared to pure grass or barley.

Keywords: legacy effect, carryover nitrogen, legumes, yield benefits

Introduction

Improving nitrogen (N) efficiency of crop rotations is key to reducing agricultural inputs. Recent research demonstrated that inclusion of pure grass leys into crop rotations provides several benefits (Hoeffner *et al.*, 2021), but to be productive such leys require substantial N fertilizer applications. Grass-legume mixtures incorporate large amounts of N into the system through symbiotic N_2 fixation and may be superior to pure grass leys in terms of carryover nitrogen (N) to the following crop (Fox *et al.*, 2020). In addition, benefits of leys might be derived from the absence of tillage for often two or three years, improved soil cover and positive effects on soil humus content (Guillaume *et al.*, 2022). Nevertheless, the amount of residual N delivered to the following crop remains difficult to predict, and the effect of ley duration is largely unexplored. Moreover, direct comparison with rotations lacking leys but optimising soil cover with catch crops and using grain legume is lacking. The objective of this study is to compare the effects of incorporating: (1) leys during 18 or 30 months; (2) legumes, either as clover in leys or as grain legume; and (3) catch crops to improve soil cover, on the yield and N nutrition of the following crops, as well as on the N efficiency of the entire crop rotations. At the current stage of this ongoing experiment, we compare effects of the preceding crops (pure grass leys, grass-clover leys, and winter barley) with subsequent fallow or a catch crop (phacelia) on grain yields of the following crops spring wheat or peas (treatments 1 to 6, Crop 22, Table 1).

Materials and methods

A field experiment was set up with 10 rotations differing in three factors: (1) duration of ley; (2) presence of legumes, either as clover in the ley or as a pea crop; and (3) continuity of soil cover (Table 1). Plots (4.5×6.5 m) were established near Zürich-Reckenholz (490 m a.s.l) in autumn 2020 on a eutric cambisol, arranged according to a randomized complete block design with five replicates. The field was uniformly used for a wheat crop prior to establishment of the experiment. Pure grass was *Lolium perenne* and grass-clover leys consisted of *L. perenne* and *Trifolium pratense*. Clover proportion in the grass-clover leys was 65% on average across 2021, assessed by sorting three of the five harvests. The leys (treatments 5 & 6,

Table 1) were destroyed chemically in February 2022 and spring wheat and pea crops sown in early March after minimal tilling. Nitrogen fertilization was as follows: barley and wheat: 100 kg N ha^{-1}; pure grass: 250 kg N ha^{-1} $year^{-1}$; grass-clover: 100 kg N ha^{-1} $year^{-1}$. Peas and catch crops were not N fertilized. All plots received P and K in non-limiting amounts for crop growth. Yields were measured on the central 1.5×6.5 m of each plot. Data were analysed by analysis of variance, and differences between treatments were tested post-hoc using Tukey's multiple comparison test.

Results and discussion

Grain yields in 2022 were significantly affected by the identity of the previous crop (ANOVA: $F_{5,24}$=10.1, P<0.001). On average, pea crops had 1.2 t ha^{-1} higher grain yields than wheat (Figure 1). While the yield of the N_2-fixing crop (pea) was as expected under Swiss conditions, wheat yield following barley and pure grass was clearly below average (Richner and Sinaj, 2017). This indicates that N availability to wheat was limiting in these treatments. In contrast, wheat following grass-clover ley had yields as high as pea and significantly higher than following barley or pure grass (+46%, Figure 1), demonstrating a distinct yield advantage through a legacy effect of the presence of legumes in the previous crop. This strong legacy effect was most probably due to residual N from the N_2-fixing activity of the grass-clover ley (Fox *et al.*, 2020). Plant analyses and the use of ^{15}N labelled fertilizer will allow us to assess how much N from non-fertilizer sources was taken up by the crops. Wheat yield following the 18-month old pure grass ley did not significantly differ from wheat yield following barley (Figure 1). Pure grass leys may increase soil humus content and therefore soil N content as compared to crops (Crème *et al.*, 2018; Hoeffner *et al.*, 2021), but at this intermediate stage of the experiment, the duration of the ley was probably too short for such an effect to occur. Moreover, we observed a poorer root and stubble decomposition of the pure grass ley compared to barley and the grass-clover ley, which might have affected N dynamics and impaired wheat establishment. Regarding the effect of soil cover, pea and wheat following barley with catch crop had 0.4 t ha^{-1} higher yields (on average) than when following barley with fallow; the effect, however, was not significant (Figure 1). Further results from this experiment will provide insights into the processes involved in N legacy effects within crop rotations: plant N content is being analysed to determine the nutritional status of the crops and ^{15}N labelled fertilizer is applied on a subplot to determine fertilizer N capture. In addition, the effects of ley duration will be tested.

Table 1. Factor levels and crop rotation in the 10 treatments.[1]

	Over whole experiment			Crop sequence to date				Forthcoming	
Treat. #	Duration of ley[2]	Legume presence	Soil cover	Winter 2020-2021	Crop 2021	Winter 2021-2022	Crop 2022	Winter 2022-2023	Crop 2023
1	0	–	–	Barley		Fallow	Wheat	Fallow	Barley
2	0	+	–	Barley		Fallow	Pea	Fallow	Barley
3	0	–	+	Barley		Catch crop	Wheat	Catch crop	Barley
4	0	+	+	Barley		Catch crop	Pea	Catch crop	Barley
5	18 m.	–	+	Pure grass			Wheat	Catch crop	Barley
6	18 m.	+	+	Grass-clover			Wheat	Catch crop	Barley
7	18 m.	–	+	Barley		Pure grass			Barley
8	18 m.	+	+	Barley		Grass-clover			Barley
9	30 m.	–	+	Pure grass					Barley
10	30 m.	+	+	Grass-clover					Barley

[1] Grey shaded cells indicate the crops for which results are shown in this article.

[2] m. = months.

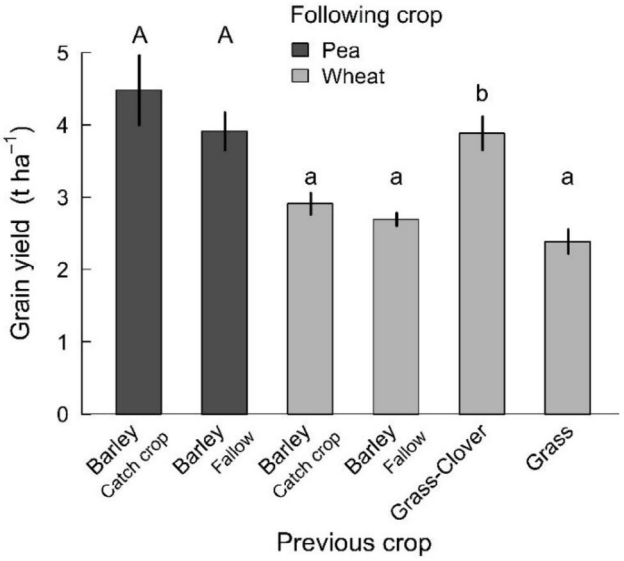

Figure 1. Grain yield of pea and wheat as affected by six previous crops differing in the presence of legumes and soil cover. Different letters indicate a difference at $P \leq 0.05$ (Tukey's multiple comparison test within each following crop; Pea: upper case, Wheat: lower case). Shown are means of 5 replicates ± standard error of the mean.

Conclusions

This ongoing experiment highlights the benefit of an 18-month period of grass-clover ley with a clover proportion of about two-thirds on the grain yield of the following crop in sparingly fertilized rotations. This short period of time was not sufficient for pure grass leys or enhanced soil cover by catch crop to have significant effects on the grain yield of the following crop. The next experimental year will allow us to test for a longer period and broaden the options for treatment comparisons.

References

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