Management of perennial weeds and nitrogen leaching in arable cropping systems

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Abstract

A crop rotation experiment was established in 1997 at three locations representing different soil types and climates. Three factors were tested: crop rotation, catch crop and manure. Catch crop reduced nitrate leaching, but prohibited stubble cultivation. The use of catch crops resulted in increased levels of perennial weeds (*E. repens*) at one location, while at another; the level of *C. arvense* was not affected by catch crops, when compared with the use of stubble cultivation. Management of perennial weeds should include considerations of where in a crop rotation to use stubble cultivation, and this should preferably not be after a pulse crop. Catch crops are a more profitable way to manage *C. arvense* than stubble cultivations.

Keywords: crop rotation, catch crop, nitrate leaching, perennial weeds, stubble cultivation

Introduction

In Denmark, perennial weeds such as *Elymus repens* L. Gould and *Cirsium arvense* L. are traditionally controlled by stubble cultivation in the autumn after harvest of a cereal or pulse crop. When the weed no longer reappears after stubble cultivation, or soil or weather conditions prohibit the cultivations, the field is ploughed either in late autumn/early winter on heavier soils or in spring prior to sowing of spring crops on lighter soils. Carrying out cultivation during autumn prohibits growing a catch crop. Since autumn and winter is the time of excess precipitation, cultivation may lead to higher risks of nutrient leaching. Contrary to this, when a catch crop is grown, nutrients are retained within the topsoil by being incorporated in the biomass of the catch crop. If the catch crop is a leguminous species, N_2-fixation can further increase the N supply for the next crop. Thus catch crops will both reduce N leaching and increase yields of the following crops. Therefore, mechanical control of perennial weeds may have negative effects for the N supply in the crop rotation. The aim of this study was to clarify the effects of catch crops on the development of perennial weeds and the N leaching at two sites under different climatic and soil conditions.

Materials and methods

A crop rotation experiment was initiated in 1996/97 at three sites in Denmark representing different soil types and climates: a coarse sand at Jyndevad, a loamy sand at Foulum and a sandy loam at Flakkebjerg. Average precipitation was 964, 704 and 626 mm at Jyndevad, Foulum and Flakkebjerg, respectively (Olesen et al., 2000). The following experimental factors were included in a factorial design with two replicates and all crops in the rotations were represented every year: i) crop rotation, with different proportions of N2-fixing crops, ii) with (+CC) and without catch crop (-CC), and iii) with (+M) and without animal manure (-M) applied as slurry. Different four-year crop rotations were compared in the experiment (Table 1), and two courses of the rotations were completed in 2004 (Olesen et al., 2000, 2002). The

Table 1. The crop rotations are carried out with the treatments: without catch crops (-CC), with catch crops (+CC) in combination with the treatments: without manure (-M) and with manure (+M). The crops undersown with catch crops and the manure application rates (kg NH_4-N/ha) are indicated.":" indicates undersown ley, "/" indicates intercropping.

	Rotation 1 (R1)	+ CC	+ M	Rotation 2 (R2)	+ CC	+ M	Rotation 4 (R4)	+ CC	+M
First course 1997-2000	Spring barley:ley Grass-clover		50	Spring barley:ley Grass clover		50	Oats	+	40
							Winter wheat	+	70
	Spring wheat	+	50	Winter wheat	+	50	Winter cereal	+	70
	Lupin	+		Pea/barley	+		Pea/barley	+	
Second course 2001-2004	Spring barley:ley Grass-clover		50	Spring barley:ley Grass-clover		50	Winter wheat	+	50
							Oats	+	50
	Oats	+	30	Winter cereal	+	50	Spring barley	+	50
	Pea/barley	+		Lupin/barley	+		Lupin/barley*		
Sites	Jyndevad			Jyndevad Foulum Flakkebjerg			Foulum Flakkebjerg		

+CC: + = catch crops in +CC treatments +M: 30-70 = kg ammonium-N/ha in +M treatments
*: Pure lupin at Foulum

plots receiving manure were supplied with anaerobically stored slurry at rates where the NH_4-N amount corresponded to 40% of the N demand of the specific rotation based on a Danish national standard. The N demands for grass-clover, pea/barley and lupin or lupin/barley were set to zero. The target rates for application are shown in Table 1. All cereal and pulse crops were harvested at maturity. The grass-clover was used solely as a green manure crop, and the cuttings were left on the ground. All straw was left in the field. The crops were irrigated at one site (Jyndevad).

Weed harrowing and row hoeing were used to control annual weeds. A reduced effort was used in the treatments with catch crops. Perennial weeds were primarily controlled by stubble cultivation in autumn after cereal and pulse crops without catch crops. *C. arvense* plants were pulled out in all plots at the time of budding, which coincided with anthesis of the cereals. At Flakkebjerg in 2000 to 2002, winter wheat was row hoed in the –CC treatments to control *C. arvense*.

Nitrate leaching was measured using ceramic suction cells installed at 0.8 m depth (Jyndevad) and at 1.0 m depth (Foulum and Flakkebjerg) in selected plots. *C. arvense* above-ground shoots were counted and weighed (fresh weight) in the whole plot at the time of anthesis of the cereals. Shoots of *E. repens* that extended above the crop were counted in five 0.1 m^2 areas in the same crops two weeks later.

Results

The nitrate leaching losses were largest at Jyndevad and least at Flakkebjerg ($p<0.001$) (Table 2). Catch crops reduced nitrate leaching in both rotations at Jyndevad and in rotation 2 at Foulum. The same tendency was seen in rotation 2 at Flakkebjerg ($p=0.09$). At Jyndevad, in six combinations of crop and year, stubble cultivation for control of *E. repens* was carried out in one of the two –CC/+M replicates only due to differences in infestation with *E. repens*. This allowed for a comparison of nitrate leaching between +CC plots, - CC plots without

Table 2. Effect of crop rotation and catch crop on nitrate leaching (kg NO_3-N ha^{-1} yr^{-1}) at the three experimental sites. Values with the same letter within a row are not significantly different (P<0.05) (Askegaard et al. 2005).

Site	Rotation 1		Rotation 2		Rotation 4	
	– CC	+ CC	– CC	+ CC	– CC	+ CC
Jyndevad	106 [a]	56 [b]	104 [a]	65 [b]		
Foulum			54 [a]	38 [b]	37 [b]	39 [b]
Flakkebjerg			35 [a]	26 [a]	29 [a]	28 [a]

stubble cultivation and –CC with stubble cultivation. Stubble cultivation after pulses (lupin and pea/barley) in the –CC plots doubled the nitrate leaching compared with no harrowing. After cereals there was no effect of stubble cultivation on nitrate leaching (Askegaard et al. 2005).

At Jyndevad, the *E. repens* infestation developed into a problem during the first few years; in several cases more than 100 shoots m^{-2} were found in plots. Stubble cultivations decreased *E. repens* infestations (Fig. 1).

At Flakkebjerg, there was a lower infestation of *C. arvense* in rotation 2 than in rotation 4, with least biomass in the crop the year after grass-clover. There was no significant difference between the biomass of *C. arvense* in –CC and +CC treatments (Fig. 2), in spite of the fact that stubble cultivations and row hoeing were carried out in the –CC and not in the +CC treatments.

Discussion

The experiment has demonstrated that there are interactions between effects of management factors such as catch crop and stubble cultivation on nitrate leaching and perennial weeds. Nitrate leaching was reduced by use of catch crops at the sandy soil and in the rotation with grass clover also at the other two sites. Stubble cultivation after pulse crops doubled the nitrate leaching compared to no stubble cultivation and no catch crop. Management of perennial weeds should include considerations of where in a crop rotation to use stubble cultivation, and this should preferably not be after a pulse crop.

In spite of the high level of *E. repens* infestations in the +CC treatments at Jyndevad, the mean of cereal and pulse yields where higher in the +CC than in the –CC treatments, probably because of an improved nutrient supply. This difference decreased from the 1st to the 2nd course, probably partly caused by the *E. repens* infestation. Stubble cultivations to control *E. repens* might not always be profitable on sandy soils, but knowledge is lacking to decide when it is necessary.

The reason why *C. arvense* biomass was the same with and without catch crops was most likely because the nutrients retained in the topsoil by the catch crops benefited the crops, which became more competitive against the weeds. Without catch crops, stubble cultivation and row hoeing decreased *C. arvense*, but also made more nutrients available for the weed, making it more competitive against the crop. There was a yield increase in the +CC treatment in rotation 4 at Flakkebjerg, probably due to the increased nutrient availability to the crop. Thus it seems that catch crops are a more profitable way to manage *C. arvense* than stubble cultivations.

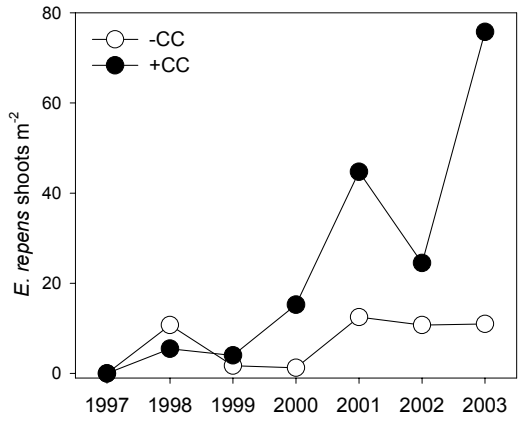

Figure 1. Development in number of *E. repens* shoots m^{-2} in spring barley at Jyndevad in the –CC treatment, which received stubble cultivations in most of the previous crops, and the +CC treatments, which were not stubble cultivated except after pulses in 2001. Mean of rotations and manure treatments.

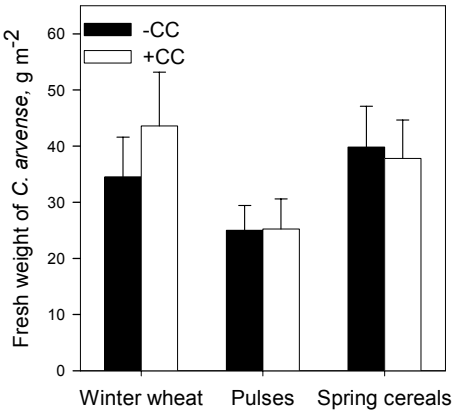

Figure 2. Fresh weight m^{-2} of *C. arvense* in different crops at Flakkebjerg without (-CC), which received stubble cultivations in most of the previous crops or with (+CC) catch crops, which were not stubble cultivated. Mean of 1999-2003, rotations and manure treatments. Bars indicate standard errors.

Conclusion

The interactions between different management tools are not always possible to predict. In this experiment, yield gains from catch crops were obtained in spite of problems with perennial weeds. Results from long-term experiments make it possible to understand and explain some of these interactions, and to point out new areas of research. Management of perennial weeds should include considerations of where in a crop rotation to use stubble cultivation, and this should preferably not be after a pulse crop.Thus it seems that catch crops are a more profitable way to manage *C. arvense* than stubble cultivations.

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