New optimized technique for mechanical control of *Elymus repens*

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Abstract

Elymus repens (coach grass) is traditionally controlled by repeated and prolonged stubble cultivation. However, the efficacy is strongly depending on weather and secondly on the exposure of rhizomes. The shorter the required period of cultivation stays the more compliance with the objective in organic farming where farmers aim at minimizing leaching of nutrients by keeping the soil plant-covered during autumn and winter.

Effective technique and strategies for uprooting, exposing and destroying *Elymus repens* are needed. In a Danish organic research project the focus is on technological solutions for uprooting, exposing and destroying of the rhizomes within a short time span. Machines of standard type, modified machines and machines constructed for other purposes have been studied.

The results show that it is difficult to achieve a high percentage of uprooting when using machines giving a high area capacity, e.g. spring loaded tine cultivator and rigid tine cultivator with modified spike discs at the rear.

Keywords: Weed control, organic farming, machine technique, *Elymus repens*.

1. Introduction

Perennial weeds, especially *Elymus repens*, is a problem in organic crop production. How the problem can be solved depends on crop species and the cropping system, e.g. dairy farming, exclusively plant production, crop rotation use of catch crops etc. (Bond & Grundy, 2001; Rasmussen et al., 2005).

Elymus repens is traditional controlled by repeated and prolonged stubble cultivation. However, the efficacy is strongly depending on weather. Exposing the rhizomes will not necessarily kill them in the humid autumn climate of e.g. Scandinavia. Furthermore this method conflicts with the objective in organic farming to retrain nutrients in the upper soil layer by keeping the soil plant-covered during autumn and winter (Melander, 2008). Post-harvest tillage may lead to leaching of nutrients, particularly nitrogen, which is strongly needed in the cropping systems (Olesen et al., 2007).

To retain nutrients in the soil catch crops sown after harvest or autumn sown crops are used, but thereby the opportunities for post-harvest tillage is limited (Rasmussen et al., 2005). These conflicting interests may force the grower to prioritize between optimal nutrient management and optimal management of perennial weeds.

To meet the need of effective technique and strategies for uprooting, exposing and destroying *Elymus repens* within a short time span, and thereby give possibilities for plant cover during autumn and winter a Danish research project has been started. The project is entitled: *Effective control of perennial weeds and intra-row weeds in organic cropping through novel technology and new management strategies* (www.weeds.elr.dk.uk).

This paper will focus on the results concerning high speed and high capacity solutions for uprooting and exposure of *Elymus repens* rhizomes. A new innovative technique has been tested and compared with existing stubble cultivator technique.

2. Materials and methods

Rigid tine cultivator and spike discs

A LEMKEN Smaragd rigid tine cultivator with two rows of tines with wing shares followed by angled and hollow discs in staggered formation and straw harrow for levelling, and at back, a tube roller for reconsolidation and depth control (LEMKEN GmbH & Co. KG., Alpen, Germany) was used. The rigid tine cultivator was in the field experiments used prior to the treatment with the developed spike discs. A CAD drawing of the spike discs are shown in figure 1.

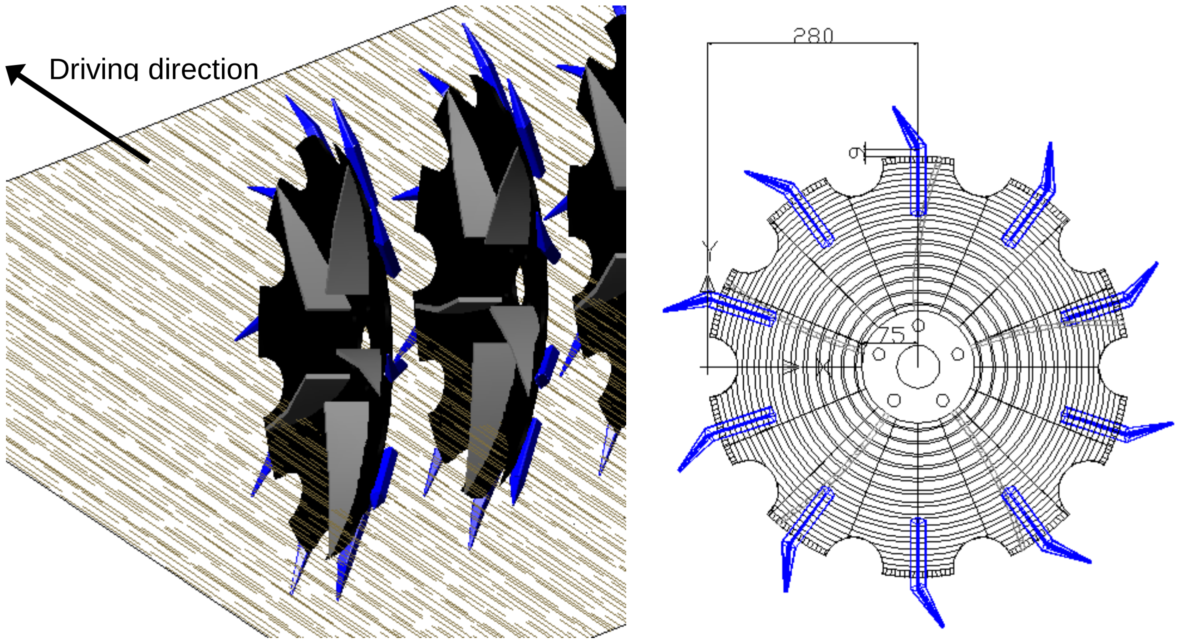

Fig 1: CAD diagrams of the developed spike tine disc for uprooting rhizomes of Elymus repens.

The theoretical background for the concave discs with spike tines and shovels mounted inside is to intercept underground rhizomes and pull them to the surface by means of disc rotation and soil movement and releasing the rhizomes as they fall on top of the cultivated soil. Figure 2 shows the effect of mounting the spike tines and shovels inside concave discs when comparing to the first row of standard concave discs on the disc cultivator.

Fig 2: Spike disc cultivation. 1) row of standard concave discs, 2) row of spike discs.

A row of the constructed spike discs was supposed to be mounted behind the roller on the tine cultivator. Due to limiting time before the field experiments, the spike discs were not moved from the disc harrow to the tine cultivator. In the field experiments the plots were cultivated first with the rigid tine cultivator followed by an additional treatment with the disc harrow.

S-tine cultivator

A MARSk STIG Uniflex 8000 with 37 spring loaded S-tines distributed on 4 rows on a 7.25 m working width was used (MARSK STIG, Slagelse, Denmark). Eight wheels ensured depth control and a straw harrow at the rear for levelling the cultivated soil. The S-tine harrow and the widely accepted tine shape for uprooting rhizomes of *Elymus repens* is shown in figure 3.

Fig 3: The spring loaded S-tine cultivator. A close up of the shape of the S-tines are displayed to the right (MARSK STIG Model 8).

Field experiments

The focus of the field experiments was on high speed and high capacity solutions for uprooting and exposing of rhizomes of *Elymus repens*. The conducted field experiments also consisted of low speed and low capacity solutions, but with theoretically more efficient uprooting, separation, and exposing of rhizomes from the upper 150 mm soil layer.

Six different implements for uprooting and exposing *Elymus repens* rhizomes was studied in a field experiment at Jyndevad Research Station (54°53' 46", +9°7' 25"). The soil is coarse sand. The used machines were a rotary cultivator with Dutchi wide wing shares in front (Howard/Kongskilde Rotalabor), rigid tine cultivator and rotary tiller (Kvik-Up harrow), rigid tine cultivator and rotary tiller (Kvik-Killer), and a beach cleaner (Beach-Tech 2800).

In table 1 the different treatments and basic machine settings for the high speed and high capacity solutions are listed.

Table 1. Treatments and machine settings

Treatment no.	Treatment/Machine	Forward speed [km/h]	No. of treat-ments	Working depth [m]
1.	Untreated			
2.	Spring loaded S-tine cultivator	9.2	2	0.15
3.	Rigid tine cultivator with spike discs	8.8	1[a)]	0.20

[a)] The treatments consisted of one operation with the rigid tine cultivator and one operation with the disc harrow with spike discs, but should be regarded as one single treatment referring to the idea of having the spike discs as part of the cultivator.

The field experiments were carried out in a full randomised block design with four replications. An untreated block was included in the test design. The experimental field and all the plots were heavily infected with *Elymus repens*. Prior to the test, the field had been grown with spring barley. The experiment was carried out the September 2nd, 2008 shortly after the harvest of the grain crop.

The size of the plots for the rigid tine cultivator with spike discs was 3 meter wide and 20 meter long. Due to the cross harrowing approach for the spring loaded S-tine harrow, the plots were extrended to 9 meter wide and 20 meter long.

The amount of *Elymus repens* rhizomes was determined in two random chosen 0.5 x 0.5 meter plots in every test site after cultivation. First all above ground rhizomes was collected within a 0.5 x 0.5 m iron frame and bagged for subsequent dry matter measurements. After that, all rhizomes below soil surface to a depth of 0.25 meter was dogged out and collected within the 0.5 x 0.5 m iron frame. By drying out the samples in a heating oven, the amount of above and below ground content of rhizome dry matter was calculated.

The number of rhizomes on soil surface was counted by placing a string at three random locations along the parcel. Every rhizome which touched the line were counted and divided into two factions: those which were completely exposed and those where a smaller or larger part of rhizome was covered with soil. Since the string was 1 m long, a total measure of 3 m line in each plot was done. Finally, 10 randomly collected rhizomes from the soil surface of each plot were used to determine the length and number of buds on the rhizomes.

One week after treatment, two digital images covering an area of 0.5 x 0.5 m were captured per plot at random locations. Leaf cover was determined one week after treatments by use of image analysis. Leaf cover is the proportion of pixels in digital images determined to be green. A leaf cover index of 0.1 specifies that 10% of the pixels were determined to be green. Weed soil cover was deduced from leaf cover estimates. The main components of the image capture standard and the image analysis procedure are not outlined in this paper. Based on Rasmussen et al. (2007) it was considered that objective assessments of weed soil cover was practicable.

Fig 4: The amount of Elymus Repens rhizomes below and above soil surface was determined by collecting all rhizomes within 0.5 x 0.5 meter plots. (Photo: Henning C. Thomsen, Jyndevad Resarch Station)

Statistical analyses

The rhizome dry weight data from the field experiments were transformed into relative units (above ground rhizomes dry weight/below + above ground rhizomes) to compare the performance of the treatments. All statistical analyses were performed with the free statistical software package R (www.r-project.org).

3. Results

The total rhizome dry matter weight ranged between 18 and 212 g per ¼ m^2 in the untreated plots, and between 97 and 252 g per ¼ m^2 in the plots treated with the S-tine cultivator and between 133 and 254 g per ¼ m^2 in the plots treated with rigid tine cultivator with spike discs. The variation of infestation of *Elymus repens* over the experimental site was in general low, but a few plots located at one end of the site had lower dry matter contents. This also explains the large range of rhizome dry weights observed for the untreated plots as two untreated plots were located at the low *Elymus repens* infestation area.

As a result of the expected spatial variation of *Elymus repens* distribution over the experimental site, the dry weight data was transformed into a ratio between the exposed rhizome dry weight and the total dry weight of rhizome at individual plots. The mean and standard deviation (SD) of the ratios are shown in Table 2.

Table 2. Uprooting and exposure results of field experiments presented as the ratio between above ground rhizomes dry weight and total rhizomes dry weight.

Treatment no.	Treatment/Machine	Rhizome uprooting and exposure ratio	
		Mean	(SD)
2.	Spring loaded S-tine cultivator	0.083	(0.030)
3.	Rigid tine cultivator with spike discs	0.064	(0.017)

LSD = 0.0209, Turkeys *t*-test.

The statistical analysis of the rhizome uprooting and exposure ratios showed no significant block effects and no significant difference between treatments. However, the visual field observations of the soil surface left after treatments with the rigid tine cultivator with spike discs showed a more even distribution of the rhizomes, i.e. no large and lumpy batches of rhizomes as observed after treatment with the S-tine cultivator. The SD of rhizome uprooting and exposure ratio for the rigid tine cultivator with spike discs was lower compared to the one of S-tine cultivator, which supports the visual impression of more even distribution of rhizomes on soil surface over the plot area.

The coverage of green weed material achieved by the treatments is shown in table 3.

Table 3. Image analyse of soil surface after treatment. Index of weed soil cover.

Treatment no.	Treatment/Machine	Weed soil cover	
		Mean	(SD)
2.	Spring loaded S-tine cultivator	0,946	0,019
3.	Rigid tine cultivator with spike discs	0,979	0,007

The statistical analysis of weed soil cover showed no significant block effects, but significant difference between treatments. The visual observations also confirmed the better coverage of leaves of *Elymus repens* and broad leaved weeds obtained with treatment of rigid tine cultivator with spike discs (Fig. 5). In weed science terminology, a fully coverage of leaves provides in general the best control effect. However, due to the experimental period of only one growing season the control of *Elymus repens* was not investigated.

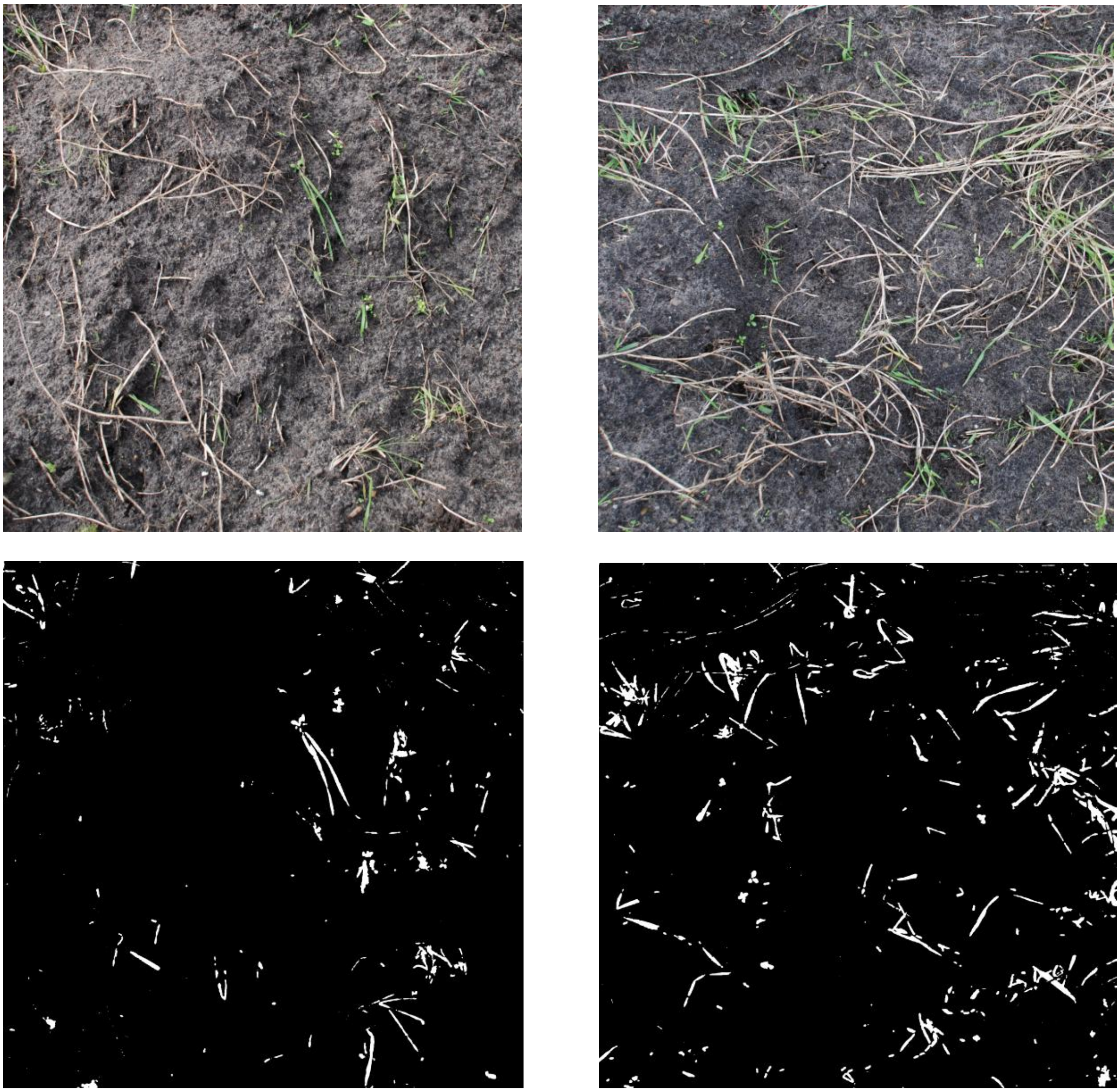

Fig 5: Illustration of the results of the image analysis. Weed soil cover from treatment with the rigid tine cultivator with spike discs to the left (index 0.979), and the spring loaded tine cultivator to the right (index 0.946). The ratio between the amounts of Elymus repens rhizomes below and above soil surface was in these two plots 0.049 and 0.071, respectively. Dry weight of total amount of Elymus repens rhizomes in these two plots were 172 g and 158 g per ¼ m^2, respectively. (Photo: Henning C. Thomsen, Jyndevad Resarch Station)

Conclusion:

Different high speed and high capacity techniques for uprooting and exposing of *Elymus repens* rhizomes were presented and studied in this paper. The results showed that it was difficult to achieve a high percentage of uprooting and exposure of *Elymus repens* rhizomes when using high capacity machines e.g. spring loaded tine cultivator or the rigid tine cultivator with spike discs at the rear.

The new designed spike discs were not capable of uprooting more rhizomes than the standard spring loaded tine cultivator. However, the rigid tine cultivator with spike discs showed a more uniform distribution of the rhizomes, i.e. no large and lumpy batches of rhizomes was observed after treatment as observed after treatment with the spring loaded tine cultivator.

The rigid tine cultivator with spike discs provided significantly better coverage of leaves of *Elymus repens* and broad leaved weeds, indicating potential better weed control efficiency. However, perennial field investigations are required to confirm that.

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