STRATEGIES TO CONTROL *CIRSIUM ARVENSE* UNDER ORGANIC FARMING CONDITIONS

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Abstract

Three strategies for controlling *Cirsium arvense* including (1) repeated stubble tillage with subsequent forage crop cultivation, (2) repeated mowing of a grass-clover ley, and (3) forage crop cultivation following a grass-clover ley ploughed in May/June (3) were investigated in field experiments over 3 years. The development of *C. arvense* shoot density was regularly assessed on sub-plots with defined thistle densities. In the medium-term (9 months), treatment 1 decreased shoot density and regrowth capacity of *C. arvense* more effectively than a mowed grass-clover ley (2). However, after 22 months, treatments 1 and 2 resulted in a similar strong reduction of *C. arvense* shoot density of 95 % and 97 %, respectively. At this time, the efficacy of treatment 3 was lower (89 %), however, not significantly different to that of treatments 1 and 2. After 26 months, the effect of all treatments was still apparent; however, the efficacy of treatment 3 was significantly lower than that of treatment 2. Generally, the different strategies showed only minor differences, thus delivering options for optimal strategies of thistle control under given specific conditions of site and cropping systems.

Introduction/Problem

Canada thistle (*Cirsium arvense* (L.) Scop.) is an aggressive, colony forming perennial weed. Once established, it is very tenacious and difficult to control (Hodgson 1968), due to a very expansive root system that can give rise to new shoots from adventitious root buds. Infestation with *C. arvense* under organic farming conditions is an increasing problem in most European countries. The spread of *C. arvense* is favoured by low crop competition, a high proportion of cereals and spring crops in the rotation (Verschwele & Häusler 2003) and missing autumn tillage (Pekrun & Claupein 2004). Perennial weeds are very difficult to control by crop competitiveness only. In order to be effective, most control options have to take place in the non-cropping period (Donald 1990, Hatcher & Melander 2003). The aim of the investigation presented here was to develop a strategy for sustainable control of *C. arvense* in organic crop production. The applied strategies were targeted on the depletion of assimilate reserves in the root system by a repeated disruption of the vegetative growth of *C. arvense*.

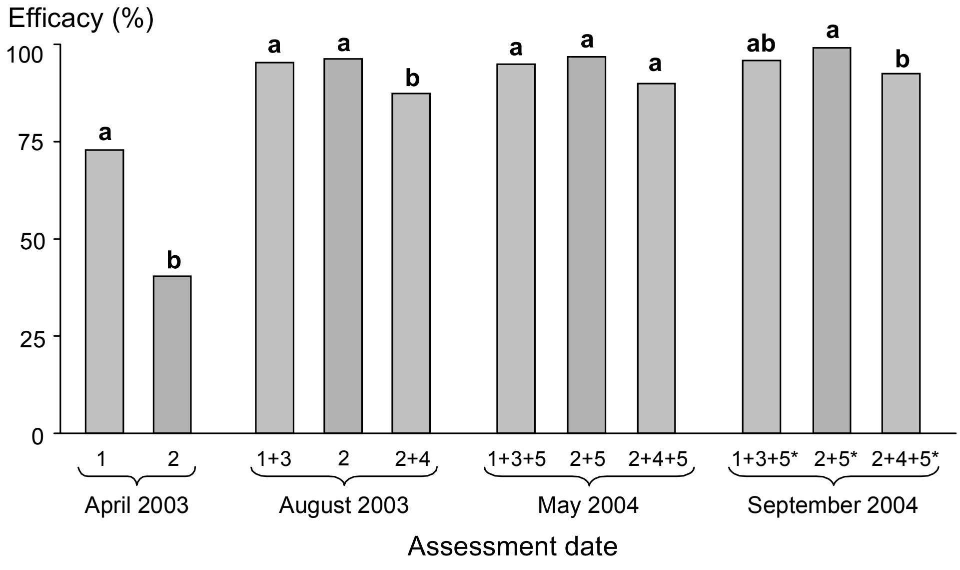
Methodology

From 2002-2004, a one-factorial field experiment was established after winter rye harvest in an area heavily infested with *C. arvense*. The trial site was located at the organic research farm 'Wiesengut' in North-Rhine Westphalia, Germany (50°48'N, 7°17'O). The experiment consisted of four replicates (plot size 10 m x 23 m). In treatment 1, repeated stubble tillage was followed by subsequent cultivation of two forage crops. Stubble cultivation (repeated three times during August and September 2002) was carried out using a stubble plough (twice) and a wing share cultivator (once). The tillage depth was successively increased (6 cm - 12 cm - 15 cm soil depth, respectively) in order to stimulate adventitious buds and to cut the emerging shoots of *C. arvense*. This method has been shown to deplete the assimilate of the root system resulting in a decreased regrowth capacity of *C. arvense* (Håkansson 2003). After seedbed preparation (mouldboard plough followed by rotary harrow combined with drilling machine), a mixture of *Vicia villosa* and *Secale cereale* (50/80 kg ha^{-1}) was sown. The forage mixture was mowed in May 2003 and then inverted by deep ploughing. In June, another forage crop (*Trifolium resupinatum* mixed with *Lolium multiflorum*: 15/20 kg ha^{-1}) was sown and mulched in July and September 2003. Treatments 2 and 3 were both based on grass-clover ley that had been undersown in winter rye in spring 2002. In treatment 2, the grass-clover ley was maintained over the whole experiment and was regularly cut (mowed 3 times and then mulched). The grass-clover ley of treatment 3 was mowed twice (September 2002, Mai 2003), than ploughed and cultivated as in treatment 1. In March 2004, in all treatments after shallow cultivation (wing share cultivator, 10-cm soil depth), deep ploughing (30-cm soil depth) and seedbed preparation, spring wheat (cv. *Combi*) was sown.

Density and size of *C. arvense* shoots were determined before establishing the treatments in April 2002 and at different times during the following years (April 2003, August 2003, May 2004, September 2004). The distribution of *C. arvense* was extremely heterogeneous (0-60 shoots per m^2). During the first assessment in April 2002, a density of 20-40 shoots per m^2 was determined in several patches. Therefore, four fixed standardised subplots of 3 m x 3 m size with densities of 1-10, 11-20, 21-30 and >30 *C. arvense* plants per m^2 per subplot were established in each plot. The following parameters were assessed in the subplots: plant density, ground cover and size (rosette radius) of *C. arvense*, crop ground cover and height.

Results and Discussion

On average, the mean number of thistles in the fixed measured standardised subplots was 10-12 shoots per m^2. This initial thistle density was the basis for the efficacy determination of all control measures. Repeated stubble tillage (treatment 1) resulted in a decline in the shoot density of *C. arvense* by about 73 % (assessed after 9 months in April 2003, Figure 1). In contrast, a patchy grass-clover stand with low shading ability and mowed only once in autumn (treatment 2) reduced shoot density less effectively. These lasting effects of stubble tillage compared with forage crop cultivation can be explained by the continuous depletion of assimilates bound in the *C. arvense* root system by stimulating the emergence of new shoots together with repeated cutting of *C. arvense* shoots (Boström & Fogelfors 1999, Håkansson 2003).



1 = repeated stubble tillage (August/ September 2002) + forage crop[1)]
2 = grass-clover ley: depending on assessment date different cultivation by mowing (September 2002, May 2003, July 2003), mulching (September 2003)
3 = forage crop[2)] cultivation after ploughing of forage crop[1)] (June 2003)
4 = forage crop[2)] cultivation after ploughing of grass-clover ley (June 2003)
5 = spring wheat cultivation in whole experimental area (March-July 2004)
5* = stubble tillage (August 2004) after spring wheat harvest (August 2004)

1) mixture of *V. villosa* & *S. cereale;* 2) mixture of *T. resupinatum* & *L. multiflorum*

Figure 1: Efficacy of control measures: Effect of repeated stubble tillage with subsequent forage crop cultivation, repeated mowing of a grass-clover ley and forage crop cultivation following a grass-clover ley on *C. arvense* density (100 % = 10-12 shoots per m^2 = mean initial density of *C. arvense* in April 2002). Different letters within the column group indicate significant differences (Tukey test, $\alpha = 0.05$).

Regrowth capacity (based on size of *C. arvense* shoots) after repeated stubble tillage was also considerably lower than after mowing of a grass-clover ley. Compared to treatment 2, repeated stubble tillage combined with forage cropping resulted in a lower share of bigger-sized thistles (Figure 2).

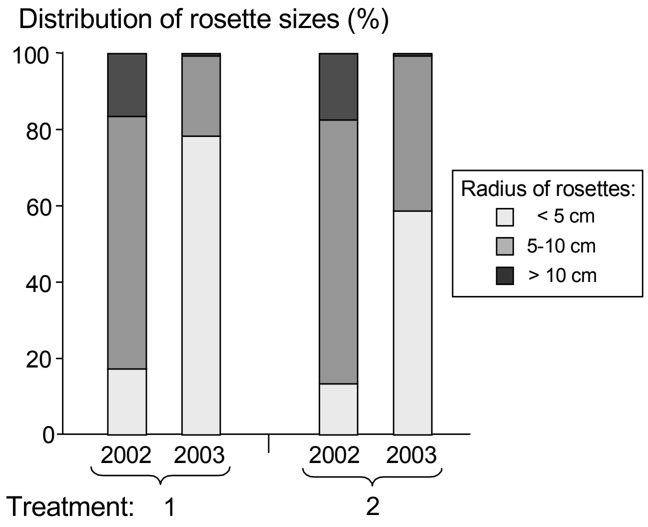


Figure 2: Effect of repeated stubble tillage combined with forage crop cultivation (mixture of *V. villosa* & *S. cereale*) (treatment 1) and mowing of a grass-clover ley once (treatment 2) on the rosette size of *C. arvense* (assessment: April 2002 & April 2003).

As shown in Figure 1, subsequent forage crop cultivation after repeated stubble tillage (treatment 1) was just as effective as a grass-clover ley mowed 3 times (September 2002, May 2003 and July 2003, treatment 2) in reducing thistle density in August 2003. The efficacy of these two treatments was high at 96 %. The efficacy of forage crop cultivation (mixture of *T. resupinatum* and *L. multiflorum*) after ploughing of grass-clover ley in June 2003 (treatment 3) was also high (88 %), however, significantly lower than that of the other two treatments. This was due to increased thistle density as a result of damage to the apical dominance of shoots during ploughing. The initially low shading ability of the forage crop was obviously not sufficient to stop the growth of emerging *C. arvense* shoots. Other studies have demonstrated the importance of a dense competitive crop stand for successful thistle suppression (Zimdahl *et al*. 1991, Dau & Gerowitt 2004).

In May 2004, 22 months after the begin of the experiment, long-term effects of treatment 1 (stubble tillage combined with competitive forage crops) and three times mowing and one mulching grass-clover ley (treatment 2) also became apparent, as the shoot density of *C. arvense* decreased (efficacy 95-97 %). The efficacy of forage crop cultivation following twice-mowed grass-clover ley (89 %, treatment 3) was not significantly different from both other treatments (Figure 1).

The results confirm other studies that have demonstrated a higher crop (grass-clover) competition in combination with repeated mowing, which significantly decreased the shoot density of *C. arvense* (Häusler *et al*. 2004). Repeated mowing of forage such as alfalfa or legume-grass mixtures can severely reduce thistle density. Hodgson (1968) found that mowing alfalfa fields twice a year reduced *C. arvense* to 1 % of its initial value after four years of alfalfa. The frequency of defoliation corresponds with the degree of reduction of root assimilates. This relation has also been demonstrated in studies where topping of *C. arvense* shoots was followed by repeated grazing (Mitchell & Abernethy 1995).

The timing of cultivation may be important for reducing *C. arvense*. Root carbohydrate reserves can vary with the season (Arny 1932, McAllister & Haderlie 1985). The lowest amount of assimilate reserves in the root system is considered to be found in early June, when flowering of *C. arvense* begins (Welton *et al*. 1929, Bakker 1960, Hodgson 1968). During May/June thistle plants are considered as susceptible to any disturbance, i.e., by deep ploughing (treatments 1 and 3) or mowing (treatment 2). Both root system and aerial shoots of undisturbed plants grow rapidly in a period immediately following this weak stage (Wehsarg 1954, Håkansson 2003), combined with efficient accumulation of carbohydrate reserves.

Dry weather conditions in summer 2003 might have caused a further reduction of *C. arvense* in the grass-clover ley. Drought stress is supposed to increase the efficacy of mechanical control of *C. arvense* (Hansen 1918). When the shoots are removed, root buds are stimulated to produce new shoots that might otherwise be suppressed, especially under conditions of low humidity (Hunter *et al*. 1985). Final assessment in September 2004, 26 months after begin of the experiment, determined efficacies of 96 % and 99 % in treatments 1 and 2, respectively, whereas the efficacy of treatment 3 (93 %) was significantly lower than that of treatment 2.

Conclusions

Our results suggest that the most effective medium-term control of *C. arvense* requires repeated stubble cultivation combined with increasing tillage depth and cultivation of a subsequent competitive forage crop. Efficient sustainable control of *C. arvense* can be achieved by using a grass-clover ley that is repeatedly mowed (at least twice in at least one season). High ground cover of grass-clover ley is compulsory to minimise light access for residual emerging *C. arvense* shoots, which limits the plants replenishment with assimilates. This strategy can be recommended especially for growers who have a flexible crop rotation and need forage. On the other hand, due to high costs and lower efficacy, the strategy of forage crop cultivation following ploughing of grass-clover ley in a phase of high susceptibility of *C. arvense* in May/June cannot be recommended.

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