Regrowth of *Cirsium arvense* from intact roots and root fragments at different soil depths

Aufwuchs von Cirsium arvense aus intakten Wurzeln und Rhizom-Fragmenten aus verschiedener Bodentiefe

Mette Goul Thomsen[1]*, Lars Olav Brandsæter[1] and Haldor Fykse[2]

[1] Norwegian Institute for Agricultural and Environmental Research, N-1432 Ås,
[2] Prof. emeritus: Norwegian University of Life Sciences, Department of Plant and Environmental Sciences, N-1432 Ås, Norway.
* Corresponding author, mette.thomsen@bioforsk.no

DOI 10.5073/jka.2014.443.028

Introduction

In the present work we measured the shoot rate from intact roots and from root fragments of *Cirsium arvense* at different digging depths and the number of leaves were used as estimate of minimum regenerative capacity. The experiments were performed on four sites with three or four repetitions of each treatment. On each site plot, the soil was removed down to a given depth within a 1 x 1 m square. All plant parts was excavated from the soil and the soil was either replaced without any root material, or roots of *C. arvense* was cut into 10 cm long fragments and replaced into the source hole. Shoot number, aboveground biomass and number of leaves were measured. Digging depth and time explained 50% - 60% of the variation in biomass ($P<0.001$). Replacement of root fragments increased the shoot number in one out of four treatments but did not affect biomass produced compared to production from undisturbed root systems. Number of leaves showed that shoots from all digging depths passed the level of minimum regenerative capacity. We conclude that the intact root system from all depths was able to regenerate within one season and it has a high contribution to the produced biomass compared with root fragments in the upper soil layers.

Keywords: Biomass, compensation point, number of leaves, root system

Zusammenfassung

In der vorliegenden Arbeit wurde die Sprossbildung aus intaktem Wurzelsystem und aus Wurzelfragmenten von *Cirsium arvense* bei verschiedenen Bodentiefen gemessen. Die Anzahl der Blätter diente zur Schätzung der minimalen Regenerationsfähigkeit. Die Experimente wurden an vier Standorten mit drei oder vier Wiederholungen der einzelnen Behandlungen durchgeführt. Auf jeder Versuchsparzelle wurde der Boden bis zu einer bestimmten Tiefe in einem 1 x 1 m-Quadrat entfernt. Alle Pflanzenteile wurden aus dem Boden entfernt, und der Boden wurde entweder ohne Wurzel oder mit 10 cm langen Wurzelteilen von *C. arvense* in den Boden zurückgegeben. Die Anzahl der Sprosse, die oberirdische Biomasse und die Anzahl der Blätter wurden gemessen. 50-60 % der Variationen der Biomasse erklärten sich aus Bodentiefe und Zeit ($P < 0{,}001$). Beim Einbringen der Wurzelfragmente stieg die Sprossdichte in einer von vier Behandlungen an, hatte aber keine Auswirkungen auf die Biomasse im Vergleich zur Produktion aus ungestörtem Wurzelsystem. Anhand der Anzahl der Blätter zeigte sich, dass Sprosse aus allen Bodentiefen die regenerative Mindestkapazität überstiegen. Wir schließen daraus, dass sich das intakte Wurzelsystem aus allen Bodentiefen innerhalb einer Saison regenerieren konnte und in hohem Maße zur produzierten Biomasse im Vergleich mit der aus Wurzelfragmenten in den oberen Bodenschichten beiträgt.

Stichwörter: Anzahl der Blätter, Biomasse, Kompensationspunkt, Wurzelsystem

Introduction

Perennial plants very often survive the winter period by storing of nutrients in the root system. During regeneration, the plant uses these nutrients for production of new roots and shoots and reaches a level of minimum regenerative capacity "the compensation point". For continued growth the plant must obtain a positive net assimilation. Roots (i.e. roots) of *Cirsium arvense* may reach a depth of 2 m, but most of the root biomass is generally located between 20 and 40 cm (NADEAU and VAN DEN BORN, 1989). After soil tillage, undisturbed roots of *C. arvense* will be present below the working depth of the tillage equipment, whereas root fragments of various sizes are distributed throughout the tilled soil profile. These fragments may play a significant role in the production of new shoots, as they are brought higher up in the profile and therefore require less energy for shoot production. Management of perennial weeds often aims at reducing the food reserves in the storage organs, and profound understanding of regrowth pattern from root fragments as well as from the undisturbed root system is therefore important. The number of shoots and the biomass production has been found to be positively correlated to length of root fragments (DOCK-GUSTAVSSON, 1997; THOMSEN *et al.*, 2011) and negatively correlated to burial depth (THOMSEN *et al.*, 2011). DOCK-GUSTAVSSON (1997) also found that the number of leaves per shoot at the level of minimum regenerative capacity was negatively correlated to the soil depth. However, little is known about the regeneration of the weed from the intact root system. The present study focusses on the development of shoots from intact roots of *C. arvense* at different digging depths compared to shoot development from root fragments present in the upper soil layers.

Material and Methods

This study includes two experiments, carried out at a total of four different sites.

Site descriptions

Experiment I was carried out at Møystad (60° 47′ N, 11° 11′ E, 200 masl) and Rolfsøy (59°14ꞌN, 10°53ꞌE, 5 masl) in 2005, both on imperfectly drained loam soils. Here we aimed at evaluating the capacity for regeneration of the established root system of *C. arvense* from five digging depths (0, 10, 20, 30 and 40 cm) and if the the compensation point would be reached for plants from all digging depths.

Experiment II (Ås A and Ås B) was performed at the Norwegian University of Life Sciences, Ås (59°40ꞌN, 10°46ꞌE, 90 masl) on a sandy loam soil in 2006 and 2011. The aim of these experiments was to compare the capacity for regeneration of the established root system and of root fragments from soil depths of 15 and 30 cm.

Trial description and assessments

All experiments were arranged in complete randomized blocks with three (Møystad and Ås) or four replications (Rolfsøy).

Experiment I. An experimental area with a high population of *C. arvense* was chosen. These trials were established in spring 2005 and the regeneration of *C. arvense* from intact root systems located below five different digging depths (0, 10, 20, 30 and 40 cm) was measured. In each plot, the soil was removed down to the given depths within a 1 x 1 m square and spread out on a plastic sheet. All roots and other plant parts were removed. Then the soil, without roots and plant parts, was replaced into the source hole and packed down to its original level. In the control plot (0 cm depth), the soil was left untreated. Throughout the season, the number of shoots and the number of leaves ≥ 5 cm were counted. In the autumn, the above-ground biomass of *C. arvense* was harvested and dried at 70 °C for 72 hours, and the dry weight was recorded.

Experiment II, Ås A and Ås B. These two experiments were started on 19-25th July 2006 and 14-16th May 2011, respectively, and harvested on 15th October and 25th October, respectively. The soil was dug out to depths of 0, 15 and 30 cm and handled as in Experiment I, but with two different treatments of the soil from 15 and 30 cm depths: 1) all roots and other underground plant parts were removed from the soil, or 2) the roots of *C. arvense* were cut into 10 cm length f and replaced with the soil. At the end of the experiment, the above-ground biomass of *C. arvense* was harvested and dried at 70 °C for 72 hours, and the dry weight determined.

To prevent *C. arvense* in the surrounding area from growing into the experimental plots, this area was frequently mown to 2-4 cm stubble height throughout the summer.

Statistical analysis

Assessment of number of shoots over time were made in the same plots and therefore of repeated nature (time series) and analyzed by a mixed model approach (‘Proc mixed’, SAS 9.2, SAS Institute inc., 2008).

Differences in the above ground biomass were tested with ANOVA (MINITAB 16, MINITAB 2011). Tukey's pairwise comparison test (95% confidence intervals) was used to compare differences between individual treatments for number of shoots, biomass and number of leaves. To evaluate the trend in biomass as affected by digging depth, a linear regression analysis was used (for more information see THOMSEN *et al.*, 2013).

Results

Experiment I:

Number of shoots. At both sites, the number of shoots of *C. arvense* increased with time and decreased with digging depth. Multiple linear regression showed that digging depth and time explained 85% and 44% of the variation in the shoot number at Møystad and Rolfsøy, respectively (P<0.001).

Number of leaves. At both sites the number of leaves (≥ 5cm in length) per shoot varied with both digging depth and time (P<0.001), and on both sites there was interaction between these two factors (the greater the depth, the smaller the leaf number) (P<0.001) (Fig. 1).

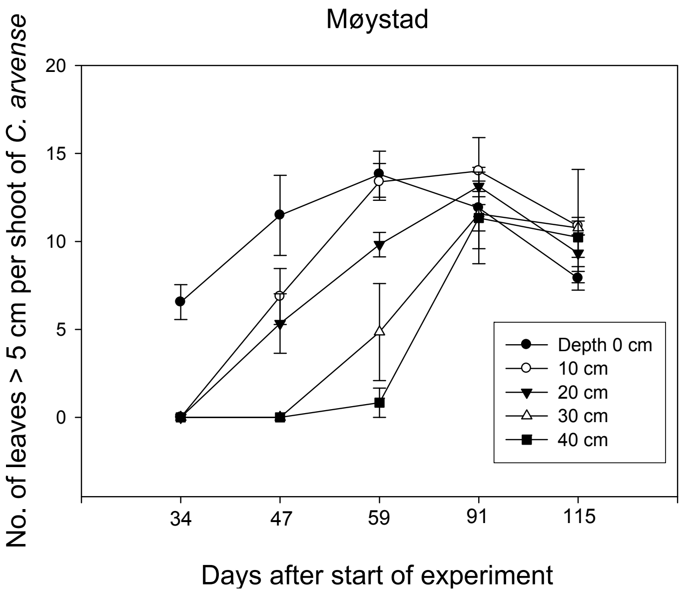

Fig. 1 Number of leaves (≥5cm) per shoot in Experiment II in relation to the number of days after the start of the experiment and the digging depth (Vertical bars: ± SE).

Abb.1 *Anzahl der Blätter (≥5cm) pro Spross in Versuch II in Bezug auf die Zeit nach Versuchsanlage und die Bodentiefe (Säulen: ± SE).*

Above-ground biomass. In general, the dry weight of the above ground biomass was reduced by increased digging depth: $r^2 = 0.49$, (P<0.001) and $r^2 = 0.60$, (P = 0.001) for Rolfsøy and Møystad, respectively (Tab. 1).

Tab. 1 Weed biomass produced in experiment I.

Abb. 1 *Unkrautbiomasse in Versuch I.*

	Digging depth	**Weed biomass[1] (g/m²)**	
		Rolvsøy	**Møystad**
Exp. I	0 cm	303,6 ab	477,6 a
	10 cm	334,0 a	358,6 a
	20 cm	236,7 ab	317,2 ab
	30 cm	120,4 ab	141,6 ab
	40 cm	44,7 b	94,3 b
[1]Different letters behind the figure indicate significant difference between vertical treatments			

Experiment II, Ås A and B

Number of shoots

Ås A and B: The number of shoots was reduced by increased digging depth (P <0.001) and it increased with time after start of the experiment (P <0,001) and the two factors interacted (P <0.001), giving a lower number of shoots with increasing depth. The control treatment gave a higher number of shoots than the remaining treatments (P <0,05). The two treatments, removal or replacement of root fragments, did not result in any differences in shoot number in Ås A, but in Ås B digging depth 30 cm and root fragments removed had a lower number of shoots than the reaming treatments (P <0,05).

Above-ground biomass Ås A and B: No difference in biomass was found between removing and replacing the underground plant parts within each digging depth (n.s.) but higher biomass production resulted from the control treatment. At Ås B, comparing the two digging depths showed that 15 cm depth with replacement of the roots yielded more biomass than the two treatments at 30 cm digging depths (P = 0.05).

Discussion

Previous studies have shown that the shoot production of *C. arvense* is reduced with increased ploughing depth (e.g. BRANDSÆTER *et al.*, 2011a) corresponding to the findings in the present experiment. The level of minimum regenerative capacity of root fragments has previously been found to be dependent on the length of the root fragments and on burial depth (DOCK-GUSTAVSSON, 1997; THOMSEN *et al.*, 2011; NKURUNZIZA and STREIBIG, 2011). DOCK-GUSTAVSSON (1997) found that 12 cm long root fragments buried at 5 cm soil depth did not regrow if disturbed when the shoots had eight to ten expanded leaves and if buried at 20 cm soil depth they did not regrow after disturbance when the shoots had four to six expanded leaves. In experiment one, we studied the intact root system and not root fragments but if we use the above figures in the present study we may expect that roots from all digging depths passed the level of minimum regenerative capacity. Roots from soil depth ≤20 cm would likely have passed this level approximately ten days before roots at >20 cm soil depth.

Shoots developing from root fragments, e.g. after soil tillage, appear to have a limited contribution to the total number of shoots or biomass produced if, as in the present study, the fragments are located above the intact root system. The overall explanation could be that the intact root system possess a high regenerative capacity and may lower the production from the root fragments by underground competition. If the root fragments are spread to other areas we know from a number of studies that they represent a very high risk of infestation (THOMSEN *et al.*, 2011).

The results of the present experiments are important in order to understand the regenerative capacity of the deeper undisturbed root system of *C. arvense* and the threat this weed poses for infestation of cropland. As a single measure, deep cutting of the root system will delay and reduce the shoot production and biomass more than shallow treatments. However, the results show that the intact root system below the average tillage depth is highly vigorous and roots below 40 cm depth reach the compensation point within the growing season. To control *C. arvense* by reducing stored food reserves, repeated and varied treatments are therefore needed. Studies by e.g. GRUBER and CLAUPEIN (2009) and BRANDSÆTER *et al.* (2011b) have shown that control of *C. arvense* may be achieved by repeated and well-timed shallow soil treatments.

Acknowledgement

Thanks to *Weed Science,* Allen Press Publishing Services, for permission to use data first published in Weed Science **61,**277–282, 2013.

References

BRANDSÆTER, L.O., A. K. BAKKEN, K. MANGERUD, H. Riley, R. ELTUN and H. FYKSE, 2011a: Effects of tractor weight, wheel placement and depth of ploughing on the infestation with perennial weeds in organic farmed cereals. European Journal of Agronomy **34,** 239-246.

BRANDSÆTER, L.O., M.G. THOMSEN, K. WÆRNHUS and H. FYKSE, 2011b: Effects of repeated clover undersowing in spring cereals and stubble treatments in autumn on *Elymus repens, Sonchus arvensis* and *Cirsium arvense*. Crop Protection. DOI:10.1016/j.cropro.2011.09.022.

DOCK-GUSTAVSSON, A-M., 1997: Growth and regenerative capacity of plants of *Cirsium arvense*. Weed Research **37,** 229-236.

GRUBER, S. and W. CLAUPEIN, 2009: Effect of tillage intensity on weed infestation in organic farming. Soil and Tillage Research **105**, 104-111.

NKURUNZIA, L., E. ROSENQVIST and J.C. STREIBIG, 2011: Photosynthesis and growth of newly intact shoots of *Cirsium arvense* and *Tussilago farfara* are resource independent. Weed Research **51,** 33-40.

NKURUNZIA, L. and J.C. STREIBIG. 2011**:** Carbohydrate dynamics in roots and roots of *Cirsium arvense* and *Tussilago farfara*. Weed Research **51,** 461-468.

SAS Institute inc. 2003. SAS 9.1.3, (2002 – 2003): SAS Institute Inc., Cary, NC, USA.

THOMSEN, M.G., L.O. BRANDSÆTER and H. FYKSE, 2011: Sensitivity of *Cirsium arvense* to simulated mechanical treatment and competition. Acta Agriculturae Scandinavica, Section B - Soil and Plant Science **61,** 693 – 700.

THOMSEN, M.G., L.O. BRANDSÆTER, and H. FYKSE, 2013: Regeneration of Canada thistle (*Cirsium arvense*) from Intact Roots and Root Fragments at Different Soil Depths. Weed Science **61,** 277–282.