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CombCut – Selective Control of Docks (*Rumex* spp.) in grassland

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Preface

This thesis is the consummation of my Master of Science degree in Plant Science at the Norwegian University of Life Sciences (NMBU) in Ås, Norway.

The research conducted for the thesis has been part of the GrateGrass project lead by NIBIO Division of Biotechnology and Plant Health. The project focuses on integrated weed management to increase yield and profitability in forage production.

Working with this thesis has given me valuable insight into agricultural field research and statistical methods related to results from field research.

I would like to thank my advisors Lars Olav Brandsæter and Björn Ringselle at NMBU and NIBIO, respectively, for guidance in my work with this thesis. Their advices regarding statistics and approaches with finding literature regarding my thesis were outstanding. I would also like to thank Torfinn Torp for helping me to learn to use the SAS statistics program.

NMBU – Ås, June 14, 2018.

Andreas Myki Beachell

1 INNHOLD

1 Abstract

Rumex spp. are known as troublesome weed species in grassland, both in pastures and on arable land, reducing both grass yield and forage quality. A novel machine called CombCut (Just Common Sense AB) has been designed to selectively cut weeds. Three different experiments in Akershus, Norway were carried out to investigate selective cutting of *Rumex* spp. in leys, with the CombCut. Vegetative and flowering *Rumex* spp. m^{-2}, *Rumex* spp. biomass and grass yield were investigated for the different treatments. The treatments were various CombCut settings, herbicide application and control treatments with normal sward management. The CombCut left several *Rumex* spp. plants uncut after treatments and there was no clear reduction of flowering nor vegetative *Rumex* spp. Running the CombCut two passes reduced weed biomass significantly compared with one-pass treatments. Grass yield was not affected by the CombCut treatments.

Even though the experiments did not show a clear effect on reducing *Rumex* spp., more information on the time of cutting, ideal field conditions for selective cutting and CombCut adjustments are needed to conclude on the effect of cutting *Rumex* spp. with the CombCut.

Key words: *Rumex,* CombCut, selective cutting

2 Introduction

The term weed usually refers to plants growing where they are not wanted and competing with cultivated plants for nutrients, water and light (Weed, n.d.; Korsmo, Vidme & Fykse, 1981). Volunteer cultivated plants propagated from previous crops or from the use of impure seed are considered weeds as well (Håkansson, 2003). Plants poisonous to people or animals and livestock may also be considered weeds (Korsmo, Vidme & Fykse, 1981).

Weeds are undesirable since they may reduce the crop yield due to competition for resources, they may have allelopathic effects, or they may reduce the quality of crops (Bridges, 1994, pp. 392).

The Norwegian government has a goal of increasing the production of grass-based forage, and forage quality (Landbruks- og Matdepartementet, 2016-2017, pp. 72, 74). *Rumex* subspecies (spp.) are known as troublesome weed species in grassland, both in pastures and on arable land (Zaller, 2004). Field experiments have shown that total grass herbage harvested is negatively related to the amount of *Rumex* plants present in the field. A two-year experiment in 1979 and 1980 showed a negative relationship between *Rumex* ground cover and grass yield, especially late in the growing season (Oswald & Haggar, 1983). In an experiment conducted by Bosworth, Hoveland and Buchanan; Rumex Crispus had a significantly greater decline in 'in vitro digestibility' than the forage species and most of the other weeds examined in the experiment thus making *R. crispus* an undesirable plant in a ley for forage production (1980, pp. 150).

Haggar (1980) conducted a survey in the UK in 1972, concluding that 288 000 ha of grassland is heavily infested with docks. In central Europe it has been estimated that 80 % of the herbicides used in conventional grassland farming are used to control *Rumex* spp. (Zaller, 2004, quotation from J. Galler). In Sweden, *Rumex* spp. are an increasing problem on farms with milk and cattle production, preventing conversion to organic farming as farmers see few alternatives to chemical control (Andersson, 2007).

R. longifolius, R. crispus and *R. obtusifolius* are the most important taller *Rumex* species occurring in Norway. *R. longifolius* can be found all over the country up to heights of 1250 meters above sea level. The species *R. crispus* and *R. obtusifolius* grow mainly along the coastline from the Swedish border and as far north as Nordland and Troms (Fykse, 1986).

2.1 *Rumex* spp. biology

Rumex longifolius is a perennial plant that mainly reproduces through dispersal of seeds. However, root fragments separated from the plant through cultivation can develop into new plants as well. It has a branched tap root. The stem is erect and measures between 40 and 130 cm. The leaves at the base of the plant are arranged in a rosette while cauline leaves alternate and are lance shaped. The panicle can be up to 50 cm in length, formed by flowers arranged in close whorls on axillary peduncles. *Rumex longifolius* flowers between June and August. On average*, R. longifolius* has 9000 seeds that have a high germination rate and are able to germinate from the soil surface and depths up to six cm. It thrives on nutrient-rich sandy loams with a high content of organic matter. (Korsmo et al., 1981, pp. 260).

Rumex Obtusifolius has an erect stem measuring from 60-120 cm which is branched on some specimens. Some plants have a red tinted stem. The leaves at the base of the plant are arranged in a rosette and are shaped ovate-oblong. The upper cauline leaves are short-petioled and lanceolate. The undersides of the leaves are usually hairy. Flowers are arranged in whorls on long pedicels attached to spreading branches. *R. obtusifolius* flowers between June and September. A plant produces on average 3 700 seeds that germinate well at shallow depths. *R. obtusifolius* prefers nutrient-rich loamy or clayey soils with high nitrogen levels (Korsmo, et al., 1981, pp. 262).

Rumex crispus is a perennial weed with a branched tap root. The plant reproduces mainly through seeds, but new plants can also emerge from root fragments cut from cultivation. *R. crispus* has an erect stem usually measuring between 40 and 100 cm. Leaves are lance shaped to oblong. The leaves at the base of the plant are arranged in a rosette and the cauline leaves alternate. The flowers are arranged in close whorls in a panicle and flowering occurs in the period between June and September. *R. crispus* produces an average of 3 700 seeds per plant that can germinate down to a depth of 4 cm. It prefers nutrient-rich heavy clayey loams (Korsmo et al., 1981, pp. 258).

2.2 Chemical & Non-Chemical Control of Rumex spp.

There are several different approaches to controlling *Rumex* spp. chemically.

Applying a non-selective, systemic herbicide like glyphosate before ley renewal will prevent emergence of *Rumex* spp. from root fragments, after cultivation (Brandsæter & Haugland, 2007).

Herbicide application in the year of establishment of the ley may eliminate the need for new applications in the following ley years. The herbicide should be applied at an early stage when the weeds have 2-4 leaves (Brandsæter & Haugland, 2007).

Rumex spp. can be controlled chemically in an established ley as well. The best time for control/herbicide application is when the *Rumex* plant is at the rosette stage, at the beginning of stem elongation. Spraying in the spring gives the best effect due to strong grass growth which will compete with *Rumex* spp. (Brandsæter & Haugland, 2007).

Several experiments have investigated different non-chemical measures to control Rumex spp. The main goal in controlling *Rumex* spp. is to avoid seed-bank build up and weaken their capacity for regrowth or regeneration by damaging above- and below ground plant parts. Biological control has been the main focus of research for non-chemical control of *Rumex* spp. However, a big amount of research has been done on cultural control and mechanical control as well (Zaller, 2004).

Fungus, herbivorous insects, applying plant extracts, natural chemicals and grazing with specific animal species are among the methods that have been tested for biological control of *Rumex* spp. (Zaller, 2004).

According to Cavers & Harper 34 herbivorous insect species can affect *Rumex* spp (as cited in Zaller, 2004). Cottam, Whittaker & Malloch investigated the effects of Gastrophysa viridula grazing and plant competition on the growth of *Rumex* obtusifolius. There was no significant effect of *G. viridula* grazing on non-competing *Rumex* plants. However, for competing *R. obtusifolius* plants, grazed plants had a significantly lower leaf area, leaf dry weight and petiole dry weight (1986).

Experiments done by Bentley et al. have shown that *Coleoptera* can reduce *Rumex* seed production as well (Zaller, 2004). Experiments with Coreus marginatus grazing on R. obtusifolius have shown a decrease in seed production and germination rate of *R. obtusifolius* (Hruskova, Honek & Pekar, 2005) However, using beetles as a control measure alone is seldom a sufficient control measure for killing *Rumex* plants (Zaller, 2004).

According to experiments done by Inman and Schubiger et al. the fungus *Uromyces rumicis* can reduce *Rumex* regrowth, leaf number, root and leaf biomass (as cited in Zaller, 2004). However, using fungi alone, as a control measure, is rarely sufficient to kill a *Rumex* plant (Zaller, 2004).

Several experiments have been conducted that show a possibility for controlling *Rumex* spp. with the combined effect of a fungal pathogen and herbivorous insects under laboratory conditions. However, there is still a lack of knowledge on how to apply these methods to field conditions (Zaller, 2004).

Cultural control focuses on preventing the establishment of Rumex spp. through grazing, undersowing, crop rotation and choice of cultivars (Zaller, 2004). The first step in a good cultural control is a dense and competitive ley. *Rumex* seedlings are often found in spots in the field with no crop cover. Shading will negatively affect seedling growth (Zaller, 2004). As *Rumex* spp. are typical ley weeds rotations with competitive annual crops, such as cereals will depress *Rumex* spp. (Håkansson, 2003).

Grazing has been tested as a measure to control *Rumex* spp. In an experiment by Zaller, grazing with a special breed of sheep, that feed on docks, were compared to cutting. Grazing gave a significantly lower height of *R. obtusifolius* and less fruit-stands than the cutting treatment. This makes grazing an interesting alternative for control of *Rumex* spp. (Zaller, 2006).

Typical ley weeds such as *Rumex* spp. increase their biomass in the ley stand with increasing age of the ley. Despite *Rumex* spp. being typical ley weeds shallow tillage is usually an insufficient measure to control *Rumex* spp. alone (Håkansson, 2003).

The ability of sprouting from root pieces of *Rumex* spp. is mainly limited to pieces from the upper 5 cm of the roots. *R. longifolius* has shown a greater ability to regenerate from root pieces than *R. crispus* and *R. obtusifolius*. Sprouting ability increases with increased weight of the root piece (Fykse, 1986).

According to Pye, Andersson & Fogelfors (2011) emergence rate is strongly related to burial depth. Deep burial of the upper part of the root is therefore crucial to control *Rumex* spp. Deep moldboard ploughing that places upper root part at the bottom of the furrow is therefore a good approach to controlling *Rumex* spp. through tillage. Quick establishment and emergence of a crop following tillage will help inhibit biomass and seed production furthermore.

As *Rumex* spp. are light sensitive tillage should be avoided on bright days or executed when dark (Zaller, 2004).

A lot of research related to controlling *Rumex* spp. has focused on the effect of cutting (Zaller, 2004). A greenhouse experiment in Belgium investigated the effect of cutting frequency on the vigour of *R. obtusifolius*. The highest cutting frequency gave the largest decrease in above ground dry matter and concentration of total sugars in the roots (Stilmant, Bodson, Vrancken & Losseau, 2010).

A field trial in the Netherlands investigated the effect of different cutting intervals in a resown grass-clover ley heavily infested by *Rumex obtusifolius*. The treatments consisted of cutting intervals of 2, 4 and 6 weeks, for a period of 12 weeks. Root biomass and number of seedlings were registered. There was a reduction in the number of *R. obtusifolius* seedlings after 24 weeks, but no difference between the different treatments. However, the shortest cutting interval gave significantly greater reduction in root mass than the longer cutting intervals after 12 weeks of treatments (Van Eekern, Feher, Smeding, Prins & Jansonius, 2006).

According to Pino et al. cutting decreases seed input into the soil seed bank (as cited in Zaller, 2004, pp. 422). Another study done by Pino, Sans & Masalles suggests that *Rumex* spp. must reach a threshold size to be able to flower. As the ratio between reproductive biomass and vegetative biomass stayed the same through most of the reproductive period seed output is strongly linked to vegetative biomass (2002).

2.3 Selective Cutting of Rumex spp.

This thesis focuses on controlling *Rumex* spp. with cutting utilizing a machine called CombCut that is patented and manufactured by a company called Just Common Sense AB that is located in Karlskrona, Sweden. The CombCut machine is constructed with a bar of knives that have a slight opening between them. The opening is adjustable.

The machine has a reel driven by a hydraulic motor that guides the weeds and crop through the knife bar (Appendix 1). The idea of the machine is to selectively cut the weeds and not the crop. For the machine to be able to selectively cut the weeds and not the crop (grass in my thesis), there must be a physical difference between the weed and the grass. If the weed has a thicker stem, a stiffer stem or more branches than the crop, selective cutting is possible (Just Common Sense AB, n.d.).

As *Rumex* spp. have a thicker and stiffer stem than most grasses in a ley, the machine has a potential to cut *Rumex* spp. Compared with earlier research on cutting *Rumex* spp., selective cutting can potentially provide better competition from the ley, as the aim is to only cut the Rumex plants with the CombCut.

2.4 Experimental Factors and Research Questions

The three different experiments conducted focus on how the CombCut effects the following factors:

- Vegetative and generative *Rumex* spp. plants m^{-2}
- Weed biomass
- Grass yield

Sampling these factors could help answer the following questions:

1. Is selective cutting a potential measure for controlling *Rumex* spp.?
2. How does selective cutting with the CombCut affect grass yield?

3 Material & Methods

The experiments were performed at three different experimental sites named Frydenhaug, Jegstad 1 and Jegstad 2.

3.1 Frydenhaug

Experimental site

In 2014, Frydenhaugjordet, a field in Aas, Norway (59º 40’ N, 10º 46’ E), 95 m above sea level, was used as a location for the experiment. The field had an already established ley, invaded by *Rumex* spp. (mostly *R. longifolius*). The experiment at this site was discontinued after 2014.

Experimental design and management

The experiment at Frydenhaug was laid out as a randomized design with three treatments, four replicates, i.e. 12 experimental plots measuring 10 x 7 m. Two of the treatments were CombCut treatments with different knife adjustments given in Table 1. One treatment had no CombCut treatments and acted as a control. Grass yield was registered with a Haldrup F55 on an area measuring 9 x 1.5 m. See Table 2 for time of treatment and data collection.

Sampling

Flowering and vegetative Rumex spp. were registered before the CombCut treatment. Flowering Rumex spp. were counted after the treatments on an area inside each plot measuring 5 x 3 m. A frame measuring 1 x 1 m was used to assist counting. Grass samples from each plot were collected for drying to calculate the dry matter yield.

3.2 Jegstad 1

Experimental site

In 2016 a field at Jegstad farm in Vestby, Norway (59º 37’ N, 10º 43’ E), 100 m above sea level, was chosen as an experimental site. The field had an established population of Rumex spp. (Mostly *R. longifolius*) in a ley consisting of ryegrass and timothy. At the time of the start characterization there were 0.37 flowering *Rumex* spp. plants m^{-2}. The ley was harvested three times each year.

Experimental design and management

A randomized block design was used as an experimental design, with four blocks, six treatments and 4 replicates, i.e. 24 experimental plots. The plots measured 9 x 7 m. There were four CombCut treatments with different knife adjustments, one herbicide treatment with the herbicide Harmony (Mattilsynet, 2015) and a treatment with no CombCut or herbicide application acting as a control. The herbicide was only applied once. See Table 1 for CombCut adjustments.

Sampling

Number of *Rumex* spp., grass yield and weed biomass were investigated for six different treatments. A start characterization of each plot was done by counting *Rumex* spp. plants on an area of 3 x 5m inside each plot with a frame measuring 1 x 1 m. After executing the treatments, flowering and vegetative *Rumex* spp. were counted inside the same 3 x 5 m area as used in the start characterization. The grass yield was registered with a Haldrup F55 harvester inside each plot on an area measuring 9 x 1.5 m. A representative grass sample was taken from each plot and dried to find the dry matter content of the grass. Weed biomass was registered by destructive harvest of the *Rumex* spp. and drying of the harvested samples to find the dry biomass. Time of data collection and treatment execution is given in Table 2. Grass yield was only registered in 2016 for this site.

3.3 Jegstad 2

Experimental site

In 2017 a new experimental site was established at Jegstad farm in Vestby, Norway (59º 37’ N, 10º 43’ E), 100 m above sea level. The field had a ley consisting of mostly ryegrass and timothy, invaded by *Rumex* spp. (mostly *R. longifolius).* At the time of the start characterization there were 1.4 flowering *Rumex* spp. plants m^{-2}. The ley was harvested three times a year.

Experimental design and management

A randomized block design with two blocks, three treatments and three replicates per block, i.e. 18 experimental plots, each measuring 9 x 7 m was used for the experiment. The experiment had two CombCut treatments with different adjustments and one treatment with normal management, i.e. harvesting, acting as a control. CombCut adjustments for the experiment are stated in Table 1. Time for execution of treatments are given in table 2.

Sampling

Rumex spp. plants were counted inside each plot, on an area of 9 x 7 m, prior to the first round of treatments with the CombCut. The number of flowering and vegetative *Rumex* spp. were counted on an area measuring 10 m^2, inside each plot, after the first and second round of treatments. A counting frame measuring 1 x 1 m was used for counting the *Rumex* spp. The grass yield was registered using a Haldrup F55 harvester on an area measuring 1.5 x 9 m. Grass samples from each plot were dried to find the dry matter content. Table 2 shows the time of data collection.

Table 1 Description of treatments for the Frydenhaug experimental site and both experimental sites at Jegstad. The table shows the CombCut adjustments read from the scale on the back of the knife bar on the CombCut. The cutting height was set to cut the inflorescence of the Rumex spp.

	Year 1			**Year 2, round 1 of treatments**			**Year 2, round 2 of treatments**		
Treatment/ Experimental site	No. of passes	Knife adjustment		No. of passes	Knife adjustment		No. of passes	Knife adjustment	
		Left scale	**Right scale**		**Left scale**	**Right scale**		**Lefts scale**	**Right scale**
Frydenhaug									
CC1 FRY	1	3	36						
CC2 FRY	1	3	70						
Control FRY	n/a	n/a	n/a						
Jegstad 1									
CC1high	1	3	36	1	3	36	1	5	40
CC2high	2	3	36	2	3	36	2	5	40
CC3low	1	3	70	1	3	70	1	5	60
CC4low	2	3	70	2	3	70	2	5	60
Herbicide	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Jegstad 2									
CCHigh				2	3	35	2	5	40
CCLow				1	3	35	1	5	60
Control				n/a	n/a	n/a	n/a	n/a	n/a

Table 2 Dates of data collection and execution of treatments for the Frydenhaug experimental site and both experimental sites at Jegstad.

Type of registration/ action	**Experimental site Frydenhaug**	**Experimental site Jegstad 1**		**Experimental site Jegstad 2**
Year	2014	2016	2017	2017
Site measurement and marking	July 14	June 30		June 24
Pre-treatment sampling	July 14-15	June 30	June 26	June 27
Treatment: CombCut	July 15	July 6	June 27	June 27
Weed count	August 12-13	July 19	July 6	July 6
Grass yield	September 5	July 21		July 5
Harvest		August 15	July 7	July 7
Herbicide application		September 12		
Treatment: CombCut		September 27	August 23	August 23
Data collection: Weed count		October 14-19	September 20	September 21
Data collectiom: Biomass Rumex spp.			September 20	
Data collection: grass yield		October 27		September 18
Harvest				

3.4 CombCut Adjustments

The knife angle of the CombCut is adjustable in both the horizontal and vertical plane. The angle in the vertical plane affects the opening between the knife and the knife holder. The horizontal angle will affect whether the crop/weed is guided a long the knife holder or the blade. See figure 1. The angle of the knives are adjusted according to two measures on the back of the machine.

Figure 1 Knife bar of the CombCut. 1: Vertical angle adjustment to increase opening between knives. 2: Horizontal angle adjustment to force leaves towards blade. 3: blade. 4: blade holder

3.5 Data Analysis

The Flowering and vegetative *Rumex* spp. counted in the experimental plots were calculated to plants m^{-2} before entering the values into the statistics program.

Results were analyzed using the PROC MIXED procedure in SAS 9.4 (SAS Institute Inc.) with repeated measures to identify differences over time for the experimental sites Jegstad 1 and Jegstad 2 for both *Rumex* spp. m^{-2} and grass yield.

The PROC MIXED procedure was used, with initial flowering and vegetative *Rumex* spp. as covariates, for comparing *Rumex* spp. m^{-2} at Frydenhaug.

The Proc Glimmix procedure was used to find contrasts for *Rumex* spp. biomass between two-pass and one-pass treatments with the CombCut at Jegstad 1.

Tukey-Kramer post hoc test in SAS 9.4 was used to identify significant differences between treatments.

4 Results

Several *Rumex* spp. plants remained uncut after the CombCut treatment.

4.1 Density of flowering and vegetative Rumex spp.

The analysis of variance on flowering *Rumex* spp. showed a significant effect of the factor time at the sites Jegstad 1 & Jegstad 2 (Table 3 & 4). At Jegstad 2 the interaction treatment*time had a significant effect on flowering *Rumex* spp. (P=0.0379; Table 4). The factor time had a significant effect on vegetative *Rumex* spp. at Jegstad 1 (P<0.0001, Table 3).

At Jegstad 1, flowering *Rumex* spp. decreased from 0.53 m^{-2} to 0 m^{-2} from the first to the second weed count for the treatment CC4low (P=0.0187; Table 6) according to the Tukey-Kramer post hoc test.

At Jegstad 2 the control had a reduction in flowering *Rumex* spp. m^{-2} from 2.5 to 0.22 between the first and second weed count (P<0.0001; Table 7), according to the Tukey-Kramer post hoc test.

4.2 Weed biomass

There was a significant difference in biomass between the herbicide treatment and treatment CC3low (P=0.019, Figure 1) according to the Tukey-Kramer post hoc test. A contrast between CC3low, CC1high (one pass with CombCut) and CC4low, CC2high (two passes with CombCut) showed a significantly lower weed biomass for the latter pair (P=0.014).

4.3 Grass yield

The factors treatment and time were significant for grass yield at Jegstad 1 (Table 1). The treatment CC3low (least aggressive Combcut adjustment) gave a 20 % higher grass yield than treatment CC2high (most aggressive CombCut adjustment) (P=0.036), according to the Tukey-Kramer post hoc test (Table 8).

The factor treatment in the experiments at Jegstad 2 and Frydenhaug did not significantly influence grass yield (Table 4 & Table 5).

Table 3 Analysis of variance (ANOVA) table for flowering Rumex spp., vegetative Rumex spp, grass yield and weed biomass at Jegstad 1. Significant P-values in bold.

	Flowering Rumex spp.	**Vegetative Rumex spp.**	**Grass yield**	**Weed biomass**
Treatment	0.34	0.19	**0.0051**	**0.0243**
Time	**<0.0001**	**<0.0001**	**<0.0001**	
Treatment*time	0.18	0.15	0.68	

Table 4 Analysis of variance (ANOVA) table for flowering Rumex spp., vegetative Rumex spp. and grass yield at Jegstad 2. Significant P-values in bold.

	Flowering Rumex spp.	**Vegetative Rumex spp.**	**Grass yield**
Treatment	0.06	0.6808	0.2988
Time	**<0.0001**	0.2364	0.5638
Treatment*time	**0.0379**	0.8897	0.5481

Table 5 Analysis of variance (ANOVA) table for flowering Rumex spp., vegetative Rumex spp. and grass yield at Frydenhaug.

	Flowering Rumex spp.	**Grass yield**
Treatment	0.3	0.72
Initial Flowering Rumex spp.	0.38	
Initial Vegetative Rumex spp.	0.84	

Table 6 Number of flowering and vegetative Rumex spp. m-2 ± SE of the mean at Jegstad 1. Flowering and vegetative Rumex spp. were registered 4 times over 2 years. P-value according to the Tukey-Kramer post hoc test. N.S.: Non significant.

Treatment		July 19, 2016	October 19, 2016	July 6, 2017	September 21, 2017	P-value
Control	Flowering	0.47 ± 0.13	0 ± 0.01	0.88 ± 0.30	0.12 ± 0.09	N.S.
	Vegetative	0.73 ± 0.23	1.18 ± 0.25	0.57 ± 0.16	1.58 ± 0.57	N.S.
CC1high	Flowering	0.08 ± 0.13	0.02 ± 0.01	0.62 ± 0.30	0.12 ± 0.09	N.S.
	Vegetative	0.4 ± 0.23	0.45 ± 0.25	0.37 ± 0.16	1.95 ± 0.57	N.S.
CC2high	Flowering	0.2 ± 0.13	0 ± 0.01	0.93 ± 0.30	0.08 ± 0.09	N.S.
	Vegetative	0.18 ± 0.23	0.67 ± 0.25	0.33 ± 0.16	1.47 ± 0.57	N.S.
CC3low	Flowering	0.33 ± 0.13	0.02 ± 0.01	0.93 ± 0.30	0.3 ± 0.09	N.S.
	Vegetative	0.45 ± 0.23	0.97 ± 0.25	0.38 ± 0.16	2.87 ± 0.57	N.S.
CC4low	**Flowering**	**0.53 ± 0.13 a**	**0 ± 0.01 b**	**0.85 ± 0.30 ab**	**0.2 ± 0.09 ab**	**0.0187**
	Vegetative	0.33 ± 0.23	0.72 ± 0.25	0.38 ± 0.16	1.47 ± 0.57	N.S.
Herbicide	Flowering	0.25 ± 0.13	0.03 ± 0.01	0.17 ± 0.30	0 ± 0.09	N.S.
	Vegetative	0.42 ± 0.23	0.23 ± 0.25	0.2 ± 0.16	0.383 ± 0.57	N.S.

Table 7 Number of flowering and vegetative Rumex spp. m-2 ± SE of the mean at Jegstad 2. Flowering and vegetative Rumex spp. registered 2 times during the growing season. Mean values in the same row quoted with different letters are different at the level α=0.05. P-value according to the Tukey-Kramer post hoc test. N.S.: Non significant.

Treatment		July 6, 2017	September 21, 2017	Level of significance
Control	**Flowering**	**2.5 ± 0.44 a**	**0.22 ± 0.09 b**	**<.0001**
	Vegetative	3.72 ± 0.94	3.53 ± 0.83	N.S.
CClow	Flowering	1.2 ± 0.44	0.13 ± 0.09	N.S.
	Vegetative	3.28 ± 0.94	3.05 ± 0.83	N.S.
CCHigh	Flowering	1 ± 0.44	0.18 ± 0.09	N.S.
	Vegetative	3.33 ± 0.94	2.88 ± 0.83	N.S.

Table 8 Grass yield at Jegstad 1, dry matter daa-1, ± standard error of the mean at Jegstad site 1. Registered 2 times in 2016. Mean values in the same row quoted with different letters are different at the level α=0.05. P-value according to Tukey-Kramer post hoc test. N.S.: Non significant.

Time of registration	**Control**	**CC3Low**	**CC1High**	**CC4Low**	**CC2High**	**Herbicide**	**SE**	**P-value**
July 21, 2016	390.8 ab	401.7 a	370.49 ab	355.69 ab	319.87 b	386.97 ab	17	0.036
October 27, 2016	217.56	181.6	182.72	166.79	128.11	229.21	24.8	N.S.

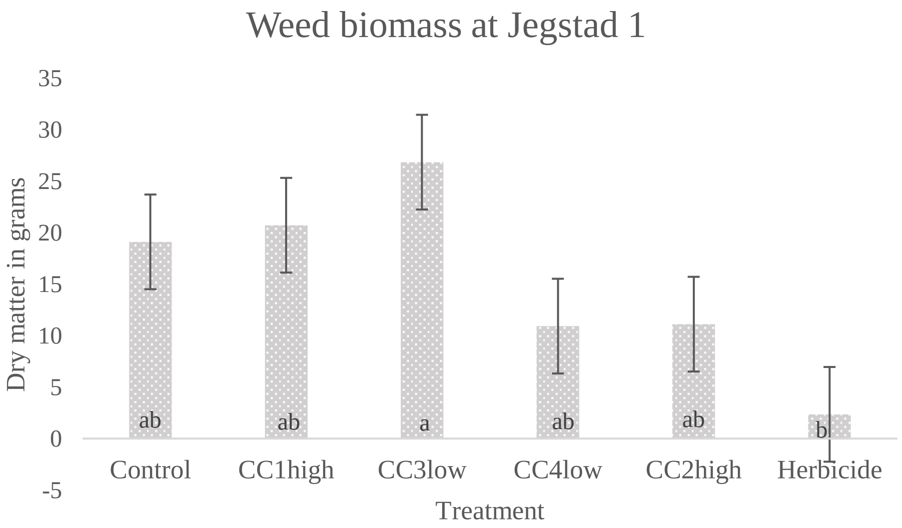

Figure 2 Weed biomass per plot ± SE at Jegstad 1. Bars quoted with different letters are different at the level α=0.05.

5 Discussion

Lack of significant results could be related to insufficient cutting from the CombCut. The reel on the CombCut machine used in 2014, 2016 and for the first treatment in 2017 was driven by the hydraulic outlet on the Tractor. The hydraulic pump on the tractor used (Massey Ferguson 265) delivered an insufficient oil flow to the hydraulic motor that runs the reel on the CombCut. This resulted in an unsatisfactory reel speed, clogging the knife bar and preventing cutting of *Rumex* spp. A tractor with a higher hydraulic capacity or external hydraulic pump run by the power take-off, on the tractor, would help prevent clogging by increasing the reel speed, as seen when using the new machine in the second treatment in 2017 at Jegstad 1 and Jegstad 2. However, even though the reel speed was higher on the machine used for the second treatment in 2017 several *Rumex* plants remained uncut after the treatment. The high density of the ley led to clogging of the knife bar during the second treatment of 2017 as well. Cutting at an earlier growth stage for the ley and weeds might help prevent clogging. A different grass species than rye grass might improve flow through the knife bar. The dense crop hindered cutting heights below the crop canopy and cutting height for the CombCut was set so the inflorescence was cut. An experiment conducted in 1988 by A. Hongo found a reduction in seed production for *R. Crispus* when reducing the cutting height (as cited in Zaller, 2004). This suggest that the effect of selective cutting could be improved by lower cutting heights.

5.1 Effect of cutting on abundance of vegetative and flowering *Rumex* spp.

The ANOVA test showed a decline in the number of flowering *Rumex* spp. throughout the growing season. This explains something about the growth rhythm and time of flowering for *Rumex spp.*, but nothing about the effects of the treatments.

For the treatments CC4low at Jegstad 1 and the Control at Jegstad 2, there was a significant decline in flowering *Rumex* spp. according to the Tukey-Kramer post hoc test. The treatment CC4low was reduced from 0.53 to 0 flowering *Rumex spp*. m^{-2}. The control at Jegstad 2 was reduced from 2.5 to 0.22 *Rumex* spp. m^{-2}. *R. longifolius*, which was the dominating species at all the experimental sites, flowers between June and August (Sjursen, 2013). As the second weed count did not occur until the end of September most *Rumex* plants were already done flowering, possibly explaining the significant decline in flowering plants. Number of plants per m^2 was low for both the treatments with significant differences. Small natural fluctuations in the amount of flowering *Rumex* spp. could therefore have altered the results giving false significant differences between the treatments.

5.2 Weed biomass

The herbicide treatment gave the only significant reduction in above ground *Rumex* weed biomass. A herbicide experiment conducted in England with the same active ingredients as Harmony, which was used in the experiment, showed a decrease in weed population of up to 100 % (Mitchell, n.d.). The herbicide treatment at Jegstad 1, however, only showed a reduction in above ground weed biomass and no significant reduction in the number of *Rumex* plants. Literature suggests that the right time for application of herbicide is when the *Rumex* plant has a large rosette, at the beginning of the stem elongation (Brandsæter & Haugland, 2007; Fykse, 1979). The herbicide in the experiment at Jegstad 1 was not applied until September 12, possibly resulting in a less successful result of the herbicide application.

A contrast between two and two treatments showed that two passes with the CombCut gave a significantly greater reduction in weed biomass compared with one pass. This indicates that cutting of *Rumex* spp. on the first pass was unsatisfactory. The contrast indicates that there is a potential effect of selective cutting at reducing above ground biomass. A study that investigated the reproductive pattern of *R. obtusifolius* found that the plant must reach a threshold size to be able to flower. This suggests that if selective cutting can reduce the above ground biomass, flowering can be inhibited, hindering input to the soil seed bank. Seed output is also influenced by size as smaller plants exhibit a lower seed output than larger plants (Pino et al., 2002).

5.3 Grass yield

The only significant difference found for grass yield was for the first registration at Jegstad 1, between the Combcut treatment CC3low, which was the least aggressive CombCut treatment, and CC2high, the most aggressive CombCut treatment. There was no significant difference in yield between CC3low and CC2high at the time of the second yield registration. The more aggressive CombCut treatment CC2high has a smaller opening between the knives, in the knife bar, making it more prone to cut grass, as well as *Rumex* plants. However, there were no differences between the treatment CC2high and the control. Natural variations in yield at the experimental site could be the reason for the significant difference in yield. The samples taken out for measuring dry matter content might have been non representable for the plot, giving false high/low dry matter content. There were no significant differences in yield between the

CombCut treatments, nor the CombCut treatments and the control at Frydenhaug and Jegstad 2.

5.4 Potential effect of selective cutting

Selective cutting of *Rumex* spp. in between each harvest would be similar to increasing the cutting frequency with respect to reducing biomass, flowering *Rumex* spp. and seed output, i.e. if the selective cutting is successful. Several studies suggest that increased cutting frequency reduces above ground biomass (Stilmant et al, 2010; Zaller, 2004, from A. Hongo 1987). The advantage of selective cutting could be the added effect of competition from the crop.

Selective cutting with the CombCut was not successful in these experiments, leaving *Rumex* spp. uncut after the treatment. The effect of selective cutting of *Rumex* spp. is therefore unclear. Selective cutting of *Cirsium Arvense* in Barley, with scissors at a height of 6 cm above the ground, significantly reduced seed production (Verwijst, Tavaziva & Lundkvist, 2017). Preliminary experiments on selectively cutting *Rumex* spp. could be done with manual cutting of the *Rumex* spp. as this ensures that the *Rumex* spp. are cut, investigating the effect of selective cutting, instead of the effect of the CombCut.

6 Conclusion

Even though the experiments did not show a clear effect on reducing *Rumex* spp., more information on the time of cutting, ideal field conditions for selective cutting and CombCut adjustments are needed to conclude on the effect of cutting *Rumex* spp. with the CombCut.

The CombCut was not successful at cutting all *Rumex* spp. plants under the conditions in these experiments, leaving several *Rumex* spp. uncut.

The CombCut showed no clear effect on reducing flowering nor vegetative *Rumex* spp.

Two-pass-treatments with the CombCut seemed to have a greater effect on reducing *Rumex* spp. biomass compared to one-pass-treatments.

Grass yield seems to be unaffected by selective cutting with the CombCut.

Preliminary experiments should be conducted to investigate the potential effect of selective cutting of *Rumex* spp. e.g. by cutting the *Rumex* spp. with scissors.

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8 Appendix

8.1 Appendix 1

CombCut machine (Just Common Sense AB). Foto: Andreas Myki Beachell

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