

The CERES Trust 2014 Graduate Student Organic Research Grant: Final Report.

Project Title: Use of Mob Grazing and other options for controlling Canada thistle and alleviating losses in forage quality, quantity, and utilization

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Abstract

Canada thistle infestations can negatively affect pasture-based livestock systems by reducing forage production and utilization. Herbicides effectively suppress Canada thistle but also injure forage legumes, an important component in Midwestern pastures. Further, producers working in organic production systems don't have access to chemical control and therefore need alternative suppression strategies. This study compared the efficacy of a fall herbicide application followed by rotational grazing; two mob grazing treatments (one year followed by rotational grazing and two consecutive years); and a rotationally grazed control on Canada thistle density and the resulting forage production and utilization. Rotationally grazed treatments were grazed 3-4 times and Mob grazed plots were grazed twice, once in the spring and once in the fall, in 2012 and 2013. Herbicide application followed by two years of rotational grazing was the most effective treatment across both years and all sites with substantial control lasting two years. By spring 2014, Canada thistle density had increased two to four fold in Mob grazed treatments at two of three sites compared to the rotationally grazed plots. At a third site non-significant reductions in stem density were observed. A third season of data collection at two of three sites shows a significant reduction of Canada thistle stems compared to the control at one site, and still significant increases in stems at the other. Mob grazing for two years increased forage production by

24-76% compared to the rotational control and those treated with a herbicide across sites in 2013. At the most productive site, herbicide application reduced clover and other broadleaf biomass, causing a 25-38% reduction in forage production when compared to rotationally grazed treatments. Mob grazing increased Canada thistle utilization at one of three sites compared to rotational grazing. While mob grazing did not provide improved thistle suppression after two years, the potential for increases in forage availability and utilization suggest that mob grazing may provide benefits beyond thistle control for producers. Additionally, reductions in forage production resulting from herbicide application in legume-rich pastures recommend further research into viable alternative control methods.

Introduction

Management intensive rotational grazing has become an established practice throughout Wisconsin and the Upper Midwest due to its economic, environmental, and production benefits (Dartt et al. 1999; Paine and Gildersleeve, 2011; Taylor and Foltz, 2006; Lyons et al. 2000). One such benefit is the prevention of weed emergence and suppression of infestations by competitive, desirable forage species in pastures that are managed using rotational grazing (Wardle et al. 1995; Trumble and Kok 1982). While weed species are less common in rotationally grazed pastures, weed infestations can still occur. Canada thistle (*Cirsium arvense* L.) (hereafter CT) has been identified as a weed of particular concern in temperate regions (Moore 1975). CT can reduce the production and utilization of desirable forage which can result in losses in animal performance (Undersander et al. 2002). For example, desirable yield losses caused by Canada thistle presence have been estimated at 2 kg ha⁻¹ for each kilogram of thistle biomass (Grekul and Bork 2004). In addition, Canada thistle's spiny leaves can reduce forage utilization by up to 60% (De Bruijn and Bork 2006).

While weed control is desired by producers, Canada thistle is notably hard to suppress due to its aggressive perennial roots (Moore 1975). Most research conducted on controlling Canada thistle in pastures and grasslands has focused on the use of herbicides, many of which, though effective (Enloe et al. 2007), can cause injury to clover populations (Bork et al. 2007) and are not registered for use in organic systems (National Organic Program). One alternative to chemically-intensive control is altering grazing to improve suppression. It has been documented that control of weed species can be enhanced by increasing weed utilization by animals (Rinella 2009; Peterson 2013), physically injuring the weed with hoof action (Popay and Field 1996), and encouraging rapid forage regrowth that facilitates interspecific competition (De Bruijn et al. 2010).

Rotational grazing systems can be modified to maximize the aforementioned impacts on Canada thistle. Mob grazing is one such practice, described by Allen et al. (2011) as Mob stocking and defined as "A method of stocking at a high

grazing pressure for a short time to remove forage rapidly as a management strategy.” Among producers and popular press, Mob grazing (sometimes referred to as ultra high stocking density) has been implicated as a grazing management system that suppresses Canada thistle and increases forage production and utilization (Kidwell 2010; Lemus 2011; Johnson 2013). However, there has been little research conducted focusing specifically on Mob grazing or its reported benefits. One study researching big bluestem (*Andropogon gerardii* Vitman) establishment found Mob grazing to be ineffective at controlling weeds when compared with atrazine (Lawrence, 1995), while three experiments effectively used Mob grazing as a technique to decrease selectivity in pasture germplasm and persistence trials (Bittman and McCartney 1993; Gildersleeve 1987; McCartney and Bittman 1994). High intensity low frequency grazing has also been documented to nearly eliminate Canada thistle after three years of grazing (De Bruijn and Bork 2005). Other studies have explored using sheep (Olson and Wallander 2001) and goats (Hejcman et al. 2014) as biological control agents, but few have focused on the use of cattle (Popay and Field, 1996). The limited and conflicting nature of the existing literature on Mob and other high intensity grazing regimes relating to weed control justifies further effort.

Definitions among rotational grazing systems are seldom universally applicable, often making distinctions unclear and confusing. While HILF grazing has been shown to effectively suppress Canada thistle, this terminology appears to be used solely in research communities (Taylor 1993; De Bruijn, 2005). Mob grazing in its most recent incarnation is seen as a producer-generated term used by grazing communities that differs from HILF grazing by using higher stocking densities, shorter grazing events, longer rest periods, and utilizing more mature forage (Chapter 2, Thomas 2012; Kidwell 2010; Holin 2013). The lack of research exploring grazing and Canada thistle control in the Midwest and the increase in organic grazing operations both support the need for more research. Further, a focus on Mob grazing, an increasingly-adopted but little-studied grazing strategy, provides important information about the utility and productivity of this form of management intensive rotational grazing. The objective of our study was to evaluate the effect of Mob grazing on forage productivity, forage utilization, and Canada thistle suppression compared to other standard practices.



Rotationally grazed treatment ~ 60,000 lbs/acre liveweight

Mob grazed treatment~ 400,000 lbs/acre liveweight

Objectives/Performance Targets

The project's objective is to develop an understanding of the efficacy of mob grazing as a biological weed abatement strategy as compared to herbicide application. Further, valuable agronomic information pertaining to mob grazing will be collected including yield, species composition, and forage utilization. The measurements that we take and the statistical and narrative interpretation that results will help to increase awareness of alternatives to chemical control methods as well as provide information about implementing such strategies. These outcomes will be directed towards members of the focus group, all of which are capable of distributing information to their considerable networks of producers and educators. Intermediate outcomes will include the extension of this information to grazing networks and sustainable agriculture organizations as well as publication in peer reviewed journals, all with the end goal of successful adoption of best practices recommended by our research. Long-term outcomes include an important contribution to a knowledge base of non-chemical weed control strategies and their implementation specific to Wisconsin and the upper Midwest. Additionally, as mob grazing continues to attract attention and interest within grazing communities, this study will pave the way for future research on the technique.

Results and Discussion

Canada thistle density

Herbicide application followed by two years of rotational grazing (H-Rgraze 2 yrs) was found to be the treatment most effective at reducing Canada thistle density. Aminopyralid + 2,4-D reduced CT densities to the lowest levels compared to other treatments across all three sites and timings except for one, demonstrating the effectiveness of this herbicide at suppressing CT for multiple years (Table 1). Effectiveness of mob grazing compared to other treatments varied by sampling time. One year after the experiment was initiated (fall 2012), Mob grazing reduced CT density 76-98% compared to Rgraze, and suppression was equivalent to or greater than H-Rgraze at all three sites. However, by spring 2013, Mob grazed treatments had similar or more CT stems m^{-2} compared to Rgraze, and 5 to 40 times more CT than the H-Rgraze treatment at all sites. Differences between fall of 2012 and spring of 2013 may be attributed to the severe drought in 2012 as CT often does not resprout in drought conditions (Wilson 1979).

Two years after the experiment was initiated (Fall 2013), Aminopyralid +2,4-D suppression was visible at only one of the three sites compared to Rgraze treatments. Lancaster maintained an eightfold reduction in CT density, while the other two sites were similar to Rgraze or Mob treated plots for one year. Mob grazing for two years resulted in two to 4 fold greater CT densities across two sites, and similar densities at the third site. The lack of precipitation in 2012 may have been a factor in this observed increase. Bare ground in the Mob grazed plots at all three sites increased three to 32 times over Rgraze by the

fall of 2012 (data not shown). This would have resulted in the high temperatures and light intensities that optimize CT germination (Bakker 1960; Moore 1975; Renz and Schmidt 2013). Also bare ground creates points of entry for the vegetative spread of CT (Amor and Harris 1975). It's feasible that the drought year created both bare ground and soil disturbance resulting from grazing less productive pastures, two factors that may have encouraged the CT spread that was observed in the fall of 2013 (Moore 1975; Bakker 1960).

By spring 2014, Canada thistle density remained high in Mob/Mob plots with a six to eightfold increase over Rgraze 2yrs at Prairie du Sac and Hollandale. Conversely, at Lancaster, Mob/Mob reduced Canada thistle stem density by 33% compared to RGraze 2yrs, but was not significantly different than any of the other treatments. Mob grazing for one year had no influence on Canada thistle density, suggesting limited benefit from implementing this approach for one year for weed suppression. While variable, our results contradict those of De Bruijn and Bork (2006) who found that 2-3 years of twice annual intense defoliations nearly eliminated CT stems. The effect of Aminopyralid and 2,4-D was still evident at Lancaster only, with a fourfold reduction in CT density. The other two sites were similar to treatments rotationally grazed for one or two years. Our results agree with other studies with respect to herbicide effectiveness 1 YAT (Enloe et al. 2007). Additionally, Almquist and Lym (2010) found that control begins to decrease slightly by 22 MAT, roughly the same timeframe in which we observed a small increase in CT stems between spring and fall 2013.

While many studies have focused on chemical control, few have directly compared results to different grazing management strategies. Studies that have found grazing treatments to suppress CT often credit interspecific competition as the primary control agent (Pywell et al. 2009), increased in the desirable forage's favor through long rest periods and rapid forage regrowth (De Bruijn et al. 2010; Edwards et al. 2000). The 2012 drought decreased forage production (see tables 2, 4, 6) and likely reduced long-term CT control in our study. Differential results with respect to site may be due to the varying productivity of the pasture sward between locations. Lancaster experienced the greatest productivity as well as the most even distribution of biomass between grasses and legume forages (Tables 6 and 7). We believe that the further increase in production found in plots Mob grazed for two years resulted in CT suppression. This hypothesis is supported by Tracy and Sanderson (2004) who found that both productive pastures and multiple forage species work in unison to effectively reduce weed populations. Pywell et al. (2009) also found that CT density was primarily affected by the competitiveness of grass species. Thus previous efforts strongly support our hypothesis that the increased productivity and contribution of multiple species observed at Lancaster is an important variable involved in the suppression of CT in any treatment that causes substantial injury or damage (e.g. herbicide, Mob grazing for multiple years).

In contrast, Prairie Du Sac and Hollandale lacked the productivity found at Lancaster. Yield and species differences resulted in 38-45% lower sward heights in mob treatments compared to Lancaster throughout the experiment (data not shown). A significant difference in forage heights was also found between years, with a 26-69% reduction in mean sward height during the drought of 2012. Forage height affects light intensity by intercepting solar radiation before reaching seedlings or the soil surface (Renz and Schmidt 2013), an important factor in weed suppression. CT Seedlings die if light intensity falls below 20% of full daylight, and at 60-70% of full daylight seedlings experience a reduction in growth (Moore 1975). Further, taller forage is often accompanied by a decrease in forage utilization and an increase in trampling as livestock tread on elongated stalks while grazing the more palatable leaves and seed heads. We suggest that in productive pastures, forage trampling may create a mulch layer that discourages CT germination and establishment. A substantial mulch layer was observed only at Lancaster (personal observation).

Pasture Productivity

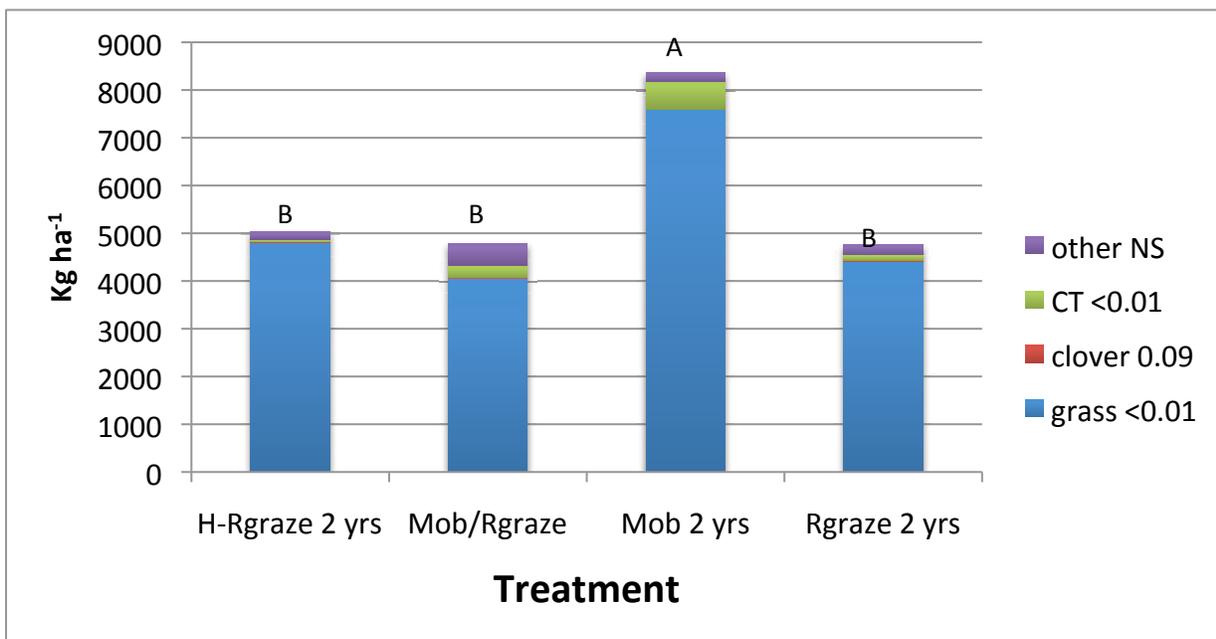
Total forage production in 2013 across sites in Mob grazed plots was 24-76% higher than other treatments, though not statistically significant at Lancaster (Tables 6 and 7). Rotationally grazed plots experienced shorter rest periods and more numerous defoliations than Mob grazed plots, inhibiting maximum regrowth and dry matter production. Higher stocking density in Mob grazed plots also allowed for increased and more even manure deposition which also may have enhanced productivity (Hansen 1996; Sanderson and Jones 2013).

Herbicides, though found to effectively control CT, also decreased non-target clover populations by 95 to 100% at all three sites 1 year after treatment (tables 2, 4, and 6). These findings align with Bork et al. (2007) who found that herbicides reduced non-thistle forbs 1 YAT. However, whereas they found an increase in grass production with decreases in forb and legume density, this pattern was not observed at any site for either year in our study. Further, total forage biomass was negatively affected by herbicide application at Lancaster when compared with RGraze 2yrs and Mob 2yrs (tables 6 and 7). This decrease in productivity is explained by reductions in all forb classes, including clovers, CT, and "other" which includes various weedy species such as dandelion (*Taraxacum officinale* Weber), wild carrot (*Daucus carota* L.), and wild parsnip (*Pastinaca sativa* L.), many of which are of acceptable forage quality when in vegetative growth stages (De Bruijn and Bork, 2006; Marten et al. 1987). Mob 2yr also reduced clover biomass 2YAT at all three sites compared to Rgraze 2yrs, agreeing with Pywell et al. (2009) who found that grazing regimes with taller residual sward height reduced non-target forb diversity. Increasing manure deposition, as happens in Mob grazed plots, may also be a reason for reduced clover biomass (Hansen 1996).

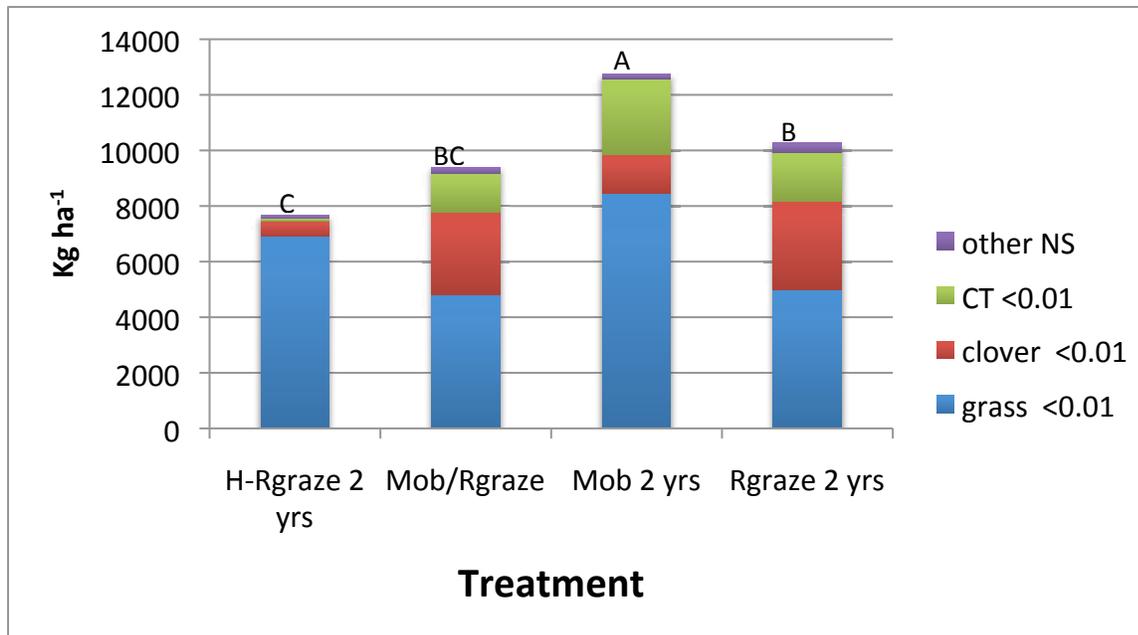
While Mob grazing for 2 years decreased clover biomass, it increased CT biomass across all sites during the second year. CT biomass was highest in Mob 2yrs at

all locations compared to other treatments, two of them significantly. It is unclear if this result indicates an increase in CT populations or a transfer of below ground energy reserves aboveground. If the latter is true, this is a requirement to improve long-term control of CT. Often not realized; however, is that CT is of high nutritive value, particularly in the earlier stages of growth (Marten et al. 1987, De Bruijn and Bork, 2006). Therefore, depending on when defoliation occurs, an increase in CT biomass could be seen as a productive contribution to the overall pasture portion of an animal's diet, especially if CT utilization can be increased through changing livestock behavior, such as through Mob grazing

The two figures below are only for 2013, and only detail two of the three sites, but they effectively illustrate the stark differences between production capacity of mob and other treatments. Also, note the substantial reduction in clover, CT, and 'other' categories in the treated plots at Lancaster, leading to an overall reduction in pasture productivity.



Pasture Productivity in 2013 at Prairie Du Sac, WI



Pasture productivity in 2013 at Lancaster, WI

Forage Utilization

Forage utilization generally followed the same pattern as forage productivity, when more forage was available, more was utilized. At Prairie Du Sac, the least productive site, CT and total utilization were consistently the highest in Mob grazed plots in both 2012 and 2013 (tables 4 and 5). Whereas at Lancaster, the most productive site, grass tended to be less utilized in Mob grazed plots than in other treatments in 2012 and more utilized in 2013 (tables 6 and 7). The drought year of 2012 was accompanied by a very early spring that allowed forages to reach advanced maturity before CT reached bud stage in mob plots. Much of this mature forage was trampled before it could be utilized, and once soiled, was refused by grazing livestock. In 2013 however, an average spring allowed CT plants to reach bud stage before forages reached full maturity, thus forage was more palatable than the previous year, decreasing trampling and increasing utilization to levels comparable to other treatments. Additionally, CT production increased in 2013 with utilization increasing accordingly, driving up overall consumption. We believe that the high level of grass, CT, and total forage utilization in Mob plots at Prairie Du Sac can be explained by the lower mean sward height and decreased biomass production. Because there was less forage to refuse and/or trample, the cattle utilized 1.5-2.5 times more total forage when compared with RGraze 2 yrs. At Hollandale, total utilization was not significantly different between treatments for either year (tables 2 and 3).

The relationship between productivity and utilization is also evident in relative forage utilization. At the less productive Prairie Du Sac, total percent utilization is 19-30% lower in RGraze than in Mob grazed plots, while at Lancaster in 2012, utilization is 25% lower in Mob than RGraze plots (see above) and not different

in 2013. Percent CT utilization generally followed the same pattern as percent total utilization save for a notable reversal at Lancaster in 2012. While total utilization was 25% lower in Mob 2yrs than Rgraze 2 yrs, CT utilization was increased by 66% in Mob plots compared to RGraze in 2012 and by 94% in 2013, though only significant in 2012. These results suggest that the decreased selectivity which leads to CT herbivory in high-intensity low frequency grazing described by De Bruijn and Bork (2006) and Peterson et al. (2013) is also evident in Mob grazing systems.

Some have suggested that grazing behavior is partially socially facilitated, with grazing animals learning what plants are palatable or poisonous through observation and mimicry (Ralphs and Provenza, 1999). At Prairie Du Sac and Lancaster, small herd sizes ensured that the same animals were used in all plots for the entire grazing season, allowing ample time for socialization that may have included CT utilization behavior spreading among the herd. Hollandale had the largest herd and the smallest plots, decreasing the chances of animals repeatedly being used in research plots, decreasing the potential for socialization relating to CT utilization at high stock densities.

Conclusion

Through increasing stocking density and lengthening rest periods, forage production and utilization, including CT production and utilization generally increased, agreeing with De Bruijn and Bork's (2006) findings. However, in contrast to their conclusions, we did not observe suppression of Canada thistle. It's possible that Wisconsin's longer growing season allows for greater CT persistence than in the Aspen Parkland ecoregion in central Alberta, where their research was conducted. Additionally, grazing protocols differed, with De Bruijn and Bork's including shorter post-graze residual (2 cm) and increased utilization and CT damage through longer grazing periods (De Bruijn and Bork 2006). Our hesitance to lengthen grazing periods resulted from a desire to closely mimic producer behavior so as to enhance potential adoption of the researched practices. Further, they found additional decreases in CT density after a third year of high-intensity grazing, with our study running for only two. While the version of Mob grazing that we applied to Wisconsin pastures proved not to be as effective as herbicide application in suppressing CT and increased thistle density at two out of three sites, at a third site we observed enhanced thistle control in plots that had been Mob grazed for two years. However, the patchy and unpredictable nature of Canada thistle created variability that eliminated statistical significance (Eber and Brandl, 2003).

We hypothesize that pasture productivity enhanced interspecific competition in favor of desirable forages, and may be an important factor in Canada thistle suppression in conjunction with Mob grazing, as others have documented (Edwards et al. 2000; Pywell et al. 2009). Additionally, the higher mean sward height resulting from long rest periods in Mob grazed plots decreased light infiltration and increased the amount of trampled forage, potentially introducing

smothering as a mode of action. Lastly, tempering the lack of CT suppression is the increase in forage biomass produced and utilized in Mob grazed plots, a windfall for producers desiring increased forage production. Given that benefits beyond potential Canada thistle control may result from Mob grazing, it's clear that more region-specific research exploring the role of grazing in weed control is needed, as well as fine-tuning grazing management to maximize production together with potential weed suppression.

Management Recommendations

Boiling complex research projects down to straight-forward recommendations is always a challenge, but one that must be at least attempted if the time, energy, and resources going into research are to be at all justified. Pertaining to Canada thistle control, a herbicide, while effective, will also kill all desirable broadleaf forages including nitrogen-fixing, protein-rich legumes, and will reduce the total amount of available forage. Herbicides are also prohibited in organic operations, necessitating viable alternatives. Mob grazing may be an effective control strategy if used in diverse, productive pastures, but may also increase thistle density in less productive swards. Although thistle populations may increase, so too will the productive capacity of the pasture as well as the total utilization of biomass, including the thistle itself. If grazed at vegetative to flower bud stage, Canada thistle has good forage quality and can be a productive portion of a well-balanced (protein – fiber) ruminant diet. If a thistle infestation is severe; however, utilization will decrease, and control may be necessary. If using non-chemical control, and if portable fencing is available, we recommend strategically using a stocking density of at least 400,000 lbs. of live weight per acre applied across the entire infestation. Infested paddocks should be grazed when the thistle has reached flower bud stage, or just before if forages are getting overly mature, to maximize impact and utilization. Animals should be left in the paddock until thistle stems are severely damaged, eaten, or trampled, after which pastures should be rested for an extended period of time (60-90 days) to allow for desirable forage to regrow and compete with reemerging thistle shoots. One grazing event in June (flower bud stage), and another in September when thistles may be flowering again may enhance potential control. This strategy should be used for at least two years, and more if possible, until acceptable control is reached.

Publications and Outreach

There are three manuscripts currently being drafted for publication in peer-reviewed journals. Beyond publications, results have been, or will soon be, presented at numerous conferences including North Central Weed Science Society meetings, the annual MOSES conference, UWEX grazing educator meetings, the annual Grassworks grazing conference, the Upper Midwest Invasive Species Conference, and the ASA, CSSA, and SSSA International Annual Meeting. Additionally, presentations have been given at numerous producer-focused pasture walks and field days. Lastly, our research was written about and a series of four videos focusing on mob grazing in the Midwest were made for Hay & Forage Grower, an industry publication with a broad readership.

Table 1. Effects of four grazing treatments on Canada thistle stem density at three study locations across two years. Treatments evaluated include 1) an herbicide application followed by rotational grazing for two years (H-Rgraze 2 yrs), 2) rotational grazing for two years (Rgraze 2 yrs), 3) Mob grazing for one year followed by one year of rotational grazing (Mob/Rgraze) and 4) Mob grazing for two years (Mob 2 yrs). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

Canada thistle stem density (shoots/m²)

Treatment	<u>Hollandale</u>				<u>Prairie Du Sac</u>				<u>Lancaster</u>			
	F '12	S '13	F '13	S '14	F '12	S '13	F '13	S '14	F '12	S '13	F '13	S '14
H-Rgraze 2 yrs	0.6 b	1.8 b	2.3 b	0.4 b	0.9 b	1.3 c	2.5 b	1.3 b	0.4 c	0.3 b	3.6 b	5.7 b
Mob/Rgraze	-	-	3.5 b	0.9 b	-	-	7.1 ab	4.1 ab	-	-	23.9 a	21.9 a
Mob 2 yrs	0.4 b†	9.5 a†	14.2 a	5.5 a	0.1 c†	11.6 a†	12.5 a	7.3 a	4.5 b†	14.3 a†	12.9 ab	16 ab
Rgraze 2 yrs	1.7 a	7.6 a	4.3 b	0.8 b	4 a	4.2 b	3.4 b	0.9 b	17.4 a	15.4 a	24.9 a	24 a
p-value	<0.01	<0.01	<0.01	<0.0	<0.01	<0.01	<0.01	0.01	<0.01	0.03	0.02	0.02

1

† Mob 2 yrs measurements for Fall '12 and Spring '13 are pooled data from Mob 1 year and Mob 2 year plots as treatments were identical during the first year of study. Fall 2013 measurements are separated with "Mob 1yr, Rotational" representing a rotational grazing treatment following one year of Mob Grazing and "Mob 2yr" representing two consecutive years of Mob Grazing

Table 2. Effects of four grazing treatments on forage biomass production, forage utilization, and percent utilization in temperate pastures at Hollandale, WI in 2012. Treatments evaluated include 1) an herbicide application followed by rotational grazing for one year (H-Rgraze), 2) rotational grazing for one year (Rgraze), and 3) Mob grazing for one year (Mob). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

2012 forage productivity and utilization

<u>Treatment</u>	<u>Forage available (kg/ha)</u>					<u>Forage utilized (kg/ha)</u>					<u>% utilization</u>	
	<u>Grass</u>	<u>Clove</u>	<u>CT</u>	<u>Othe</u>	<u>Total</u>	<u>Grass</u>	<u>Clove</u>	<u>CT</u>	<u>Othe</u>	<u>Total</u>	<u>Total</u>	<u>C.</u>
<u>t</u>		<u>r</u>		<u>r</u>			<u>r</u>		<u>r</u>			<u>thistle</u>
H-Rgraze	3701 a	0‡	51 b	146 b	3898 b	2738 a	0‡	30 b	136 b	290 3	76 a	43
Mob [§]	2793 b	1896 a	595 a	525 a	5809 a	994 b	1365	266 a	378 a	300 2	51 b	47
Rgraze	3335 ab	684 b	461 a	627 a	5106 ab	2292 a	548	299 a	364 a	350 3	69 a	65
p-value	0.09	0.09	<0.01	<0.01	0.06	<0.01	NS	<0.01	0.02	NS	<0.01	NS

‡Not included in the ANOVA statement as no variability was present

§Pooled Mob 1 year and Mob 2 year treatments as protocols were identical the first year of study.

Table 3. Effects of four grazing treatments on forage biomass production, forage utilization, and percent utilization in temperate pastures at Hollandale, WI in 2013. Treatments evaluated include 1) an herbicide application followed by rotational grazing for two years (H-Rgraze 2 yrs), 2) rotational grazing for two years (Rgraze 2 yrs), 3) Mob grazing for one year followed by one year of rotational grazing (Mob/Rgraze) and 4) Mob grazing for two years (Mob 2 yrs). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

2013 forage productivity and utilization

Treatment	Forage available (kg/ha)					Forage utilized (kg/ha)					% utilization	
	Grass	Clove	CT	Other	Total	Grass	Clove	CT	Other	Total	Total	C. thistle
H-Rgraze 2 yrs	6827	9 b	241 b	111 b	7188	460	6 b	91	73 b	477	67 a	38
		r			ab	8				8		
Mob/Rgraze	6619	132	405 b	257	7415	450	103	22	206	503	68 a	49
e		b		ab	ab	0	b	0	ab	0		
Mob 2 yrs	7426	68 b	1196	470 a	9160 a	373	55 b	47	402 a	466	51 b	37
			a			4		8		9		
Rgraze 2 yrs	5604	699 a	328 b	413	7045 b	334	540 a	15	311	434	61 a	43
				ab		2		0	ab	4		
p-value	NS	<0.01	<0.01	0.07	0.08	NS	<0.01	NS	0.07	NS	<0.01	NS
		1					1					

Table 4.. Effects of four grazing treatments on forage biomass production, forage utilization, and percent utilization in temperate pastures at Prairie Du Sac, WI in 2012. Treatments evaluated include 1) an herbicide application followed by rotational grazing for one year (H-Rgraze), 2) rotational grazing for one year (Rgraze), and 3) Mob grazing for one year (Mob). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

2012 forage productivity and utilization

Treatment	Forage available (kg/ha)					Forage utilized (kg/ha)					% Utilization	
	Grass	Clove	CT	Othe	Total	Grass	Clove	CT	Othe	Total	Total	C. thistle
H-Rgraze	2840 ab	1	24 c	217 b	3081 b	220 5	1	19 b	145	2368 b	76 ab	79 ab
Mob [§]	3538 a	48	321 a	616 a	4524 a	298 1	42	278 a	534	3748 a	83 a	88 a
Rgraze	2727 b	26	129 b	829 a	3710 b	198 3	25	52 b	429	2485 b	67 b	40 b
p-value	0.06	NS	<0.01	0.03	<0.01	NS	NS	<0.01	NS	<0.01	0.06	0.04

[§]Pooled Mob 1 year and Mob 2 year treatments as protocols were identical the first year of study.

Table 5. Effects of four grazing treatments on forage biomass production, forage utilization, and percent utilization in temperate pastures at Prairie Du Sac, WI in 2013. Treatments evaluated include 1) an herbicide application followed by rotational grazing for two years (H-Rgraze 2 yrs), 2) rotational grazing for two years (Rgraze 2 yrs), 3) Mob grazing for one year followed by one year of rotational grazing (Mob/Rgraze) and 4) Mob grazing for two years (Mob 2 yrs). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

2013 forage productivity and utilization

Treatment	Forage available (kg/ha)					Forage utilized (kg/ha)					% Utilization	
	Grass	Clove	CT	Other	Total	Grass	Clove	CT	Othe	Total	Total	C. thistle
H-Rgraze 2 yrs	4808 b	13 ab	47 c	163	5031 b	2921 b	13	28 b	99	3056 b	62 ab	40 ab
Mob/Rgraze	4651 b	19 ab	254 b	463	4787 b	2683 b	15	78 b	425	3200 b	67 ab	43 ab
Mob 2 yrs	7603 a	2 b	580 a	183	8368 a	5869 a	2	504 a	168	6543 a	79 a	87 a
Rgraze 2 yrs	4403 b	34 a	109 bc	220	4766 b	2474 b	31	41 b	89	2612 b	55 b	29 b
p-value	<0.01	0.09	<0.01	NS	<0.01	<0.01	NS	<0.01	NS	<0.01	0.03	0.10

Table 6. Effects of four grazing treatments on forage biomass production, forage utilization, and percent utilization in temperate pastures at Lancaster, WI in 2012. Treatments evaluated include 1) an herbicide application followed by rotational grazing for one year (H-Rgraze), 2) rotational grazing for one year (Rgraze), and 3) Mob grazing for one year (Mob). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

2012 forage productivity and utilization

Treatment	Forage available (kg/ha)					Forage utilized (kg/ha)					% Utilization	
	Grass	Clover	CT	Other	Total	Grass	Clover	CT	Other	Total	Total	C. thistle
H-Rgraze	6250	79 c	0 ‡	22 b	6357 b	4921 a	76 c	0 ‡	12 b	4995 ab	80 a	0 ‡
Mob [§]	7612	1320 b	1642	68 b	10618 a	2681 b	924 b	1058	67 ab	4921 b	46 c	68 a
Rgraze	6364	1945 a	1793	213 a	10314 a	4020 ab	1502 a	581	182 a	6285 a	61 b	41 b
p-value	NS	<0.01	NS	0.01	<0.01	0.02	<0.01	NS	0.06	0.09	<0.01	0.03

‡Not included in the ANOVA statement as no variability was present

§Pooled Mob 1 year and Mob 2 year treatments as protocols were identical the first year of study.

Table 7. Effects of four grazing treatments on forage biomass production, forage utilization, and percent utilization in temperate pastures at Lancaster, WI in 2013. Treatments evaluated include 1) an herbicide application followed by rotational grazing for two years (H-Rgraze 2 yrs), 2) rotational grazing for two years (Rgraze 2 yrs), 3) Mob grazing for one year followed by one year of rotational grazing (Mob/Rgraze) and 4) Mob grazing for two years (Mob 2 yrs). Treatments were replicated four times at each site. Letter codes indicate significance of pairwise tests within columns.

2013 forage productivity and utilization

Treatment	Forage available (kg/ha)					Forage utilized (kg/ha)					% Utilization	
	Grass	Clover	CT	Other	Total	Grass	Clover	CT	Other	Total	Total	Coefficient of variation
H-Rgraze 2 yrs	6914 b	559 c	85 b	105	7662 c	4308	473 b	12 b	62	4781 b	62	14
Mob/Rgraze	4799 c	2988 a	1384 a	235	9405 bc	2860 b	2020 a	249 b	111	5144 b	54	18
Mob 2 yrs	8454 a	1400 b	2734 a	159	12747 a	4287 a	1031 b	1827 a	158	7303 a	57	68
Rgraze 2 yrs	4999 c	3184 a	1739 a	351	10272 b	3005 b	2280 a	629 ab	261	6176 ab	60	35 a
P-value	<0.01	<0.01	<0.01	NS	<0.01	0.01	<0.01	<0.01	NS	0.04	NS	<0.01

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