

HABITAT CHARACTERISTICS OF MUSKTHISTLE POPULATIONS
IN THE FLINT HILLS OF KANSAS

by

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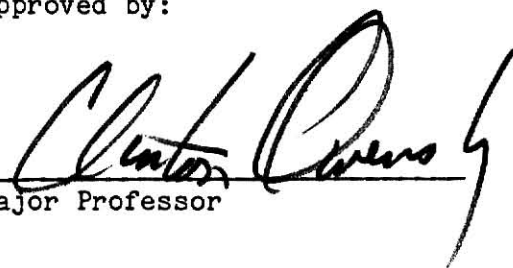
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HABITAT CHARACTERISTICS OF MUSKTHISTLE POPULATIONS IN THE FLINT HILLS OF KANSAS

Introduction

Muskthistle (Carduus nutans L.), a member of the sunflower family (Compositae), is a noxious weed in Kansas (Nilson 1976) that is invading the rangelands of the Flint Hills. During its reproductive stage, muskthistle can be six feet tall and have large purple to pink, rarely white, flowers (McCarty et al. 1980) (Fig. 1). The large lobed leaves are spiny and can form dense canopies (McCarty 1979) (Figs. 2a, 2b).

Muskthistle is usually established on waste or disturbed sites (Feldman et al. 1968), but in the Flint Hills, it also occurs on stream banks and stream beds and is advancing onto pastures. The invasion of muskthistle onto pastures concerns farmers and ranchers because animal performance lessens where infestations are high (Kok 1975). Control methods consist primarily of applying some type of herbicide to the plant, though some mechanical methods have proven effective (Delahunty 1960 and 1961).

Biological control is one of the most recent methods to be tried. Two different insects, one which attacks the seeds, and one which attacks the basal rosette, are now being introduced with some success (Hodgson and Rees 1976; Kok 1975).

Regardless of the control practice used, control can be made effective if habitat and physiological characteristics of muskthistle populations are considered. The purpose of this study was to determine the habitat characteristics of muskthistle populations in the Flint Hills.



Fig. 1 Bolted muskthistle in bloom growing on a native prairie grass pasture.



Fig. 2a Thick stand of bolted muskthistle forming a thick canopy cover.



Fig. 2b Muskthistle rosette showing how large a ground canopy it can form (note pencil for scale).

Materials and Methods

The study area was within Riley and Pottawatomie counties where 20 pairs of grassland sites were chosen, 14 in Riley and 6 in Pottawatomie. Each pair consisted of an infested site and an uninfested site and were not more than 100 m apart. Range site, soil type, and parent material were the same for each pair.

All sites, except for one pair, 9 infested and uninfested, were grazed and none had been burned for at least 3 years.

Sites were classified and analyzed by range sites: loamy lowland, loamy upland, clay upland, and limy upland (Riley County Soil Survey 1975).

Sampling occurred from the first week of October to the first week of November, 1981. A second count of muskthistles was made at the end of May, 1982.

Vegetative measurements taken were muskthistles per square meter, percent species composition, percent canopy cover, percent basal cover, percent bare ground, percent litter cover, and average depth of litter. Except for muskthistles per m^2 and percent canopy cover, all other parameters were determined by the modified step-point system (Owensby 1973). To determine the number of points to be taken at each site, the minimal sample area technique was used (Cain and Castro 1959; Mueller-Dombois and Ellenberg 1974).

In comparing the species composition between infested and uninfested sites, to determine the degree of similarity, Sørensen's index of similarity was used (Mueller-Dombois and Ellenberg 1974).

Percent canopy cover was determined by the canopy coverage method of Daubenmire (1959) using twenty 1 m^2 circular plots. The following

groups for canopy cover were used: short grass, 0-10 cm; medium grasses, 10-20 cm; tall grasses, 20+ cm; decumbent forbs; medium forbs, up to 20 cm; tall forbs, 20+ cm; and woody species.

On infested sites, circular plots were permanently marked with a stake in the middle, and the number of muskthistles, rosettes in the fall and bolted muskthistles in the spring, were counted.

Soil samples were taken with a Uhland Sampler (Foth et al. 1982) and oven dried at 120°C for 48 hours. The soil was divided into A and B horizons with a sample taken from each, except where no B horizon existed. Percent organic matter, percent moisture (by volume), pH, bulk density, and particle size composition were then determined from these samples.

Organic matter was determined colorimetrically (Graham 1948) and pH was determined by the glass electrode pH meter (McLean 1980). Moisture was determined by the estimation procedure of Gupta and Larson (1979), and particle size composition was determined by the hydrometer method (Foth et al. 1982).

These and other soil characteristics, such as parent material soil texture, and soil type, are listed for each site in Appendix Table 1.

All parameters were entered in simple linear regressions, and in a multiple regression model.

Analysis of variance and Duncan's multiple range test were used to analyze vegetative and soil measurements across all range sites in a completely randomized design and a general linear models and least significant difference test was used to analyze vegetative and soil measurements by range sites in a randomized complete block design. The

stepwise procedure was used to obtain the multiple regression model. Means separation was done using $p < .10$.

Results and Discussion

Influence of Vegetative and Soil Characteristics

Between infested and uninfested range sites, percent canopy cover appeared to be the most important factor, being significantly greater on all uninfested sites than on infested sites (Table 1). Therefore, a high canopy cover (140% or more) should aid in preventing an invasion of muskthistle. McCarty and Scifres (1969) indicated that muskthistle was less competitive when it was in the shade, and results of this study support that. They also reported that bare ground was conducive to muskthistle seedling establishment, but that occurred only on loamy upland sites in this experiment.

On loamy upland sites, sparse shallow litter was also conducive to muskthistle seedling establishment which was opposite of what Evans and Young (1972) found in their study on weed seed germination. They indicated that litter was a favorable site for muskthistle seed germination.

High percent species composition of grass (Table 1) appeared to be a deterrent to muskthistle establishment which agreed with work by Doing, et al. (1969).

It could not be determined in this comparison that any of the soil characteristics favored muskthistle establishment (Tables 2 and 3).

When vegetative and soil characteristics were compared across all range sites and between infested and uninfested sites, high percent

Table 1 Comparison between infested and uninfested range sites of vegetative characteristics in the fall.

	Loamy Lowland			Loamy Upland			Clay Upland			Limy Upland		
	INF ¹	SL ²	UIN ³	INF	SL	UIN	INF	SL	UIN	INF	SL	UIN
% Canopy Cover	112.90	.003	189.15	110.74	.008	160.33	120.08	.08	153.78	93.83	.08	141.87
% Basal Cover	6.58	.73	7.10	9.07	.65	8.55	8.90	.19	10.55	6.53	.95	6.43
% Bare Ground	26.43	.38	13.48	37.96	.06	16.70	44.26	.97	44.68	60.46	.99	60.33
% Litter Cover	67.00	.40	79.43	52.96	.06	74.74	46.82	.86	44.77	32.97	.99	33.27
Avg. Depth of Litter (cm)	1.47	.17	2.22	.61	.03	1.56	.95	.62	.73	.47	.91	.40
% Grass ⁴	82.70	.07	97.90	83.10	.02	97.80	82.42	.03	97.58	74.10	.13	88.80

¹Infested. ²Significance level. ³Uninfested. ⁴Includes sedges and rushes.

Table 3 Comparison between infested and uninfested range sites of soil pH and bulk density in the fall.

	Loamy Lowland			Loamy Upland			Clay Upland			Limy Upland		
	INF ¹	SL ²	UIN ³	INF	SL	UIN	INF	SL	UIN	INF	SL	UIN
pH A horizon	7.25	.91	7.20	6.51	.74	6.40	6.00	.51	5.75	7.23	.45	6.83
pH B horizon	7.63	.78	7.20	6.20	.89	6.27	5.86	.87	5.94	7.37	.61	7.07
Bulk Density A horizon	1.40	.74	1.38	1.28	.55	1.25	1.21	.84	1.22	1.19	.62	1.22
Bulk Density B horizon	1.35	.34	1.27	1.28	.26	1.35	1.28	.36	1.33	1.24	.18	1.35

¹ Infested. ² Significance level. ³ Uninfested.

canopy cover and percent grass were the most important deterrents to muskthistle establishment (Table 4).

Influence of Species Composition

On loamy lowland sites, a predominance of annual brome (Bromus spp. L.) and an absence of sideoats grama (Bouteloua curtipendula (Michx.) Torr.), big bluestem (Andropogon gerardi Vitman), little bluestem (Andropogon scoparius Michx.), and indiagrass (Sorghastrum nutans (L.) Nash), though significant only for indiagrass, existed on muskthistle infested sites (Table 5).

On loamy upland and clay upland sites, percentages of Kentucky bluegrass (Poa pratensis L.) and annual brome were similar on infested and uninfested sites, but big bluestem and little bluestem percentages were lower on infested sites.

All species were similar on infested and uninfested limy upland sites.

Comparisons between range sites indicated that loamy lowland was most dissimilar in species composition for the eight species listed on Table 5. For comparison of all species, between infested and uninfested sites, loamy lowland again was the most dissimilar (Table 6). The highest number of muskthistle rosettes existed on the loamy lowland site in the fall (Fig. 4) which indicated that infested sites that are highly dissimilar to uninfested sites of the same type, especially those that lack warm-season grasses but have an abundance of cool-season grasses, were susceptible to invasions of muskthistle.

Comparison of species composition between infested and uninfested sites across all range sites again indicated that a predominance of

Table 4 Comparison between all combined infested and uninfested sites of site characteristics in the fall.

	INF ¹	SL ²	UIN ³
% Canopy Cover	111.44	.0001	161.36
% Basal Cover	8.14	.60	8.55
% Bare Ground	40.92	.12	31.00
% Litter Cover	50.93	.15	60.47
Avg. Depth of Litter (cm)	.87	.08	1.27
% Organic Matter A horizon	4.36	.37	4.02
% Organic Matter B horizon	2.92	.58	2.76
% Moisture ⁵ A horizon	7.62	.37	6.07
% Moisture ⁵ B horizon	6.87	.32	5.56
pH A horizon	6.62	.13	6.43
pH B horizon	6.51	.86	6.48
Bulk Density A horizon	1.27	.71	1.26
Bulk Density B horizon	1.29	.13	1.33
% Grass ⁴	81.47	.0001	96.41

¹ Infested. ² Significance level. ³ Uninfested.

⁴ Includes sedges and rushes. ⁵ Percent by volume.

Table 5 Comparison between infested and uninfested range sites of the percent species composition of sites in the fall.

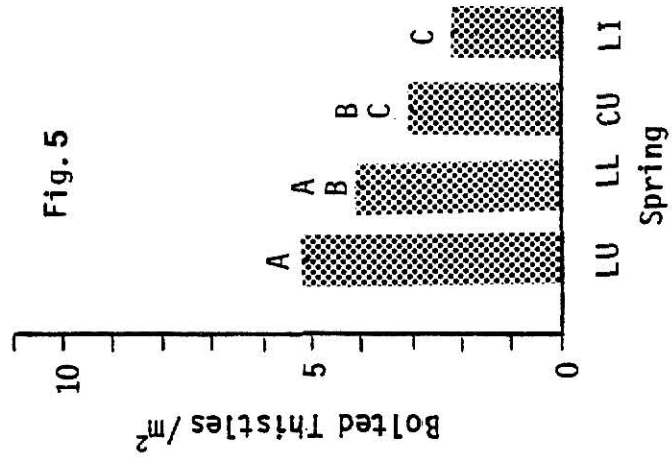
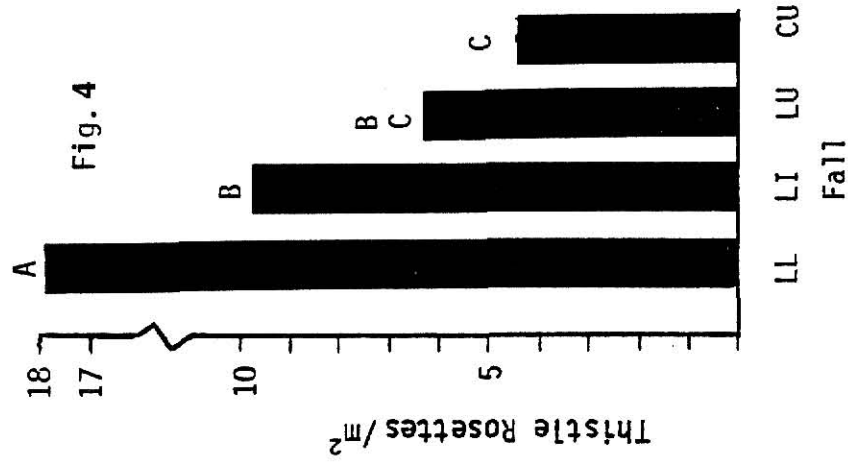
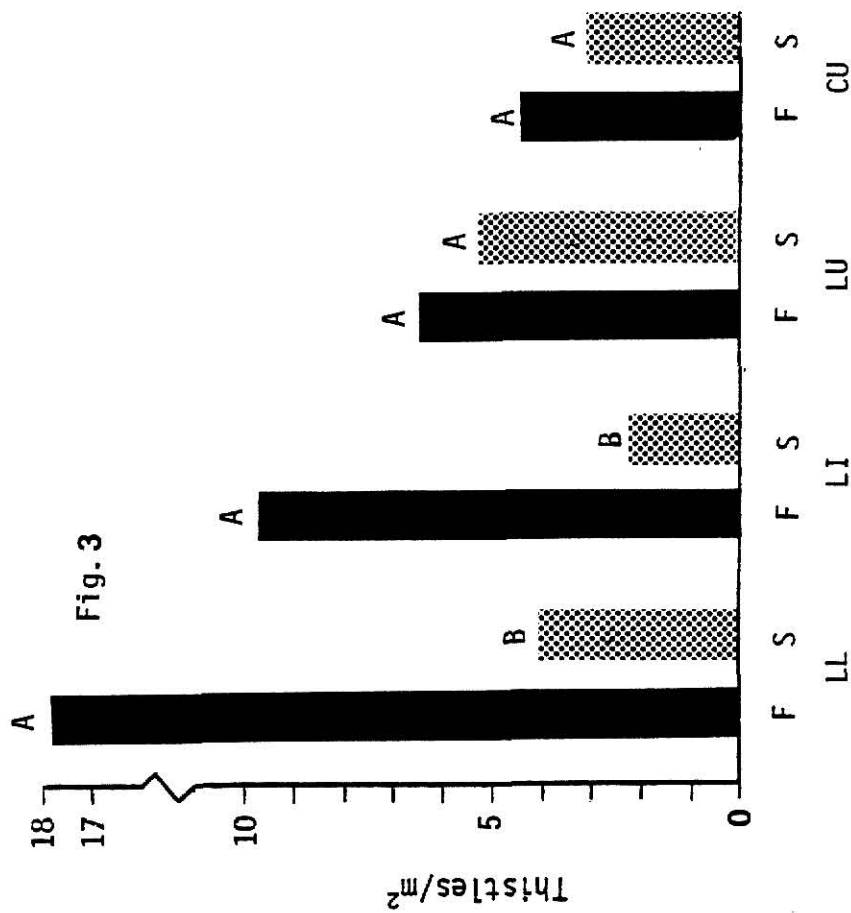
	Loamy Lowland			Loamy Upland			Clay Upland			Limy Upland		
	INF ¹ %	SL ²	UIN ³ %	INF %	SL	UIN %	INF %	SL	UIN %	INF %	SL	UIN %
<i>Poa pratensis</i>	19.85	.64	13.70	22.67	.76	19.60	29.88	.37	20.07	1.26	.98	.83
<i>Bromus</i> spp.	44.05	.07	19.80	24.30	.29	13.91	6.77	.84	4.63	11.46	.46	.36
<i>Bromus inermis</i>	.80	.80	3.67	6.51	.84	4.71	13.85	.44	6.41	30.63	.66	36.67
<i>Carex</i> spp.	12.87	.14	19.87	8.03	.79	8.96	3.80	.85	3.11	0.00	.81	1.23
<i>Bouteloua curtipendula</i>	0.00	.97	.25	4.38	.41	10.07	2.17	.86	11.42	12.50	.72	8.77
<i>Andropogon gerardi</i>	0.00	.16	8.22	2.16	.01	14.11	2.82	.08	11.25	2.93	.71	5.43
<i>Andropogon scoparius</i>	0.00	.79	1.00	0.00	.08	5.13	1.73	.03	8.67	2.10	.93	2.47
<i>Sorghastrum nutans</i>	0.00	.01	5.82	0.00	.43	1.30	1.38	.21	3.65	0.00	1.00	0.00

¹ Infested. ² Significance level. ³ Uninfested.

Table 6 Index of similarity of infested and uninfested paired sites.

Site	Index	Site	Index
Loamy Lowland		Loamy Upland	
1	.48	2	.63
9	.57	7	.69
17	.33	11	.38
18	.41	12	.53
		15	.40
average	.45	16	.53
Clay Upland		20	.35
5	.25		
6	.59	average	.50
8	.53	Limy Upland	
10	.19	3	.39
13	.80	4	.40
19	.53	14	.64
average	.48	average	.48

Index of similarity = $\frac{2c}{a+b}$, where a = number of species in the infested site, b = number of species in the uninfested site, and c = number of species in common to both sites (Mueller-Dombois, and Ellenberg, 1974).



Figs. 3, 4, 5 (3) Comparison between fall(F) and spring(S) of the number of muskthistles per square meter for infested range sites (loamy lowland(LL), loamy upland(LU), clay upland(CU), and limy upland(LI)); (4) comparison between range sites for fall only; and (5) comparison between range sites for spring only. Means with the same letter are not significantly different; $p < .10$.

annual brome, and less warm-season grasses, except sideoats grama, existed on sites infested with muskthistle (Table 7).

Comparison of Vegetative and Soil Characteristics and Species Composition Between Infested Sites

Muskthistle populations were greater on loamy lowland infested sites than on the other three range sites in the fall (Fig. 4), but were similar on loamy lowland and loamy upland infested sites in the spring (Fig. 5).

The significant drop in the number of bolted muskthistle in the spring from the number of rosettes in the fall on loamy lowland and limy upland sites indicated that on those two sites, undetermined winter and spring environmental factors were influential in controlling muskthistle populations (Fig. 3). There were no significant reductions on loamy upland and clay upland sites.

In the fall, factors which favored greater muskthistle populations (loamy lowland or limy upland sites) were a relatively low percent basal cover (Table 8), a relatively high percent moisture in the B horizon (only loamy lowland) (Table 9), a relatively high pH (Table 10), and a relatively high percent species composition of annual brome (only loamy lowland) (Table 11). Warm-season grass percentages were similar on all infested sites.

Average depth of litter was also greater on infested loamy lowland sites than on infested loamy upland and limy upland sites. Since some litter favored higher populations of muskthistle, that indicated an optimum level of litter existed, above or below which establishment of muskthistle was reduced.

Table 7 Comparison between all infested and uninfested sites of the percent species composition of sites in the fall.

	¹ INF %	² SL	³ UIN %
Poa pratensis	21.06	.37	15.75
Bromus spp.	21.06	.06	10.28
Bromus inermis	11.19	.79	9.81
Carex spp.	6.53	.68	8.23
Bouteloua curtipendula	4.06	.30	8.32
Andropogon gerardi	2.04	.002	10.78
Andropogon scoparius	.84	.02	4.97
Sorghastrum nutans	.45	.02	2.72

¹ Infested. ² Significance level. ³ Uninfested.

Table 8 Comparison between infested range sites of vegetative characteristics in the fall.

	LL ¹ SL ² LU ³			LL SL CU ⁴			LL SL LI ⁵		
% Canopy Cover	112.90	.92	110.74	112.90	.73	120.08	112.90	.45	93.83
% Basal Cover	6.57	.07	9.07	6.57	.10	8.90	6.57	.98	6.53
% Bare Ground	26.43	.38	37.96	26.43	.19	44.27	26.43	.04	60.47
% Litter Cover	67.00	.29	52.96	67.00	.14	46.82	67.00	.04	32.97
Avg. Depth of Litter (cm)	1.48	.08	.61	1.48	.29	.95	1.48	.09	.47
% Grass ⁶	82.70	.96	83.10	82.70	.97	82.41	82.70	.33	74.10
	LU SL CU			LU SL LI			CU SL LI		
% Canopy Cover	110.74	.61	120.08	110.74	.46	93.83	120.08	.27	93.83
% Basal Cover	9.07	.89	8.90	9.07	.09	6.53	8.90	.12	6.53
% Bare Ground	37.96	.59	44.27	37.96	.12	60.47	44.27	.27	60.47
% Litter Cover	52.96	.60	46.82	52.96	.17	32.97	46.82	.35	32.97
Avg. Depth of Litter (cm)	.61	.43	.95	.61	.78	.47	.95	.37	.47
% Grass	83.10	.92	82.41	83.10	.26	74.10	82.41	.31	74.10

¹Loamy lowland. ²Significance level. ³Loamy upland. ⁴Clay upland. ⁵Limy upland. ⁶Includes sedges and rushes.

Table 9 Comparison between infested range sites of soil organic matter and moisture in the fall.

	LL ¹	SL ²	LU ³	LL	SL	CU ⁴	LL	SL	LI ⁵
% Organic Matter A horizon	2.93	.22	4.24	2.93	.09	4.82	2.93	.04	5.63
% Organic Matter B horizon	1.80	.22	3.00	1.80	.29	2.75	1.80	.02	4.30
% Moisture ⁶ A horizon	9.98	.27	5.95	9.98	.52	7.56	9.98	.74	8.50
% Moisture ⁶ B horizon	12.63	.05	4.46	12.63	.08	6.02	12.63	.09	6.01

	LU	SL	CU	LU	SL	LI	CU	SL	LI
% Organic Matter A horizon	4.24	.55	4.82	4.24	.24	5.63	4.82	.50	5.63
% Organic Matter B horizon	3.00	.76	2.75	3.00	.19	4.30	2.75	.09	4.30
% Moisture A horizon	5.95	.62	7.56	5.95	.52	8.50	7.56	.81	8.50
% Moisture B horizon	4.46	.65	6.02	4.46	.70	6.01	6.02	.99	6.01

¹ Loamy lowland. ² Significance level. ³ Loamy upland. ⁴ Clay upland. ⁵ Limy upland. ⁶ Percent by volume.

Table 10 Comparison between infested range sites of soil pH and bulk density in the fall.

	LL ¹	SL ²	LU ³	LL	SL	CU ⁴	LL	SL	LI ⁵
pH A horizon	7.25	.08	6.51	7.25	.005	6.00	7.25	.97	7.23
pH B horizon	7.37	.04	6.20	7.37	.006	5.87	7.37	1.00	7.37
Bulk Density A horizon	1.40	.03	1.28	1.40	.001	1.21	1.40	.003	1.19
Bulk Density B horizon	1.35	.35	1.28	1.35	.32	1.28	1.35	.20	1.25

	LU	SL	CU	LU	SL	LI	CU	SL	LI
pH A horizon	6.51	.16	6.00	6.51	.12	7.23	6.00	.01	7.23
pH B horizon	6.20	.47	5.87	6.20	.04	7.37	5.87	.006	7.37
Bulk Density A horizon	1.28	.13	1.21	1.28	.13	1.19	1.21	.78	1.19
Bulk Density B horizon	1.28	1.00	1.28	1.28	.64	1.25	1.28	.61	1.25

¹ Loamy lowland. ² Significance level. ³ Loamy upland. ⁴ Clay upland. ⁵ Limy upland.

Table 11 Comparison between infested range sites of the percent species composition of sites in the fall.

	¹		²		³		⁴		⁵		
	LL %	SL %	LL %	SL %	LU %	LL %	SL %	CU %	LL %	SL %	LI %
Poa pratensis	19.85	.81	22.67			19.85	.41	29.88	19.85	.20	1.26
Bromus spp.	44.05	.09	24.30			44.05	.003	6.77	44.05	.02	11.47
Bromus inermis	.80	.58	6.51			.80	.23	13.85	.80	.02	30.63
Carex spp.	12.87	.25	8.03			12.87	.04	3.80	12.87	.01	0.00
Bouteloua curtipendula	0.00	.58	4.38			0.00	.79	2.17	0.00	.21	12.50
Andropogon gerardi	0.00	.39	2.16			0.00	.59	2.82	0.00	.64	2.93
Adropogon scoparius	0.00	1.00	0.00			0.00	.62	1.73	0.00	.61	2.10
Sorghastrum nutans	0.00	1.00	0.00			0.00	.50	1.38	0.00	1.00	0.00

¹ Loamy lowland. ² Significance level. ³ Loamy upland. ⁴ Clay upland. ⁵ Limy upland.

Table 11 cont.

	LU ¹ %	SL ²	CU ³ %	LU %	SL	LI ⁴ %	CU %	SL	LI %
<i>Poa pratensis</i>	22.67	.49	29.88	22.67	.10	1.26	29.88	.04	1.26
<i>Bromus</i> spp.	24.30	.09	6.77	24.30	.31	11.47	6.77	.71	11.47
<i>Bromus inermis</i>	6.51	.42	13.85	6.51	.04	30.63	13.85	.16	30.63
<i>Carex</i> spp.	8.03	.25	3.80	8.03	.08	0.00	3.80	.42	0.00
<i>Bouteloua curtipendula</i>	4.38	.76	2.17	4.38	.36	12.50	2.17	.26	12.50
<i>Andropogon gerardi</i>	2.16	.88	2.82	2.16	.89	2.93	2.82	.98	2.93
<i>Andropogon scoparius</i>	0.00	.57	1.73	0.00	.57	2.10	1.73	.92	2.10
<i>Sorghastrum nutans</i>	0.00	.42	1.38	0.00	1.00	0.00	1.38	.53	0.00

¹ Loamy upland. ² Significance level. ³ Clay upland. ⁴ Limy upland

These factors may have been influential during the winter months in controlling muskthistle populations. The lower basal cover may have allowed more exposure (freezing, drying) to the rosettes, and the higher percent moisture may have caused more severe frost-heaving damage to the rosettes. The higher pH may have been favorable to seed germination, but not to stand establishment. Since some litter favored higher populations of muskthistle, that indicated an optimum level of litter existed, above or below which establishment of muskthistle was reduced.

Simple Linear Regressions

The positive relationship of percent moisture in the B horizon in the fall and percent organic matter in the fall with the number of bolted muskthistles in the spring (Figs. 6, 7 and 8), indicated that high populations of muskthistles can be found on sites that have relatively high amounts of those two soil parameters.

The negative relationship of percent canopy cover in the fall with bolted muskthistles in the spring indicated that on sites with high canopy cover, populations of muskthistle should be low or non-existent (Fig. 9). No other parameters showed a significant relationship.

Multiple Regression Prediction Model

The multiple regression equation obtained was:

$$Y = -6.59 + (.07) \text{ percent canopy cover} + (-.41) \text{ percent basal cover} + (.03) \text{ percent species composition of Kentucky bluegrass} + (.07) \text{ percent species composition of annual brome} + (.85) \text{ percent organic matter in the A horizon} + (.11) \text{ percent litter cover} + (-5.55) \text{ average depth of litter (cm)}.$$

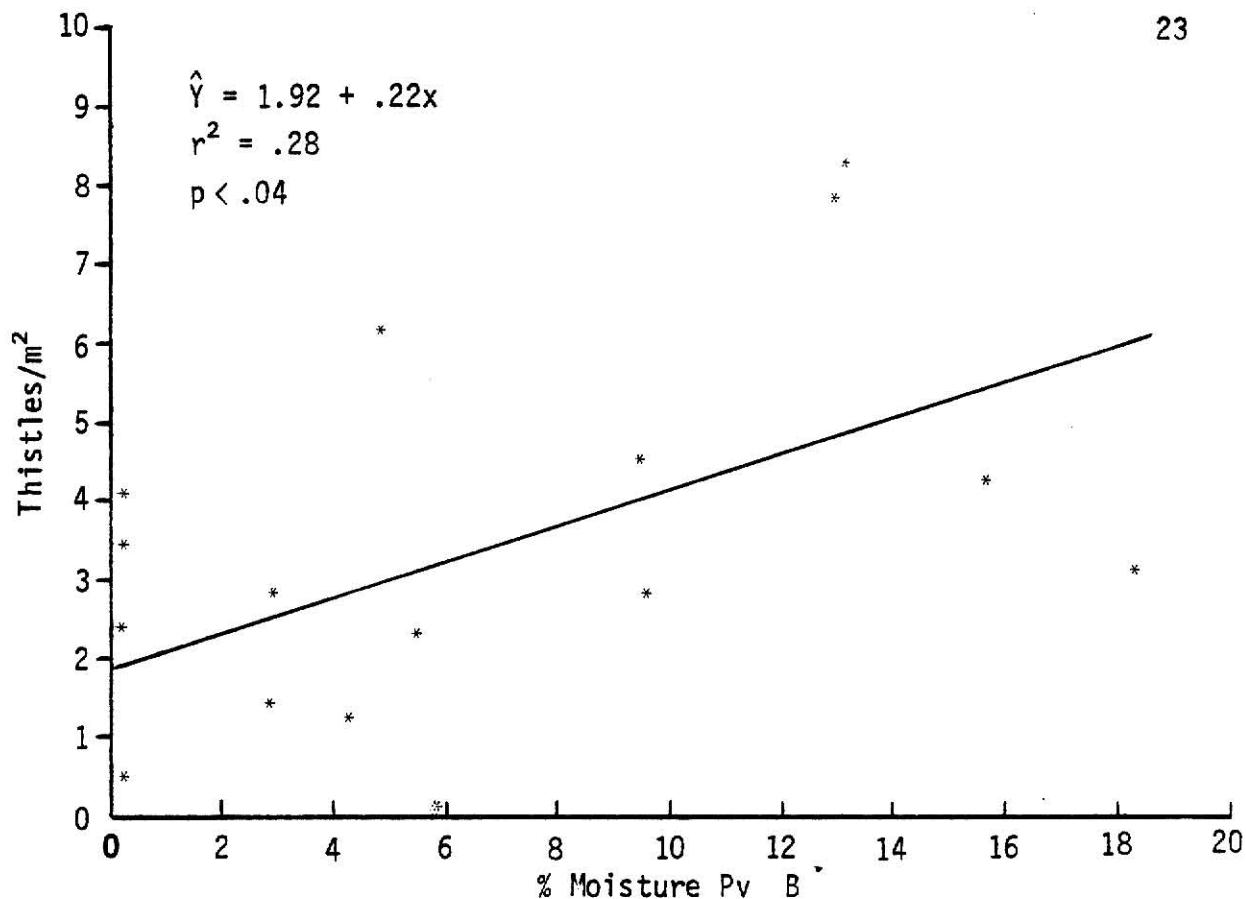


Fig. 6 Relationship between percent soil moisture in the fall in the B horizon and the number of bolted muskthistles per square meter in the spring.

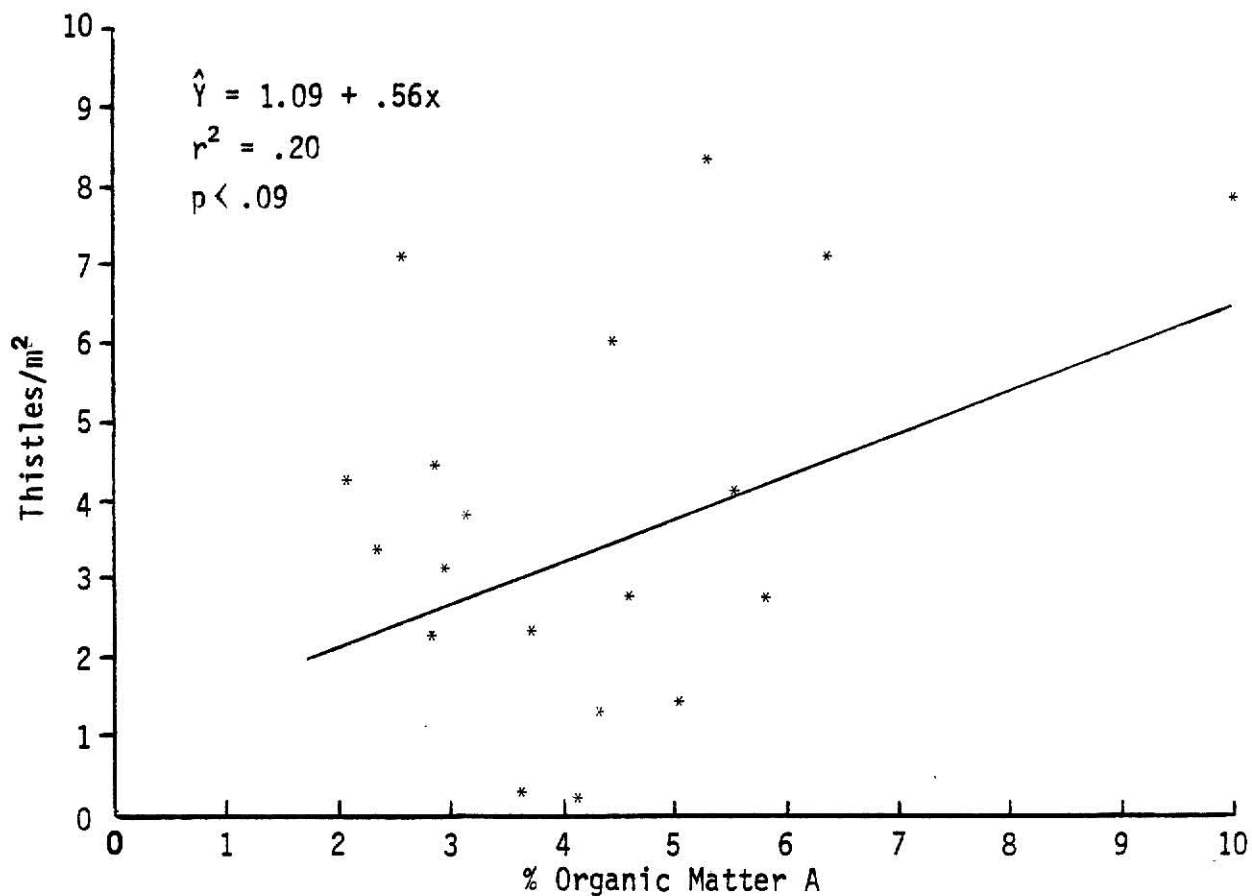


Fig. 7 Relationship between the percent soil organic matter in the fall in the A horizon, and the number of bolted muskthistles per square meter in the spring.

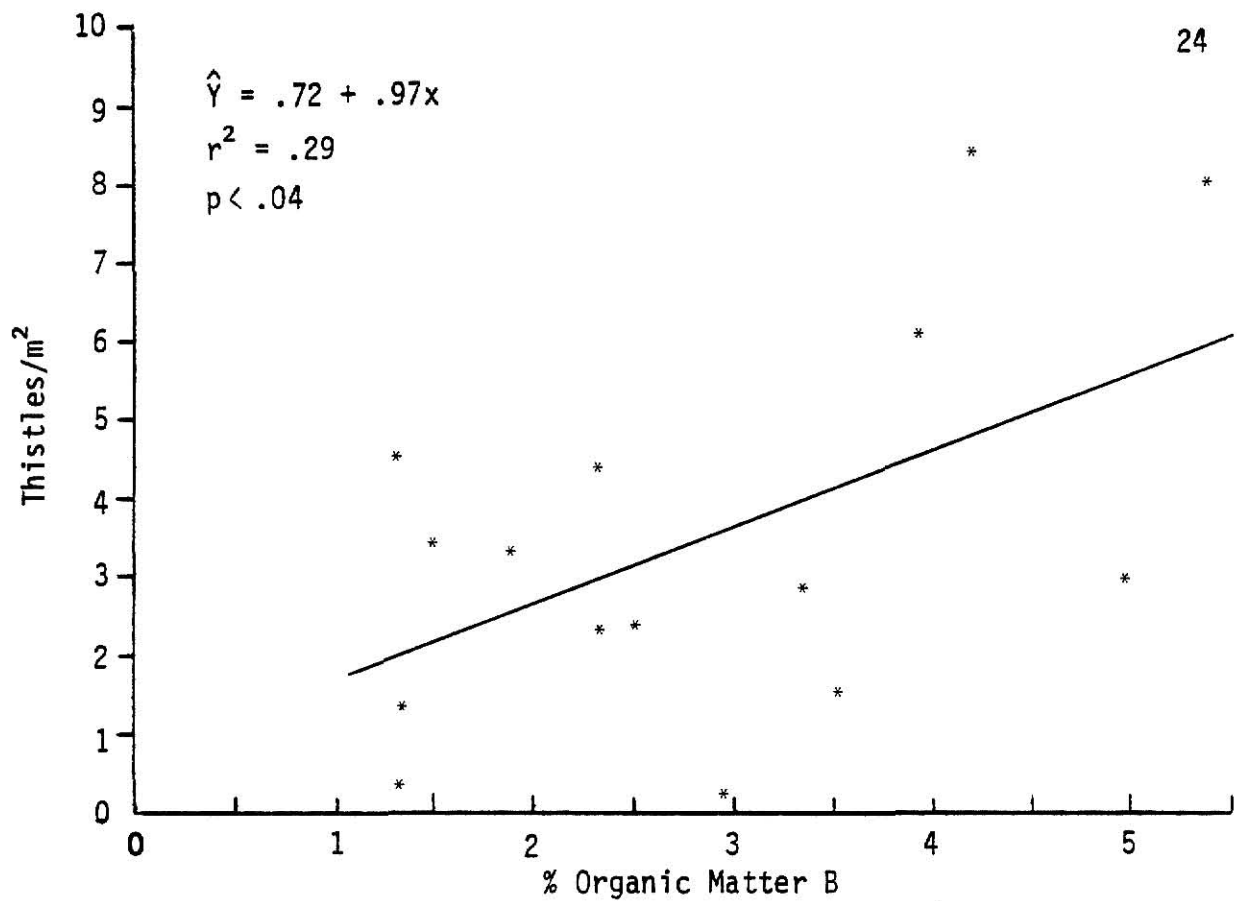


Fig. 8 Relationship between the percent soil organic matter in the fall, in the B horizon, and the number of bolted muskthistles per square meter in the spring.

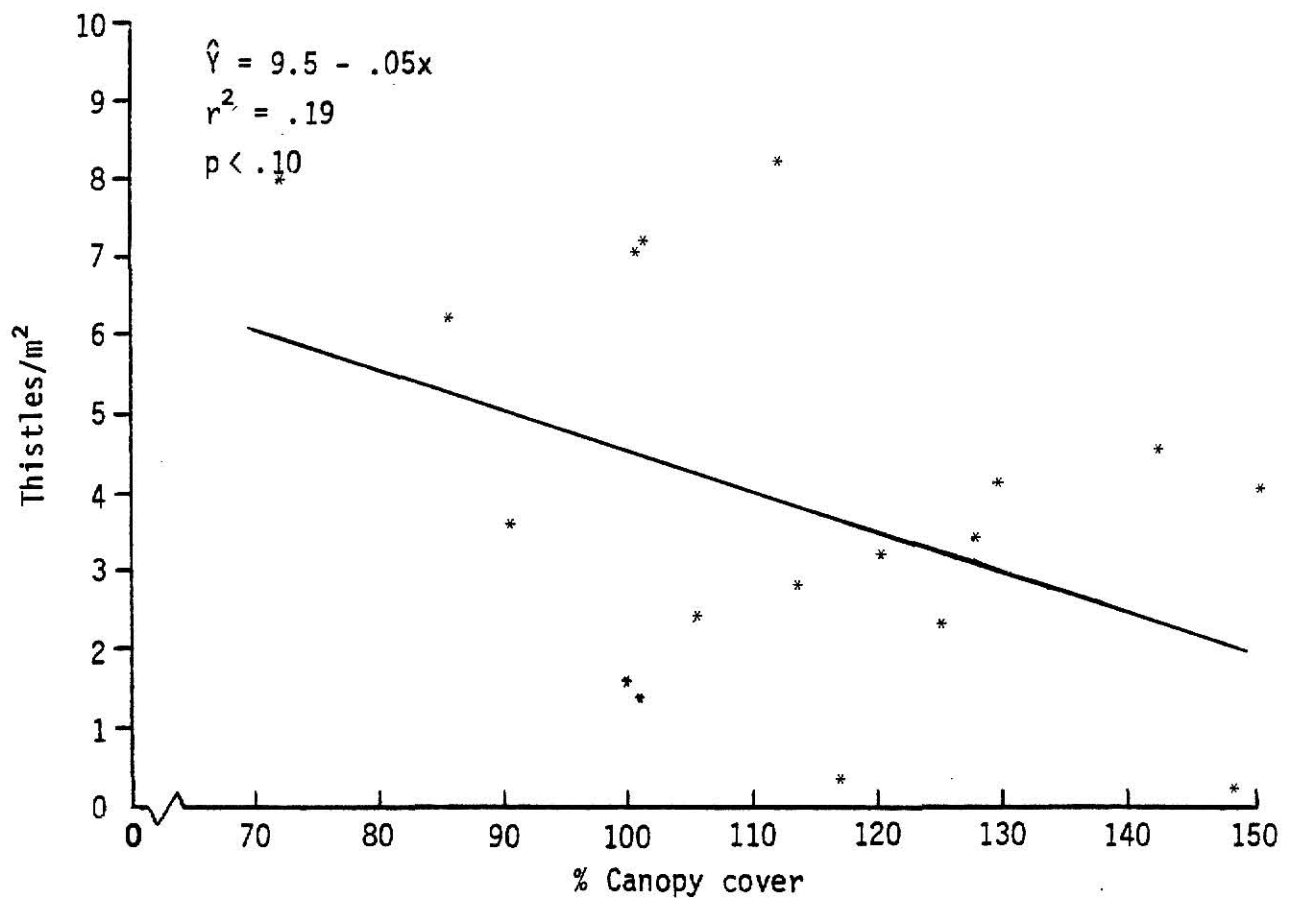


Fig. 9 Relationship between the percent canopy cover in the fall, and the number of bolted muskthistles per square meter in the spring.

where Y = the number of bolted muskthistles per m^2 in the spring. $R^2 = .86$.

Prediction of the spring population size of an existent muskthistle infestation can be made from the model based on fall characteristics, but not of a possible future infestation. Therefore, the model was only useful when the infestation of muskthistle has already occurred. For example, canopy cover was shown to be a deterrent to establishment of muskthistle, but a positive relationship, however small, was shown in the model.

Percent canopy cover, percent basal cover, percent species composition of Kentucky bluegrass and annual brome contributed 26% to the model while percent organic matter in the A horizon contributed 19%, percent litter cover contributed 16% and average depth of litter contributed 25%, therefore the average depth of litter was the most important factor.

The model can show where management should be concentrated and how much and what kinds of control measures are needed to reduce muskthistle populations.

For example, one could allow a buildup of deep litter by reducing grazing, or by applying a hay (straw, native grass, etc.) mulch onto the pasture.

Early intensive stocking with yearling steers could increase basal cover, fall litter and percent species composition of big bluestem. Burning the pasture in late spring would reduce the percent species composition of Kentucky bluegrass (Launchbaugh and Owensby 1978).

Conclusions

Among the range sites, loamy lowland sites and loamy upland sites were most susceptible to infestations of muskthistle.

The habitat characteristics which favored muskthistle establishment were a relatively low percent canopy cover, a relatively high percent bare ground, a small amount of litter, a high percent species composition of annual brome, a low percent species composition of warm-season grasses, and moist sandy soils with relatively high percent organic matter and pH.

Since each range site was unique, those conditions which favored muskthistle establishment were relative to conditions that were found on the uninfested site of the same range site type.

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Appendix

Part I. Literature Review: Muskthistle Physiology, Growth Habits
and Habitat Characteristics

Introduction

Muskthistle (Carduus nutans L.) is an exotic in North America (McCarty et al. 1980). Its native distribution is Europe, Western Siberia, Asia Minor, and North Africa (Kok 1975; McCarty et al. 1980; Moore and Frankton 1974; Moore and Mulligan 1956).

In North America, the earliest report of muskthistle was in 1852 when it was seen growing along the shore from washed up seed that was pumped from the holds of ships (McCarty 1979; McCarty et al. 1980). In 1878, muskthistle was reported to be growing in Ontario, Canada (Mulligan and Frankton, 1954). Other continents and islands, being colonized by Europeans, such as Australia and New Zealand have had infestations since the late 1800's (Delahunty 1960; 1961).

Today, the Appalachian and Plains states have the largest infestations of muskthistle in America (Dunn 1977). In the central plains, muskthistle has been growing for more than 60 years (Surles and Kok 1978). In eastern Montana, it was identified in 1921 and was spreading rapidly westward (Hodgson and Rees 1976). In 1932, muskthistle was observed in Washington County, Kansas and Seward County, Nebraska (Bare 1979; Fuller 1969) and by 1948, it had spread to seven additional northcentral Kansas counties (Bare 1979; Gates 1940; Stevens 1948). In 1963, muskthistle was declared a noxious weed in Kansas (Nilson 1968).

Muskthistle is now found in more than half of the state with the highest density being in the eastern half, though it is rapidly spreading to the west (Bare 1979; Barkley 1968; Nilson 1968).

For all of the United States, 360 counties have infestations of economic impact with many more having potentially economic infestations (Dunn 1977). The area with the most rapid spread is in the western states, especially on uncultivated lands (Hodgson and Rees 1976; Hull and Evans 1973).

Muskthistle is usually found on disturbed sites, such as waste areas, roadsides, railroad right-of-ways, and building sites (Furrer and McCarty 1966; Mulligan and Frankton 1954; Nilson 1968; Vance et al. 1977; Wunderlin 1969). Other common sites are pastures, meadows, alfalfa fields, and poorly cultivated fields (Barkley 1968; Nilson 1968; Vance et al. 1977).

Muskthistle grows in a wide range of soils, from clay to sand (McKellar 1955). In one study, muskthistle was found on shallow rocky soils, but not in deep, well-drained soils (Stuckey and Forsyth 1971). Other studies indicated that muskthistle only grew on shallow, well-drained soils (Moore and Frankton 1974; Mulligan and Frankton 1954). Still another study showed that muskthistle grew in deep, well-drained to poorly-drained soils as well as shallow, well-drained soils (Fuller 1969).

Life Cycle and Plant Characteristics

Physiology

Muskthistle is primarily a biennial (Feldman 1965; Feldman et al. 1968), but can also be an annual if vegetation is sparse, the soil is fertile, and ample rainfall exists (Feldman et al. 1968; McCarty 1964; McCarty et al 1967). If rosettes establish in the fall, muskthistle can be a winter annual (Feldman et al. 1968; McCarty 1964).

Muskthistle has two stages of growth, vegetative and reproductive represented by a rosette, and an elongate stem, with terminal and axillary flowers, respectively (Delahunty 1960). Its large taproot can penetrate two to four feet (McCarty et al. 1967) and be 3 inches to 8 feet tall at maturity (McCarty 1979).

Germination

Germination of muskthistle seed is greatest in the fall (Delahunty 1960), but does occur through spring and into summer (Doing et al. 1969; Feldman 1965; Feldman et al. 1968). As a biennial, seed germinates in fall and early spring (Sept.-May) and bolt the next spring to early summer. As an annual, it germinates in spring and bolts early that fall. As a winter annual, it germinates in fall and bolts in the following spring to summer (Lacefield and Gray 1970; McCarty 1964).

Seed germinates better in moist soils (Medd and Lovett 1978; Medd and Smith 1978), but cold wet seed dies (McCarty et al. 1969). Seed can germinate on the soil surface (Wilson 1979), but germination is better at depths of .5-1.5 cm (McCarty et al. 1969; Wilson 1979). Trapped

moisture under shallow litter can germinate muskthistle seed (Evans and Young 1970; Feldman et al. 1968).

Favorable temperatures for germination are between 30°C and 15°C (Doing et al. 1969; McCarty et al. 1969; Medd and Lovett 1978a).

Muskthistle seed germinates in a wide range of environmental conditions (soil, water, temperature) (Evans et al. 1979), but seed that is too deep (>3 cm) (McCarty et al. 1969) in waterlogged soils, or in soils of very high or very low pH will not germinate (Doing et al. 1969; Stuckey and Forsyth 1971).

Dry muskthistle seed can lie dormant and survive for long periods of time under normal environmental conditions (McCarty et al. 1969). Two studies indicated that no seed dormancy was required (Delahunty 1962; Doing et al. 1969). However, one study indicated an 8 week dormancy period was required and further study showed that with no dormancy, germination was 2%; with 8 weeks dormancy, germination was 50%; and with 1 year dormancy, germination was 90% (Lacefield and Gray 1970).

Other studies have shown muskthistle seeds to germinate at ranges of 60% to 95% depending on the condition of the seed and how long it was dormant (Feldman 1965; Feldman et al. 1968; McCarty 1964).

Competition Factors of Seedling Establishment

Muskthistle seedlings need plenty of light and are less competitive in the shade (Doing et al. 1969; Feldman et al. 1968; Medd and Lovett 1978a). That is to the advantage of muskthistle in areas that are sprayed because the shading foilage will protect the young rosettes from the spray. In alfalfa, muskthistle seedlings die in the shade of the

rapidly growing legume, but if the alfalfa is grazed, the seedlings survive (Delahunty 1962).

Where grazing or some other activity has caused bare spots to occur, muskthistle seedlings can become established (Delahunty 1962; Doing et al. 1969; Evans and Young 1972; Feldman et al. 1968; McKellar 1955), but heavy grazing can control muskthistle if a dense mat of grass like buffalograss is maintained (Doing et al. 1969; McKellar 1955). Heavy grazing on annual grasslands will also control muskthistle (Doing et al. 1969).

Muskthistle will invade pastures in good to excellent condition, especially those being grazed (Feldman et al. 1968). That is possible because muskthistle is getting established in late fall and early spring when warm-season species are still dormant (McCarty 1979).

Flowering

Before flowering, muskthistle must undergo vernalization (Medd and Lovett 1978b). Flowering is determinate with the terminal head flowering first, followed by the axillary heads down the stem (McCarty and Scifres 1969). One study indicated that in Nebraska, flowering began early June and ended late September (Feldman et al. 1968). Another indicated that in Nebraska, flowering began early June to late August. A third study indicated that in Kentucky, flowering began mid May and ended late August (Lacefield and Gray 1970).

Seed Production and Dispersal Mechanisms

Seed dispersal is 7-10 days after blooming with 1200 to 1500 seeds being produced on the terminal head, and about 25 seeds on each of the

axillary heads (McCarty et al. 1967). Depending upon the conditions, 10,000 to 11,000 seeds per plant (Feldman et al. 1968; McCarty 1964) and possibly 120,000 seeds per plant (Lacefield and Gray 1970) can be produced. With good conditions more than 3000 seedlings can be established from a single parent (McCarty and Scifres 1969).

Studies indicated that muskthistle seed was spread by windborne achenes as was Canada thistle seed (McCarty et al. 1969; Wilson 1979). Other studies indicated that dispersal by wind was not significant, that the plumes usually separated from seed at maturity so that seeds remained in the flower head (Delahunty 1962; Stuckey and Forsyth 1971). One of the studies further indicated that most of the seed was found within 5 feet of the parent, so that which was transported long distances was by some other means (Stuckey and Forsyth 1971).

Genetic Characteristics

Nomenclature

Discussion continues on the classification of muskthistle. Two taxonomists indicated that there were only two varieties of muskthistle, Carduus nutans var. nutans, and C. N. var leiophyllus (Mulligan and Frankton 1954). Others indicated that included under the common name of muskthistle are Carduus macrocephalus and C. theormeri (McCarty et al. 1980). Two others indicated that three subspecies of Carduus nutans existed, macrolepis, thoermeri, and leiophyllus (Moore and Frankton 1974). All of these have the common name muskthistle or noddlingthistle.

Hybridization with Plumelessthistle

It was discovered in 1956 and later in 1964 that muskthistle, Carduus nutans, hybridized with plumelessthistle (Carduus acanthoides) (Moore and Mulligan 1956 and 1964). Most of the plants studied in Canada and Nebraska were determined to be hybrids of these two species (Fuller 1969; McCarty and Hatting 1975; Moore and Mulligan 1964; Mulligan and Moore 1961).

A recent study indicated that great uniformity was exhibited by muskthistle grown from seeds gathered from many areas and established on one site (McCarty 1979). Later, when muskthistle and plumelessthistle were grown together, no evidence of hybridization was seen (McCarty et al. 1980).

Characteristically, plumelessthistle favors rough, well-drained soils over limestone or shale and muskthistle favors moist heavy soils (Moore and Mulligan 1956; Mulligan and Frankton 1954). Given that the two species hybridize, it would be useful to index how close the hybrid is to either parent species. That helps forecast where that particular hybrid would be found.

A good hybrid index was developed in Canada using six parts of the plant which differ in plumelessthistle from muskthistle. Values ranged from 0 to 16 with 0 indicating plumelessthistle and 19 indicating muskthistle (Moore and Mulligan 1956; Mulligan and Moore 1961).

In Nebraska, hybrids with a high index were found near the bottom of hills and on stream banks in clayloam soils, while near the top of hills in sandy loam soils, hybrids with a low index were found. Hybrids with intermediate indexes were found in between (Fuller 1969). That same relationship existed in Canada (Mulligan and Frankton 1954). That

information aids in determining where either species might invade. In Gray county, Ontario, Canada, conditions favored plumelessthistle and from 1957 to 1962, muskthistle and similar hybrids were replaced by plumelessthistle and similar hybrids (Moore and Mulligan 1964; Mulligan and Moore 1961).

A cytological analysis can also aid in determining how close the hybrid is to one species or the other. The number of chromosomes in plumelessthistle is $2n = 22$, in muskthistle it is $2n = 16$, and hybrids will have intermediate numbers (Mulligan and Moore 1961).

Another aid in predicting where muskthistle and plumelessthistle and their hybrids might invade is to determine plant associations. Plants found growing with muskthistle were: Poa compressa, Verbascum thapsus, Erigeron strigosus, Polygonum convolvulus, Rumex crispus, Cirsium vulgare, Cirsium arvense, Taraxacum officinale, Tragopogon pratensis, and Ambrosia artemisiifolia; and plants found growing with plumelessthistle were: Poa compressa, Verbascum thapsus, Echium vulgare, Rumex acetosella, Hieracium florentinum, Cynoglossum officinale, and Rudbeckia hirta (Mulligan and Frankton 1954).

Factors Affecting the Spread of Muskthistle

In 1958, muskthistle began to rapidly spread in Nebraska as a result of introduction of new hybrid crosses (Fuller 1969).

In both the U.S. and New Zealand, drought caused rapid spread of muskthistle (Delahunty 1960 and 1961; Fuller 1969). In the U.S., drought resistant varieties naturally resulted from environmental pressures, and these varieties then proliferated.

Mismanagement of a pasture, allowing overgrazing, can also cause muskthistle to invade (Klingman and McCarty 1958).

One reason muskthistle has been so successful has been because it has escaped its natural enemies, both plant and animal, that were left in Europe (Frick 1974). An effort has been made to introduce insects that will control populations of muskthistle (Kok 1975; Surles and Kok 1978).

In Canada, muskthistle populations were drastically reduced as a result of land developments (Moore and Mulligan 1964). Also in Canada, muskthistle populations were reduced or eliminated by competition with wild carrot (Daucus carota) a native species of North America (Moore and Mulligan 1964).

Effect of Muskthistle on Livestock

Muskthistle invasion has an economic impact. Besides out competing productive forages, forages growing in the same area with muskthistle will not be utilized by livestock, particularly cattle (Kok 1975; Wunderlin 1969). However, muskthistle sprayed with hormonal herbicide is very palatable to cattle (Delahunty 1960).

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Part II. Table A - 1. Soil characteristics for each site.

Site	Parent Material	Soil Type	Horizon	Depth in.	Particle Size Composition %Sand %Silt %Clay	Texture	Bulk Density	Organic Matter %	Moisture %	pH
Loamy Lowland										
1 infested	Alluvium	Alluvial	A	0-12	15 62 23	silt loam	1.40	4.3	10.65	6.9
			B	12-24	15 58 27	silty clay loam	1.38	1.3	4.23	7.2
1 uninfested	Alluvium	Alluvial	A	0-12	17 60 23	silt loam	1.31	3.6	11.16	6.9
			B	12-24	18 65 17	silt loam	1.27	3.3	10.21	6.6
9 infested	Alluvium	Alluvial	A	0-12	14 50 36	silty clay loam	1.33	2.5	.36	7.2
			B	-	-	-	-	-	-	-
9 uninfested	Alluvium	Alluvial	A	0-12	17 56 27	silty clay loam	1.33	1.9	1.46	7.1
			B	-	-	-	-	-	-	-
17 infested	Alluvium	Kennebec Silty Clay Loam	A	0-12	16 60 24	silt loam	1.45	2.0	11.64	7.4
			B	12-24	16 64 20	silt loam	1.38	2.3	15.52	7.5
17 uninfested	Alluvium	Kennebec Silty Clay Loam	A	0-12	21 56 23	silt loam	1.48	2.3	3.39	7.4
			B	12-24	21 57 22	silt loam	1.30	2.4	6.17	7.5
18 infested	Alluvium	Kennebec Silty Clay Loam	A	0-12	18 55 27	silty clay loam	1.41	2.9	17.27	7.5
			B	12-24	24 51 25	silt loam	1.28	1.8	18.16	7.4
18 uninfested	Alluvium	Kennebec Silty Clay Loam	A	0-12	24 49 27	clay loam	1.39	2.6	3.20	7.4
			B	12-24	21 55 24	silt loam	1.25	2.3	13.72	7.5
Limy Upland										
3 infested	Calcareous Clayey Shale	Clime-Sogn Complex	A	0-12	20 63 17	silt loam	1.13	6.0	13.11	7.2
			B	12-24	26 58 16	silt loam	1.29	4.4	5.63	7.5
3 uninfested	Calcareous Clayey Shale	Clime-Sogn Complex	A	0-6	26 60 14	silt loam	1.17	8.2	10.08	7.4
			B	6-12	24 61 15	silt loam	1.38	5.4	0.00	7.5
4 infested	Calcareous Clayey Shale	Clime-Sogn Complex	A	0-8	26 51 23	silt loam	1.17	5.1	3.89	7.3
			B	8-16	20 57 23	silt loam	1.20	3.5	2.81	7.2
4 uninfested	Calcareous Clayey Shale	Clime-Sogn Complex	A	0-6	22 59 19	silt loam	1.25	6.1	19.19	7.3
			B	6-12	28 52 20	silt loam	1.36	2.0	15.07	7.5
14 infested	Shale	Clime Silty Clay Loam	A	0-6	21 62 17	silt loam	1.27	5.8	8.51	7.2
			B	6-12	19 62 19	silt loam	1.25	5.0	9.58	7.4
14 uninfested	Shale	Clime Silty Clay Loam	A	0-12	16 57 27	silty clay loam	1.25	3.0	5.71	5.8
			B	12-24	18 55 27	silty clay loam	1.31	3.0	7.67	6.2

Table A - 1 cont.

Site	Parent Material	Soil Type	Horizon	Depth in.	Particle Size Composition %Sand %Silt %Clay	Texture	Bulk Density	Organic Matter %	Moisture %	pH
Loamy Upland										
2 infested	Alluvium	Tully Silty Clay Loam	A	0-12	20 57 23	silt loam	1.37	3.1	2.55	7.2
2 uninfested	Alluvium	Tully Silty Clay Loam	B	-	-	-	-	-	-	-
7 infested	Loess	Wymore Silty Clay Loam	A	0-6	20 63 17	silt loam	1.40	5.0	14.21	7.1
7 uninfested	Loess	Wymore Silty Clay Loam	B	6-12	18 16 21	silt loam	1.37	1.5	0.00	7.3
11 infested	Limestone	Benfield-Florence Complex	A	0-8	12 58 30	silty clay loam	1.35	2.8	0.00	5.7
11 uninfested	Limestone	Benfield-Florence Complex	B	8-24	12 55 33	silty clay loam	1.31	2.5	0.00	5.5
12 infested	Cherty Limestone	Benfield-Florence Complex	A	0-8	14 61 25	silt loam	1.39	1.9	0.00	6.2
12 uninfested	Cherty Limestone	Benfield-Florence Complex	B	8-24	14 57 29	silty clay loam	1.39	1.6	0.00	6.3
15 infested	Alluvium	Reading Silty Clay Loam	A	0-12	20 59 21	silt loam	1.23	5.5	6.98	7.3
15 uninfested	Alluvium	Reading Silty Clay Loam	B	-	-	-	-	-	-	-
16 infested	Alluvium	Reading Silty Clay Loam	A	0-10	18 61 21	silt loam	1.22	5.8	9.57	7.3
16 uninfested	Alluvium	Reading Silty Clay Loam	B	-	-	-	-	-	-	-
20 infested	Glacial Till	Pawnee Loam	A	0-12	16 56 28	silty clay loam	1.20	5.3	11.13	7.2
20 uninfested	Glacial Till	Pawnee Loam	B	12-24	16 57 27	silty clay loam	1.27	4.2	12.96	7.2
			A	0-12	14 58 28	silty clay loam	1.13	5.0	4.73	6.8
			B	12-24	12 62 26	silt loam	1.28	4.8	9.88	6.9
			A	0-12	23 54 23	silt loam	1.26	6.3	15.09	6.3
			B	-	-	-	-	-	-	-
			A	0-12	16 60 24	silt loam	1.16	4.5	7.98	5.8
			B	12-24	16 59 25	silt loam	1.28	4.0	10.36	5.9
			A	0-12	20 58 22	silt loam	1.26	4.4	5.93	6.5
			B	12-24	16 64 20	silt loam	1.16	3.8	4.88	7.1
			A	0-12	16 64 20	silt loam	1.23	5.5	2.10	6.2
			B	12-24	14 56 30	silty clay loam	1.39	3.5	3.69	6.0
			A	0-12	38 44 18	loam	1.28	2.3	0.00	5.4
			B	12-24	26 36 38	clay loam	1.38	1.5	0.00	5.0
			A	0-6	40 41 19	loam	1.23	2.0	.41	5.4
			B	6-24	35 35 30	clay loam	1.38	2.3	1.85	5.2

Table A - 1 cont.

Site	Parent Material	Soil Type	Horizon	Depth in.	Particle Size Composition %Sand %Silt %Clay	Texture	Bulk Density	Organic Matter	Moisture %	pH
Clay Upland										
5 Infested	Clayey Shale	Irwin Silty Clay Loam	A	0-12	24 62 14	silt loam	1.29	3.6	3.13	6.7
5 uninfested	Clayey Shale	Irwin Silty Clay Loam	B	12-24	12 66 22	silt loam	1.37	1.3	0.00	6.2
			A	0-12	14 60 26	silt loam	1.33	1.8	4.47	5.6
6 Infested	Clayey Shale	Irwin Silty Clay Loam	B	12-24	14 54 32	silty clay loam	1.45	.6	0.00	5.4
6 uninfested	Clayey Shale	Irwin Silty Clay Loam	A	0-16	16 64 20	silt loam	1.22	4.1	13.07	5.2
			B	16-24	14 61 25	silt loam	1.18	2.9	5.89	5.0
			A	0-10	14 59 27	silty clay loam	1.27	3.0	0.00	5.5
			B	10-20	14 59 27	silty clay loam	1.25	3.3	.82	6.0
8 Infested	Clayey Shale	Irwin Silty Clay Loam	A	0-8	16 63 21	silt loam	1.20	4.6	.41	5.2
8 uninfested	Clayey Shale	Irwin Silty Clay Loam	B	8-24	12 48 40	silty clay	1.31	3.3	2.43	5.5
			A	0-12	14 51 35	silty clay loam	1.25	3.5	5.93	5.2
			B	12-24	11 44 45	silty clay	1.31	2.0	5.95	7.1
10 Infested	Alluvium	Tulley Silty Clay Loam	A	0-12	13 54 33	silty clay loam	1.32	2.8	6.92	7.0
10 uninfested	Alluvium	Tulley Silty Clay Loam	B	12-24	12 47 41	silty clay	1.50	1.3	9.34	6.8
			A	0-12	15 59 26	silt loam	1.17	4.4	10.59	5.8
			B	12-24	14 55 31	silty clay loam	1.25	3.3	9.07	5.6
13 Infested	Shale	Dwight-Irwin Complex	A	0-8	16 56 28	silty clay loam	1.21	3.8	1.94	5.5
13 uninfested	Shale	Dwight-Irwin Complex	B	8-24	11 44 45	silty clay	1.28	2.3	5.65	5.3
			A	0-8	16 61 23	silt loam	1.16	4.9	.49	5.5
			B	8-24	11 42 47	silty clay	1.40	1.6	0.00	5.6
19 Infested	Colluvium	Tulley Silty Clay Loam	A	0-12	22 56 22	silt loam	1.00	10.0	19.88	6.4
19 uninfested	Colluvium	Tulley Silty Clay Loam	B	12-24	24 56 20	silt loam	1.04	5.4	12.80	6.4
			A	0-12	26 46 28	clay loam	1.12	5.3	6.69	6.9
			B	-	-	-	-	-	-	-

PART III

SITE POTOS AND DESCRIPTIONS

Site: 1A (infested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Alluvial

Soil texture:

A. silt loam 0 - 12"

B. silty clay loam 12" - 24"

Parent material: alluvium



Site: 1B (uninfested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Alluvial

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12: - 24"

Parent material: alluvium



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 2A (infested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Tully silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. none

Parent material: alluvium



Site: 2B (uninfested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Tully silty clay loam

Soil texture:

A. silt loam 0 - 6"

B. silt loam 6: - 12"

Parent material: alluvium

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 3A (infested)

Range site: limy upland

Topographic site: valley floor

Soil type: Clime-Sogn complex

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: calcareous clayey shale



Site: 3B (uninfested)

Range site: limy upland

Topographic site: valley floor

Soil type: Clime-Sogn complex

Soil texture:

A. silt loam 0 - 6"

B. silt loam 6"- 12"

Parent material: limestone



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 4A (infested)

Range site: limy upland

Topographic site:

Soil type: Clime-Sogn complex

Soil texture:

A. silt loam 0 - 8"

B. silt loam 8"- 16"

Parent material: calcareous clayey shale



Site: 4B (uninfested)

Range site: limy upland

Topographic site: hillside

Soil type: Clime-Sogn complex

Soil texture:

A. silt loam 0 - 6"

B. silt loam 6"- 12"

Parent material: limestone

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 5A (infested)

Range site: clay upland

Topographic site: valley floor

Soil type: Irwin silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: clayey shale



Site: 5B (uninfested)

Range site: clay upland

Topographic site: valley floor

Soil type: Irwin silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silty clay loam 12"- 24"

Parent material: clayey shale



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 6A (infested)

Range site: clay upland

Topographic site: valley floor

Soil type: Irwin silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: clayey shale



Site: 6B (uninfested)

Range site: clay upland

Topographic site: valley floor

Soil type: Irwin silty clay loam

Soil texture:

A. silty clay loam 0 - 12"

B. silty clay loam 12"- 24"

Parent material: clayey shale

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 7A (infested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Wymore silty clay loam

Soil texture:

A. silty clay loam 0 - 8"

B. silty clay loam 8"- 24"

Parent material: loess



Site: 7B (uninfested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Wymore silty clay loam

Soil texture:

A. silt loam 0 - 8"

B. silty clay loam 8"- 24"

Parent material: loess



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 8A (infested)

Range site: clay upland

Topographic site: hillside

Soil type: Irwin silty clay loam

Soil texture:

A. silt loam 0 - 8"

B. silty clay 8"- 24"

Parent material: clayey shale



Site: 8B (uninfested)

Range site: clay upland

Topographic site: hillside

Soil type: Irwin silty clay loam

Soil texture:

A. silty clay loam 0 - 12"

B. silty clay 12"- 24"

Parent material: clayey shale

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 9A (infested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Alluvial

Soil texture:

A. silty clay loam 0 - 12"

B. none

Parent material: alluvium



Site: 9B (uninfested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Alluvial

Soil texture:

A. silty clay loam 0 - 12"

B. none

Parent material: alluvium



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 10A (infested)

Range site: clay upland

Topographic site: valley floor

Soil type: Tulley silty clay loam

Soil texture:

A. silty clay loam 0 - 12"

B. silty clay 12"- 24"

Parent material: alluvium



Site: 10B (uninfested)

Range site: clay upland

Topographic site: valley floor

Soil type: Alluvial

Soil texture:

A. silt loam 0 - 12"

B. silty clay loam 12"- 24"

Parent material: alluvium

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 11A (infested)

Range site: loamy upland

Topographic site: hillside

Soil type: Benfield Florence complex

Soil texture:

A. silt loam 0 - 1"

B. none

Parent material: limestone



Site: 11B (uninfested)

Range site: loamy upland

Topographic site: hillside

Soil type: Benfield Florence complex

Soil texture:

A. silt loam 0 - 12"

B. none

Parent material: cherty limestone



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 12A (infested)

Range site: loamy upland

Topographic site: hillside

Soil type: Benfield Florence complex

Soil texture:

A. silty clay loam 0 - 12"

B. silty clay loam 12"- 24"

Parent material: cherty limestone



Site: 12B (uninfested)

Range site: loamy upland

Topographic site: hillside

Soil type: Benfield Florence complex

Soil texture:

A. silty clay loam 0 - 12"

B. silt loam 12"- 24"

Parent material: cherty limestone

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 13A (infested)

Range site: clay upland

Topographic site: hillside

Soil type: Dwight Irwin

Soil texture:

A. silty clay loam 0 - 8"

B. silty clay 8"- 24"

Parent material: shale



Site: 13B (uninfested)

Range site: clay upland

Topographic site: hillside

Soil type: Dwight Irwin

Soil texture:

A. silt loam 0 - 8"

B. silty clay 8"- 24"

Parent material: shale



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 14A (infested)

Range site: limy upland

Topographic site: valley floor

Soil type: Clime silty clay loam

Soil texture:

A. silt loam 0 - 6"

B. silt loam 6"- 12"

Parent material: shale



Site: 14B (uninfested)

Range site: limy upland

Topographic site: valley floor

Soil type: Clime silty clay loam

Soil texture:

A. silty clay loam 0 - 12"

B. silty clay loam 12"- 24"

Parent material: shale

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 15A (infested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Reading silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. none

Parent material: alluvium



Site: 15B (uninfested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Reading silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: alluvium



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 16A (infested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Reading silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: alluvium



Site: 16B (uninfested)

Range site: loamy upland

Topographic site: valley floor

Soil type: Reading silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silty clay loam 12"- 24"

Parent material: alluvium

SITE PHOTOS AND DISCRIPTIONS cont.

Site: 17A (infested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Kennebec silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: alluvium



Site: 17B (uninfested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Kennebec silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"- 24"

Parent material: alluvium



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 18A (infested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Kennebec silty clay loam

Soil texture:

A. silty clay loam 0 - 12"

B. silt loam 12"- 24"

Parent material: alluvium



Site: 18ⁿ (uninfested)

Range site: loamy lowland

Topographic site: streambank

Soil type: Kennebec silty clay loam

Soil texture:

A. clay loam 0 - 12"

B. silt loam 12"- 24"

Parent material: alluvium

SITE PHOTOS AND DESCRIPTIONS cont.

Site: 19A (infested)

Range site: clay upland

Topographic site: hillside

Soil type: Tully silty clay loam

Soil texture:

A. silt loam 0 - 12"

B. silt loam 12"-24"

Parent material: colluvium



Site: 19B

Range site: clay upland

Topographic site: hillside

Soil type: Tully silty clay loam

Soil texture:

A. clay loam 0 - 12"

B. none

Parent material: colluvium



SITE PHOTOS AND DESCRIPTIONS cont.



Site: 20A (infested)

Range site: loamy upland

Topographic site: hillside

Soil type: Pawnee loam

Soil texture:

A. loam 0 - 12"

B. clay loam 12"- 24"

Parent material: glacial till



Site: 20B (uninfested)

Range site: loamy upland

Topographic site: hillside

Soil type: Pawnee loam

Soil texture:

A. loam 0 - 6"

B. clay loam 6"- 24"

Parent material: glacial till

PART IV

Table A - 2 General linear models analysis of muskthistle populations, rosettes per square meter for fall and bolted muskthistles per square meter for spring.

DEPENDENT VARIABLE: VALUE FALL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	9608.82622180	3202.94207393	9.47	0.0001	0.070243	215.8313
ERROR	376	127176.00535714	338.23405689		STD CLV		VALUE MEAN
CORRECTED TOTAL	379	136784.83157895			18.29114072		8.22105263

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	9608.82622180	9.47	0.0001	3	9608.82622180	9.47	0.0001
SEASON	0	0.00000000	.	.	0	0.00000000	.	.
RANGETYP*SEASON	0	0.00000000	.	.	0	0.00000000	.	.

DEPENDENT VARIABLE: VALUE SPRING

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	423.75112782	141.25037594	0.23	0.0001	0.061592	105.5389
ERROR	376	6456.18571429	17.17076667		STD CLV		VALUE MEAN
CORRECTED TOTAL	379	6879.93684211			4.14375514		3.92631577

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	423.75112782	8.23	0.0001	3	423.75112782	8.23	0.0001
SEASON	0	0.00000000	.	.	0	0.00000000	.	.
RANGETYP*SEASON	0	0.00000000	.	.	0	0.00000000	.	.

Table A - 3 General linear models analysis of vegetative and soil characteristics, CANOPY - percent canopy cover, BASAL - percent basal cover, GROUND - percent bare ground, LITTER - percent litter cover, DEPTHMP - avg. depth of litter, GRASS - percent species composition of grass, MOISTA and MOISTB - percent moisture in the A and B horizons, OMA and OMB - percent organic matter in the A and B horizons, PHA and PHB - pH in the A and B horizons, BULKA and BULKB - bulk density in the A and B horizons.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: CANOPY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	T-VALUE	PR > F	C.V.
MODEL	7	30891.20057143	4413.02979552	4.09	0.0026	0.472077	24.0884	
ERROR	32	34545.61142857	1079.55035714		STD DEV		CANOPY MEAN	
CORRECTED TOTAL	39	65436.82000000			32.85651104		136.40000000	

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGLTYP	3	3789.61119048	1.17	0.3364	3	3789.61119048	1.17	0.3364
INFEST	1	24720.06400000	23.08	0.0001	1	24720.06400000	22.35	0.0001
RANGLTYP*INFEST	3	2131.53338095	0.67	0.5746	3	2131.53338095	0.67	0.5746

DEPENDENT VARIABLE: BASAL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	T-VALUE	PR > F	C.V.
MODEL	7	74.57048810	10.65292687	2.57	0.0449	0.341850	25.3896	
ERROR	32	143.56726190	4.48647693		STD DEV		BASAL MEAN	
CORRECTED TOTAL	39	218.13775000			2.11813053		8.34250000	

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	64.91102391	4.92	0.0073	3	64.91102391	4.92	0.0070
INFEST	1	1.64625000	0.37	0.5457	1	1.64625000	0.30	0.5852
RANGETYP*INFEST	3	3.01921429	0.60	0.6224	3	3.01921429	0.60	0.6224

Table A - 3 cont.

DEPENDENT VARIABLE: GRCHUD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	9465.01660714	1352.14437243	3.20	0.0110	0.411671	57.1793
ERROR	32	13526.66714296	422.70834821		STD DEV		GRCHUD MEAN
CORRECTED TOTAL	39	22991.6775000			20.55987228		35.95750000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	7547.52667857	5.95	0.0024	3	7547.52667857	5.95	0.0024
INFEST	1	985.05635000	2.33	0.1367	1	644.46191746	1.52	0.2259
RANGETYP*INFEST	3	932.42767857	0.74	0.5387	3	932.42767857	0.74	0.5387

DEPENDENT VARIABLE: LITTER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	9604.22221429	1372.03174490	3.21	0.0108	0.412795	37.0955
ERROR	32	13662.11678571	426.94114955		STD DEV		LITTER MEAN
CORRECTED TOTAL	39	23266.3390000			20.66255429		55.69500000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	7621.55775000	5.55	0.0024	3	7621.55775000	5.55	0.0024
INFEST	1	910.11600000	2.15	0.1540	1	596.67036429	1.38	0.2484
RANGETYP*INFEST	3	1072.54846429	0.84	0.4834	3	1072.54846429	0.84	0.4834

DEPENDENT VARIABLE: DEPTHWP

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	12.31203571	1.75896224	3.35	0.0142	0.400160	71.1414
ERROR	32	18.45571429	0.57674107		STD DEV		DEPTHWP MEAN
CORRECTED TOTAL	39	30.76775000			0.75933471		1.05150000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	7.52810714	4.53	0.0089	3	7.52810714	4.53	0.0039
INFEST	1	1.04225000	2.34	0.1014	1	1.11258411	1.92	0.1744
RANGETYP*INFEST	3	2.74367357	1.36	0.2120	3	2.74367357	1.36	0.2555

Table A - 3 cont.

DEPENDENT VARIABLE: GRASS									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F	C.V.
MODEL	7	2629.41433333	375.63061905	2.08	0.0190				12.4439
ERROR	32	4178.49666667	130.57802083		STD DEV				GRASS MEAN
CORRECTED TOTAL	39	6807.91100000			11.42707403				38.53500000
DEPENDENT VARIABLE: MOISTA									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F	C.V.
RANGETYP	3	396.80100000	1.01	0.3958					
INFEST	1	2232.03600000	17.09	0.0002	396.80100000				1.01
RANGETYP*INFEST	3	0.57733333	0.00	1.0000	2000.35048885				15.32
					0.57733333				0.00
DEPENDENT VARIABLE: MOISTA									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F	C.V.
MODEL	7	141.49855786	25.92836541	0.78	0.6110				84.3817
ERROR	32	1067.71903214	33.36621575		STD DEV				MOISTA MEAN
CORRECTED TOTAL	39	1249.21759000			5.77635004				6.34500000
DEPENDENT VARIABLE: MOISTB									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F	C.V.
RANGETYP	3	97.82966679	0.88	0.4031					
INFEST	1	24.18025000	0.72	0.4009	87.82966679				0.94
RANGETYP*INFEST	3	69.48864107	0.69	0.5024	15.53526229				0.47
					65.48864107				0.69
DEPENDENT VARIABLE: MOISTB									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F	C.V.
MODEL	7	254.20825435	36.31546453	1.35	0.2654				33.7057
ERROR	25	672.59069667	26.90386278		STD DEV				MOISTB MEAN
CORRECTED TOTAL	32	926.79895152			5.18687072				6.19212121
DEPENDENT VARIABLE: MOISTB									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F	C.V.
RANGETYP	3	218.10769000	2.70	0.0071					
INFEST	1	11.60267253	0.43	0.5174	220.33237002				2.70
RANGETYP*INFEST	3	24.98099232	0.30	0.8225	7.72499503				0.29
					26.46009232				0.30

Table A - 3 cont.

DEPENDENT VARIABLE: ONA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	33.45196429	4.77895204	1.63	0.1495	0.268632	90.2823
ERROR	32	91.05170571	2.84536030		STD DEV		C 4A 4LAD
CORRECTED TOTAL	39	124.50375000			1.08682155		4.18750000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	30.21404762	3.54	0.0255	30.21404762	3.54	0.0255
INFEST	1	1.19025000	0.42	0.5224	0.75523885	0.28	0.6007
RANGETYP*INFEST	3	2.04766667	0.24	0.8673	2.04766667	0.24	0.3679

DEPENDENT VARIABLE: ONB

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	13.44345455	1.92049351	1.22	0.3270	0.255157	44.1208
ERROR	25	39.23533332	1.56941553		STD DEV		CME MEAN
CORRECTED TOTAL	32	52.67878788			1.25276228		2.83559354

SOURCE	DF	TYPE I SS	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	10.31575758	2.19	0.1141	10.52901230	2.24	0.1088
INFEST	1	0.3489543	0.22	0.6423	0.17307927	0.11	0.7420
RANGETYP*INFEST	3	2.77670754	0.59	0.6274	2.77670754	0.59	0.6274

DEPENDENT VARIABLE: PHA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	11.08284524	1.59326361	3.79	0.0042	0.453291	9.9099
ERROR	32	13.36650476	0.41771577		STD DEV		PHA MEAN
CORRECTED TOTAL	39	24.44935000			0.64630535		6.52250000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	10.60463095	8.46	0.0003	10.470463055	8.46	0.0003
INFEST	1	0.34825000	0.32	0.5721	0.27131429	0.28	0.3524
RANGETYP*INFEST	3	0.13556429	0.11	0.9545	0.113596625	0.11	0.9545

Table A - 3 cont.

DEPENDENT VARIABLE: PHB

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	11.66012121	1.665716317	3.27	0.0121	0.478182	10.9576
ERROR	25	12.65866667	0.50634667		STD DEV		PHB MEAN
CORRECTED TOTAL	32	24.31878788			0.71158640		0.49393939

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	11.39812121	7.50	0.0010		11.32961074	7.45	0.0010
INFEST	1	0.01422371	0.03	0.8682		0.05641470	0.10	0.7550
RANGETYP*INFEST	3	0.19777629	0.12	0.9453		0.16777629	0.12	0.9453

DEPENDENT VARIABLE: BULKA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	0.17994274	0.02570611	3.69	0.0049	0.446733	6.5983
ERROR	32	0.22285476	0.00696421		STD DEV		BULKA MEAN
CORRECTED TOTAL	39	0.40279750			0.08345195		1.26475000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	0.17459750	0.36	0.0003		0.17459750	0.36	0.0003
INFEST	1	0.0030250	0.04	0.8362		0.0000813	0.00	0.9730
RANGETYP*INFEST	3	0.00504274	0.24	0.9668		0.00504274	0.24	0.9668

DEPENDENT VARIABLE: BULKA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	0.04510939	0.00644420	0.76	0.6247	0.175616	7.0305
ERROR	25	0.21176333	0.00847053		STD DEV		BULKA MEAN
CORRECTED TOTAL	32	0.25687273			0.05203550		1.30509091

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	0.00244405	0.10	0.9014		0.0059105	0.04	0.9895
INFEST	1	0.01314226	1.19	0.1932		0.01667722	1.26	0.2722
RANGETYP*INFEST	3	0.02752124	1.05	0.3746		0.02752125	1.04	0.3746

Table A - 4 General linear model analysis of percent species composition of KB - Kentucky bluegrass, AB - annual brome, SB - smooth brome, SE - sedges, SO - sideoats grama, BB - bug bluestem, LB - little bluestem, IG - Indiangrass.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: KB

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	2843.85046429	406.26463776	1.16	0.3545	0.201894	101.9417
ERROR	32	11261.79528571	351.93122763		STD DEV		KB MEAN
CORRECTED TOTAL	39	14110.64575000			18.75983016		18.40250000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	2450.80510714	2.32	0.0923	3	2450.80510714	2.32	0.0938
INFEST	1	282.49225000	0.80	0.3770	1	212.31645714	0.60	0.4430
RANGETYP*INFEST	3	115.55310714	0.11	0.9540	3	115.55310714	0.11	0.9540

DEPENDENT VARIABLE: AB

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	5794.88542857	827.8407551	2.54	0.0338	0.557134	115.2061
ERROR	32	18423.91257143	575.5937540		STD DEV		AB MEAN
CORRECTED TOTAL	39	16223.80400000			18.35280225		15.67000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	4042.77130095	4.13	0.0133	3	4042.77130095	4.13	0.0133
INFEST	1	1164.24100000	3.57	0.0673	1	1253.20960317	3.94	0.0559
RANGETYP*INFEST	3	587.67304762	0.60	0.6189	3	587.67304762	0.60	0.6189

Table A - 4 cont.

DEPENDENT VARIABLE: SR									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.		
MODEL	7	4345.71690048	620.81695578	2.31	0.0507	0.335231	156.2895		
ERROR	32	3617.64130552	269.30129092		STD DEV		SB MEAN		
CORRECTED TOTAL	39	12963.36000000			16.41040191		10.50000000		
SOURCE	DF	TYPE I SS	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F		
RANGETYP	3	4097.48244048	5.07	0.0055	4097.48244048	5.07	0.0055		
INFEST	1	19.04600000	0.07	0.7920	0.05915000	0.00	0.5893		
RANGETYP*INFEST	3	229.19225000	0.28	0.8368	229.19225000	0.28	0.9368		
DEPENDENT VARIABLE: SE									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.		
MODEL	7	1228.32832143	175.47547449	4.11	0.0025	0.473208	88.6068		
ERROR	32	1367.42142857	42.73191964		STD DEV		SE MEAN		
CORRECTED TOTAL	39	2595.74975000			6.52696503		7.37750000		
SOURCE	DF	TYPE I SS	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F		
RANGETYP	3	1123.62796429	8.76	0.0002	1123.62796429	8.76	0.0002		
INFEST	1	29.07625000	0.68	0.4156	40.25625714	0.94	0.3390		
RANGETYP*INFEST	3	75.63010714	0.59	0.6261	75.63010714	0.59	0.6261		
DEPENDENT VARIABLE: SU									
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.		
MODEL	7	823.04255552	117.57750850	3.72	0.0043	0.130393	206.2447		
ERROR	32	5211.30119048	162.85216220		STD DEV		50 MEAN		
CORRECTED TOTAL	39	6034.34375000			12.76135242		6.11750000		
SOURCE	DF	TYPE I SS	F VALUE	PR > F	TYPE IV SS	F VALUE	PR > F		
RANGETYP	3	432.17767857	0.83	0.4995	432.17767857	0.83	0.4555		
INFEST	1	191.05025000	1.11	0.2997	75.44785694	0.45	0.5067		
RANGETYP*INFEST	3	209.81463055	0.47	0.7233	209.81463055	0.45	0.7334		

Table A - 4 cont.

DEPENDENT VARIABLE: DB

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	976.77786905	139.53969554	2.12	0.0704	0.516404	126.7383
ERROR	32	2110.30989095	65.94718378		STD DEV		BE MEAN
CORRECTED TOTAL	39	3097.08775000			R.12078714		6.40750000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	119.33185714	0.60	0.6209	3	119.33185714	0.60	0.6209
INFEST	1	763.60225000	11.57	0.0018	1	542.17080075	8.22	0.0073
RANGETYP*INFEST	3	95.44376190	0.48	0.6968	3	95.44376190	0.43	0.6968

DEPENDENT VARIABLE: LB

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	351.99228095	50.27034014	1.75	0.1377	0.276754	134.8533
ERROR	32	919.60761905	28.73773810		STD DEV		LB MEAN
CORRECTED TOTAL	39	1271.59990000			5.36075910		2.90000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	113.41552381	1.32	0.2864	3	113.41552381	1.32	0.2864
INFEST	1	170.56900000	5.94	0.0206	1	100.98285714	3.51	0.0700
RANGETYP*INFEST	3	67.90385714	0.79	0.6097	3	67.90385714	0.79	0.6097

DEPENDENT VARIABLE: IG

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	7	141.00016667	20.14288095	2.12	0.0680	0.317904	175.4697
ERROR	32	302.53083333	9.45408854		STD DEV		IG MEAN
CORRECTED TOTAL	39	443.53100000			5.07475010		1.56500000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
RANGETYP	3	51.81058333	1.82	0.1621	3	51.81058333	1.83	0.1621
INFEST	1	52.90000000	5.60	0.0292	1	49.59890556	5.22	0.0290
RANGETYP*INFEST	3	36.28951667	1.22	0.2981	3	36.28951667	1.23	0.2981

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HABITAT CHARACTERISTICS OF MUSKTHISTLE POPULATIONS
IN THE FLINT HILLS OF KANSAS

by

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B. S., Brigham Young University, 1980

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Abstract

Muskthistle (Carduus nutans L.), a noxious weed in Kansas, causes many problems for farmers and ranchers. A recognition of muskthistle growth and habitat needs would be an aid in its control. Such recognition was the purpose of this study.

In Riley and Pottawatomie counties 20 paired (infested and uninfested) range sites were measured in the fall, 1981, for several vegetative and soil characteristics, including a count of muskthistles per square meter in the fall and spring, 1982, on infested sites. The range sites studied were loamy lowland, loamy upland, clay upland and limy upland.

Among the range sites, loamy lowland sites and loamy upland sites were most susceptible to infestations of muskthistle.

The habitat characteristics which favored muskthistle growth were a relatively low percent canopy cover, a relatively high percent bareground, a small amount of litter, a high percent species composition of annual brome (Bromus spp. L.), a low percent species composition of warm-season grasses, and moist sandy soils with a relatively high percent organic matter and pH.

Since each range site was unique, those conditions which favored muskthistle establishment were relative to conditions that were found on the uninfested site of the same range site type.