EVALUATION OF EASTERN REDCEDAR (JUNIPERUS VIRGINIANA L.) INFESTATIONS IN THE NORTHERN KANSAS FLINT HILLS

by 5357

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INTRODUCTION

The recent rapid invasion of eastern redcedar (*Juniperus virginia* L.) into the tallgrass prairie has been of concern to ranchers and professional range managers.

During the last four or five years redcedars have become prominent in areas where ranchers do not remember seeing them previously. Some pastures have much worse invasions than adjoining ones. The factors involved in rapid invasion of eastern redcedar are not known. Opinions held by local landowners include a reported large increase in starling (*Sturnus vulgaris britannicus* Bullough) populations in the early 1960's. It is generally accepted (17, 22) that redcedar seeds are spread by various species of birds. Parker (17) reported starlings as one such species. The decline of some rodent species might have resulted in less destruction of redcedar seedlings. U.S. Forest Service (22) states that some small mammals damage young redcedar seedlings. Both those hypotheses might have some validity, but they cannot be substantiated since statistical information is not available on populations of wildlife species in the study area.

Fire is known to have a drastic effect on redcedar stands. Annual burning will almost eliminate redcedar in grassland.

This study was initiated to determine if certain management and environmental factors were associated with eastern redcedar invasion.

REVIEW OF LITERATURE

Eastern redcedar invasion into Kansas Flint Hills rangeland is affected by dissemination and germination of seeds, and survival of seedlings. Barton (4) reports that dormant redcedar embryos require an after-ripening period of about 90 days at about 5° C. Barton reported that 10° C was totally ineffective in the after-ripening period, and 1° C was considerably less effective than was the 5° C treatment. Barton (4) further reported that effective after-ripening periods must follow moisture penetration of the seedcoat. This requires exposure to moisture for 2 to 8 weeks (25° C was the most effective temperature tested) before the after-ripening period starts.

Chadwick (6) states that redcedar seeds (even following stratification) should be planted at least thirty days before the soil temperature reaches 16° C. He also reported that germination was best at soil surface temperatures of 10° C - 13° C and that redcedar seed germination was considerably retarded when the soil surface temperature exceeds 18° C.

Meines (14), working at Halsey, Nebraska, concluded that a fairly heavy mulch was necessary during most years in order to hold sufficient moisture around the redcedar seed. Mulch also had the effect of insulating the soil and keeping it cool later in the spring.

Parker (16) found that mechanical scarification of redcedar seeds before planting hastened germination but did not increase the final germination percentage. Barton (4) and Cortrufo (8) reported that the period of time required for moisture to penetrate the seedcoat of redcedar could be greatly reduced by treatment with citric or sulfuric acid solutions for a period ranging from 30 minutes to 8 hours. Webster and Ratliffe (24) obtained a similar response by treating the seed with a solution of sodium hydroxide for 20 minutes followed by washing and soaking in clear water for several hours. These treatments were somewhat similar to the treatment a seed would receive by passing intact through the digestive tract of an animal.

According to Parker (18) and Southeastern Forestry Experiment Station workers (21), survival of young redcedar seedlings was best in the shade, but shading was detrimental to the seedlings after the first year or so.

It has been postulated that eastern redcedar thrives only on soils high in lime. Arend (3) and Read and Walker (20) found that the high lime content of soil under stands of redcedar was a result of redcedar foliage falling on the soil. Arend's (3) work showed that after 44 years pH of the surface 3 inches of soil was 7.0 under redcedar compared to 5.0 in the check area. Read and Walker (20) found that some redcedar foliage had over 2% Ca. They also reported higher soil pH and increased earthworm activity in soil under redcedar than under pine cover.

Eastern redcedar is not capable of suckering or resprouting (22). When the top was cut off below the lowest limb, or when killed by fire, the tree roots also die from lack of top growth to support them. Fire is known to severely limit redcedars (3). Arend (3) concluded that the chief reason redcedars are found mostly on shallow limy soils in the Ozarks (Missouri) was because fire had eliminated them from areas where sufficient grass grew to support a hot fire. He also illustrated how redcedar had increased in some areas since fire had largely been eliminated. He reported that Sharp county, Arkansas, records showed that a landowner searched his 700 acre tract in 1845 and found only 12 young redcedars. The landowner transplanted these to his farmstead. Redcedar is now plentiful on the same land.

Redcedar dissemination is similar to that of several other species in that seeds are spread primarily by birds and small mammals (17, 22). Observations by Parker (17) in the Duke Forest in North Carolina indicate that at least the following bird species eat redcedar seeds: waxwings, robins, starlings, thrushes, mocking birds, and occasionally doves. U.S. Forest Service (22) lists these bird species that feed on redcedar seeds: quail, grouse, pheasant, and wild turkey. Most birds took redcedar seeds primarily when there was a shortage of other feed supplies, especially during days when snow or ice covered the ground. Parker's (17) work indicates that doves digested the seed they ate. The seed passed through the digestive tract of waxwings, starlings, and thrushes undigested. Passage through the birds' digestive tract hastened and improved the seed germination, but was not shown to be essential for germination (17).

Most germination of redcedar seeds under natural conditions occurs the second year after dispersal by birds (22), but a few germinated during the first spring and a few more during the third spring.

Graf, et al. (12), working in Henry County, Iowa, found as many as 60 seedlings per acre in an area 3/8 mile or farther from the nearest established seed source, which indicates that animals effectively spread seeds.

In 1939, Albertson (1) reported that up to 80% of eastern redcedar died in the drought of the 1930's in the three areas studied in the Hays, Kansas area near the western edge of the range of this species. Pool (19) found in eastern Nebraska that no great damage was suffered by redcedar due to the same drought.

Information about effects of grazing management on redcedar invasions was conspicuously lacking in the literature reviewed. Such information should be helpful in making range management decisions to reduce the invasion problems.

STUDY AREAS AND METHODS

The study area was in the True Prairie of the Flint Hills of northeast Kansas near Manhattan. Vegetation in this area is predominantly big and little bluestem (*Andropogon gerardi* Vitman and *A. scoparius* Michx.), indiangrass (*Sorghastrum nutans* (L.) Nash), switchgrass (*Panicum virgatum* L.) and numerous forbs and woody species of lesser importance. The average annual rainfall for the 16-year period (1954-1969) was 1.79 inches greater than at Manhattan (Appendix Table 1). Sixty-nine percent of the precipitation fell in the period April thru September. The average frost-free period was from about April 20 to October 10. The elevation of the study pastures was approximately 1,100 feet above mean sea level.

Range sites.

The soils of the study areas were grouped into range sites to eliminate soil differences as a variable. Soils within a range site have essentially the same plant community and production potential when in climax condition.

Loamy upland range site consists of soils having sufficient depth of medium-textured soil to support primarily big bluestem and indiangrass when in climax condition. Predominant slopes are 1 - 5%.

Limestone breaks consist of soils occurring on predominantly 15 - 30% slopes. Loss of moisture by runoff is greater than on loamy upland, but the soil has sufficient depth to support vegetation similar to that found on loamy upland. Limestone rocks usually occur throughout the profile and on the surface.

Clay upland consists of soils occurring on 0 - 3% slopes mostly on the tops of ridges. The soil is finer-textured and more droughty than loamy upland. Vegetation is highly variable but contains big and little bluestem with a higher percentage of secondary grasses than loamy upland.

Limy upland, though similar to loamy upland, has chunks of limestone occurring in the profile and on the surface. The soil is sufficiently deep and with water relations favoring vegetation similar to that on loamy upland. The predominant slopes are 3 - 8%.

True Prairie range sites are described in detail by Anderson and Fly (2).

Experimental design.

Eight pastures (designated as main study areas) were selected in Riley and Pottawatomie counties. Criteria for pasture selection included availability of management records, willingness of the landowner to cooperate, and the presence of the range sites to be studied. Four of these pastures were lightly to moderately infested (5-20 trees/acre), and four were heavily invaded (30+ trees/acre) with eastern redcedar.

The main study areas were all grazed pastures with known management histories for the period 1960 - 1968. They ranged in size from 63 to 237 acres and totaled 1,062 acres (Appendix Table 2).

One hundred circular, tenth-acre plots (37.25 ft. diameter) were located in the heavily-invaded pastures and one hundred were located in the lightly to moderately-invaded ones. The number of plots in each pasture was in proportion to the pasture size, approximately one for each five acres of total area. A total of 200 plots were used as representing the study pastures. Information was recorded for each plot.

Plot locations within a pasture were chosen along lines 330 ft. apart running the length of the pastures. The distances between plots on these lines were determined by picking three digit numbers from a table of random numbers. Values smaller than 80 feet were ignored to prevent overlap between plots. Alternate plot locations were included at random in each pasture, since some plots did not fall within the four range sites being studied. The plots were located in the field by pacing from known landmarks and by use of a compass to hold the desired direction. Initial determinations were made by use of maps obtained from the work unit offices of the Soil Conservation Service, but the final range site designation was made in the field for each plot.

<u>General information collected</u>.

Information collected on each main study area included: number of trees which produced seeds in 1969, the kind of range site, the estimated range condition class, the direction of slope exposure, other brush species present, and estimated abundance of other brush. Height, diameter, and age relationships were recorded for 100 trees. Twenty-five of these were from each of the four range sites being studied. Heights were measured to the nearest inch. Diameter was measured at soil level.

Growth Ring Analysis.

Tree- age determination was made under 10X magnification as described by Glock (10) on an entire cross section cut at ground level from each of the redcedars in the plots.

Some cross-sections of the first cuttings of redcedar were oven-dried. The dry specimens were harder to smooth for growth ring counting and growth rings on the dry wood were harder to see than those which were not dried. Penetrating machine oil was used to improve the visibility of the rings on the dry specimens. The less dense wood of the areas of relatively fast growth absorbed the oil faster than did the dense outer wood.

Two redcedar cross-sections were sent to Dr. Waldo S. Glock of the University of Colorado at Boulder. His age estimates agreed with those of the author on one cross-section and disagreed by one year on the other. The ages reported in this paper are the best available approximations of the ages, but they should not be taken as absolute. Determination of the exact age of a tree ring analysis is questionable, especially for a redcedar, according to Glock (10). The dating of eastern redcedar seems to be more difficult than for many other species since this species frequently has 1 to 3 false rings during a growing season (9). The density of the wood in a false ring grades both ways from the center of the ring while the density of the wood in a true ring breaks abruptly at the outside edge. Glock (10) states that false rings are much more common in young trees than in mature ones. Slow growth of young trees (caused by weather or other hindering factors) is commonly associated with false rings. Glock (11) states "False rings reveal themselves by a certain haziness," but in his opinion tree age cannot be determined with exact certainty (personal communication). Other hindering factors included defoliation, mechanical injury, frost damage, rainfall distribution, and competition by neighboring trees.

Supplemental Pastures.

Thirty supplemental pastures were observed to give a broader base to the study. Ten pastures in each of the following categories were selected: essentially no redcedar invasion, light to moderate invasion, and heavy invasion of redcedar. Information recorded for the supplemental pastures included grazing history for the period 1960 - 1968, whether or not the pastures were burned, and a visual estimate of redcedar invasion. Pasture histories were secured from landowners and/or operators.

RESULTS AND DISCUSSION

Age Class Distribution.

Approximately 48% of the redcedars on all plots germinated in 1963 and 1964, and 96% were less than ten years old.[1/] Differences in number of redcedar established among years existed only in the heavily-invaded pastures (Table 1).

Table 1. Average number of redcedar trees per acre and their year of establishment.

Tree	Years of Establishment									
Density	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Heavy	7.8	2.0	13.2	18.0	53.5	32.2	19.0	19.8	4.2	4.2
Light	0.5	0.2	0.8	0.5	3.0	3.0	0.2	3.2	2.2	2.0
Overall L.S.D. .05 = 13.7										

1/ Detailed age class distribution over years is shown in Appendix Table 4.

Effect of Grazing Management.

Management factors other than burning or mechanical removal which were significantly related to redcedar invasion include growing-season cattle stocking rates for the year of germination plus the grazing in the preceding year. Effects of grazing as much as three years before the year of seed germination appear to have affected redcedar stands presumably by changing the amount of mulch. Correlation co-effecients of stands and cattle stocking rate for year of redcedar establishment and for prior seasons were similar in all cases where the stocking rate was constant over years. The effects could therefore not be satisfactorily separated.

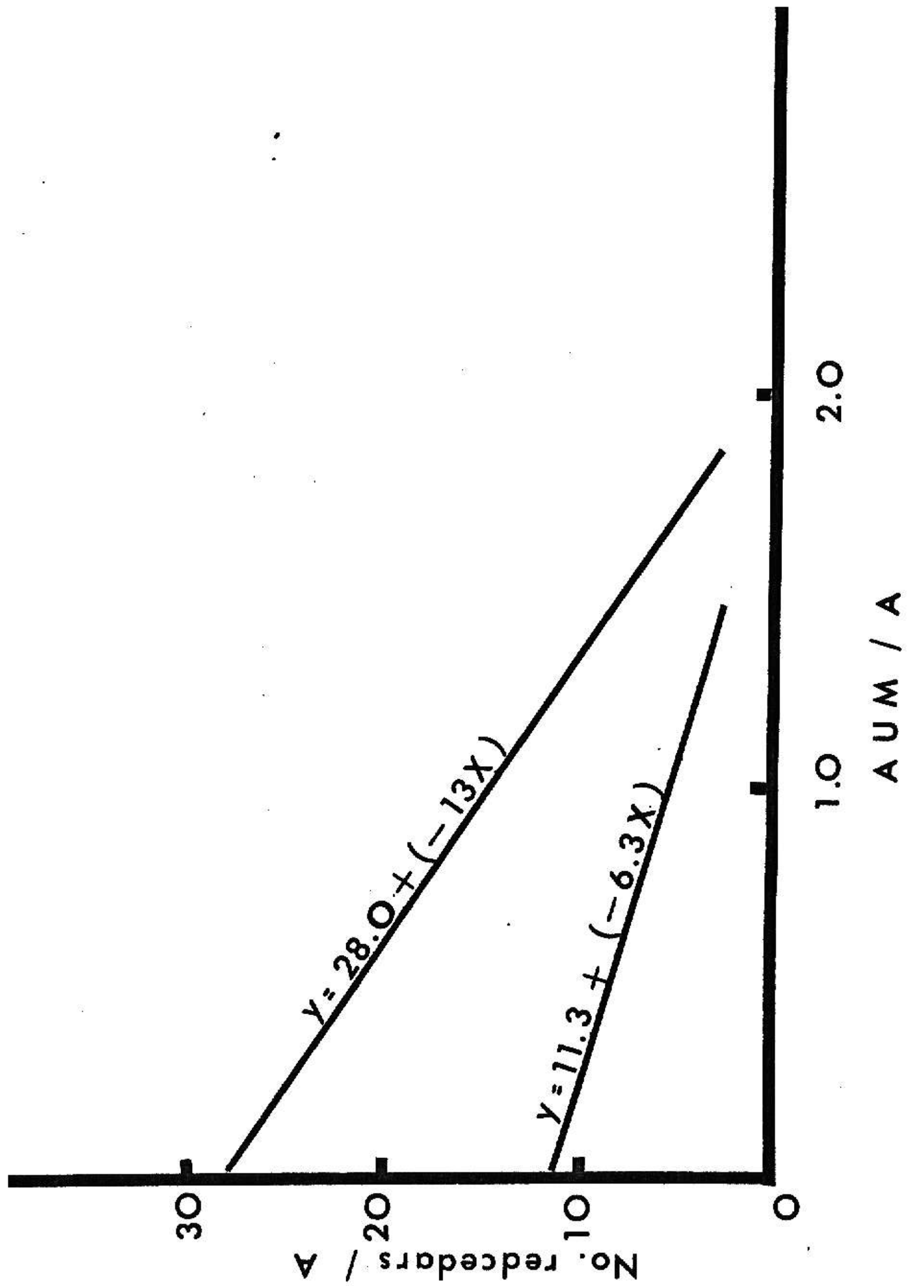
Growing season stocking rate. Redcedar invasion rate generally declined as growing-season (May - October) cattle stocking rate increased. That was true for the overall analysis of sites and pastures as well as for loamy upland and limestone break sites. The clay upland and limy upland range sites showed no statistically significant trends in relation to growing season stocking rate. The 1963 redcedar invasion rate declined 6.3 trees per acre per AUM of additional grazing. In 1964 the decline was 13.8 trees per acre per additional AUM of additional grazing. These two years were the worst for redcedar invasions during the study period. Relationship between redcedar numbers and growing-season stocking rate is shown in Figure 1 for all sites and pastures for the 1963 and 1964 redcedar invasion. Heavier stocking rates during the growing season resulted in fewer redcedars.

Redcedar establishment in 1968 did not follow the trend described by Meines (14) wherein successful establishment of redcedar from seeds required cool, moist soil. In 1968 heavier grazing during the

Figure 1. Relationship between growing season cattle stocking rate and redcedar numbers over all sites and pastures for two years of greatest redcedar invasion rate.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.



y = 28.0 + (−13X)
y = 11.3 + (−6.3X)
AUM / A
No. redcedars / A
0
1.0
2.0
10
20
30

growing season increased redcedar invasion. Apparently there was a critical amount of soil mulch required for redcedar establishment. Too much or too little mulch appeared to retard redcedar invasion.

Non-Growing Season Stocking Rate. Non-growing season cattle stocking rate affected redcedar invasion on some sites in some years. In all cases where a significant trend (P=0.10) was found, an increase in non-growing season cattle stocking rate resulted in a decreased redcedar invasion rate. That effect was shown in 1964 on the lightly invaded pastures (B=-0.23), in 1966 on the limestone breaks site in all pastures (B=0.83) and in the 1967 analysis over all sites and pastures, (Figure 2) (B=-2.3). In each case the "B" value represents the change in the dependent variable (redcedar number) per unit change in the independant variable (cattle stocking rate). These decreased redcedar invasion rates were perhaps due to the decreased amount of mulch left on the soil following winter grazing. Less mulch would be expected to result in less redcedar germination and/or survival (Meines (14).

Precipitation Effects.

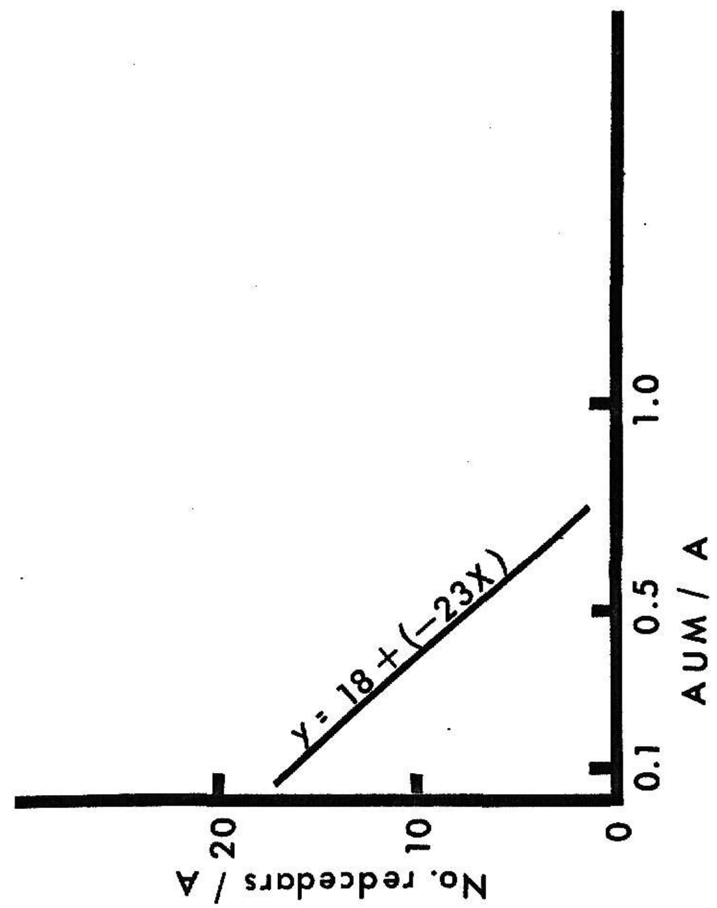
Total precipitation during the year of redcedar establishment had a slight, but statistically significant, effect on redcedar invasion. On the heavily invaded areas, as precipitation increased, invasion rate decreased by 0.02 trees per plot.

Precipitation during years prior to redcedar establishment was not shown to influence redcedar numbers.

Effect of Combination of Stocking Rate and Total Annual Precipitation

Current year's non-growing season cattle stocking rate and current and previous year's precipitation, and numbers of redcedar trees

Figure 2. Relationship between non-growing season cattle stocking rate and redcedar invasion for 1967.


y = 18 + (−23X)
No. redcedars / A
20
10
0
0.1
0.5
1.0
AUM / A

were multiply correlated on all pastures. Correlation and regression co-efficients are shown in Table 2.

Non-growing season stocking rate had a differential effect on redcedar establishment between heavily-and lightly-invaded pastures. As non-growing-season stocking rate increased on heavily-invaded pastures redcedar numbers increased, but on lightly-invaded pastures the reverse was true. As current and previous year's precipitation increased, redcedar number declined on both heavily-invaded and lightly-invaded pastures. The multiple correlation on heavily-invaded pastures indicated that as non-growing season stocking rates increased and precipitation of the year of establishment and the previous year declined, redcedar numbers increased.

The multiple regression equation accounted for only 22.6% of the variability on the heavily-invaded pastures and 14.4% on the lightly-invaded ones. The balance of the variability is apparently due to factors not considered in this study.

Frequency of Occurrence of Associated Brush and Tree Species.

Apparently the same factors which retard redcedar invasion generally retard the invasion of Osage Orange (*Maclura pomifera* Raf.), roughleaf dogwood (*Cornus drummondi* Meyer), honeylocust (*Gleditsia triaconthos* L.), and smooth sumac (*Rhus glabra* L.). Buckbrush (*Symphoricarpos orbiculatus* Moench), and elm (Ulmus L. sp.) were at least as abundant in the pastures which were with redcedar as in the heavily invaded ones. (Table 3). Data is given in more detail in Appendix Table 5.

Table 2. Multiple regression relationship between precipitation and stocking rate (All sites and pastures).

Variable	Regression Coefficient of the Variable		Contribution to R^2.	
	Heavy Invasion	Light Invasion	Heavy	Light
Non growing season stocking rate	+2.151	-0.088	0.006	0.003
Current year's precipitation	-0.040	-0.006	0.042	0.013
Previous year's precipitation	-0.019	-0.003	0.003	0.005
R^2			0.051	0.021

Table 3. Frequency of occurrence (%) of other woody species in the main study plots.

Redcedar Density	Osage Orange	Buckbrush	Roughleaf Dogwood	Elm	Honey Locust	Wild Plum	Aromatic Sumac	Smooth Sumac
Heavy	4.5	25.8	25.0	1.0	4.5	3.2	14.2	52.8
Light	0.0	51.2	3.2	12.2	0.0	0.8	2.8	9.8

Overall $LSD_{.05}$ = 12.4

In the secondary study pastures which were free of redcedar, buckbrush and elm were also reduced by fire which was generally associated with absence of redcedars. Elm is not a serious problem on rangeland in most of the area.

Comparison of Age with Diameter and Height of Redcedars.

Year of germination compared with average diameter at ground level and height (including 1970 growth until May 7, 1970) are given in Appendix Table 6. Range of diameter and height are also included. Least squares linear regression lines are shown for all range sites in Figures 3 and 4.

Slope Exposure.

No significant differences were found to exist between redcedar populations on different directions of slope exposure (Figure 5).

Fire and Cutting.

Fire and cutting were the only factors consistently associated with absence of redcedar invasion in the thirty supplemental pastures. Although the information from these pastures was not statistically analyzed, information in Appendix Table 3 does not show any apparent relationship between stocking rate and redcedar invasion. All pastures

Figure 3. Relationship between age and basal diameter of redcedars for all sites.

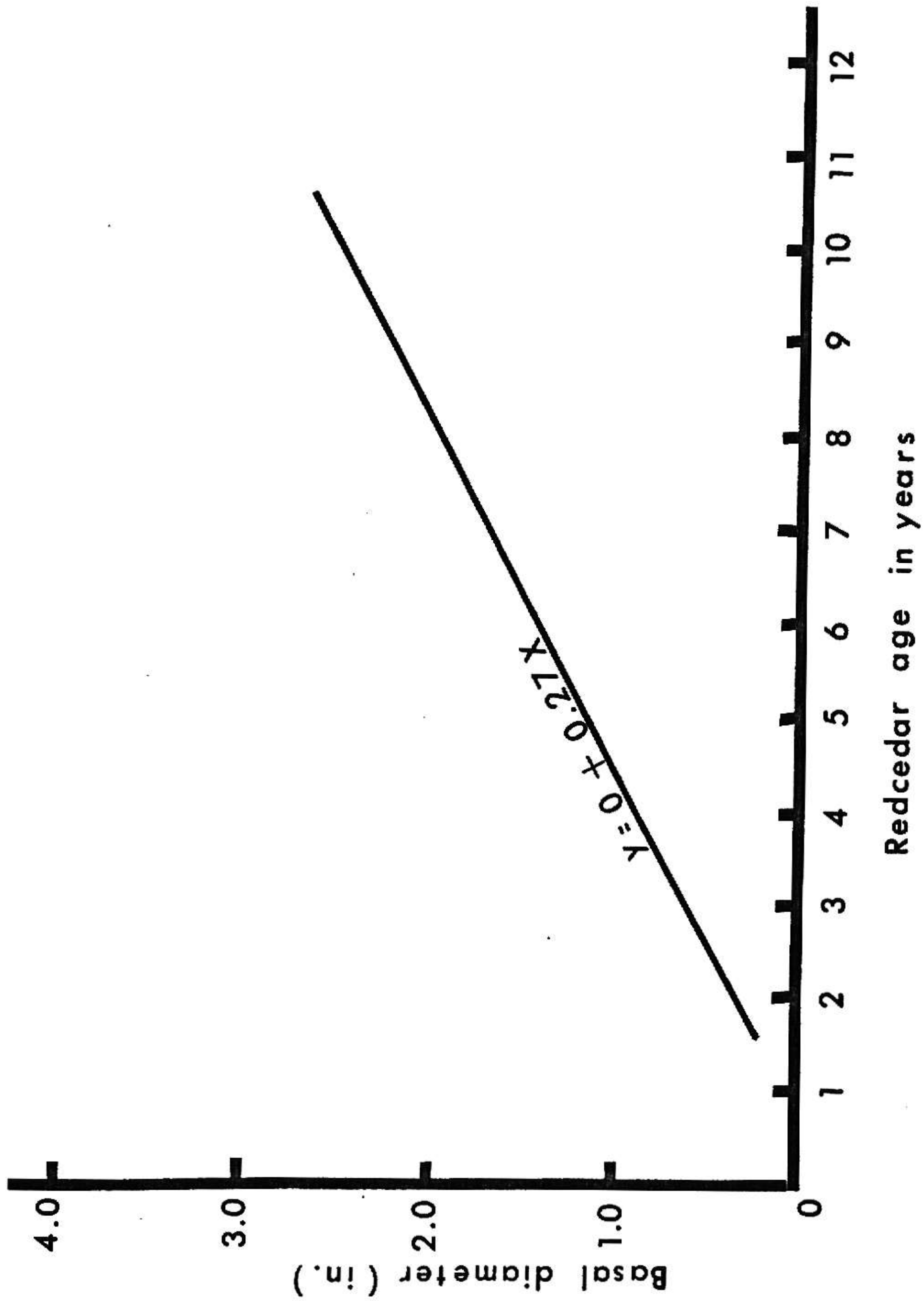
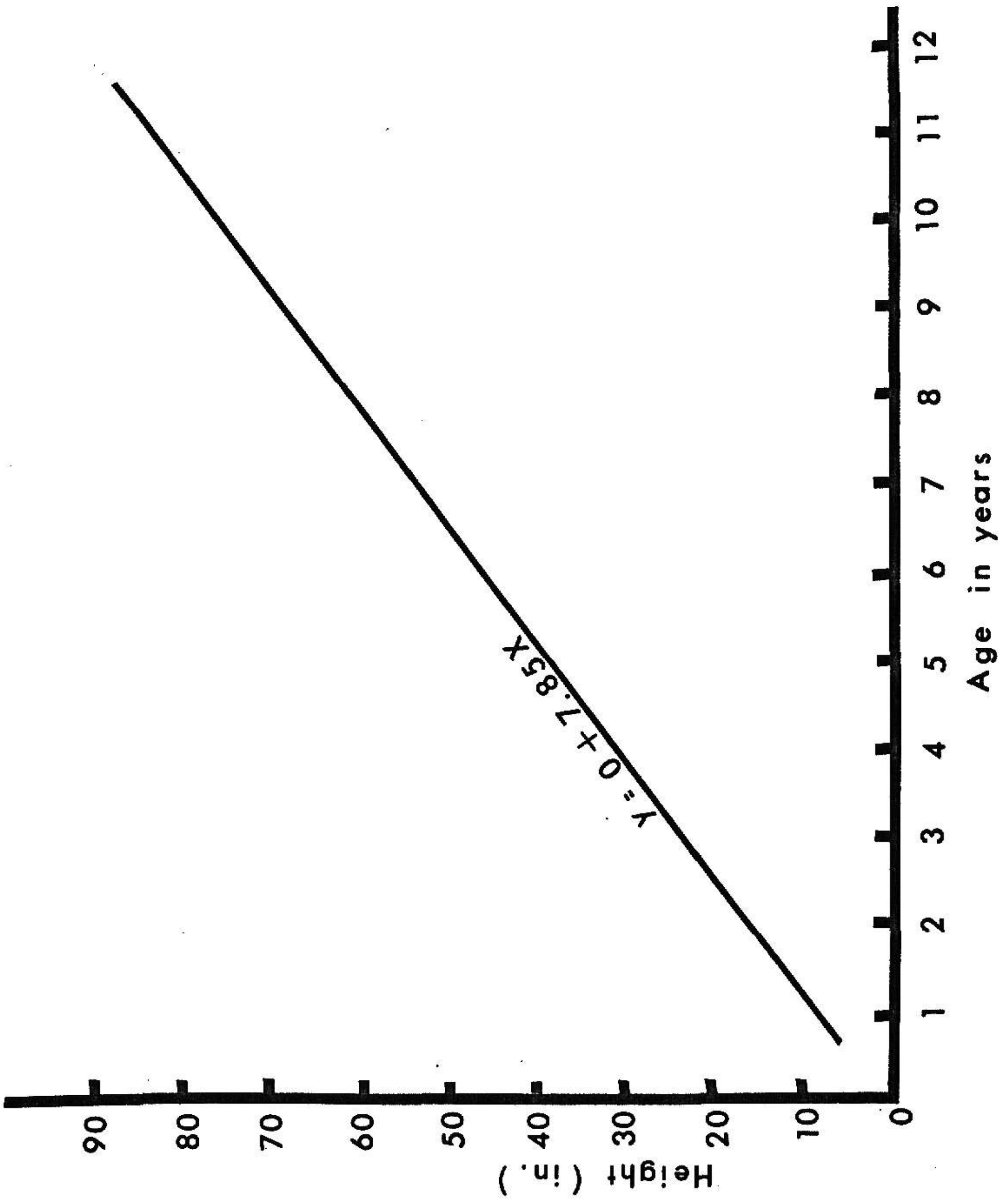
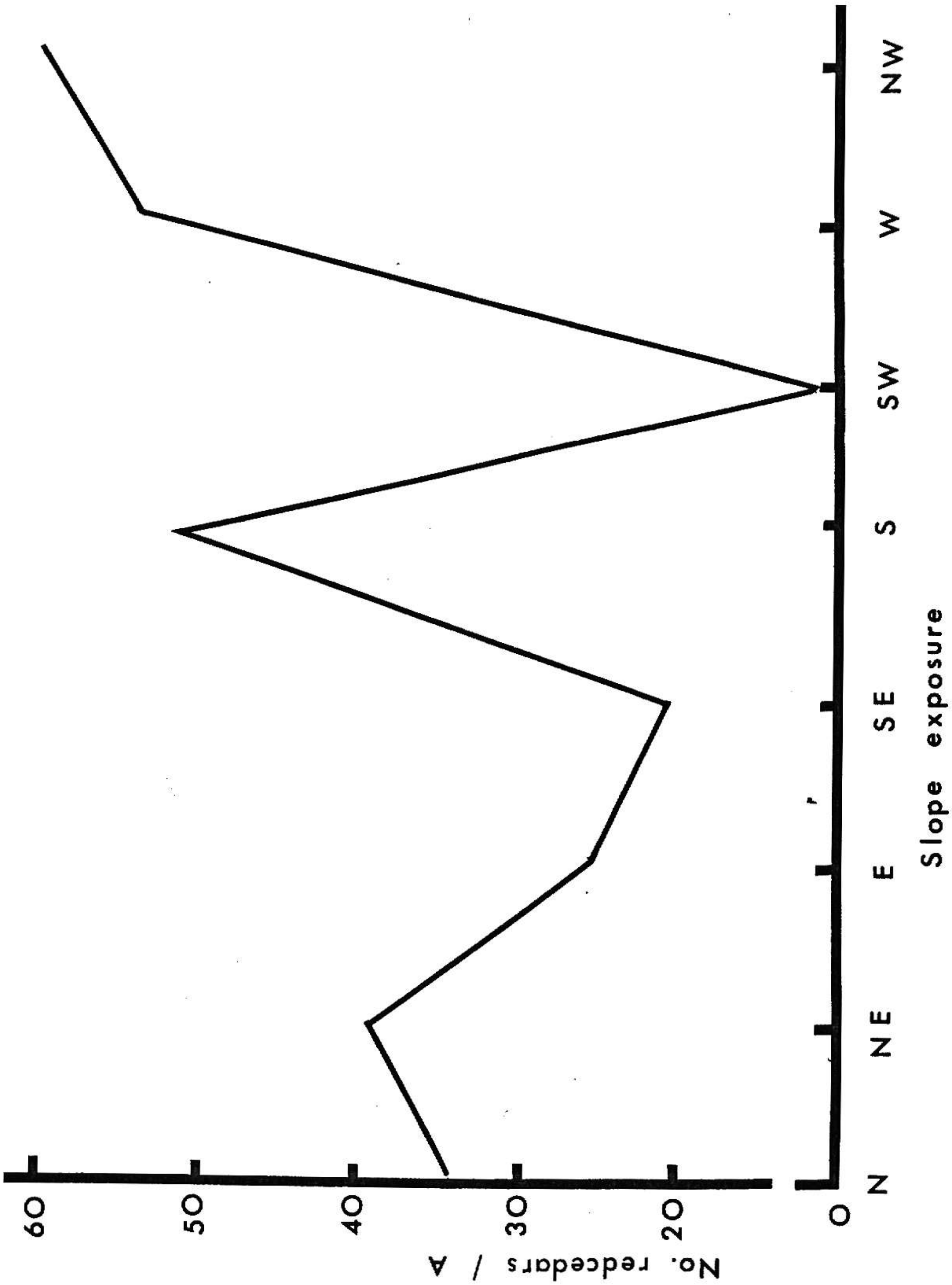

Y = 0 + 0.27 X
Redcedar age in years
Basal diameter (in.)
0
1.0
2.0
3.0
4.0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 4. Relationship between redcedar age and height (all sites).



Height (in.)
0
10
20
30
40
50
60
70
80
90
Age in years
1
2
3
4
5
6
7
8
9
10
11
12
y = 0 + 7.85X

Figure 5. Relationship between redcedar number and direction of slope exposure.


No. redcedars / A
60
50
40
30
20
0
N
NE
E
SE
S
SW
W
NW
Slope exposure

found to be redcedar free were either burned or had the redcedars mechanically removed.

Main study pasture number one was burned in April of 1969. Dead redcedars which could still be identified were included in the count. Many of the smaller seedlings probably were consumed in the fire and therefore were not included. This was the only main study pasture which burned in the period 1960 through 1969. A count was made of the redcedar which were killed by this fire. Approximately 63% of the redcedars of all age classes were dead. This pasture was grazed at about 1.2 A.U.M per acre during the 1968 growing season. The findings involving the effect of fire on redcedar seed germination and/or survival agreed with the conclusions of Arend (3) and with the U.S. Forest Service (22) who state that fire is one of the most important single factors which limited redcedar stands in the areas studied.

Although no detailed information was gathered on proximity of a seed source, this distance appeared to affect invasion rate.

CONCLUSIONS

Factors affecting redcedar germination and/or seedling survival appeared to be stocking rate and precipitation. These factors affect mulch accumulation, which is related to redcedar establishment. If the amount of mulch present falls short of a critical amount or exceeds that amount, redcedar invasion appears to be retarded.

Fire was the most common factor associated with absence of redcedar. Fire apparently affected redcedars both by direct killing and by limiting mulch accumulations.

Observations of some old stands of redcedars (70 years old approximately) supported the idea that eventually redcedars would give way to hardwood forest on soils which once were tallgrass prairie. The factors studied here do not fully explain redcedar invasions. Further study might concentrate on factors directly affecting production, dispersal, and germination of seed.

Although heavy grazing appears to retard redcedar invasion, it may also reduce beef production and wildlife cover and increase water runoff.

Occasional fires seemed to be sufficient to control redcedar in areas studied. Fire each 5 - 7 years probably is sufficient for redcedar control. After trees were large enough to shade out grass around them, fire was not an effective control measure.

Often seed production may be a limiting factor in redcedar invasion. It would appear from this study that secondary invasions may begin as early as 6 or 7 years after primary redcedar invasions since some 1964 seedlings produced seed in 1969.

Another factor may possibly be that grazing animals accidentally nipped the young seedlings during the first year. Cattle would be more apt to bite off a first year seedling in heavily stocked pasture than in lightly stocked ones.

SUMMARY

Redcedar invasion into rangeland of the True Prairie near Manhattan, Kansas was studied. Number of redcedars per acre, management histories of the pastures, other brush species present, age, height and basal diameters of redcedars, range site, slope exposure, and range condition were recorded.

Redcedar invasion rate was found to be affected by grazing intensity both during and after the growing season. Heavy stocking generally caused a decrease in redcedar number. Fire and mechanical removal were the only factors shown to be consistently associated with absence of redcedar invasion.

Other brush species present were found to be generally affected by the same factors which affected redcedar invasion.

The least squares regression line for age vs. height showed an expected average growth rate of 7.85 inches per year following the first two years of growth. The expected average increase in basal diameter was 0.27 inches per year for redcedars up to 10 years old.

Redcedar invasion rate was not significantly related to range site or condition, but direction of slope exposure was found to influence redcedar number. The southwest exposure had the lowest population of redcedars.

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APPENDIX

Appendix Table 1. Monthly precipitation (in inches) at Manhattan and Westmoreland U. S. Weather Bureau Stations from 1954 through 1969.

Manhattan

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1954	T	1.60	0.28	2.16	4.48	5.71	2.14	5.36	1.23	3.15	0	0.48	26.59
1955	1.68	2.23	0.20	2.57	4.70	2.55	2.39	0.29	3.39	4.84	0.30	0.60	25.74
1956	0.69	2.23	0.19	1.83	1.77	4.04	4.76	4.10	0.06	2.11	1.30	0.51	23.59
1957	0.30	0.55	3.27	3.93	3.66	7.16	2.88	2.09	5.63	3.50	2.31	0.78	36.06
1958	1.32	1.40	2.45	1.42	2.61	7.94	12.06	3.85	7.52	2.74	0.73	0.35	44.39
1959	1.14	0.93	2.11	1.41	7.82	2.33	3.11	2.68	4.30	4.01	0.21	0.46	30.51
1960	1.50	1.95	1.79	3.27	3.04	4.62	5.87	5.95	2.75	2.59	0.07	1.00	34.40
1961	0.03	0.83	2.87	3.01	7.79	4.09	3.37	1.54	7.72	4.17	2.06	0.76	38.24
1962	0.81	1.35	2.06	1.11	6.60	4.51	2.22	5.65	4.18	2.96	1.33	0.29	33.07
1963	0.48	0.06	1.84	1.70	2.47	2.90	1.24	1.80	2.16	2.16	1.41	0.29	18.51
1964	0.38	0.44	2.01	4.22	2.92	6.58	3.68	3.71	2.68	0.31	3.53	1.27	31.73
1965	2.33	2.09	2.50	1.64	2.39	12.01	3.27	3.12	8.39	1.36	0.29	2.23	41.62
1966	0.71	0.67	0.06	2.08	1.87	1.74	2.36	3.58	0.60	0.78	0.06	0.91	15.42
1967	0.38	0.21	1.59	5.02	2.95	9.86	3.10	1.42	7.97	3.08	0.77	1.24	37.59
1968	0.81	0.36	T	3.13	3.52	3.16	5.71	6.24	1.98	5.28	1.45	1.74-	33.38
1969	0.46	1.02	2.27	4.90	3.77	4.28	8.11	0.69	2.09	4.33	0.11	1.20	31.47
16 year average:	0.81	1.12	1.59	2.71	3.96	5.22	4.14	3.25	3.92	2.96	1.00	0.88	31.50

Appendix Table 1 Continued.

Westmoreland

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1954	0.07	1.69	0.72	2.00	5.13	6.05	2.68	7.57	1.87	1.99	T	0.64	30.41
1955	2.20	2.03	0.24	3.48	3.46	4.70	2.30	1.05	3.81	3.76	0.11	0.37	27.51
1956	0.55	0.31	0.23	1.94	2.69	4.92	6.39	2.97	0.11	1.77	1.61	0.35	23.84
1957	0.63	0.67	3.84	3.88	5.09	8.56	5.36	2.35	3.02	4.06	2.35	0.70	40.51
1958	1.59	1.06	2.27	1.84	2.10	6.03	11.01	2.36	9.24	0.24	0.98	0.07	38.79
1959	0.90	0.72	2.07	2.46	8.66	1.96	2.56	1.34	5.53	4.40	0.17	0.77	31.54
1960	1.57	1.70	1.70	2.72	2.70	3.58	3.35	4.79	3.92	1.81	0.07	1.22	29.13
1961	0.04	1.32	4.47	4.40	8.28	5.77	5.47	2.53	7.27	3.00	2.22	0.85	45.62
1962	0.90	1.07	1.85	1.16	7.29	5.71	2.01	4.87	3.91	2.20	0.91	0.49	32.37
1963	0.45	T	1.78	1.54	3.60	3.98	2.42	2.79	1.68	1.66	1.36	0.22	21.48
1964	0.45	0.67	1.75	4.83	4.06	8.33	2.01	4.13	3.12	0.13	3.71	1.00	34.37
1965	2.19	1.12	2.58	1.72	1.46	11.36	3.56	3.05	9.02	0.57	0.33	2.07	39.03
1966	0.60	0.84	0.04	1.31	0.92	6.34	2.97	4.68	1.45	0.73	0.03	0.88	20.79
1967	0.24	0.14	3.06	4.41	3.25	10.93	4.79	2.07	6.91	3.47	0.82	1.22	41.31
1968	0.21	0.45	T	2.95	4.34	2.99	14.30	8.71	1.35	5.24	1.62	1.65	43.81
1969	0.56	0.99	2.14	5.32	4.32	4.77	5.69	1.39	1.94	4.01	0.10	1.10	30.37
16 year average:	0.82	0.92	1.80	2.87	4.21	6.00	4.80	3.54	4.01	2.45	1.02	0.85	33.29

Appendix Table 2. Size, location and landowners of the study pastures.

Pasture No.	Owner	Invasion Problem	Acres	Section Township Range		County
1.	H. J. Kunze	Heavy	237	9 - 7 S	7 E	Pottawatomie
2.	Mrs. Virgil Renz	Heavy	185	19 - 7 S	8 E	Pottawatomie
3.	Howard Fasse	Heavy	78	10 - 8 S	6 E	Riley
4.	Beverly Stagg	Heavy	65	17&20 - 10 S	7 E	Riley
5.	Kansas State Univ.	Moderate	177	28&33 - 9 S	7 E	Riley
6.	H. L. Nelson	Moderate	67	27 - 8 S	6 E	Riley
7.	G. E. Visser	Moderate	63	33 - 8 S	6 E	Riley
8.	M. W. Rudolph	Moderate	190	3 - 9 S	6 E	Riley

Appendix Table 3. Pasture histories of three classes of redcedar invasion in thirty secondary study pastures.

Pasture No.	Cedar Problem	Fire	Class of Livestock	Average Growing Season Grazing AUM/Acre	Average Off Season Grazing	Mechanical Removal	Pasture Size (Acre)
1.	Heavy	0		1.2	0	0	80
2.	H	0	Steers	1.2	0	0	160
3.	H	0	Cow-calf	1.0	0.1	0	160
4.	H	0	Cow-calf	1.5	0.8 (No winter grazing until 1964)	Some	100
5.	H	0	Cow-calf	0.9	0.4	0	20
6.	H	0	0	0	0	0	40
7.	H	0	0	0	0	0	30
8.	H	0	Cow-calf	0.8	0	0	320
9.	H	0	Cow-calf	1.0	0.1	0	240
10.	H	0	Steers	1.3	0	0	80
11.	Moderate	1958	Cow-calf	1.5	0.2	0	160
12.	M	0	Cow-calf	1.2	0.8	0	120
13.	M	0	Dairy cows	1.5	1.5	0	35
14.	M	0	Cow-calf	1.1	0	0	160
15.	M	0	Steers	1.0	0	1965	120
16.	M	0	Cow-calf	0.9	0	0	500

Appendix Table 3 Continued.

Pasture No.	Cedar Problem	Fire	Class of Livestock	Average Growing Season Grazing AUM/Acre	Average Off Season Grazing	Mechanical Removal	Pasture Size (Acre)
17.	M	0	Steers	1.7	0	0	80
18.	M	0	Steers	1.2	0	0	40
19.	M	0	Cow-calf	1.0	0	0	100
20.	M	1964	Cow-calf	1.0	0.8	0	100
21.	None	1967	Cow-calf	0.7	0.5	Annual	100
22.	N	1968	Cow-calf	1.1	0.5	0	50
23.	N	1961	Cow-calf	1.2	0	0	160
24.	N	1961-1968	Cow-calf	1.0	0	0	120
25.	N	Each 2-3 years	Cow-calf	1.0	0.5	0	100
26.	N	Annual	Steers	0.9	0	0	880
27.	N	Annual	Steers	0.9	0	0	200
28.	N	0	Cow-calf	1.5	0	Annual	120
29.	N	Annual	Steers	1.1	0	0	40
30.	N	1964-1968	Cow-calf	0.9	0.9	Frequently	320

Appendix Table 4. Age class distribution of redcedar in the main study areas.

Pasture No.	Average No. Redcedars Per Acre	Average number of redcedars per acre by year of establishment 1968	1967	1966	1965	1964	1963	1962	1961	1960	older than 1960
Heavy invasion											
1.	88.3	1.5	1.3	5.7	9.4	17.2	25.1	11.3	10.2	1.3	5.2
2.	56.1	3.6	2.1	9.3	6.1	8.9	18.6	5.0	1.4	0	1.1
3.	71.5	0	2.5	16.7	8.3	13.3	23.3	4.2	0.8	0.8	1.6
4.	27.6	0	1.5	4.6	3.8	3.8	12.3	0	0	0.8	0.8
Light invasion											
5.	4.5	0	0.3	0.5	0	1.1	1.5	0.3	0.5	0	0.3
6.	3.1	0	0	0	0	1.5	0.8	0	0	0	0.8
7.	6.6	0.8	0.8	1.7	0.8	1.7	0.8	0	0	0	0
8.	9.3	1.8	1.8	2.4	0	1.1	1.3	0.3	0.3	0.3	0
Overall Average	38.0	1.3	1.3	4.6	3.9	7.0	11.3	3.7	2.8	0.5	1.7

Appendix Table 5. Frequency (percent of plots in which the species was present) of occurrence of other brush species in main study plots.

Pasture No.	Osage orange	Buckbrush	Roughleaf Dogwood	Elm	Honeylocust	Wild Plum	Aromatic Sumac	Smooth Sumac
Heavy Invasion								
1.	2%	15%	28%	4%	0	6%	15%	11%
2.	0	57%	25%	0	10%	7%	18%	43%
3.	8%	8%	0	0	0	0	8%	80%
4.	8%	23%	46%	0	8%	0	16%	77%
Light Invasion								
5.	0	36%	8%	25%	0	0	6%	28%
6.	0	54%	0	8%	0	0	0	8%
7.	0	54%	0	0	0	0	0	0
8.	0	61%	5%	16%	0	3%	5%	3%

Appendix Table 6. Age, diameter, and height of redcedars from loamy upland, limy upland, clay upland, and limestone breaks range sites.

Year of germination	Average Diameter at Ground Level	Average Height	Range of Diameters	Range of Heights	No. in this age class sample
1969	0.04"	2.0"	0	0	3
1968	0.12"	8"	-	-	1
1967	0.28"	12.5"	0.20" - 0.23"	11" - 15"	4
1966	0.47"	20.2"	0.31" - 0.67"	12" - 24"	9
1965	0.71"	26.1"	0.51" - 1.18"	16" - 42"	7
1964	0.84"	30.3"	0.63" - 1.26"	21" - 47"	8
1963	1.12"	43.4"	0.83" - 1.89"	24" - 64"	28
1962	1.60"	58.2"	1.06" - 2.28"	29" - 75"	15
1961	1.62"	57.4"	0.47" - 2.48"	30" - 76"	14
1960	2.32"	73.3"	0.94" - 3.07"	24" - 90"	7
1959	3.27"	84.5"	3.15" - 3.39"	79" - 90"	2
1958	2.13"	70.0"	-	-	1
1957	3.03"	80.0"	3.0" (both)	80" - 83"	2

EVALUATION OF EASTERN REDCEDAR
(JUNIPERUS VIRGINIANA L.) INFESTATIONS
IN THE NORTHERN KANSAS FLINT HILLS

by

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B. S., Oklahoma State University, 1960

AN ABSTRACT OF A MASTER'S THESIS

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Redcedars (*Juniperus virginiana* L.) were cut from two hundred randomly located tenth-acre plots in four major range sites in eight pastures. Total numbers of redcedars, year of redcedar germination, slope exposure, range site, associated brush species, and management histories were recorded for each plot.

Thirty supplemental pastures were rated according to the extent of their redcedar invasion. Pasture histories were compared with redcedar invasion.

Age of one hundred redcedars from these four range sites was correlated with height and basal diameter.

In the absence of fire and mechanical removal, growing season stocking rate, found to be the most important factor affecting redcedar invasion rate, generally was inversely related to invasion rates.

Precipitation and growing-season stocking rate had a significantly related effect on redcedar number. Redcedar invasion rate declined as precipitation increased when grazing rate remained constant.

Fire was found to be the most important factor associated with an absence of redcedar invasions. Mechanical removal was the only other factor consistently associated with low redcedar numbers.

The comparison of redcedar age with height and diameter showed that redcedar increased in height by approximately 7.85 inches and in diameter by 0.27 inches each year.

Invasion of associated brush species was found to be generally retarded by the same factors which reduced redcedar invasion rates.