3-1974

The Effect of 2,4-D, Grazing Management and Nitrogen Fertilizer on Pasture Production

M. K. McCarty

M. L. Cox

D. L. Linscott

Research Bulletin

260

March 1974

The Effect of 2,4-D, Grazing Management and Nitrogen Fertilizer on Pasture Production

by

M. K. McCarty
M. L. Cox
D. L. Linscott

University of Nebraska–Lincoln College of Agriculture
The Agricultural Experiment Station
H. W. Ottoson, Director

SUMMARY

Mowing for 14 years did not reduce stands of perennial, broadleaf weeds. Plots sprayed with 2,4-D each year, and those seeded to adapted grasses accompanied by treatment with 2,4-D, reduced perennial broadleaf weed stands 90 percent. Nitrogen fertilization evaluated across all weed control treatments, reduced forb stands 43 and 32 percent, respectively, for the early and late dates of application where plots were rotationally grazed. Where the plots were protected from grazing only the early fertilization practice significantly reduced stands of perennial broadleaf weeds.

Early mowing did not reduce populations of annual broadleaf weeds but all other weed control treatments were partially effective. Nitrogen fertilization reduced annual broadleaf weeds where plots were rotationally grazed. Only the early fertilization application reduced stands where plots were protected from grazing. Across both levels of management the plots receiving early fertilizer had only one-third as many annual broadleaf weeds as the unfertilized plots.

The major broadleaf weed in the pasture plots, western ironweed, was reduced 71 and 38 percent respectively by early and late mowing treatments. It was reduced by more than 99 percent in plots that were sprayed with 2,4-D, and also where grass was seeded and supplementally sprayed with 2,4-D. Grazing control had no effect on stands of western ironweed. Its populations were not affected by nitrogen fertilization.

Dandelion stands greatly increased in plots that were mowed each year. There was also a large difference in the numbers of plants in the grazed and ungrazed areas with 123 and 17 per 40 square feet, respectively. Nitrogen fertilizer influenced populations of dandelions with roughly one-half as many found in the plots receiving early fertilizer as in the plots receiving no fertilizer.

Basal frequency of perennial cool-season grasses in the native plots was not influenced by weed-control treatment or grazing intensity. Basal frequency of plots fertilized at the early date was roughly 50 percent greater than those receiving no fertilizer. The plots receiving late fertilizer had basal frequency values about midway between the early fertilizer and no fertilizer values.

Basal frequencies of perennial warm-season grasses were the inverse of those noted for the cool-season grasses. Values were three times as large where no fertilizer was applied compared with early fertilization. The late fertilizer values were intermediate between the other two. There was a slight but significantly larger value for the ungrazed plots as compared with rotationally grazed plots.

In plots seeded to cool-season grasses, addition of nitrogen fertilizer at the early date resulted in vigorous stands of smooth brome or intermediate wheatgrass with relatively few broadleaf weeds or annual grasses. The portions receiving no fertilizer decreased in vigor, the cool-season grass stand was lost and invasion of the warm-season perennial grasses, primarily indiangrass and big bluestem, took place. In plots seeded to warm-season grasses addition of nitrogen fertilizer at the early date was accompanied by loss of stand and invasion of smooth brome and Kentucky bluegrass. Where no fertilizer was added, there was negligible invasion by the smooth brome and Kentucky bluegrass. In the ungrazed portions blue grama and sand lovegrass were eliminated from the stand.

Yields of desirable grasses were increased with nitrogen fertilization. In plots where weed control had been most effective the response of the desirable forage to nitrogen application was greatest. There were smaller amounts of broadleaf weeds produced where fertilizer was applied at the early date.

CONTENTS

Issued March 1974, 1,500

The Effect of 2,4-D, Grazing Management and Nitrogen on Pasture Production

M. K. McCarty, Milo L. Cox and D. L. Linscott[1]

INTRODUCTION

Many pastures in eastern Nebraska and surrounding areas have gradually decreased in productivity. Over a long period of heavy grazing, native warm-season grasses have been largely replaced with Kentucky bluegrass[2], other less desirable grasses, and broadleaf weeds.

Some people believe that perennial grasses will increase and undesirable broadleaf weeds will decrease if grazing pressure is reduced. This has been a prominent recommendation for pasture improvement in the Plains region.

A program was started by Klingman (6) in 1949 to study the effectiveness of protection from grazing in changing the botanical composition and yield of a pasture where the predominant forage was Kentucky bluegrass. Several weed control treatments were included in this experiment to determine if mowing or spraying would hasten the return of more desirable forage. After weed control and differential grazing treatments had been applied annually for three years, definite trends were evident toward increased yields of desirable forage, together with marked reductions of broadleaf weeds.

In 1953, Cox (3) began a program of nitrogen fertilization on portions of the original experimental plots to determine whether or not nitrogen would further speed up the rate of improvement. This bulletin reports the effects of increased fertility as well as the cumulative effects of weed control and grazing management of the original experiment on the vegetative composition of the treated plots. Some effects on the soil environment are also noted.

---

[1]Research Agronomist, Agricultural Research Service; Assistant Professor, Nebraska Agricultural Experiment Station (Chief, Rural Development Division, Agency for International Development, U.S. State Department, Washington, D.C.), and Research Agronomist, Agricultural Research Service, U.S. Department of Agriculture, Ithaca, N. Y. Cooperative investigation by the Agricultural Research Service, U.S. Department of Agriculture and the Nebraska Agricultural Experiment Station.

[2]Scientific names of plants with authorities are shown in the Appendix.

REVIEW OF LITERATURE

Fertilization of grassland for increased forage production has been intensively studied and reported. Little work has been reported, however, on the botanical composition changes brought about by fertilization. These changes have been noted by various workers, particularly in the Eastern United States. The experiments were usually designed to measure yield differences and the composition data were recorded as visual estimates.

Aldous (1), from fertilizer and management studies on permanent pastures in Kansas, reported that most of the tall, native, warm-season grasses have been replaced by Kentucky bluegrass, annual grasses, and broadleaf weeds. He indicated that many farm pastures retained enough stunted plants of the prairie species to restore the original stand when conservative grazing was practiced. He further reported that the vegetation tended to return to native species faster on soils of fair to good fertility than on soils of low fertility when grazing practices improved.

Dore (4), reporting on work done in Canada, indicated that large botanical composition changes occurred following fertilizer applications. Lime and several mineral fertilizers were applied to a series of plots at three locations. White clover was the first species to increase rapidly. In the year fertilizer was added, it quickly occupied all of the bare ground between the other plants. In the second and third years, the desirable grasses increased and undesirable weeds decreased. He reported that Kentucky bluegrass increased as much as fivefold in four years on some of the plots. Grazing was unrestricted and, with the attendant livestock concentration on the fertilized plots, this effect could not be separated with accuracy from fertilzer treatment effects.

Grava (5) applied fertilizer to native pastures in Kansas that had not been grazed for several years and found that nitrogen applications greatly increased Kentucky bluegrass in native warm-season grass stands. Fifty pounds of nitrogen per acre tripled the abundance of bluegrass stems while the native grasses remained at about the same density or decreased. Total yield increased with all nitrogen rates used. Since no weed control treatments were used in the experiment, yields of broadleaf weeds were greatly increased by nitrogen applications, but their numbers did not increase significantly.

MATERIALS AND METHODS

In this study, the area selected was a weedy farm pasture 8 miles south of Lincoln, Nebraska that had no known history of cultivation. Experimental plots were located on a fairly uniform, undulating to gently sloping soil, designated as Pawnee silty clay loam. The soil was of glacial origin and the surface was well drained. The 8- to 12-inch deep surface soil consisted of dark gray to almost black, friable, granular silty clay loam. The 10- to 14-inch upper part of the subsoil consisted of brown or grayish-brown, dense, massive clay containing enough sand to give it a gritty feeling. The lower part of the subsoil was light brown or yellowish-brown, moderately compact, gritty clay loam containing small lime concretions. At a depth of four to five feet this layer rested on calcareous glacial drift.

Pawnee silty clay loam has been described as having poor internal drainage. In the experimental area, however, the soil was in excellent physical condition. Organic matter was high, the soil was well aggregated, and internal drainage was adequate. The phosphorus status was adequate as indicated by soil analysis and by the excellent growth of alfalfa and sweetclover in nearby plots.

The original weed control experiment was started in 1950 in a rundown weedy native pasture. The study included four weed control treatments, three seeding treatments on which weeds were also controlled, and an untreated check. Weed control treatments and the seeding treatments were applied across three levels of grazing management in a split-plot design and were replicated four times. The experiment provided an opportunity to measure the effect of treatments alone and in all combinations. Details of the treatments:

1. Check, no weed control treatments applied.
2. Tractor mowed at a height of 2½ to 3 inches about June 10.
3. Mowed about July 5. Techniques used were the same as those in June.
4. The isopropyl ester of (2,4-dichlorophenoxy) acetic acid (2,4-D) at 1 lb/A was applied in June. The herbicide was applied in water diluent at 20 gallons of spray per acre with a tractor mounted sprayer.
5. The isopropyl ester of 2,4-D at 1 lb/A was applied in July by the method indicated for the June treatment. Dates of herbicide application coincided with the June and July dates of mowing.
6. Seeded to smooth brome and supplementally sprayed with 2,4-D.
7. Seeded to intermediate wheatgrass and supplementally sprayed with 2,4-D.
8. Seeded to a warm-season grass mixture and supplementally sprayed with 2,4-D. The mixture consisted of 7 pounds of big bluestem, 2 pounds of sand lovegrass, 2 pounds of switchgrass and 4 pounds of blue grama seed per acre.

Fertilizer applications were made to a part of the above described experiment; the portions protected from grazing and rotationally grazed. Fertilizer was applied at 55 pounds N/A as ammonium sulfate to a portion of each of the four weed control treatments, the check, and the seeded treatments. Yearly, from 1953 through 1964, applications were made on April 20 to a part of each plot, and on June 20 to another part of each plot. A third portion was left unfertilized. The three fertilizer treatments were randomly arranged in each plot. Repeat applications were made to the same subplots in subsequent years.

Populations of broadleaf weeds in five permanent 2- by 4-foot sample areas in the fertilized and check subplots were counted in 1954, 1955, 1960, and 1964. Stems of all perennnial weeds and plants of annual weeds were counted. As there were two levels of management and four replications, the vegetation in a total of 40 samples, 2- by 4-feet in area, was counted for each weed control-fertility treatment.

Occurrence of grass by species was determined by a modified line interception method. The basal frequency of occurrence of plants was noted by species in each square centimeter along 12 randomly located 1-meter lines per subplot or 48 lines per management-fertility treatment and 288 lines for a weed-control treatment (12 lines per subplot by 4 replications by 2 grazing managements by 3 fertilizer treatments).

Production and consumption of plant material was determined by a modification of the method described by Klingman, *et al.* (7). Within each fertilizer treatment in the rotationally grazed area, two 4- by 4-foot quadrats were located. These quadrats were selected so they would be similar and representative of the area. By random selection, one quadrat was protected from grazing by a wire cage 5 by 5 feet in size.

Near the end of the growing season each quadrat was clipped at ground level. The clipped material was separated into desirable grasses, weed grasses, and broadleaf weeds. The separated materials were oven-dried and weighed. Plant growth under the cages was considered as production while the difference between the caged and uncaged paired plots was considered consumption. In the ungrazed portion, single quadrats were employed as there was no consumption and only total production data for each of the three classes were taken.

In October 1957, soil samples for chemical analyses were taken in triplicate composites at depths of 0-6, 6-12, and 12-24 inches with a standard King tube. In October 1962, soil samples for soil reaction were taken from the 0-6 inch horizon. Samples were removed from the first three reps of each of the previously described management, fertilizer, and weed-control plots with the exception of late mowing, late spraying, and intermediate wheat-grass plots. All samples were air dried before analysis.

Soil reaction was determined with a glass electrode using a 50-50 dilution of soil and distilled water. Organic matter was determined by the Walkey-Black method as modified by Smith and Weldon (9). Available soil phosphorus was extracted with Bray's No. 1 solution (0.03 N NH_4F in 0.025 N HCl) (2). Phosphorus in the extract was determined colorimetrically as the phosphomolybdate complex. Total nitrogen was determined by the boric acid modification of the Kjeldahl method. All calculations were based on oven dry samples (48 hours at 105°C).

Cores for bulk-density determinations were taken with a Uhland sampler. Density was determined by standard methods. Vegetation and litter were removed before sampling.

RESULTS AND DISCUSSION

Botanical Composition as Affected by Treatments

Broadleaf Weeds

Weed population counts were made in June 1964, before weed-control treatments were applied. These data (Table 1) represent the cumulative effects of weed-control treatments and grazing-management practices applied annually since 1950 and fertilizer applications made annually since 1953.

Weed-control treatments produced marked differences in populations of broadleaf weeds. Perennial weeds in the rotationally grazed

Table 1. Number of important perennial broadleaf weeds in June 1964, following 14 years of weed control treatment under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

	Number of stems in 40 square feet[b]				
	Nitrogen applied[c]				
Weed control treatment	Early	Late	None	Average	Treatment average
Rotationally grazed:					
Check	391	436	682	503 ef	574 a
Mowed, June 10	554	657	867	693 e	616 a
Mowed, July 5	432	570	781	594 ef	489 a
2,4-D, June 10	92	56	154	100 g	96 b
2,4-D, July 5	23	36	61	40 hi	38 bc
Smooth brome[d]	76	40	130	82 gh	49 bc
Intermediate wheatgrass[d]	54	130	87	90 g	76 b
W.S.G. mixture[d]	10	9	104	41 hi	25 c
Average	204 n	242 p	358 q	268	
Ungrazed:					
Check	501	659	776	645 ef	
Mowed, June 10	410	590	616	538 ef	
Mowed, July 5	246	440	467	384 f	
2,4-D, June 10	50	99	128	92 gh	
2,4-D, July 5	34	42	30	35 hi	
Smooth brome[d]	1	8	38	15 j	
Intermediate wheatgrass[d]	42	36	106	61 ghi	
W.S.G. Mixture[d]	4	11	14	10 j	
Average	161 m	236 np	272 p	223	
Fertilizer average	182 r	239 s	316 t		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

Table 2. Number of annual broadleaf weeds in June 1964, following 14 years of weed control treatment under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	34	89	104	75 de	97 a
Mowed, June 10	92	154	228	158 d	130 a
Mowed, July 5	31	32	99	54 e	34 b
2,4-D, June 10	14	14	20	16 f	13 b
2,4-D, July 5	10	4	7	7 gh	17 b
Smooth brome[d]	38	99	152	96 de	55 b
Intermediate wheatgrass[d]	57	118	331	169 d	87 b
W.S.G. mixture[d]	6	12	12	10 fgh	44 b
Average	35 n	65 n	119 p	73 y	
Ungrazed:					
Check	103	84	170	119 d	
Mowed, June 10	30	132	147	103 de	
Mowed, July 5	5	20	14	13 fg	
2,4-D, June 10	4	10	16	10 fgh	
2,4-D, July 5	28	35	20	28 f	
Smooth brome[d]	<1	2	37	13 fg	
Intermediate wheatgrass[d]	2	11	5	6 h	
W.S.G. mixture[d]	10	164	61	78 de	
Average	23 m	57 n	59 n	46 z	
Fertilizer average	29 r	61 s	89 t		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

plots and in the plots protected from grazing (Table 1) did not differ significantly. The major portion of the apparent difference was due to dandelion, which did show significance for management when taken alone.

Differences in weed populations from nitrogen application were not large but were consistent with smallest numbers on plots receiving early fertilizer and largest numbers on nonfertilized plots. Late fertilized plots were intermediate. Where plots were protected from grazing, portions given early fertilizer had the smallest number of broadleaf weeds. Portions receiving no fertilizer did not differ significantly from the late fertilizer set. Populations within the various weed control treatments varied considerably but the relationship between fertilizer treatments remained nearly constant. Both sets of plots that received fertilizer and were grazed under a rotational system had fewer perennial broadleaf weeds than the nonfertilized plots.

Numbers of annual broadleaf weeds were lowest in plots receiving early fertilizer, intermediate in the late fertilizer plots and most numerous in plots receiving no fertilizer (Table 2). Where rotationally grazed, the same relationship existed. On the ungrazed plots, those receiving early fertilizer were significantly less infested with annual broadleaf weeds than the late fertilized or nonfertilized plots.

Excellent control of ironweed was obtained (Table 3) where sprayed with 2,4-D or where plowed and reseeded with a supplemental treatment with 2,4-D. Protection from grazing for the 14-year period apparently had only a minor effect on total numbers. Ironweed was the major broadleaf perennial weed in the experiment in which the effects of nitrogen fertilization were not evident over the 11 years.

Good control was obtained on false boneset (Table 4). The use of 2,4-D was an effective treatment as well as the plowing and reseeding with the supplemental use of 2,4-D. False boneset was somewhat later developing than ironweed. Late spray treatment appeared to result in somewhat lower numbers under all management fertilizer practices compared with the early spray treatment. Because of the inherent variability of these plants, this difference was not large enough for

Table 3. Ironweed stands in June 1964, following 14 years of weed control treatment under two levels of grazing as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	146	185	138	157 d	133 a
Mowed, June 10	44	42	36	41 f	52 b
Mowed, July 5	102	99	99	100 de	83 b
2,4-D, June 10	0	0	<1	<1 g	<1 c
2,4-D, July 5	0	0	1	<1 g	<1 c
Smooth brome[d]	0	0	<1	<1 g	<1 c
Intermediate wheatgrass[d]	0	0	<1	<1 g	<1 c
W.S.G. mixture[d]	0	<1	<1	<1 g	<1 c
Average	37	41	34	37	
Ungrazed:					
Check	150	108	71	110 d	
Mowed, June 10	65	105	21	64 f	
Mowed, July 5	42	102	56	66 ef	
2,4-D, June 10	0	0	<1	<1 g	
2,4-D, July 5	0	0	0	0 g	
Smooth brome[d]	0	0	<1	<1 g	
Intermediate wheatgrass[d]	0	1	<1	<1 g	
W.S.G. mixture[d]	0	0	<1	<1 g	
Average	32	39	19	30	
Fertilizer average	34	40	27		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

Table 4. False boneset stands in June 1964, following 14 years of weed control treatment under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	18	68	107	64 d	66 a
Mowed, June 10	12	28	26	22 e	46 ab
Mowed, July 5	6	33	43	27 e	34 b
2,4-D, June 10	0	1	5	2 ghi	2 c
2,4-D, July 5	0	1	1	1 i	<1 c
Smooth brome[d]	<1	3	13	5 fg	3 c
Intermediate wheatgrass[d]	2	15	16	11 ef	7 c
W.S.G. mixture[d]	0	<1	4	1 i	1 c
Average	5 l	18 jk	27 j	17	
Ungrazed:					
Check	18	92	92	68 d	
Mowed, June 10	29	109	74	70 d	
Mowed, July 5	12	30	83	42 d	
2,4-D, June 10	0	0	6	2 hi	
2,4-D, July 5	0	0	0	0 i	
Smooth brome[d]	0	0	2	<1 i	
Intermediate wheatgrass[d]	2	1	8	4 gh	
W.S.G. mixture[d]	<1	<1	1	<1 i	
Average	8 l	29 j	33 j	23	
Fertilizer average	6 r	24 s	30 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

statistical significance. Protection from grazing again did not affect total numbers of false boneset. In fact, the plots that were mowed and protected from grazing showed a higher incidence of false boneset plants primarily because of seedling establishment.

Fertilizer applications materially affected the number of false boneset plants. Under both levels of grazing, fewer false boneset plants were found in the early fertilizer treatments, and the greatest numbers were found in the plots that received no nitrogen fertilizer. False boneset numbers in the late fertilizer treatments were intermediate. The counts of false boneset include seedlings as well as the established stems. Subplots that received no fertilizer had less accumulation of litter and less germination and establishment of the false boneset seedlings in the nonfertilized plots.

Control of heath aster (Table 5) was nearly complete when sprayed with 2,4-D or where plowing and reseeding was done with supplemental spray of 2,4-D. Numbers of heath aster were fewer under both mowing treatments than the untreated check. The check plots under

Table 5. Heath aster stands in June 1964, following 14 years of weed control treatment under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	31	24	178	78 e	110 a
Mowed, June 10	7	8	11	9 g	51 b
Mowed, July 5	12	2	23	13 fg	23 c
2,4-D, June 10	0	0	0	0 h	0 d
2,4-D, July 5	0	0	0	0 h	0 d
Smooth brome[d]	0	0	<1	<1 h	<1 d
Intermediate wheatgrass[d]	2	0	0	<1 h	<1 d
W.S.G. mixture[d]	0	0	0	0 h	<1 d
Average	6 np	4 p	26 m	12 y	
Ungrazed:					
Check	25	110	291	142 e	
Mowed, June 10	51	21	210	94 e	
Mowed, July 5	10	44	49	34 f	
2,4-D, June 10	0	0	0	0 h	
2,4-D, July 5	0	0	0	0 h	
Smooth brome[d]	0	0	0	0 h	
Intermediate wheatgrass[d]	0	0	0	0 h	
W.S.G. mixture[d]	0	0	<1	<1 h	
Average	11 mnp	22 mn	69 k	34 z	
Fertilizer average	9 r	13 r	48 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

both levels of grazing showed rather large increases in numbers of stems of aster over the 14-year period. This increase was greater in the plots protected from grazing than those given moderate grazing use. Effects of nitrogen fertilization were striking in that lowest numbers of aster plants were found in the early fertilized treatments under both management practices, and the largest numbers were in the subplots that received no nitrogen fertilization.

Dandelion plants are considered susceptible to 2,4-D treatment applied at the right time. Although the sprayed plots in this experiment were treated for 14 consecutive years, only 2 or 3 seasons found the dandelions actively growing at time of spraying. On an average, during the last 5 years of this experiment, first buds on dandelion occurred about April 15 and first blooms about April 20. By May 10 the seeds are firm and beginning to disseminate. By the second week in June, when the first spray treatment was scheduled, hot weather had usually arrived and the dandelion plants were more or less dormant. Foliar application rates of 1 lb/A had little effect on the mature

Table 6. Dandelion stands in June 1964, following 14 years of weed control treatment under 2 levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	28	30	69	42 e	24 b
Mowed, June 10	345	463	609	472 d	276 a
Mowed, July 5	254	342	476	357 d	201 a
2,4-D, June 10	19	24	49	30 e	16 b
2,4-D, July 5	4	3	8	5 ghi	3 b
Smooth brome[d]	12	16	88	39 e	19 b
Intermediate wheatgrass[d]	12	10	24	15 efg	8 b
W.S.G. mixture[d]	5	2	71	26 ef	15 b
Average	85 m	111 m	174 k	123 y	
Ungrazed:					
Check	3	4	11	6 fgh	
Mowed, June 10	56	63	124	81 e	
Mowed, July 5	26	29	78	45 e	
2,4-D, June 10	<1	1	3	2 hi	
2,4-D, July 5	<1	3	1	2 hi	
Smooth brome[d]	0	0	<1	<1 i	
Intermediate wheatgrass[d]	<1	<1	0	<1 i	
W.S.G. mixture[d]	2	4	4	3 ghi	
Average	11 p	13 p	28 n	17 z	
Fertilizer average	48 r	62 s	101 t		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with 1/4 and 1/2 lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

established plants, but it did control any seedlings that had germinated during the spring. Populations were maintained, however, because germination continued during the season following periods of extended moisture. Also, germination and seedlings were established in the fall.

Protection from grazing allowed accumulation of litter and debris. Numbers of plants under this management practice were much fewer than in the rotationally grazed portion of the experiment (Table 6). In a more heavily grazed portion of the mowed treatments, not a part of the fertilizer experiment, dandelion populations were even greater than reported here.

Fertilization at either date decreased dandelion numbers 50 percent compared with the nonfertilized check. The fertilizer-dandelion relationship was the same in rotationally grazed plots as in the ungrazed plots although stands of dandelion were much smaller in the ungrazed areas.

Although relatively low numbers of yarrow were present in the pasture, the management and weed-control interactions were significant (Table 7). Apparently protection from grazing for the 14-year period was influential in keeping the number of yarrow plants down. A trend toward greater numbers of yarrow plants in the nonfertilized areas was masked statistically by the more even distribution of population in the mowed plots. The fertilizer effect was apparent in the check plots and in the three reseeded sets of plots which were rotationally grazed. Where the reseeded plots were protected from grazing, few yarrow plants became established.

Groundcherry stands (Table 8), although fairly sparse, had a significantly lower population in the early mowed and seeded plots. Stem numbers were not affected by fertilizer treatments. Mowing and rotational grazing gave partial control of this species. Observations over the years indicate that groundcherry was increasing in the sprayed plots. This aspect was probably misleading because of the scarcity of other broadleaf weeds in the sprayed plots.

Under the best conditions for herbicidal action, 2,4-D spray had a

Table 7. Yarrow stands in June 1964, following 14 years of weed control treatment under 2 levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	0	13	20	11 d	6 ab
Mowed, June 10	9	10	13	10 d	5 ab
Mowed, July 5	8	13	18	13 d	8 a
2,4-D, June 10	2	0	0	<1 e	<1 b
2,4-D, July 5	0	0	<1	<1 e	<1 b
Smooth brome[d]	2	6	7	5 d	3 ab
Intermediate wheatgrass[d]	0	0	2	<1 e	<1 b
W.S.G. mixture[d]	0	0	3	1 e	<1 b
Average	3 np	5 n	8 m	5 y	
Ungrazed:					
Check	0	4	2	2 e	
Mowed, June 10	0	0	1	<1 e	
Mowed, July 5	6	0	2	3 e	
2,4-D, June 10	0	<1	0	<1 e	
2,4-D, July 5	0	0	0	0 e	
Smooth brome[d]	0	0	2	<1 e	
Intermediate wheatgrass[d]	0	0	<1	<1 e	
W.S.G. mixture[d]	<1	0	1	<1 e	
Average	<1 p	<1 p	1 p	<1 z	
Fertilizer average	2 r	3 r	4 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

Table 8. Groundcherry stands in June 1964, following 14 years of weed control treatment under 2 levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	14	16	14	15 e	14 a
Mowed, June 10	5	2	<1	2 gh	7 b
Mowed, July 5	7	4	5	6 fg	14 a
2,4-D, June 10	16	7	14	12 ef	13 a
2,4-D, July 5	15	14	14	14 e	16 a
Smooth brome[d]	2	1	2	2 gh	1 c
Intermediate wheatgrass[d]	10	7	10	9 ef	6 bc
W.S.G. mixture[d]	3	3	4	3 gh	2 bc
Average	9	7	8	8	
Ungrazed:					
Check	18	16	9	14 e	
Mowed, June 10	12	13	10	12 ef	
Mowed, July 5	25	22	17	21 e	
2,4-D, June 10	11	18	12	13 e	
2,4-D, July 5	16	18	18	17 e	
Smooth brome[d]	0	0	3	1 h	
Intermediate wheatgrass[d]	3	2	3	3 gh	
W.S.G. mixture[d]	<1	2	1	1 h	
Average	10	11	9	10	
Fertilizer average	10	9	8		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

temporary effect on the groundcherry plants. Sometimes slight curling of leaves and twisting of stems were observed within a few days following 2,4-D treatment, but after 10 days to 2 weeks the plants no longer displayed effects of herbicide.

Several species of perennial weeds occurred in limited numbers that could not be analyzed separately and they were grouped (Table 9). This grouping includes such species as prairie sage, blazing star, smooth goldenrod, whorled and common milkweed, western ragweed, pitchers sage, cinquefoil, and pussytoes. Plants with rhizomatous growth habit added to the variability. Fertilization was effective in reducing numbers of these broadleaf weeds taken as a group. The pattern remained the same as noted previously: early fertilized portions had lowest populations of the broadleaf weeds; nonfertilized treatments had the largest populations; and late fertilizer treatments were intermediate in number.

The extreme variability in numbers of these weeds tended to mask the effects management and weed control have exerted on the various populations. Almost twice as many weeds of this class were found in

Table 9. Stands of all other perennial weeds in June 1964, following 14 years of weed control treatment under 2 levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treat-ment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	154	100	151	135 de	219 a
Mowed, June 10	131	106	170	136 de	176 a
Mowed, July 5	44	77	117	79 ef	126 ab
2,4-D, June 10	54	25	85	55 fgh	65 abc
2,4-D, July 5	4	18	37	20 hij	18 bc
Smooth brome[d]	59	14	21	31 ghi	22 bc
Intermediate wheatgrass[d]	27	98	34	53 fgh	53 abc
W.S.G. mixture[d]	2	2	19	8 ij	6 c
Average	59 mn	55 m	79 n	65	
Ungrazed:					
Check	287	326	295	303 d	
Mowed, June 10	198	278	176	217 de	
Mowed, July 5	127	212	182	174 de	
2,4-D, June 10	39	80	107	75 efg	
2,4-D, July 5	18	21	12	17 hij	
Smooth brome[d]	1	8	29	13 ij	
Intermediate wheatgrass[d]	36	31	94	54 fgh	
W.S.G. mixture[d]	2	4	6	4 j	
Average	88 np	120 p	113 p	107	
Fertilizer average	74 r	88 rs	96 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

ungrazed areas when compared with the areas grazed moderately. The averages also indicate large differences because of weed control treatment with 2,4-D treated areas averaging roughly one-fifth of check while the mowed areas were reduced less than 50 percent. Plowing apparently reduced the number of these broadleaf weeds; and, where no grazing has occurred, numbers have remained lower than the check. In the plots rotationally grazed, a population of weeds has reappeared in the intermediate wheatgrass plots.

Annual broadleaf weed populations fluctuated widely from year to year because of environmental conditions and seed supplies in the soil. Data for annual broadleaf weeds are summarized into two groups as follows: (1) annual ragweed (Table 10); and (2) stands of other annual weeds (Table 11). Stands of all annuals were relatively sparse in 1964, when only the annual ragweed was in sufficient abundance to merit discussion. The 2,4-D treatments, the late mowing practice, and seeding the warm-season grass mixture have effectively reduced annual ragweed numbers.

Protecting plots from grazing was also effective in helping keep

Table 10. Annual ragweed stands in June 1964, following 14 years of weed control treatment under 2 levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b] — Nitrogen applied[c]: Early	Late	None	Average	Treatment average
Rotationally grazed:					
Check	27	68	94	63 g	73 b
Mowed, June 10	88	150	222	153 f	122 a
Mowed, July 5	17	30	92	46 g	27 cd
2,4-D, June 10	6	11	13	10 h	8 d
2,4-D, July 5	4	1	2	2 i	2 d
Smooth brome[d]	36	98	135	90 fg	51 bc
Intermediate wheatgrass[d]	54	116	320	163 f	84 b
W.S.G. mixture[d]	6	10	8	8 hi	6 d
Average	30 np	61 m	111 k	67 y	
Ungrazed:					
Check	51	59	140	83 fg	
Mowed, June 10	23	110	141	91 fg	
Mowed, July 5	2	11	9	7 hi	
2,4-D, June 10	2	4	9	5 hi	
2,4-D, July 5	6	2	1	3 i	
Smooth brome[d]	<1	2	34	12 h	
Intermediate wheatgrass[d]	2	9	3	5 hi	
W.S.G. mixture[d]	3	8	1	4 i	
Average	11 q	26 p	42 n	26 z	
Fertilizer average	20 r	43 s	76 t		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with 1/4 and 1/2 lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

numbers of ragweed down. The protected plots, on an average, had fewer annual ragweed than the plots rotationally grazed, except for the check plots which were essentially the same. Although the late mowing treatment was effective in controlling the ragweed in the ungrazed plots, the early mowing treatment resulted in either no control or an increase in ragweed population. Annual ragweed seedlings at the time of early mowing (second week of June) were an inch or less in height. Clipping with the mower actually served as a beneficial treatment to the ragweed by reducing the competition. Growth of other plants in the plots was inhibited. In addition, possible canopy or shading effects were minimized.

The established pattern of nitrogen fertilizer effect was seen again in the population distribution of annual ragweed. In this case, however, there appeared to be a significant difference between the early and late fertilized treatments as well as between the late fertilized and the nonfertilized treatments (Table 10). This pattern was partly accounted for by the fact that the late starting annual ragweed plants

Table 11. Stands of other annual weeds in June 1964, following 14 years of weed control treatment under 2 levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Number of stems in 40 square feet[b]				Treat-ment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	2	3	3	3	13 b
Mowed, June 10	0	<1	3	1	4 b
Mowed, July 5	12	2	6	7	6 b
2,4-D, June 10	8	2	6	5	5 b
2,4-D, July 5	4	2	3	3	13 b
Smooth brome[d]	1	1	16	6	4 b
Intermediate wheatgrass[d]	3	<1	2	2	1 b
W.S.G. mixture[d]	<1	0	3	1	38 a
Average	4 st	1 t	5 rs	4	
Ungrazed:					
Check	37	12	19	23	
Mowed, June 10	4	14	2	7	
Mowed, July 5	3	6	4	4	
2,4-D, June 10	2	5	6	4	
2,4-D, July 5	21	30	17	23	
Smooth brome[d]	<1	0	2	1	
Intermediate wheatgrass[d]	<1	1	1	1	
W.S.G. mixture[d]	6	155	60	74	
Average	9 rs	28 r	14 r	17	
Fertilizer average	6	15	10		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

[d] Plots seeded in 1950, supplementally sprayed with ¼ and ½ lb/A 2,4-D ester in 1950 and 1951, and 1 lb/A in 1952, '53, '54, '55, '58, and '61. Warm-season grass (W.S.G.) plots mowed in 1950 instead of sprayed with 2,4-D.

benefitted from the late application of nitrogen by nearly as much as the established grasses. This trend was especially pronounced when little or no moisture stresses, or relatively few moisture stresses, occurred during July and August. Although numbers of other annuals were small, they appeared to react the same to fertilizer treatment.

Grasses

The pasture in this experiment was in poor condition in 1950 because of overgrazing for many years. Changes in botanical composition under natural conditions occurred slowly. When a selection pressure of considerable intensity is applied, rapid changes take place in botanical composition. Such a phenomenon has been described for the broadleaved populations as affected by the applied weed-control treatments and grazing practices. The accompanying changes in the grass portion of the plant population take place more slowly.

Basal frequencies of occurrence of all the grass species were taken

Table 12. Basal frequency of perennial cool-season grasses in June 1964, following 14 years of weed control treatments under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Basal frequency in percent[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	24.6	19.6	18.3	20.8	20.4
Mowed, June 10	22.1	16.8	13.9	17.6	18.9
Mowed, July 5	24.0	19.7	13.2	19.0	19.9
2,4-D, June 10	27.2	22.8	16.4	22.1	21.9
2,4-D, July 5	28.8	22.6	17.8	23.1	21.6
Average	25.3 e	20.3 f	15.9 h	20.5	
Ungrazed:					
Check	21.9	19.0	19.0	20.0	
Mowed, June 10	25.1	19.9	15.9	20.3	
Mowed, July 5	25.0	20.2	17.0	20.8	
2,4-D, June 10	24.9	20.9	19.1	21.6	
2,4-D, July 5	21.5	21.2	17.8	20.2	
Average	23.7 e	20.3 f	17.8 g	20.6	
Fertilizer average	24.5 r	20.3 s	16.8 t		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

Table 13. Basal frequency of perennial warm-season grasses in June 1964, following 14 years of weed control treatments under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Basal frequency in percent[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	.5	1.6	2.0	1.4 cd	1.2
Mowed, June 10	.7	1.7	2.3	1.6 cd	2.2
Mowed, July 5	.7	2.5	3.6	2.3 bcd	3.0
2,4-D, June 10	1.0	2.4	4.4	2.6 abc	2.1
2,4-D, July 5	1.7	1.3	3.4	2.1 bcd	2.6
Average	.9 k	1.9 m	3.1 n	2.0 y	
Ungrazed:					
Check	.4	1.4	1.6	1.1 d	
Mowed, June 10	1.6	1.5	5.3	2.8 abc	
Mowed, July 5	2.9	3.1	5.4	3.8 a	
2,4-D, June 10	.5	1.1	3.2	1.6 cd	
2,4-D, July 5	2.6	2.4	4.3	3.1 ab	
Average	1.6 km	1.9 m	4.0 n	2.5 z	
Fertilizer average	1.2 r	1.9 r	3.6 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

Table 14. Basal frequency of annual cool-season grasses in June 1964, following 14 years of weed control treatments under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Basal frequency in percent[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	.2	.3	1.7	.7 e	.6 a
Mowed, June 10	.0	.0	.0	.0 e	.0 b
Mowed, July 5	2.9	2.1	3.0	2.6 d	1.5 a
2,4-D, June 10	.4	.1	2.6	1.1 e	.8 a
2,4-D, July 5	1.0	1.9	4.6	2.5 d	1.3 a
Average	.9 j	.9 j	2.4 i	1.4 y	
Ungrazed:					
Check	.1	.7	.6	.5 e	
Mowed, June 10	.0	.0	.0	.0 e	
Mowed, July 5	.0	.6	.5	.4 e	
2,4-D, June 10	.0	.7	.9	.5 e	
2,4-D, July 5	.4	.0	.1	.1 e	
Average	.1 k	.4 j	.4 j	.3 z	
Fertilizer average	.5 r	.6 r	1.4 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

in the summer of 1964 and were tabulated in four categories (Tables 12, 13, 14, 15). Because some species were scarce, the total grass population was divided into the following categories: perennial warm-season, perennial cool-season, annual warm-season, and annual cool-season grasses. The results, recorded in 1964, represent the cumulative effect of 14 years of weed-control treatment and controlled grazing, plus the additional influence of 11 years of nitrogen fertilization.

The perennial warm-season grasses were composed of big and little bluestem, switchgrass, indiangrass, side-oats grama, and blue grama and were sparsely scattered over the pasture. The principal grass cover was perennial cool-season grasses, primarily Kentucky bluegrass. The annual warm-season grasses were primarily prairie threeawn and scattered annual dropseeds. Two annual bromes, hairy chess and downy brome, made up the bulk of the annual cool-season grasses with a small occurrence of little barley.

Early and late nitrogen fertilization brought an increase in basal frequency of the cool-season perennial grasses compared with no fertilization (Table 12). Less increase was noted for the late fertilizer treatment compared with the early fertilizer treatment. This same relative influence existed under both levels of grazing intensity; however, the greatest range was under the rotationally grazed management. Although populations were much smaller among the perennial

Table 15. Basal frequency of annual warm-season grasses in June 1964, following 14 years of weed control treatments under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Basal frequency in percent[b]				Treatment average
	Nitrogen applied[c]				
	Early	Late	None	Average	
Rotationally grazed:					
Check	.0	.2	.6	.3 gh	.2 c
Mowed, June 10	2.6	6.7	8.2	5.8 d	3.3 a
Mowed, July 5	.7	2.7	7.0	3.5 e	2.4 b
2,4-D, June 10	.6	4.2	5.0	3.3 e	1.8 b
2,4-D, July 5	.1	2.1	2.6	1.6 f	.9 c
Average	.8 n	3.2 m	4.7 m	2.9 y	
Ungrazed:					
Check	.0	.0	.1	<.1 h	
Mowed, June 10	.0	.2	2.3	.8 g	
Mowed, July 5	.2	.1	4.0	1.4 f	
2,4-D, June 10	.0	.0	1.0	.3 gh	
2,4-D, July 5	.1	.2	.6	.3 gh	
Average	.1 n	.1 n	1.6 n	.6 z	
Fertilizer average	.4 r	1.6 s	3.2 t		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.

[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.

[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

warm-season grasses compared with cool-season grasses, the influence of the fertilization was reversed (Table 13). The largest populations of the perennial warm-season grasses were in the subplots that received no fertilizer, while the smallest populations were in the subplots which received the early fertilizer treatment. Late fertilizer treated subplots had warm-season grass populations of intermediate value.

Mowing at the early date has given control of the cool-season annual grasses (Table 14). This treatment occurred after the cool-season annual grasses had tillered and flowering culms had exerted but before viable seed were produced. The largest populations were in the plots where late mowing occurred after the seeds were mature. Mowing in July tended to reduce vigor of much of the perennial cover and stimulated more rapid breakdown of surface litter. Both factors contributed to increased germination and establishment of cool-season annual grasses.

Fertilization, weed control, and grazing management were effective in determining the final cover of grasses (Table 16). On the basis of total population of grasses, there was a slightly greater population where the pastures were grazed to some extent compared with ungrazed areas. A difference of this nature could be related to the ability of annuals to germinate and to become established. In 1964, the warm-season annuals contributed largely to the population differences

Table 16. Basal frequency of all grasses in June 1964, following 14 years of weed control treatments under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Weed control treatment	Basal frequency in percent[b] — Nitrogen applied[c]: Early	Late	None	Average	Treatment average
Rotationally grazed:					
Check	25.4	21.8	22.9	23.4 h	22.6 c
Mowed, June 10	25.6	24.9	25.4	25.3 fgh	24.7 bc
Mowed, July 5	28.6	27.8	27.6	28.0 efg	27.2 a
2,4-D, June 10	29.4	29.8	28.6	29.3 ef	26.8 ab
2,4-D, July 5	31.6	30.3	28.6	30.2 e	27.0 ab
Average	28.1 k	26.9 km	26.6 mn	27.2 y	
Ungrazed:					
Check	22.5	21.1	21.9	21.8 h	
Mowed, June 10	26.8	21.8	23.7	24.1 gh	
Mowed, July 5	27.9	24.2	27.1	26.4 efg	
2,4-D, June 10	25.4	22.8	24.6	24.2 gh	
2,4-D, July 5	24.6	23.8	22.8	23.8 gh	
Average	25.4 n	22.7 p	24.0 p	24.1 z	
Fertilizer average	26.8 r	24.8 s	25.3 s		

[a] Treatments applied annually 1950 through 1964, fertilizer 1953 through 1964.
[b] Means in a column or row followed by the same letter are not significantly different at the 5 percent level.
[c] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

between the management levels. These differences were found primarily in the late fertilized and nonfertilized areas, with most abundance in the nonfertilized rotationally grazed plots. Numbers of warm-season annual grasses were limited in the ungrazed plots, particularly where nitrogen fertilizer was applied.

The abundance of annual grasses at any one time reflected climatic conditions at the various periods of the year. The fall and early spring periods, when the cool-season annuals would be germinating and becoming established, were below normal in precipitation. In 1963, March was near normal, with April and May precipitation slightly above normal, encouraging the warm-season species. Precipitation in the fall of 1963 was much below normal followed by a dry period in early spring. Adequate April and May moisture in 1964 then contributed to an annual grass population comprised primarily of the warm-season species.

Plots for the seeding portion of the experiment were plowed in the fall of 1949 with the seedbed being prepared for seeding in the spring of 1950. Cool-season grasses were seeded about mid-March and the warm-season grass mixture was seeded about mid-May. The cool-season grass plots were sprayed with ¼ lb/A of 2,4-D June 8, 1950 for control of broadleaf weeds in the seedling grasses. Instead of being sprayed, the warm-season grass plots were mowed on July 21, 1950. In 1951, all the seeded plots were sprayed with ½ lb/A 2,4-D. From 1952

Table 17. Basal frequency of grasses in June 1964, in the plots seeded to smooth brome in 1950, following 14 years under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

Species	Basal frequency in percent											
	Rotationally grazed						Protected from grazing					
	Nitrogen applied[b]						Nitrogen applied[b]					
	Early		Late		None		Early		Late		None	
	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964
Desirable Grasses												
Smooth brome	9.8	12.6	9.8	9.2	9.6	7.7	10.7	15.5	10.1	14.5	10.2	11.4
Intermediate wheatgrass	0.0	<0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Kentucky bluegrass	4.5	8.2	3.1	8.3	3.5	7.1	0.9	<0.1	1.4	0.2	1.2	2.7
Big bluestem	0.0	0.0	0.0	0.0	0.0	0.6	0.2	<0.1	0.0	0.0	<0.1	0.8
Indiangrass	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Sand lovegrass	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Blue grama	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other desirable	<0.1	0.1	0.3	0.7	0.3	1.0	0.0	0.0	0.2	0.0	0.1	0.2
Total desirable	14.4	21.1	13.3	18.2	13.6	17.0	11.8	15.6	11.7	14.7	11.6	16.2
Weed Grasses												
Annual bromes	1.7	0.0	0.5	0.0	1.1	0.1	0.6	0.0	1.2	0.0	0.5	0.0
Prairie threeawn	0.4	0.3	0.6	2.2	0.8	6.5	0.0	0.0	<0.1	0.0	0.3	0.2
Grass-like weeds	<0.1	0.3	0.2	0.7	0.6	1.0	<0.1	0.0	0.1	0.0	0.1	0.3
Other weed grasses	0.0	0.0	<0.1	0.1	0.3	0.1	<0.1	0.0	0.0	0.0	<0.1	0.0
Total weed grasses	2.1	0.6	1.4	3.0	2.9	7.6	0.7	0.0	1.3	0.0	0.9	0.5
Total all species	16.5	21.7	14.7	21.2	16.5	24.5	12.5	15.6	13.0	14.7	12.5	16.7

[a] Fertilizer applied annually from 1953 through 1964.

[b] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

through 1955, the seeded plots received an annual application of 1 lb/A 2,4-D. This treatment was also applied in 1958 and 1961.

Some marked changes in vegetative composition have occurred in the plots seeded to smooth brome following application of fertilizer and under two levels of grazing intensity (Table 17). Where rotationally grazed, the Kentucky bluegrass increased in all cases particularly where nitrogen fertilizer was applied. The smooth brome increased in basal frequency under early fertilization, stayed roughly the same where late fertilizer was used, and decreased where no fertilizer was added. Warm-season grasses invaded the smooth brome as the fertility level declined. This was primarily big bluestem and indiangrass. Over the 11-year period, the annual bromes have decreased essentially to zero. Where early fertilizer was applied, the small population of prairie threeawn remained unchanged. There was an increase in prairie threeawn in the late fertilized plots and a large increase in the nonfertilized plots.

In plots protected from grazing, portions that received fertilizer increased in the basal frequency of the smooth brome to the virtual exclusion of all other species. In the portion that received no fertilizer, the smooth brome has steadily declined in vigor and cover accompanied by a small increase in Kentucky bluegrass and a strong invasion of the warm-season grasses. Although the basal frequency of the warm-season grasses was not large, the size of the plants gave it an aspect of those grasses, overtopping the nitrogen deficient smooth brome.

Intermediate wheatgrass plots showed a larger loss of stand and a larger increase in Kentucky bluegrass (Table 18) than the smooth brome plots. Also, there was an invasion of smooth brome into the intermediate wheatgrass plots. The large amounts of annual bromes, present in 1954, gradually decreased until little was found in 1964. Where ungrazed, the decline in stand was most pronounced where no nitrogen fertilizer was applied. There was also invasion of warm-season grasses, big bluestem and indiangrass, in sufficient quantity to give these plots an aspect of the warm-season grasses.

Some striking changes in vegetative composition have taken place in plots seeded to the warm-season-grass mixture (Table 19). Early nitrogen fertilization promoted the cool-season grasses with increase of the Kentucky bluegrass and invasion by smooth brome. The invasion of smooth brome was more pronounced in the area protected from grazing than in the portion rotationally grazed. Where fertilizer was not applied there has been an increase in amount of both big bluestem and indiangrass under both levels of grazing intensity. Blue grama has been eliminated and sand lovegrass greatly reduced in the ungrazed plots. These grasses also have been reduced in the rotationally grazed plot where nitrogen fertilizer was added. The annual bromes have decreased and only a few individual plants were observed.

Table 18. Basal frequency of grasses in June 1964, in the plots seeded to intermeditae wheatgrass in 1950, following 14 years under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

	Basal frequency in percent											
	Rotationally grazed						Protected from grazing					
	Nitrogen applied[b]						Nitrogen applied[b]					
	Early		Late		None		Early		Late		None	
Species	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964
Desirable Grasses												
Smooth brome	<0.1	3.6	0.0	2.0	0.2	3.2	0.0	5.8	<0.1	3.6	0.1	5.1
Intermediate wheatgrass	9.7	7.2	10.0	6.8	11.8	4.2	13.6	9.9	14.5	10.8	10.9	6.5
Kentucky bluegrass	4.8	10.9	6.3	9.6	3.4	10.1	1.8	2.9	2.3	4.2	2.2	5.3
Big bluestem	0.0	0.2	0.2	0.5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.9
Indiangrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.4
Switchgrass	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Sand lovegrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Blue grama	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other desirable	0.1	<0.1	1.2	0.3	0.5	1.0	<0.1	<0.1	0.1	0.0	0.1	0.1
Total desirable	14.7	21.9	16.8	19.3	16.0	18.7	15.4	18.5	17.1	18.9	13.4	18.2
Weed Grasses												
Annual bromes	8.2	0.0	3.4	0.0	3.4	<0.1	3.2	0.0	2.0	0.0	2.8	0.0
Prairie threeawn	0.0	<0.1	<0.1	0.3	0.5	1.6	0.0	0.0	<0.1	0.0	0.0	<0.1
Grass-like weeds	0.2	0.1	0.1	0.5	0.3	0.6	<0.1	0.1	0.2	0.2	<0.1	0.3
Other weed grasses	0.0	0.1	0.1	0.0	0.0	0.5	0.0	0.0	<0.1	<0.1	0.0	<0.1
Total weed grasses	8.4	0.2	3.6	0.8	4.2	2.7	3.2	0.1	2.2	0.3	2.9	0.4
Total all species	23.1	22.2	20.4	20.0	20.5	21.4	18.6	18.6	19.3	19.2	16.3	18.6

[a] Fertilizer applied annually from 1953 through 1964.

[b] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

Table 19. Basal frequency of grasses in June 1964, in the plots seeded to a warm-season grass mixture in 1950, following 14 years under two levels of grazing management as affected by nitrogen fertilization for 11 years at Lincoln, Nebr.[a]

	Basal frequency in percent											
	Rotationally grazed						Protected from grazing					
	Nitrogen applied[b]						Nitrogen applied[b]					
	Early		Late		None		Early		Late		None	
Species	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964
Desirable Grasses												
Smooth brome	0.3	2.7	0.1	1.0	<0.1	0.1	0.1	7.7	0.1	2.5	0.1	0.7
Intermediate wheatgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Kentucky bluegrass	6.9	12.3	5.3	7.7	4.5	7.9	2.2	4.3	1.8	2.1	1.2	5.8
Big bluestem	1.5	4.8	2.9	5.1	3.4	7.4	3.1	1.4	4.3	3.7	6.0	7.3
Indiangrass	0.1	1.7	0.5	4.0	0.3	4.2	0.4	0.2	0.8	0.5	0.8	2.1
Switchgrass	4.4	1.9	5.7	3.2	5.4	1.4	6.7	4.8	6.7	9.3	6.2	4.1
Sand lovegrass	1.2	0.4	2.1	1.0	2.7	0.5	0.6	0.0	0.9	0.0	1.0	0.1
Blue grama	0.4	0.0	1.4	0.7	0.6	1.1	0.0	0.0	0.1	0.0	<0.1	0.0
Other desirable	<0.1	0.0	0.3	0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1
Total desirable	14.9	24.0	18.4	22.7	17.0	22.7	13.2	18.5	14.6	18.1	15.4	20.1
Weed Grasses												
Annual bromes	11.1	0.0	3.7	<0.1	3.6	0.0	6.1	0.0	1.8	<0.1	2.2	0.1
Prairie threeawn	0.1	0.0	0.4	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Grass-like weeds	0.0	<0.1	0.5	0.0	0.4	0.1	<0.1	<0.1	<0.1	0.0	<0.1	0.3
Other weed grasses	0.2	0.0	0.2	0.0	0.2	0.0	0.2	0.0	<0.1	0.0	0.1	0.0
Total weed grasses	11.4	<0.1	4.8	0.1	4.5	0.3	6.3	<0.1	1.8	<0.1	2.3	0.4
Total all species	26.3	24.0	23.2	22.8	21.5	23.0	19.6	18.6	16.4	18.2	17.7	20.5

[a] Fertilizer applied annually from 1953 through 1964.

[b] Fertilizer—early, 55 lb/A N April 20; late, 55 lb/A N June 20.

Prairie threeawn has been eliminated where nitrogen fertilizer was applied and only small amounts were present in the nonfertilized areas.

Production of Vegetation as Affected by Treatment

The return expected from any investment of money, energy, or time on pasture improvement is increased production of desirable forage.

Effects of weed control treatment, differential grazing management and use of nitrogen fertilizers on the vegetative composition of pasture have been described in previous sections. This information has been augmented by the quantitative determination of forage production reported in this section. Clipping studies were conducted in 1954, 1955, and 1960. The material harvested from the sample areas was separated into three classes of vegetation, desirable grasses, weed grasses, and broadleaf weeds or forbs. This material was dried by standard methods to obtain oven-dried weights. Yields were converted to pounds per acre on an oven-dry basis (Table 20).

It is interesting to compare total production of forage during 1954, 1955, and 1960 (Table 20). Moisture was limited early in 1954 resulting in less than maximum early fertilizer effects on grass production. Moisture later in the season, however, was more nearly adequate. Grass yield from the late fertilized plots did not reflect the early moisture shortage. In 1955, a moisture shortage existed throughout the growing season. The early deficiency was severe causing much vegetation of the fertilized plots to wilt by the middle of May. Because soil moisture was never adequate during this season, recovery was negligible. Moisture supply and distribution in 1960 were nearly normal, and forage production should be considered more representative of production in this region.

Both mowing treatments reflected lower total production compared with other weed-control treatments because the material dropped was not salvaged for hay production. Smooth brome plots produced the least vegetation of all plots where no fertilizer was added. This was a combination of gradual impoverishment of the smooth brome through continuous use plus little or no weed component in the yield.

Although total vegetation production was greatest on the check plots, it was lowest in production of desirable forage of the plots not mowed. On the smooth brome areas early fertilizer resulted in an increased yield of 1,800 pounds per acre compared with the nonfertilized area. A similar increase was obtained by use of late fertilizer on the warm-season-grass mixture. As an average across all weed-control treatments, 55 pounds of nitrogen fertilizer caused an increase of nearly 1,000 pounds of desirable forage per acre.

Little information is available regarding response of the

Table 20. Production of vegetation in pasture plots given differential weed control treatments for 10 years as affected by nitrogen fertilization for 7 years, with comparative figures for 1954 and 1955. Plots moderately grazed under a rotationally grazed system of management.

Weed control treatment	Type of vegetation	Pounds dry matter per acre								
		Early fertilizer			Late fertilizer			No fertilizer		
		1954	1955	1960	1954	1955	1960	1954	1955	1960
Check	Desirable grass	3,780	2,110	3,240	2,650	1,590	3,310	2,460	1,610	2,380
	Weedy grass	500	300	170	380	240	140	170	150	180
	Forbs	870	600	1,910	1,420	940	2,060	1,400	780	2,240
	Total	5,150	3,010	5,320	4,440	2,770	5,510	4,030	2,540	4,800
Early mow	Desirable grass	1,990	1,240	1,980	1,840	1,330	1,650	1,540	1,380	1,300
	Weedy grass	40	50	40	70	40	150	50	80	130
	Forbs	310	200	880	720	160	1,340	440	180	1,250
	Total	2,340	1,490	2,900	2,630	1,530	3,140	2,030	1,640	2,680
Late mow	Desirable grass	1,310	630	2,520	1,340	630	2,710	1,460	1,030	2,170
	Weedy grass	130	330	460	180	330	520	150	130	520
	Forbs	200	130	550	400	180	900	310	90	930
	Total	1,640	1,090	3,530	1,920	1,140	4,130	1,920	1,250	3,620
Early spray	Desirable grass	4,130	1,930	3,910	3,520	2,920	3,700	3,160	2,600	2,810
	Weedy grass	350	670	170	410	130	150	290	200	610
	Forbs	140	160	140	120	100	80	140	100	310
	Total	4,620	2,760	4,220	4,050	3,150	3,930	3,590	2,900	3,730
Late spray	Desirable grass	4,240	1,400	4,660	4,030	2,020	3,880	3,370	1,600	3,600
	Weedy grass	400	550	350	400	290	890	450	330	960
	Forbs	130	100	60	170	200	130	270	310	100
	Total	4,770	2,050	5,070	4,600	2,510	4,900	4,090	2,240	4,660
Warm-season grass mixture	Desirable grass	4,230	5,280	3,540	5,300	5,650	5,370	4,180	4,520	2,650
	Weedy grass	1,540	200	20	620	90	10	410	130	30
	Forbs	10	40	20	0	0	90	20	0	50
	Total	5,780	5,520	3,580	5,920	5,740	5,470	4,610	4,650	2,730
Smooth brome	Desirable grass	5,250	3,380	4,230	3,970	2,570	2,980	3,630	2,440	2,430
	Weedy grass	70	10	10	40	10	70	30	10	30
	Forbs	20	0	10	10	0	60	10	0	90
	Total	5,340	3,390	4,250	4,020	2,580	3,110	3,670	2,450	2,550
		4,230	2,760	4,120	3,940	2,770	4,310	3,420	2,510	3,540

broadleaf-weed component to nitrogen fertilization. The seeded treatments that received 2,4-D for broadleaf-weed control early in the experiment show negligible amounts of weed growth. The two sets of plots than received 2,4-D alone are relatively free of weeds. These data check nicely with the numerical tabluation of weeds given in a previous section. The plots that were weed free also showed the best response to nitrogen fertilizer. This response ranged from 1,000 pounds increase on the spray plots with early fertilizer to 2,600 pounds increase on the warm-season grass plots with late fertilizer.

Numbers of broadleaf weeds were essentially the same in the mowed plots as in the check plots. Successive mowing treatments, however, had reduced vigor (8) with the average production in the two mowed plots being roughly one-half that produced in the check plots. The greater response of mowed plots to the nitrogen fertilizer as compared with the check plot would indicate that recovery from the mowing treatment was assisted by the fertilizer. The small decrease in production of broadleaf weeds, when averaged across all treatments, would indicate that the fertilizer was less effectively utilized by the weeds than by the grass.

Soil Properties as Affected by Treatment

Eight years of reduced grazing or protection from grazing resulted in a decrease in bulk density of the surface 3 inches of soil (Table 21).

Table 21. Effect of differential grazing on the bulk density of a Pawnee silty clay loam (surface three inches).

Management	Percent water at sampling	Bulk density[a]
Continuously grazed		
Check	14.1	1.14
Mowed	12.2	1.19
Sprayed, 2,4-D	12.4	1.20
Smooth brome	10.6	1.21
Warm-season mix	14.3	1.10
Average	......	1.17a
Rotationally grazed		
Check	14.5	1.17
Mowed	13.3	1.15
Sprayed, 2,4-D	14.8	1.10
Smooth brome	12.3	1.13
Warm-season mix	21.5	1.17
Average	......	1.14a
Ungrazed		
Check	17.4	1.01
Mowed	14.9	1.08
Sprayed, 2,4-D	14.5	1.05
Smooth brome	16.1	1.04
Warm-season mix	25.1	1.04
Average	......	1.04b

[a] Means with identical letters do not differ significantly at the 5 percent level.

Plots protected from grazing were significantly lower in density (1.04 g/cc) than plots rotationally grazed (1.14 g/cc) or heavily grazed (1.17 g/cc). Surface soils in plots receiving the heaviest grazing pressures were slightly more dense than in plots that had been grazed intermittently. Differences in density of the soils were caused primarily by the compacting action of animal hoofs. Root growth was more abundant in the less heavily grazed plots thus accounting in part for the decreased bulk density. The major cause for density changes, however, was animal-induced compaction.

Grazing management had no significant effect on soil reaction, organic matter, or total nitrogen (Table 22). This observation was expected considering the relatively short time (eight years) involved. Available phosphorus content, however, in the upper foot of the heavily-grazed plots was greater compared with the less heavily grazed and the ungrazed plots. Where grazing was not controlled, animals were present for a long period each year (May 1–November 15). Animal droppings apparently supplied the additional phosphorus found in the upper levels of soil sampled.

Weed-control treatments for eight years had no significant effect on soil reaction, available phosphorus, organic matter, or total nitrogen of the soil (Table 23).

Ammonium sulfate fertilization, at the rate of 55 pounds nitrogen per year, had a marked effect on soil reaction (Table 24). The acidity of fertilized plots (pH 5.57 - 5.61) was greater than that of controls (pH 5.89) after only four years of application. Nine years of fertilizer application decreased the pH to 5.22 - 5.23 (Table 25).

Part of the increased density of cool-season grasses was caused by early stimulation at a time when moisture was adequate for growth. Cool-season species had a competitive advantage for water. The competitive ability of warm-season grasses might have been enhanced if a more favorable surface soil reaction had been maintained. Liming may be necessary to maintain stands of warm-season grasses receiving annual application of nitrogen fertilizer.

Table 22. Soil reaction, phosphorus, organic matter, and total nitrogen of a Pawnee silty clay loam after eight years of different grazing management.

Grazing management	Chemical determination[a]											
	Soil reaction (pH)			Phosphorus (Bray No. 1) ppm			Organic matter, %			Total nitrogen, %		
	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″
Continuously grazed	5.96a	5.86b	6.05c	12.82d	7.37e	5.02f	5.30g	4.08h	3.06i	0.247j	0.192k	0.143m
Rotationally grazed	5.86a	5.81b	5.94c	9.03dd	5.67ee	4.57f	5.76gg	4.36h	3.09i	0.257j	0.204k	0.157m
Ungrazed	5.92a	5.78b	5.88c	9.40dd	5.49ee	4.70f	5.40g	4.34h	3.17i	0.254j	0.194k	0.153m

[a] Identical number of letters within a column indicate non-significance at the 5 percent level.

Table 23. Soil reaction, phosphorus, organic matter, and total nitrogen of a Pawnee silty clay loam after eight years of weed control treatment.

Weed control treatment	Chemical determination[a]											
	Soil reaction (pH)			Phosphorus (Bray No. 1) ppm			Organic matter, %			Total nitrogen, %		
	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″
Control	5.91a	5.68b	5.90c	9.56d	5.71e	4.56f	5.83g	4.22h	3.02i	.260j	.287k	.153m
Mowed	5.89a	5.74b	5.93c	11.06d	6.15e	4.84f	5.43g	4.10h	3.03i	.262j	.203k	.158m
Sprayed, 2,4-D	5.95a	5.91b	5.96c	9.84d	6.10e	4.58f	5.22g	4.13h	3.14i	.250j	.198k	.140m
Plowed & seeded warm-season mixture	5.89a	5.84b	5.97c	10.26d	5.77e	4.39f	5.58g	4.53h	3.12i	.243j	.199k	.148m
Smooth brome	5.93a	5.89b	6.03c	11.41d	7.15e	5.76f	5.37g	4.31h	3.22i	.249j	.199k	.150m

[a] Identical number of letters within a column indicate non-significance at the 5 percent level.

Table 24. Soil reaction, phosphorus, organic matter, and total nitrogen of a Pawnee silty clay loam as affected by four years of ammonium sulfate fertilization.

Annual fertilizer management	Chemical determination[a]											
	Soil reaction (pH)			Phosphorus (Bray No. 1) ppm			Organic matter, %			Total nitrogen, %		
	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″	0–6″	6–12″	12–24″
April application 55 lb N as $(NH_4)_2SO_4$	5.57a	5.69b	5.82c	8.81d	5.68e	4.49f	5.67g	4.48h	3.09i	.260j	.198k	.156m
June application 55 lb N as $(NH_4)_2SO_4$	5.61a	5.73b	5.85c	8.98d	5.85e	4.57f	5.70g	4.37h	3.08i	.259j	.199k	.152m
No fertilizer	5.89a	5.79b	5.91c	9.22d	5.58e	4.73f	5.58g	4.35h	3.08i	.255j	.199k	.155m

[a] Identical number of letters within a column indicate non-significance at the 5 percent level.

Table 25. Soil reaction (pH) of a Pawnee silty clay loam as affected by 9 years of weed control treatments, differential grazing managements, and nitrogen fertilization.

Weed control measures	Continuously grazed	Rotationally grazed		Ungrazed	
	not fertilized	fertilized	not fertilized	fertilized	not fertilized
Check	5.85	5.40	5.59	5.40	5.60
Early mowing	5.75	5.12	5.51	5.25	5.72
Early spraying	5.67	5.06	5.62	5.20	5.74
Warm-season mix	5.84	5.25	5.67	5.09	5.58
Smooth brome	5.88	5.28	5.76	5.19	5.55
Average	5.80a[a]	5.22c	5.63b	5.23c	5.63b

[a] Fertilizer means with identical letters do not differ significantly at the 10 percent level. Weed control treatment means were not significantly different.

LITERATURE CITED

1. Aldous, A. E. 1935. Management of Kansas permanent pastures. Kans. Agr. Exp. Sta. Bul. 272: 1–44.
2. Bray, R. T. and Kurtz, L. T. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59: 39–45.
3. Cox, Milo L. 1956. Some effects of nitrogen fertilization on vegetative composition and yield of permanent pasture given differential weed control and grazing management treatments. Diss. Abs. Vol. 16, No. 12, P. 2261, Univ. of Nebr.
4. Dore, W. G. 1936. Pasture Studies X. Succession and variation in the botanical composition of permanent pastures. Sci. Agr. 16: 569–590.
5. Grava, John. 1953. Fertilizers for native pastures. Fert. Conf. Handb., Dept. of Agron., Kans. State Col.
6. Klingman, Dayton L. and M. K. McCarty. 1958. Interrelations of methods of weed control and pasture management at Lincoln, Nebr., 1949–55. U. S. Dept. of Agr. Tech. Bul. 1180. 49 pp.
7. Klingman, D. L., Miles, S. R. and Mott, G. O. 1943. The cage method for determining consumption and yield of pasture herbage. Jour Amer. Soc. Agron. 35: 739–746.
8. McCarty, M. K. and D. L. Linscott. 1963. Growth of ironweed as affected by mowing and storage root removal. WEEDS 11: 223–225.
9. Smith, H. W. and Weldon, M. D. 1940. A comparison of some methods for the determination of soil organic matter. Soil Sci. Soc. Amer. Proc. 5: 177–182.

APPENDIX

Species

Common Name	*Scientific Name*
Aster, heath	*Aster ericoides* L.
Barley, little	*Hordeum pusillum* Nutt.
Blazing star	*Liatris punctata* Hook.
Bluegrass, Kentucky	*Poa pratensis* L.
Bluestem, big	*Andropogon gerardi* Vitman
Bluestem, little	*Andropogon scoparius* Michx.
Boneset, false	*Kuhnia eupatorioides L.*
Brome, smooth	*Bomus inermis* Leyss.
Brome, downy	*Bromus tectorum* L.
Chess, hairy	*Bromus commutatus* Schrad.
Cinquefoil	*Potentilla* spp.
Cyperus, slender	*Cyperus filiculmis* Vahl
Dandelion	*Taraxacum officinale* Weber
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A. Gray
Fleabane, daisy	*Erigeron* spp.
Foxtail	*Setaria* spp.
Goldenrod, smooth	*Solidago missouriensis* Nutt.
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.
Grama, sideoats	*Bouteloua curtipendula* (Michx.) Torr.
Groundcherry	*Physalis* spp.
Ironweed, western	*Vernonia baldwini* Torr.
Lovegrass, sand	*Eragrostis trichodes* (Nutt.) Wood
Marestail (horseweed)	*Conyza canadensis* L.
Milkweed, common	*Asclepias syriaca* L.
Milkweed, western whorled	*Asclepias subverticillata* L.
Poverty grass	*Sporobolus vaginiflorus* (Torr.) Wood
Pussytoes	*Antennaria campestris* Rydb.
Ragweed, common	*Ambrosia artemisiifolia* L.
Ragweed, western	*Ambrosia psilostachya* DC.
Rush	*Juncus* spp.
Sage, prairie	*Artemisia ludoviciana* var. *gnaphalodes.* (Nutt.) T & G
Snow-on-the-mountain	*Euphorbia marginata* Pursh.
Switchgrass	*Panicum virgatum* L.
Thistle, bull	*Cirsium vulgare* (Savi) Tenore
Thistle, musk	*Carduus nutans* L.
Thistle, Flodman's	*Cirsium flodmani* Rydb.
Thistle, wavyleaf	*Cirsium undulatum* (Nutt.) Spreng.
Threeawn, prairie	*Aristida oligantha* Michx.
Vervain, hoary	*Verbena stricta* Vent.

Wheatgrass, intermediate . . . . *Agropyron intermedium* **(Host) Beauv.**
Yarrow, common . . . . *Achillea millefolium* **L.**