Effects of Fertilization and Climatic Conditions on Prairie Hay

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Prairie Hay

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Prairie hay is an important crop in many areas of Oklahoma. Approximately 380,000 acres of native grass meadows are harvested annually for hay. Most of these meadows are located in the central and eastern counties of the state. Farmers and ranchers utilizing these acreages for native grass hay are concerned with practical and effective means for maintaining and improving yields and the quality of hay obtained.

This study was undertaken to determine the effects of various fertilizer treatments on yield and composition of prairie hay growing on a deep, medium textured, permeable upland prairie soil, Norge loam, with 3 to 5 percent slope.

Procedure

This field experiment was established in 1929 on a virgin native grassland at the Oklahoma Agricultural Experiment Station, Agronomy Farm, near Stillwater. The 11 soil fertility treatments in this experiment compared two nitrogen fertilizers, sodium nitrate and ammonium sulphate, applied at two rates with and without superphosphate (20%) and muriate of potash (50%). Phosphate only and phosphate with potassium treatments were included without the nitrogen additions. Every third plot in this experiment was used as a check (no fertilizer) plot for a total of 10 check plots, all other treatments were in duplicate. Details of the kinds and amounts of fertilizer used in the various treatments are shown in Table 1.

All fertilizers were applied by broadcasting during the spring months. Applications were made in March and April during the period 1929 to 1940, and after May 1 from 1941 to 1945.

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Hay yields were obtained by mowing and field weights determined as air-dry hay. Samples were taken from each plot for chemical analysis. The dates of cutting for each year are shown in Table 7, page 9.

Fertilizer treatments were discontinued after 1946. Yields were obtained in 1947, 1949, 1950, 1951, and 1952 in order to measure possible residual effects of the previous year's fertilization. Yield data for 1948 were lost.

Results

Hay Yields

A summary of the average hay yields with statistical analyses from the various soil fertility treatments for the 18-year period, 1929 through 1946, is included in Table 2. The average yields for 1947, 1949, 1950, 1951 and 1952, are also presented. Hay yields from each treatment by year for the entire period of the experiment are presented in Table 8, page 11.

The highest average hay yield of 4039 pounds per acre for the period of study, 1929 through 1946, was obtained from the annual fertilizer treatment equivalent to 42-20-12.5 (sodium nitrate). The lowest average yield of 3097 pounds per acre was obtained from the

Table 1.—Soil fertility treatments applied annually to the native grass meadow study, 1929-1946, Stillwater, Oklahoma.

Treatment	Symbol	Plot Designation	Fertilizer Treatment per Acre
1.	0	Check	No Fertilizer Applied
2.	P	0-20-0	100 lbs. 20% Superphosphate
3.	PK	0-20-12.5	100 lbs. 20% Superphosphate 25 lbs. 50% Muriate of Potash
4.	N_1 (NH_4)	21-0-0 $(NH_4)_2SO_4$	100 lbs. Ammonium Sulfate
5.	N_1 (NO_3)	21-0-0 $NaNO_3$	137 lbs. Sodium Nitrate
6.	N_2(NH_4)	42-0-0 $(NH_4)_2SO_4$	200 lbs. Ammonium Sulfate
7.	N_2(NO_3)	42-0-0 $NaNO_3$	274 lbs. Sodium Nitrate
8.	N_1 PK (NH_4)	21-20-12.5 $(NH_4)_2SO_4$	100 lbs. Ammonium Sulfate 100 lbs. 20% Superphosphate 25 lbs. 50% Muriate of Potash
9.	N_1 PK (NO_3)	21-20-12.5 $NaNO_3$	137 lbs. Sodium Nitrate 100 lbs. 20% Superphosphate 25 lbs. 50% Muriate of Potash
10.	N_2 PK (NH_4)	42-20-12.5 $(NH_4)_2SO_4$	200 lbs. Ammonium Sulfate 100 lbs. 20% Superphosphate 25 lbs. 50% Muriate of Potash
11.	N_2 PK (NO_3)	42-20-12.5 $NaNO_3$	274 lbs. Sodium Nitrate 100 lbs. 20% Superphosphate 25 lbs. 50% Muriate of Potash

The field plot design included 10 check (no fertilizer) plots and two plots of each of the fertilized plots. Every third plot in the experiment was a check plot.

check (no fertilizer) plots. The difference of 942 pounds of hay per acre was statistically significant. The average yield of the non-fertilized check plots was significantly lower than the plots receiving annual treatments of 21-0-0 (sodium nitrate), 21-20-12.5 (sodium nitrate), 42-20-12.5 (ammonium sulphate), and 42-20-12.5 (sodium nitrate). However, the annual yields obtained from the differentially fertilized plots were extremely variable during this period. Significant differences as a result of fertilizer treatment were obtained in only three of the eighteen years of this part of the experiment.

The average hay yields obtained from the 1947 and 1949-1952 period were considerably higher for all plots. No fertilizer was applied during those years. The average hay yield of 4240 pounds per acre from the check plots that had never received fertilizer during the experiment was higher than yields from plots that had previously been fertilized annually with 21-0-0 (ammonium sulphate), 21-0-0 (sodium nitrate), and 42-0-0 (ammonium sulphate). The highest average hay yield of 5474 pounds per acre during this latter period was obtained from plots that were previously fertilized annually with 42-20-12.5 (ammonium sulphate).

Rainfall and Hay Yields

A summary of monthly rainfall data at the Agronomy Farm for the years 1929 through 1946 is shown in Table 11, page 20. There ap-

Table 2.—Average yields of prairie hay as affected by various soil fertility treatments (pounds per acre).

Fertilizer Treatment	1929-1946	1947 and 1949-1952
1. Check (no fertilizer)	3097	4240
2. 0-20-0	3349	5159
3. 0-20-12.5	3252	5184
4. 21-0-0 $(NH_4)_2 SO_4$	3294	4080
5. 21-0-0 $Na NO_3$	3531	4038
6. 41-0-0 $(NH_4)_2SO_4$	3436	4150
7. 42-0-0 $NaNO_3$	3445	4390
8. 21-20-12.5 $(NH_4)_2 SO_4$	3492	4979
9. 21-20-12.5 $Na NO_3$	3684	4364
10. 42-20-12.5 $(NH_4)_2 SO_4$	3983	5608
11. 42-20-12.5 $Na NO_3$	4039	5474

† Check (no fertilizer) yields represent the mean from 10 plots; other treatment yields are means of two plots for each fertilizer treatment. The 1948 yield figures were lost.

Multiple Range test for effects of soil fertility treatment on average yield of prairie hay, 1929-1946. F = 8.68

Treatment:	1	3	4	2	6	7	8	5	9	10	11
Av. Yield:	3097	3252	3294	3349	3436	3445	3492	3531	3684	3983	4039

Any two means not underscored by the same line are significantly different at the five percent level of confidence.

Table 3.—Correlation of amount of rainfall and prairie hay yields 1929-1946.†

Rainfall Periods	Average Yield All Plots	Average Yield Check Plots	Average Yield 21 lbs. N/A Plots	Average Yield 42 lbs. N/A Plots
Nov. 1 to cutting date	.46	.65**	.54*	.63**
Jan. 1 to cutting date	.51*	.53*	.46	.53*
Apr. 1 to cutting date	.55*	.59*	.48*	.57*

† A perfect correlation coefficient would be 1.00.
* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

peared to be a relationship between rainfall and hay yields by year for this period. An attempt was made to correlate annual rainfall occurring during three different periods of time prior to hay harvest with the average yields by year. Results of these correlations are shown in Table 3. These three rainfall periods were compared with the average yield of all plots, with average yields from the plots not fertilized, the average yield of all plots that received 21 pounds of nitrogen per acre each year, and lastly, with the average yield from plots that received 42 pounds of nitrogen per acre per year.

The rainfall period November 1 to cutting date was selected to indicate the influence of late fall and winter moisture with the rainfall during the normal growing season on subsequent hay yields. Highly significant correlations between the rainfall during this period and the average yield of check plots and the yields from those plots that received 42 pounds of nitrogen per acre per year were obtained. A signifi-

Table 4.—Average nitrogen, phosphorus, potassium and calcium composition of prairie hay as affected by various fertility treatments, 1929-1946.*

Treatment	% N	% P	% K	% Ca
1. Check (no fertilizer)	.740	.082	1.141	.406
2. 0-20-0	.754	.121	1.148	.398
3. 0-20-12.5	.731	.157	1.200	.407
4. 21-0-0 $(NH_4)_2SO_4$	.779	.073	1.183	.398
5. 21-0-0 $NaNO_3$	.804	.075	1.138	.399
6. 42-0-0 $(NH_4)_2SO_4$	.809	.069	1.130	.399
7. 42-0-0 $NaNO_3$	.851	.078	1.174	.391
8. 21-20-12.5 $(NH_4)_2SO_4$	.761	.119	1.201	.408
9. 21-20-12.5 $NaNO_3$	.768	.121	1.182	.431
10. 42-20-12.5 $(NH_4)_2SO_4$	.846	.104	1.163	.389
11. 42-20-12.5 $NaNO_3$	.848	.107	1.249	.394

* These figures represent the means from samples analyzed from 10 check plots and two plots each fertilizer treatment for each of the 18 years, 1929-1946.

cant correlation was obtained in relating rainfall in this period with the average yield from plots that received 21 pounds of nitrogen per acre annually.

The rainfall period January 1 to cutting date was selected to indicate the influence of late winter rainfall combined with the spring and summer rainfall on subsequent hay yields. The rainfall during this period gave significant correlations with the average yield from all plots, with the average yield of all plots that received no fertilizer, and with average yields from those plots that received 42 pounds of nitrogen per acre per year.

The rainfall period April 1 to cutting date was assumed to be representative of the precipitation during the normal growing season of the grasses. Significant correlations were obtained for all four comparisons, the average yield of all plots, the average yield of the plots that received no fertilizer, the average yield of those plots that received 21 pounds of nitrogen per acre, and those plots that received 42 pounds of nitrogen per acre. A regression was calculated for these relationships and one of the correlations—the inches of rainfall from April 1 to harvest date—related to the pounds of forage for the yields of prairie hay by year for the period 1929-1946 is shown in Figure 1.

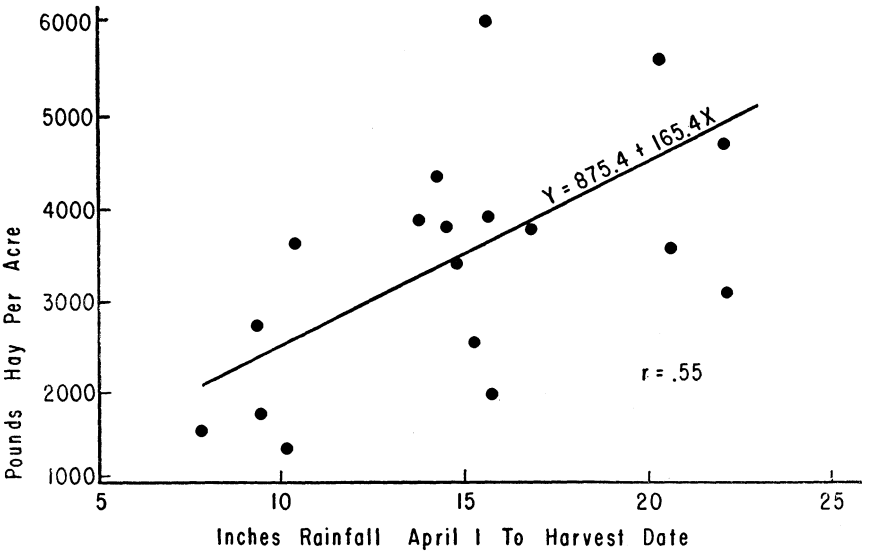

Fig. 1—Influence of rainfall on average yields of prairie hay 1929-1946, Stillwater, Oklahoma.

The amount and distribution of rainfall was obviously a governing factor in determining the yields of prairie hay obtained during each year of the experiment. The amount of moisture significantly influenced the response of the prairie grasses to the various nitrogen fertilizer treatments.

Chemical Composition

Chemical analyses for percent nitrogen, phosphorus, potassium and calcium in prairie hay samples taken from the experimental plots each year, 1929-1946, are shown in Table 9, page 14. A summary of the average hay analyses for this period as affected by the various soil fertility treatments is shown in Table 4.

In general, these data indicate that hay from the nitrogen fertilized plots had a higher nitrogen content than hay from plots that received no nitrogen fertilizer. The lowest average nitrogen content for this period was obtained from the check (no fertilizer) plots of .74 percent. The highest average nitrogen content, .851 percent, was obtained from the plots fertilized annually with 42-0-0 as sodium nitrate.

The phosphorus content of hay samples from plots receiving annual applications of superphosphate (20%) was higher than the hay taken from the plots not receiving phosphorus fertilizer. The lowest average phosphorus content of .069 percent was obtained in the hay receiving annual treatments of 42-0-0 as ammonium sulphate. The highest average phosphorus content of .157 percent was contained in

Table 5.—Chemical composition of native prairie hay showing moisture, crude protein, crude fiber, ether extract, nitrogen free extract and ash content from 1929 to 1940, at Stillwater, Oklahoma.

	Chemical Composition in Percent					
Year	Moisture	Protein	Ether Extract*	Crude Fiber*	Nitrogen Free Extract	Ash
1929	4.72	3.87	1.16	32.74	48.72	8.79
1930	5.05	3.93	1.60	29.71	50.68	9.03
1931	5.10	5.44	1.64	30.24	48.05	9.53
1932	5.25	5.63	1.35	30.80	48.72	8.25
1933	5.44	5.56	1.39	31.58	45.11	10.92
1934	4.69	5.13	.99	25.03	45.14	19.02**
1935	5.42	5.06	1.44	30.23	49.61	8.24
1936	5.38	5.19	1.75	27.70	51.19	8.79†
1937	4.44	7.88	1.33	27.94	51.07	7.34
1938	4.12	2.31	1.07	34.88	52.13	5.49
1939	4.08	3.63	1.63	29.02	52.95	8.69
1940	4.30	5.63	1.70	29.35	51.01	8.01

* Analyses for ether extract and crude fiber made by Dr. J. E. Webster, Agricultural Chemistry Department, Oklahoma Agricultural Experiment Station.
** Sample contained 11.46% SiO_2
† Sample contained 1.41% SiO_2

hay from the 0-20-12.5 treatments. Average potassium and calcium content were not related to soil treatment.

The chemical composition of composite hay samples from all plots were collected each year, 1929-1940. Results of analysis on these samples for moisture, protein, ether extract, crude fiber, nitrogen free extract and ash are shown in Table 5. The composition of hay varied within relatively narrow ranges for most of these components with no consistent relationship between annual date of cutting and the variation in composition.

Rainfall and Hay Composition

The three periods of rainfall used in correlations with hay yields were also used to test possible relationships of rainfall and variation in chemical composition.

A summary of correlations obtained from testing the relationships of rainfall and hay composition of percent nitrogen, phosphorus and calcium is presented in Table 6.

Table 6.—The correlations of the amount of rainfall on percent nitrogen, phosphorus and calcium content of prairie hay, 1929-1946.*

	Plot Treatment					Plot Treatment		
Rainfall Periods	All Plots % N	No Fert. % N	21 lb. N % N	42 lb. N % N	All Plots % P	No Fert. % P	20 lb. P_2O_5 % P	All Plots % Ca
November 1 to cutting date	—.29	—.19	—.39	—.27	—.15	.06	—.21	—.28
January 1 to cutting date	—.10	—.28	—.42	—.35	—.31	—.16	—.17	—.32
April 1 to cutting date	—.16	—.15	—.19	—.16	—.08	—.01	—.02	—.32

* A perfect correlation coefficient would be 1.00 or −1.00.

Table 7.—Date of cutting prairie grass for hay and chemical analyses, Stillwater, Oklahoma, 1929 to 1951.

Year	Month	Day	Year	Month	Day
1929	August	20	1940	August	24
1930	August	6	1941	August	6
1931	August	6	1942	July	31
1932	August	29	1943	July	20
1933	September	20	1944	August	4
1934	November	10	1945	August	26
1935	July	17	1946	August	6
1936	July	10	1947	August	8
1937	September	8	1948	August	7
1938	November	1*	1949	August	3
1939	October	20	1950	July	29
			1951	July	26

* Cut late to permit grass to mature seed and improve stand following the effects of severe drouth from 1933 to 1937.

The nitrogen content of hay from all plots was negatively related to rainfall. Nitrogen content was lowered as the amount of rainfall increased during the three periods tested. This negative relationship was consistent and was greater for hay from the plots that received nitrogen fertilizer annually.

Phosphorus content of hay decreased as the amount of rainfall increased during these three rainfall periods. Essentially the same relationships held regardless of the annual phosphorus fertilization treatment. Calcium content of hay from all plots was also negatively related to rainfall during these three rainfall periods.

The negative influence of rainfall for the period January 1 to harvest date, 1929-1946, and percent nitrogen content of hay from all plots fertilized annually with 21 pounds nitrogen during this period is shown in Figure 2.

Soil Analyses

Each plot in this field experiment was carefully sampled in 1943 following the 15 years of fertilizer treatment. Soil samples were col-

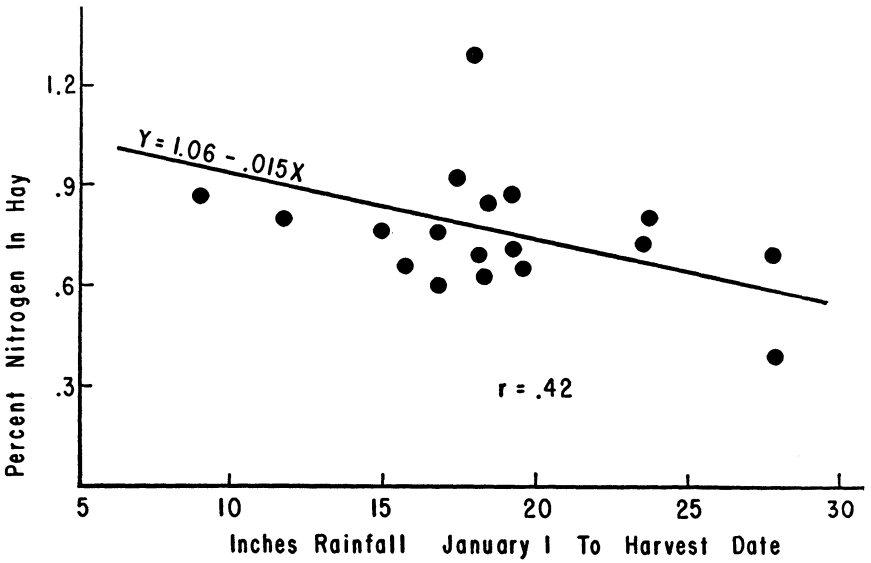

Fig. 2—Influence of rainfall on average nitrogen content of prairie hay fertilized annually with 21 pounds nitrogen per acre, 1929-1946, Stillwater, Oklahoma.

Table 8.—Average yields of prairie hay as affected by various soil fertility treatments, Stillwater, Oklahoma, 1929-1951.†

No.	Fert. Treat. (lbs./acre)	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
1.	Check (no fert.)	3341	3182	1191	4900	3550	1650	3880	1389	1903	2664	2635
2.	0-20-0	3406	2835	981	5150	3865	1850	3960	1810	2080	2794	2735
3.	0-20-12.5	2889	2790	1030	4720	3050	1560	4000	1425	2091	3060	2530
4.	21-0-0 $(NH_4)_2SO_4$	3447	3533	1172	5175	2940	1795	5080	1570	1906	2902	2290
5.	21-0-0 $NaNO_3$	3570	3668	1204	5835	3325	2100	5210	1535	1688	2946	2320
6.	42-0-0 $(NH_4)_2SO_4$	3870	3690	1063	5910	2833	1925	4200	1450	1884	3289	2765
7.	42-0-0 $NaNO_3$	3543	4140	1025	5355	3978	1560	4520	1390	1645	3322	2560
8.	21-20-12.5 $(NH_4)_2SO_4$	3679	4050	1401	4370	3160	1195	4520	1675	2124	2636	2665
9.	21-20-12.5 $NaNO_3$	3652	4185	1352	5700	2995	1335	4600	1675	2015	2881	2640
10.	42-20-12.5 $(NH_4)_2SO_4$	4360	4680	1534	6540	2778	1750	4240	1705	2233	4171	2680
11.	42-20-12.5 $NaNO_3$	4523	4485	1539	6435	4250	2410	4680	1550	1731	3933	2580
	Average	3576	3597	1217	5313	3395	1717	4294	1482	1924	3020	2629
	Stnd. Error	541	356	229	7.49	547	379	374	165	256	413	235
	Treatment F	1.65	7.78*	1.58	2.03	1.78	1.65	4.10	1.63	1.14	3.82	1.15

No.	Fert. Treat. (lbs./acre)	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1.	Check (no fert.)	3831	3537	4896	3995	3427	4732	2603	4180		4343	5193	3125
2.	0-20-0	359	473	404	384	3825	6861	2342	4950		6049	5120	4518
3.	0-20-12.5	7.06*	6.77*	2.72	2.07	3660	6643	2995	4650		5584	5825	4680
4.	21-0-0 $(NH_4)_2SO_4$	3430	2780	4486	3708	4295	5652	2287	4400		4188	4685	3050
5.	21-0-0 $NaNO_3$	3420	3261	5173	4450	4245	6953	2505	4300		4395	4575	2885
6.	42-0-0 $(NH_4)_2SO_4$	3605	3436	4901	4150	3555	5570	2396	4200		4395	4305	3700
7.	42-0-0 $NaNO_3$	3583	3420	4846	3390	3920	6480	2723	4300		4602	5175	3485
8.	21-20-12.5 $(NH_4)_2SO_4$	3528	3572	5173	4180	4543	6006	2723	4350		5274	5935	4355
9.	21-20-12.5 $NaNO_3$	4651	3997	4846	3945	4930	7899	3222	5000		5325	3540	3595
10.	42-20-12.5 $(NH_4)_2SO_4$	3932	3332	4630	3950	4015	7329	3594	5450		6256	5500	5225
11.	42-20-12.5 $NaNO_3$	4106	4356	5227	4425	4305	7639	3430	4950		5894	6315	4738
	Average	3659	4215	5064	4220	3962	6045	2755	4497		4912	5169	3724
	Stnd. Error	5249	5020	5391	4415	492	937	435					
	Treatment F	4585	4552	5771	4265	2.01	4.23	2.36					

† Check (no fertilizer) yields represent the mean from 10 plots. Other treatment yields are means of two plots for each fertilizer treatment. The 1948 yield figures were lost. No fertilizer was applied after 1946.
* Indicates significance at the 0.05 level.

lected at depths of 0 to 3 inches, 3 to 6 inches, and 6 to 12 inches. Soil analyses included pH, percent organic matter, percent total nitrogen, total exchangable bases, exchangable calcium and soluble phosphorus. A detailed summary of the results of these soils analyses are presented in Table 10, page 19.

The percent organic matter and percent total nitrogen in the soil were essentially the same for all plots in the field experiment regardless of soil fertility treatment.

Soil pH was slightly lower in the 0 to 3 inch soil samples from those plots fertilized with ammonium sulphate. This increase in soil acidity was reflected in slightly lower total exchangable bases and exchangable calcium in these surface soil samples. Ammonium sulphate is an acidic type of fertilizer material and continued application in large amounts may be expected to influence soil reaction.

The soluble phosphorus content of the 0 to 3 inch soil samples was slightly higher for all plots that received annual applications of superphosphate equivalent to 20 pounds P_2O_5 per acre.

Summary

The effect of 18 years continuous fertilization on yields and chemical composition of prairie hay was studied during the period 1929-1946. Residual effects of these fertilizer treatments were measured during the period 1947-1952. Yield data for 1948 were lost.

Significant differences in hay yield as a result of fertilizer treatment were obtained in three of the 18 years that fertilizer was applied. The highest average yield, 4039 pounds per acre, was obtained from plots receiving the equivalent of 42-20-12.5 applied per acre with sodium nitrate as the nitrogen carrier. This average yield was 942 pounds higher than the average of the check (no fertilizer) plots for this period.

The average yield of the check plots for the period 1947-1952 were higher than average yields from three treatments that had previously received nitrogen fertilizer.

The amount and distribution of rainfall was a governing factor in determining yields of prairie hay and significantly influenced response to nitrogen fertilization.

Hay from plots fertilized with nitrogen had higher contents of nitrogen than hay receiving no nitrogen fertilization. The phosphorus content of hay samples from plots fertilized with superphosphate was higher than hay from plots that did not receive the treatment.

Nitrogen, phosphorus and calcium content of hay decreased with increasing amounts of rainfall that occurred during seasonal periods

preceding the hay harvest.

There was essentially no difference in chemical characteristics of the soil following 15 years of continuous differential fertilizer treatment. Soil pH of surface soil samples (0-3 inch depth) from plots fertilized with ammonium sulphate were slightly lower than the soil samples from other fertilizer treatments.

Table 9.—Chemical composition of native prairie hay harvested from fertilized and unfertilized plots on series 4400, Okla. Agri. Exp. Sta. (Agronomy Farm) during the 22 year period, 1929-1950.

Treatment & rate in pounds per acre	1929				1930				1931				1932			
	N	P	K	Ca	N	P	K	Ca	N	P	K	Ca	N	P	K	Ca
None	0.63	0.09	1.19	0.30	0.65	0.07	1.10	0.47	0.76	0.09	0.92	0.61	0.96	0.14	1.13	0.32
Sodium Nitrate-137	0.66	0.08	1.16	0.31	0.64	0.07	1.04	0.50	0.83	0.08	0.85	0.58	0.91	0.10	1.21	0.35
Sodium Nitrate-274	0.56	0.11	1.31	0.23	0.69	0.06	1.28	0.68	0.93	0.08	0.92	0.68	1.04	0.12	*	0.29
Ammonium Sulphate-200	0.66	0.07	1.15	0.24	0.77	0.06	1.29	0.83	0.83	0.07	0.95	0.54	0.80	0.11	*	0.26
Sodium Nitrate-137 Superphosphate-100 Muriate of Potash-25	0.57	0.09	1.19	0.28	0.65	0.11	1.34	0.73	0.67	0.11	0.86	0.53	0.65	0.14	0.89	0.28
Ammonium Sulphate-100 Superphosphate-100 Muriate of Potash-25	0.58	0.10	1.19	0.26	0.68	0.11	1.37	0.71	0.82	0.10	0.90	0.55	0.79	0.13	*	0.32
Sodium Nitrate-274 Superphosphate-100 Muriate of Potash-25	0.60	0.08	1.24	0.25	0.66	0.08	1.22	0.48	0.77	0.09	0.78	0.52	1.06	0.09	*	0.32
Ammonium Sulphate-200 Superphosphate-100 Muriate of Potash-25	0.64	0.09	1.20	0.32	0.69	0.08	1.24	0.33	0.89	0.10	0.72	0.40	0.89	0.09	*	0.32
Superphosphate-100 Muriate of Potash-25	0.60	0.10	1.05	0.31	0.68	0.08	1.17	0.42	0.57	0.11	0.86	0.55	0.87	0.10	*	0.39
Superphosphate-100	0.61	0.08	1.05	0.23	0.59	0.09	0.98	0.33	0.77	0.11	0.97	0.61	0.95	0.14	*	0.32
Ammonium Sulphate-100	0.63	0.07	1.18	0.25	0.65	0.07	1.20	0.52	0.82	0.07	0.96	0.51	0.82	0.10	1.24	0.30

*Samples were discarded before the analyses were made.

Table 9.—Continued

Treatment & rate in pounds per acre	1933				1934				1935				1936			
	N	P	K	Ca	N	P	K	Ca	N	P	K	Ca	N	P	K	Ca
None	0.86	0.13	1.18	0.51	0.85	0.11	0.70	0.54	0.76	0.09	1.57	0.30	0.73	0.09	1.45	0.50
Sodium Nitrate-137	0.81	0.11	0.98	0.49	0.93	0.08	0.55	0.54	0.81	0.08	1.63	0.38	0.81	0.09	1.43	0.48
Sodium Nitrate-274	0.92	0.15	1.12	0.50	0.78	0.09	0.51	0.54	0.87	0.08	1.54	0.24	0.87	0.09	1.71	0.42
Ammonium Sulphate-200	0.84	0.14	1.10	0.50	0.71	0.07	0.49	0.53	0.78	0.06	1.45	0.27	0.89	0.08	1.55	0.48
Sodium Nitrate-137 Superphosphate-100 Muriate of Potash-25	0.80	0.19	1.07	0.68	0.83	0.11	0.63	0.53	0.72	0.10	1.64	0.31	0.93	0.14	1.51	0.51
Ammonium Sulphate-100 Superphosphate-100 Muriate of Potash-25	0.73	0.16	1.18	0.46	0.69	0.07	0.49	0.50	0.75	0.11	1.61	0.23	0.80	0.16	1.48	0.50
Sodium Nitrate-274 Superphosphate-100 Muriate of Potash-25	0.98	0.12	1.32	0.41	0.79	0.09	0.61	0.49	0.78	0.11	0.85	0.29	0.88	0.14	1.61	0.43
Ammonium Sulphate-200 Superphosphate-100 Muriate of Potash-25	1.35	0.11	0.55	0.58	0.63	0.06	0.37	0.54	0.84	0.11	1.39	0.30	0.97	0.16	1.47	0.45
Superphosphate-100 Muriate of Potash-25	0.78	0.11	1.12	0.65	0.60	0.05	0.52	0.57	0.75	0.13	1.73	0.29	0.73	0.15	1.61	0.44
Superphosphate-100	0.80	0.15	1.07	0.57	0.72	0.10	0.52	0.54	0.72	0.13	1.35	0.28	0.71	0.16	1.60	0.45
Ammonium Sulphate-100	0.82	0.14	1.10	0.52	0.79	0.06	0.49	0.55	0.74	0.07	1.48	0.26	0.83	0.08	1.61	0.50

Table 9.—Continued

Treatment & Rate in pounds per acre	1937					1938					1939				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
None	1.23	0.14	1.59	0.31	0.16	0.33	0.04	0.58	0.19	0.08	0.53	0.05	0.42	0.31	0.12
Sodium Nitrate-137	1.35	0.15	1.79	0.25	0.14	0.41	0.03	0.60	0.16	0.06	0.59	0.04	0.43	0.29	0.11
Sodium Nitrate-274	1.29	0.13	1.74	0.28	0.19	0.40	0.03	0.59	0.16	0.08	0.70	0.05	0.41	0.30	0.14
Ammonium Sulphate-200	1.23	0.11	1.72	0.27	0.17	0.38	0.03	0.59	0.14	0.07	0.67	0.04	0.41	0.29	0.12
Sodium Nitrate-137 Superphosphate-100 Muriate of Potash-25	1.30	0.16	1.55	0.31	0.16	0.40	0.10	0.69	0.20	0.05	0.60	0.07	0.40	0.34	0.13
Ammonium Sulphate-100 Superphosphate-100 Muriate of Potash-25	1.26	0.17	1.75	0.28	0.18	0.43	0.10	0.66	0.19	0.09	0.69	0.08	0.44	0.33	0.13
Sodium Nitrate-274 Superphosphate-100 Muriate of Potash-25	1.41	0.16	1.56	0.34	0.20	0.39	0.09	0.74	0.16	0.08	0.76	0.08	0.56	0.28	0.12
Ammonium Sulphate-200 Superphosphate-100 Muriate of Potash-25	1.39	0.15	1.72	0.28	0.11	0.36	0.06	0.78	0.14	0.08	0.71	0.08	0.44	0.31	0.12
Superphosphate-100 Muriate of Potash-25	1.23	0.16	1.50	0.26	0.13	0.34	0.08	0.56	0.17	0.07	0.53	0.07	0.44	0.26	0.09
Superphosphate-100	1.23	0.18	1.50	0.27	0.13	0.32	0.08	0.69	0.16	0.06	0.56	0.07	0.46	0.34	0.11
Ammonium Sulphate-100	1.33	0.14	1.70	0.30	0.16	0.33	0.04	0.61	0.18	0.07	0.58	0.04	0.36	0.31	0.11

Table 9.—Continued

	1940					1941				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
None	0.82	0.09	1.00	0.39	0.16	0.59	0.06	1.29	0.40	0.19
Sodium Nitrate-137	0.94	0.09	1.18	0.32	0.14	0.70	0.06	1.28	0.37	0.18
Sodium Nitrate-274	0.97	0.08	1.05	0.32	0.16	0.71	0.06	1.38	0.33	0.20
Ammonium Sulphate-200	0.98	0.08	1.15	0.34	0.15	0.65	0.07	1.26	0.33	0.18
Sodium Nitrate-137 Superphosphate-100 Muriate of Potash-25	0.96	0.16	1.11	0.39	0.17	0.66	0.12	1.39	0.35	0.20
Ammonium Sulphate-100 Superphosphate-100 Muriate of Potash-25	0.92	0.14	1.06	0.38	0.16	0.60	0.12	1.35	0.38	0.18
Sodium Nitrate-274 Superphosphate-100 Muriate of Potash-25	1.20	0.16	1.43	0.33	0.14	0.64	0.09	1.56	0.34	0.18
Ammonium Sulphate-200 Superphosphate-100 Muriate of Potash-25	1.05	0.16	1.36	0.33	0.14	0.64	0.10	1.48	0.35	0.16
Superphosphate-100 Muriate of Potash-25	0.84	0.14	1.71	0.41	0.14	0.55	0.15	1.44	0.36	0.17
Superphosphate-100 Ammonium Sulphate-100	0.84	0.15	1.13	0.40	0.14	0.60	0.14	1.37	0.37	0.16
	0.93	0.09	1.21	0.37	0.14	0.68	0.06	1.38	0.41	0.18

Table 9.—Continued

	1942					1943					1944				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
None	0.72	0.07	1.40	0.35	0.19	0.74	0.06	1.41	0.55	0.21	0.82	0.06	1.24	0.44	0.29
Sodium Nitrate-137	0.83	0.07	1.30	0.35	0.15	0.89	0.06	1.44	0.47	0.24	0.89	0.06	1.27	0.42	0.29
Sodium Nitrate-274	0.85	0.06	1.35	0.33	0.20	1.00	0.06	1.39	0.63	0.19	1.06	0.06	1.29	0.40	0.27
Ammonium Sulphate-200	0.75	0.06	1.34	0.33	0.19	1.04	0.05	1.40	0.53	0.17	0.93	0.05	0.94	0.43	0.27
Sodium Nitrate-137 Superphosphate-100 Muriate of Potash-25	0.81	0.16	1.42	0.36	0.18	0.94	0.13	1.62	0.51	0.24	0.87	0.11	1.47	0.51	0.31
Ammonium Sulphate-100 Superphosphate-100 Muriate of Potash-25	0.79	0.16	1.39	0.39	0.17	0.86	0.13	1.55	0.51	0.19	0.85	0.13	1.48	0.46	0.27
Sodium Nitrate-274 Superphosphate-100 Muriate of Potash-25	0.83	0.16	1.61	0.33	0.23	1.04	0.12	1.62	0.60	0.23	0.94	0.10	1.71	0.45	0.28
Ammonium Sulphate-200 Superphosphate-100 Muriate of Potash-25	0.76	0.14	1.52	0.31	0.19	0.97	0.11	1.69	0.58	0.18	0.91	0.11	0.96	0.52	0.27
Superphosphate-100 Muriate of Potash-25	0.82	0.15	1.58	0.34	0.13	0.98	0.13	1.65	0.63	0.16	0.81	0.14	1.17	0.49	0.30
Superphosphate-100 Muriate of Potash-25	0.80	0.15	1.44	0.36	0.16	1.00	0.11	1.48	0.67	0.17	0.82	0.14	1.03	0.48	0.26
Ammonium Sulphate-100	0.81	0.07	1.31	0.31	0.15	0.86	0.07	1.60	0.63	0.17	0.91	0.06	1.31	0.44	0.28

Table 9.—Continued

	1945				1946				1947			
	N	P	K	Ca	N	P	K	Ca	N	P	K	Ca
None	0.73	0.05	1.36	0.34	0.69	0.05	1.02	0.49	0.69	0.05	1.40	0.47
Sodium Nitrate-137	0.76	0.05	1.32	0.34	0.71	0.05	1.03	0.45	0.72	0.05	1.53	0.47
Sodium Nitrate-274	0.88	0.05	1.38	0.30	0.81	0.04	0.99	0.41	0.78	0.04	1.33	0.43
Ammonium Sulphate-200	0.92	0.05	1.48	0.31	0.73	0.04	0.94	0.44	0.73	0.05	1.47	0.48
Sodium Nitrate-137 Superphosphate-100 Muriate of Potash-25	0.72	0.07	1.52	0.33	0.75	0.10	0.97	0.54	0.72	0.09	1.39	0.48
Ammonium Sulphate-100 Superphosphate-100 Muriate of Potash-25	0.74	0.07	1.42	0.39	0.72	0.10	1.09	0.50	0.69	0.10	1.46	0.48
Sodium Nitrate-274 Superphosphate-100 Muriate of Potash-25	0.83	0.06	1.76	0.31	0.71	0.10	1.05	0.49	0.69	0.08	1.45	0.49
Ammonium Sulphate-200 Superphosphate-100 Muriate of Potash-25	0.86	0.07	1.73	0.33	0.76	0.10	1.16	0.49	0.68	0.10	1.46	0.48
Superphosphate-100 Muriate of Potash-25	0.75	0.08	1.59	0.31	0.73	0.12	1.24	0.49	0.67	0.11	1.64	0.48
Superphosphate-100	0.79	0.08	1.64	0.35	0.75	0.12	1.23	0.56	0.76	0.11	1.76	0.43
Ammonium Sulphate-100	0.77	0.05	1.46	0.32	0.72	0.04	1.10	0.48	0.70	0.04	1.43	0.47

Table 9.—Continued.

Treatment & rate in pounds per acre	1948				1949				1950				
	N	P	K	Ca	N	P	K	Ca	N	P	K	Ca	Mg
None	0.93	0.08	1.26	0.40	1.36	0.05	1.34	0.39	0.71	0.08	0.84	0.33	0.15
Sodium Nitrate-137	0.92	0.08	1.23	0.39	1.35	0.05	1.35	0.46	0.67	0.09	0.82	0.45	0.15
Sodium Nitrate-137	0.97	0.08	1.34	0.37	1.31	0.05	1.36	0.38	0.71	0.07	0.87	0.42	0.11
Muriate of Potash-25	0.98	0.08	1.31	0.37	1.38	0.06	1.45	0.36	0.68	0.07	0.96	0.26	0.14
Sodium Nitrate-274	0.96	0.10	1.25	0.44	1.22	0.08	1.27	0.40	0.68	0.10	0.83	0.30	0.16
Ammonium Sulphate-200	0.96	0.11	1.33	0.41	1.16	0.08	1.38	0.40	0.65	0.10	0.84	0.40	0.12
Superphosphate-100													
Ammonium Sulphate-100													
Superphosphate-100	0.98	0.11	1.43	0.35	1.28	0.09	1.34	0.36	0.76	0.11	0.89	0.24	0.14
Muriate of Potash-25													
Sodium Nitrate-274													
Superphosphate-100													
Muriate of Potash-25													
Ammonium Sulphate-200	1.01	0.13	1.58	0.39	1.41	0.10	1.48	0.38	0.73	0.10	0.81	0.41	0.13
Superphosphate-100													
Muriate of Potash-25													
Superphosphate-100	1.09	0.12	1.54	0.34	1.27	0.10	1.46	0.40	0.69	0.07	0.81	0.26	0.14
Muriate of Potash-25													
Superphosphate-100	0.95	0.11	1.40	0.34	1.49	0.09	1.41	0.42	0.71	0.10	0.80	0.28	0.19
Ammonium Sulphate-100	1.35	0.07	1.23	0.43	1.33	0.05	1.31	0.38	0.66	0.07	0.80	0.28	0.15

Table 10.—Results from soil analyses following 15 years of various fertilizer treatments on native grass, 1929-1943.

Soil Depth— Plot No.	pH 0-3	pH 3-6	pH 6-12	O. M.% 0-3	O. M.% 3-6	O. M.% 6-12	Total N% 0-3	Total N% 3-6	Total N% 6-12	Total Exch. Bases me./100 gms. 0-3	Total Exch. Bases me./100 gms. 3-6	Total Exch. Bases me./100 gms. 6-12	Exch. Ca me./100 gms. 0-3	Exch. Ca me./100 gms. 3-6	Exch. Ca me./100 gms. 6-12	Soluble P ppm 0-3	Soluble P ppm 3-6	Soluble P ppm 6-12
Check 1	6.2	6.0	5.8	3.7	3.1	2.5	.16	.14	.11	12.8	11.9	12.7	9.6	8.8	9.0	10	6	5
Treat- 4	6.2	5.9	5.8	4.1	3.3	2.6	.17	.14	.12	12.8	11.7	13.2	9.0	8.8	9.2	9	6	5
ment 7	6.1	5.8	5.7	3.9	3.1	2.7	.18	.14	.13	13.0	11.4	11.7	9.5	8.4	8.2	11	7	5
10	6.1	6.1	5.8	3.8	2.8	2.7	.17	.14	.13	12.2	10.5	11.2	9.1	7.5	7.1	13	9	5
13	6.1	5.9	5.9	3.6	2.8	2.8	.16	.12	.14	12.0	10.0	10.9	8.9	7.1	7.6	13	8	5
16	6.2	6.1	5.7	3.8	3.3	3.0	.16	.14	.13	12.6	11.7	12.0	9.5	8.8	8.8	13	9	5
19	6.4	6.2	6.2	4.2	3.1	3.1	.18	.16	.14	12.4	11.1	11.8	9.4	8.3	8.3	10	5	5
22	6.5	6.2	6.1	3.9	3.1	2.4	.17	.14	.12	11.8	10.0	10.3	8.8	7.3	7.0	10	6	4
25	6.2	6.0	5.9	4.3	2.7	2.3	.18	.14	.12	12.3	9.5	9.6	9.2	7.0	6.8	12	7	5
28	6.2	6.0	5.9	4.3	2.7	2.2	.17	.13	.11	11.0	9.1	9.4	8.0	6.6	6.7	11	6	5
0-20-0																		
14	6.1	5.9	5.8	4.2	3.1	2.5	.19	.14	.11	11.7	10.3	10.9	9.4	7.6	7.7	24	10	5
26	6.3	6.1	6.0	4.0	2.8	2.3	.18	.13	.10	12.3	9.4	9.6	9.5	6.9	6.8	18	9	5
0-20-12.5																		
15	6.1	5.9	5.8	4.0	3.4	3.0	.17	.14	.12	12.5	9.6	10.5	9.8	7.0	7.5	18	8	6
27	6.1	5.9	5.8	4.3	3.0	2.2	.18	.13	.12	11.5	8.9	9.3	8.9	6.8	6.5	18	8	5
21-0-0 $(NH_4)_2SO_4$																		
3	5.9	5.8	5.8	4.0	3.4	3.1	.18	.15	.13	11.9	11.8	12.6	9.0	8.6	9.2	9	7	5
30	5.7	5.9	6.0	3.8	2.7	2.1	.18	.14	.11	9.4	8.8	9.8	7.1	6.6	6.8	10	6	4
21-0-0 $NaNO_3$																		
2	6.3	6.2	6.0	3.9	3.0	2.6	.18	.14	.11	13.2	12.2	13.0	9.9	9.1	9.1	10	7	5
29	6.1	6.0	6.1	4.1	2.8	2.4	.18	.14	.11	11.0	9.0	9.6	8.2	6.6	6.5	12	6	4
42-0-0 $(NH_4)_2SO_4$																		
9	5.2	5.7	5.8	3.8	2.9	2.8	.17	.14	.16	8.3	9.7	11.2	6.5	7.4	8.0	10	8	5
21	5.8	6.0	6.2	3.8	3.0	2.5	.18	.14	.11	9.0	10.1	10.8	7.1	7.8	7.6	8	6	4
42-0-0 $NaNO^3$																		
8	6.0	6.1	6.2	3.6	3.1	2.6	.16	.14	.12	11.1	11.2	12.2	8.1	8.3	8.2	9	6	4
20	6.4	6.6	6.7	3.8	3.0	2.7	.18	.14	.11	11.9	10.6	11.2	8.2	7.7	7.4	10	6	4
21-20-12.5 $(NH_4)_2SO_4$																		
6	5.8	5.8	5.7	4.1	3.3	2.8	.18	.15	.13	12.0	11.0	12.3	9.2	8.2	8.7	18	7	5
18	6.1	6.1	6.1	4.3	3.2	2.6	.18	.14	.12	11.7	11.0	11.7	8.9	8.6	8.5	20	8	5

Table 10.—Continued.

Soil Depth— Plot No.	pH 0-3	pH 3-6	pH 6-12	O. M.% 0-3	O. M.% 3-6	O. M.% 6-12	Total N% 0-3	Total N% 3-6	Total N% 6-12	Total Exch. Bases me./100 gms. 0-3	Total Exch. Bases me./100 gms. 3-6	Total Exch. Bases me./100 gms. 6-12	Exch. Ca me/100 gms. 0-3	Exch. Ca me/100 gms. 3-6	Exch. Ca me/100 gms. 6-12	Soluble P ppm 0-3	Soluble P ppm 3-6	
21-20-12.5 $NaNO_3$																		
5	6.1	6.0	5.8	4.2	3.4	2.9	.19	.16	.13	13.3	11.5	12.5	9.8	8.7	8.9	20	8	6
17	6.4	6.3	6.3	4.4	3.3	3.0	.17	.13	.12	13.8	12.0	12.2	10.5	9.1	8.9	17	9	5
42-20-12.5 $(NH_4)_2SO_4$																		
12	5.3	5.7	5.8	3.5	3.1	2.4	.16	.14	.11	8.9	9.8	11.0	6.9	7.5	7.9	22	9	5
24	5.7	6.0	6.1	4.0	3.1	2.8	.18	.13	.11	8.7	8.9	10.1	7.1	7.2	7.5	15	9	5
42-20-12.5 $NaNO_3$																		
11	5.9	6.0	6.1	3.4	3.1	2.8	.15	.15	.13	11.5	10.5	11.2	8.3	7.6	7.5	24	9	6
23	6.3	6.5	6.6	3.6	2.9	2.4	.16	.13	.10	11.5	10.5	10.8	9.0	8.1	7.5	13	7	5

Table 11.—Rainfall data in inches per month, Agronomy Farm, Stillwater, Oklahoma, 1929-1951.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1929	.19	1.66	4.19	7.97	8.99	2.11	2.66	.43	2.66	4.38	1.74	.10	37.08
1930	2.13	2.15	.35	2.47	6.23	2.36	.04	3.84	.91	2.02	1.36	2.19	26.05
1931	.86	1.04	2.15	2.88	2.02	2.24	3.56	3.04	1.97	1.09	8.49	.44	29.78
1932	3.74	1.95	.34	.56	2.11	6.43	7.69	4.22	.75	1.25	.50	3.85	33.39
1933	.32	1.41	6.04	2.21	2.19	.02	3.93	5.08	1.73	4.25	2.40	1.85	31.43
1934	1.99	.85	1.05	2.48	2.58	1.58	.63	2.56	7.38	2.60	2.54	.87	27.11
1935	.67	1.38	3.12	1.74	2.76	9.02	.70	3.38	2.51	2.13	2.46	2.02	31.89
1936	.12	.14	.02	1.33	4.44	2.01	.48	.00	5.91	2.74	.04	1.46	18.69
1937	.52	.16	1.14	1.79	2.63	6.68	1.64	3.61	2.59	2.68	2.71	1.20	27.35
1938	.61	2.71	6.38	5.32	5.46	4.51	3.33	4.06	2.54	.26	2.73	.48	38.39
1939	2.80	.45	1.05	2.62	2.40	4.16	3.14	3.16	.17	1.16	1.36	.69	23.16
1940	.47	3.15	.16	5.85	1.11	3.81	2.57	5.19	1.08	.90	4.59	1.75	30.63
1941	.65	1.83	.43	3.29	7.12	3.77	.85	2.13	4.93	9.73	1.34	1.59	37.66
1942	1.10	1.41	.49	9.87	.94	9.69	1.24	7.19	3.54	1.75	.53	1.93	39.68
1943	.00	.60	1.25	1.36	12.89	1.09	.55	1.91	2.87	3.67	.18	3.64	30.01
1944	1.36	1.43	1.96	5.22	2.91	4.02	1.93	2.82	3.23	2.76	5.50	2.26	35.40
1945	.99	1.40	1.64	3.91	.53	7.90	2.75	1.44	16.17	.71	.00	.07	37.51
1946	3.55	1.46	3.05	1.95	3.99	3.31	.18	3.65	1.51	.45	4.69	.69	28.48
1947	.65	.09	.62	8.22	6.74	2.67	2.01	.33	1.89	.48	1.27	1.50	26.47
1948	.10	1.24	3.11	2.83	3.41	6.89	3.83	3.73	.07	.31	1.52	.19	27.23
1949	4.47	1.07	1.55	1.57	9.35	2.29	2.73	2.13	4.62	3.32	.00	1.47	34.57
1950	.89	1.19	.39	1.58	5.23	2.16	6.58	3.06	1.25	.27	.88	.03	23.51
1951	1.05	2.45	.90	4.27	4.41	5.40	3.80	3.04	7.47	3.72	1.59	.05	38.15
Average	1.27	1.36	1.80	3.53	4.37	4.09	2.47	3.04	3.38	2.29	2.11	1.32	31.03