YIELD AND COMPOSITION OF CORN FORAGE as Influenced by Soil Fertilization

By K. E. Harshbarger, W. B. Nevens,
R. W. Touchberry, A. L. Lang,
G. H. Dungan

Bulletin 577
UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION

CONTENTS

The courtesy of the Coke Oven Ammonia Research Bureau, Inc., the Midwest Soil Improvement Committee, and the Spencer Chemical Company in furnishing the fertilizer and a portion of the funds used in this investigation is gratefully acknowledged. The authors are indebted to Dorothy Dillon, Assistant in Dairy Science, and F. E. Walker, student assistant in Dairy Science, for aid in computing the analyses of variance, and to Robert Kern and David McConnell for completing the chemical analyses of samples.

Urbana, Illinois June, 1954

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station

Yield and Composition of Corn Forage as Influenced by Soil Fertilization

By K. E. Harshbarger, W. B. Nevens, R. W. Touchberry, A. L. Lang, and G. H. Dungan[1]

THE RAPIDLY EXPANDING USE of fertilizers in the production of corn has raised questions concerning the effect of fertilizer application on the yield of corn forage. Does the use of fertilizer increase only the grain yield, or is the larger yield of grain accompanied by an increase in the weight of leaves and stalks? Reports indicate that soil fertilization may enhance the protein content of corn grain. Does it also increase the protein content of the stalks and leaves? To answer these questions an investigation was carried out during the five years 1947 through 1951. This publication presents a brief report of the results obtained.

PREVIOUS INVESTIGATIONS

Many investigations of the effect of soil fertilization on the composition of the corn plant have been made. A few representative reports of such investigations are briefly reviewed here.

In all cases fertilization of soils not containing an adequate supply of plant nutrients increased the yield of corn forage or corn grain. Several investigators reported (1, 2, 5, 6, 7, 8, 10, 12)[2] a higher percentage of protein in corn forage grown on fertilized plots than in corn forage grown on comparable unfertilized plots. In some of these experiments (1, 8, 10, 12), the composition of the grain and stover was determined separately, with indications that fertilization had enhanced the protein content of both portions of the crop. A favorable effect of nitrogen fertilization on the protein content of corn grain was reported by several investigators (1, 3, 4, 8, 9), although in one instance (11) the report showed a lower protein content of the grain when the soil was treated with manure. Hamilton *et al* (3) investigated the composition of corn grain grown on plots which had been under the same

[1] K. E. Harshbarger, Assistant Professor of Dairy Production; W. B. Nevens, Professor of Dairy Cattle Feeding; R. W. Touchberry, Assistant Professor of Dairy Cattle Genetics; A. L. Lang, Professor of Soil Fertility; and G. H. Dungan, Professor of Crop Production.

[2] See "Literature Cited," pages 18 and 19.

system of soil treatments for 70 years. They reported that "fertilization applied to the soil in these plots definitely increased the weight of the kernel, and the (percentage) content of protein, fat, and total phosphorus." Whitson *et al* (11) also found that the cropping system influenced the protein content of the corn crop.

In several of the investigations mentioned above, the conclusions were based upon yields and analyses of mature grain and stover. The objective of the experiment reported in this paper was to determine the effect of soil fertilization upon the yield and composition of corn forage at the silage-harvest stage.

PRESENT INVESTIGATION

The corn was grown on fields of the Dairy Science farm. During the first three years of the trials, the experimental field (P) was one which had grown chiefly corn and alfalfa and had received frequent heavy applications of barnyard manure. In 1950 and 1951, the experimental field (M) was part of a recently purchased farm which had been operated for many years in a cash-grain system of farming. The productivity of this field was relatively low.

The two fields used are on dark to moderately dark-colored soils that developed under prairie vegetation. Field P, used during 1947, 1948, and 1949, is on Drummer silty clay loam, Brenton silt loam, and Proctor silt loam. The productivity indexes for these soil types for the production of forage are 110, 120, and 115, respectively.[1] Field M, used during 1950 and 1951 is on Drummer silty clay loam and Brooklyn, Thorp, and Flanagan silt loams. The productivity indexes of the latter soil types for the production of forage are 110, 75, 90, and 125, respectively, or somewhat lower, on the whole, than those of field P. The productivity index indicates the relative ability of the soil type to produce the major forage crops grown in the region when the soil is cleared, drained, and treated with limestone, phosphate, and potash where needed in amounts as indicated by soil tests. A forage-crop index of 100 indicates a yield per acre of approximately 2½ tons of hay or 120 pasture-days per animal unit.

Each experimental block was 247 feet long and contained four rows of each of five hybrids, or a total of 20 rows. The corn was drilled in rows 40 inches apart. The plants were spaced from 12 to 16 inches apart in the row (average distance for most plots falling within

[1] Illinois Soil Type Descriptions. Illinois Agricultural Experiment Station AG1433. 1950.

the range of 13 to 15 inches), giving a population of 11,000 to 12,000 plants per acre. Blocks treated with fertilizer were alternated with untreated blocks. The field was four experimental blocks long by two blocks wide, and contained four replications of fertilized and four replications of unfertilized blocks. The field was planted without open cross borders. Before harvest, the corn plants in the one-rod wide cross borders were removed by hand-cutting. Fallow borders were maintained at sides and ends of the field.

The order of planting the hybrids in the different blocks was randomized. The hybrids selected for the test were ones that had been shown by previous silage investigations[1] to be adapted to east-central Illinois for both silage and grain production. They were Illinois Hybrids 206, 784, 972A-1, 2119(W), and U. S. Hybrid 13, identified in the tables as Nos. 1, 2, 3, 4, and 5, respectively. When grown at Urbana, four of these have about the same maturity dates, but Illinois Hybrid 2119(W) usually requires a few more days than the others to reach maturity.

Table 1. — Rates and Method of Applying Fertilizer to Corn Plots

Year	Kind of fertilizer	Pounds applied to the acre	How applied
1947	8-8-8	300	Drilled before planting
	Ammonium sulfate	150	Sidedressed July 15
1948	8-8-8	200	Row dropped
	Ammonium nitrate	200	Sidedressed July 3[a]
1949	8-8-8	200	Row dropped
	Ammonium sulfate	200	Sidedressed at first cultivation
1950	8-8-8	200	Row dropped
	Ammonium sulfate	200	Sidedressed June 30
1951	8-8-8	200	Row dropped
	Ammonium sulfate	200	Sidedressed June 20

[a] Only two of the four "fertilized" plots (Nos. 3 and 7) were sidedressed because the corn had grown so tall that some of it was breaking under the machine.

Fertilizer was applied to the plots at planting time and as a side-dressing at the last cultivation. Details of the fertilizer treatments are shown in Table 1.

Measuring forage yields. The method of measuring the yields on which this report is chiefly based was field sampling of the standing crop. Sampling was started three to four weeks before harvesting the crop for the silo and was carried out at 7- to 10-day intervals. The plants in the four rows of each hybrid in a block were counted and every 35th plant removed by hand-cutting. A sample of a hybrid

[1] Nevens, W. B., and Dungan, G. H. Yields of corn hybrids harvested for silage. Illinois Agricultural Experiment Station Bulletin 533. 1949.

from one block contained from 20 to 30 plants, except in 1947 when a thinner stand resulted in samples containing only 15 to 20 plants. Each sample was tied and tagged and taken at once to the Agronomy field laboratory, where it was weighed and the ears removed. The ears were weighed and placed on drying racks, where they remained for several weeks. When they had reached air-dry condition, they were weighed and shelled, and dry-matter tests of the grain and cobs were made. The stalks, leaves, and husks (termed the leaf-stalk fraction) were chopped, and subsamples weighing 4 to 5 pounds each were taken for determination of dry matter. Drying was done in a large oven at 95° to 100° C.

Shortly after obtaining the final field samples in 1949, 1950, and 1951, a combined harvest of the residual forage of the unfertilized blocks and another of the residual forage of the fertilized blocks were made. Weights of the forage were obtained, and random samples were taken from the loads for dry-matter determination.

Analytical methods. Protein determinations were made by the Kjeldahl-Arnold-Gunning method on the dried samples of grain and the leaf-stalk portions of the forage. Crude-fiber determinations were made on the leaf-stalk fraction by the A.O.A.C. method.[1]

Analyzing the yield differences. Variations in topography, soil type, crop productivity, and numerous other factors may affect yields and composition of the corn crop. To determine whether any significant differences existed in the yields and chemical composition of the fertilized and unfertilized corn, the data were analyzed by the method of "analysis of variance."

EFFECTS OF FERTILIZATION ON YIELDS

The data supplied information concerning the effect of fertilization on the yields of fresh forage and dry matter in forage and also on the protein contents of the grain and leaf-stalk fractions of the forage. Some data were obtained on the crude-fiber content of the leaf-stalk part of the forage.

Yields of Entire Forage

Yields of forage were measured by field sampling and in three of the years by following up the sampling harvests with complete harvest of the residual forage. A summary of the results is shown in Table 2.

[1] Association of Official Agricultural Chemists. Official and Tentative Methods. 1945.

Table 2. — Yields of Corn Forage as Determined From Field Samples and From Complete Harvest of Unfertilized and Fertilized Blocks

Date of harvest	Unfertilized			Fertilized		
	Fresh matter	Dry matter	Dry matter	Fresh matter	Dry matter	Dry matter
	lb.	*perct.*	*lb.*	*lb.*	*perct.*	*lb.*
Sept. 4, 1947[a]	19,490	19.5	3,800	21,580	19.6	4,230
Sept. 15, 1947[a]	20,590	25.4	5,230	22,190	25.1	5,570
Sept. 22, 1947[a]	20,290	27.8	5,640	21,780	27.6	6,010
August 24, 1948[a]	36,020	22.6	8,140	39,040	21.9	8,550
August 31, 1948[a]	34,210	27.1	9,270	39,290	25.2	9,900
Sept. 7, 1948[a]	32,800	31.8	10,430	35,210	31.1	10,950
August 16, 1949[a]	33,850	20.0	6,770	39,510	20.3	8,020
August 23, 1949[a]	32,340	23.1	7,470	36,550	23.5	8,590
August 30, 1949[a]	32,070	27.1	8,690	36,860	27.1	9,990
Sept. 1, 1949[b]	30,400	27.6	8,390	34,510	27.5	9,490
August 29, 1950[a]	22,560	21.5	4,850	31,110	21.6	6,720
Sept. 5, 1950[a]	22,300	23.5	5,240	31,550	23.3	7,350
Sept. 12, 1950[a]	22,670	26.6	6,030	31,120	26.9	8,370
Sept. 13, 1950[b]	20,000	26.6	5,320	29,090	26.5	7,710
August 21, 1951[a]	24,980	20.7	5,170	32,650	20.4	6,660
August 28, 1951[a]	26,830	20.5	5,500	36,460	20.6	7,510
Sept. 4, 1951[a]	27,080	25.3	6,850	35,410	24.2	8,570
Sept. 12, 1951[b]	22,020	28.2	6,210	29,110	28.0	8,150

[a] Determinations based on field samples.
[b] Determinations based upon complete harvest. An adjustment was made in the yield to take into account the forage removed in sampling.

The yield figures in this and similar tables are the means for all five hybrids, each of which was grown in four replicated blocks.

The yields of fresh forage to the acre showed little or no increase from one harvest date to the next except in one season (1951) when there was a moderate rise from the first to the third sampling dates. On the other hand, the yields of dry matter rose rapidly from one sampling harvest to the next. As shown in the table, these increases in dry-matter yield were associated with rapid increases in the percentage of dry matter of the forage.

The yields of forage as measured by complete harvest were slightly lower than those obtained by field sampling, but on the whole the two methods of measurement agreed fairly well. The discrepancy is accounted for by a number of factors, such as differences between hand and machine harvest in the height of cut and small errors due to random sampling of loads of forage.

Strong seasonal effects were noted. The yield of fresh forage in 1948 was more than 50 percent larger than in 1947, and the yield of dry matter in 1948 was nearly double that of the preceding season. In all seasons of the study, the yields were large as compared with average yields for the state. In Illinois average yields of corn forage utilized for silage are about 10 tons to the acre, according to data of the U. S. Department of Agriculture.

Table 3. — Analyses of Variance for Yields of Dry Matter in Tons per Acre of Corn Forage

(Based on last three field-sampling harvests of each year)

Source	1947		1948		1949		1950		1951	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Total	119	.....	119	.....	119	.....	119	.....	119	.....
Hybrids	4	.60**	4	4.71**	4	.20	4	.73	4	1.19**
Harvest dates (stages)	2	8.98**	2	14.09**	2	9.91**	2	5.11**	2	8.46**
Blocks	7	.60	7	.68	7	3.54	7	5.10**	7	4.21**
Treatments[a]	1	1.07	1	2.15	1	11.27	1	33.30**	1	22.63**
Blocks within treatments	6	.52	6	.44	6	2.25	6	.40	6	1.14
Hybrids × blocks	28	.051	28	.42**	28	.27*	28	.090*	28	.16**
Hybrids × stages	8	.022	8	.22	8	.066	8	.21**	8	.17**
Blocks × stages	14	.024	14	.28	14	.15	14	.077	14	.11**
Hybrids × blocks × stages	56	.042	56	.19	56	.14	56	.048	56	.039

* Significant at 5% level of probability. ** Significant at 1% level of probability. [a] Unfertilized vs. fertilized.

Fertilization caused an increase in the dry-matter yield of the forage. In 1947, 1948, and 1949, the increase was smaller than in the following two years. The dry-matter yields at the last sampling dates of 1947, 1948, and 1949 show that fertilization brought about an increase of about 8 percent, while a similar comparison for 1950 and 1951 shows an increase of about 33 percent caused by fertilization. The complete-harvest data for the last two years show an increase of approximately 37 percent in yields as a result of fertilizer treatment.

It was pointed out above that the field employed for the 1947, 1948, and 1949 trials was one that had frequently received applications of manure, while the field employed for the last two years of the study had been depleted of fertility through continuous cropping in a cash-grain system. It is believed that the difference in fertility levels of the two fields accounts for the difference in response to fertilizer applications.

Analyses of variance of the dry-matter yield data from the field-sampling harvests were computed for each year (Table 3). In each year there was a highly significant difference between harvest dates. There was also a highly significant difference between hybrids in three of the years. The difference between harvest dates was expected because of the rapid build-up of dry matter in the crop which caused a marked rise in yield from one date to the next. The explanation for the difference between hybrids may be the later maturity of one hybrid. The highly significant difference between unfertilized and fertilized blocks in 1950 and 1951 appears to be a direct result of fertilizer treatment. The increase in yield caused by fertilization during the first three years of the trials was small and not significant.

Part of Crop Formed by Ears

One way to determine whether the application of fertilizer to corn increases only the amounts of ears or of both the ears and the leaf-stalk fraction is to determine the percentage of the dry matter of the entire forage that is made up of ears. This study was made for each of the sampling dates (Table 4).

The rapid increase in the proportion of ears during the brief period covered by sampling is striking. For example, in 1947 the ears comprised only 11 percent of the dry matter of the unfertilized corn on the first sampling date (August 28), but by September 22 this proportion had climbed to 48.9 percent. Rapid increases were found also in the other years.

Highly significant differences between hybrids in the proportion of ears in the forage were found (Table 5). One of the explanations for this difference lies in the late maturity of one of the hybrids. Because of the rapid development of ears during the sampling period, a highly significant difference in ear content between the successive harvest dates would be expected, and such a difference was found for each year.

Table 4. — Percentage of Dry Matter Formed by Ears in Corn Forage Grown in Unfertilized and Fertilized Blocks

Date of harvest by field sampling	Percentage of dry matter in corn forage formed by ears in—	
	Unfertilized blocks	Fertilized blocks
August 28, 1947	11.0	11.8
September 4, 1947	25.3	26.4
September 15, 1947	41.2	41.6
September 22, 1947	48.9	47.8
August 16, 1948	22.9	22.2
August 24, 1948	37.5	36.1
August 31, 1948	48.5	47.6
September 7, 1948	54.8	54.9
August 16, 1949	25.4	26.0
August 23, 1949	33.8	34.7
August 30, 1949	42.8	40.8
August 22, 1950	15.1	20.7
August 29, 1950	25.2	30.4
September 5, 1950	33.1	39.3
September 12, 1950	44.1	48.7
August 21, 1951	21.3	24.7
August 28, 1951	29.2	33.2
September 4, 1951	43.5	38.3

The difference between the unfertilized and fertilized corn with respect to the proportion of ears in the dry matter of the forage was highly significant in 1950, but in the other seasons the difference was not significant. It appears, therefore, that in four of the five years the larger yield from the fertilized corn as compared with the unfertilized crop was accounted for by greater quantities of leaves and stalks as well as ears.

Yields of Leaf-Stalk Fraction

Further support is given to the findings concerning the effect of fertilizer applications on yields of forage by a study of the influence of fertilization on the dry-matter yields of the leaf-stalk fraction. In contrast to the rapid build-up of dry matter in the ears during the three to four weeks of field sampling, there was little change in the dry-matter yield of the leaf-stalk portion during the same period (Table 6).

Table 5. — Analyses of Variance for Percentage of Dry Matter Formed by Ears in Corn Forage Grown in Unfertilized and Fertilized Blocks

Source	1947		1948		1949		1950		1951	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Total	159	....	159	....	119	....	159	....	119	....
Hybrids	4	427.37**	4	580.39**	4	531.09**	4	384.07**	4	583.60**
Harvest dates (stages)	3	10,904.04**	3	8,000.87**	2	2,594.42**	3	5,879.16**	2	3,216.01**
Blocks	7	15.57	7	10.22	7	43.21	7	190.94**	7	209.70
Treatments[1]	1	4.32	1	20.95	1	1.14	1	1,167.48**	1	16.73
Blocks within treatments	6	17.45	6	8.43	6	50.22	6	28.18	6	241.87
Hybrids × blocks	28	11.32**	28	12.54	28	4.92	28	5.71	28	13.70
Hybrids × stages	12	11.52**	12	13.99	8	2.04	12	68.13**	8	13.03
Blocks × stages	21	5.06	21	6.94	14	11.32**	21	5.26	14	97.98**
Hybrids × blocks × stages	84	3.47	84	8.95	56	3.40	84	5.07	56	13.18

** Significant at 1% level of probability. [1] Unfertilized vs. fertilized.

Table 6. — Yields of Dry Matter in Leaf-Stalk Fraction of Corn Forage From Unfertilized and Fertilized Blocks

Date of harvest by field sampling	Pounds of dry matter per acre from—	
	Unfertilized blocks	Fertilized blocks
September 4, 1947	2,748	3,004
September 15, 1947	2,893	3,051
September 22, 1947	2,629	2,979
August 24, 1948	5,048	5,412
August 31, 1948	4,761	5,169
September 7, 1948	4,684	4,922
August 16, 1949	5,041	5,934
August 23, 1949	4,988	5,545
August 30, 1949	4,996	5,982
August 29, 1950	3,615	4,642
September 5, 1950	3,470	4,451
September 12, 1950	3,387	4,280
August 21, 1951	4,019	5,007
August 28, 1951	3,863	5,017
September 4, 1951	3,813	5,296

The difference in yield between unfertilized and fertilized blocks was highly significant in the last two seasons and significant in two other years (Table 7). In only one year was the difference between yields at different harvest dates highly significant, while in four years it was not significant. The data indicate, therefore, that fertilization was a causative factor in the larger yields of dry matter in the leaf-stalk fraction of the forage from the fertilized blocks.

EFFECTS OF FERTILIZATION ON CHEMICAL COMPOSITION

Protein Content of Shelled Corn

During the last three years of the trials, samples of shelled corn of each of the five hybrids grown in four replicated blocks on unfertilized land and four replicated blocks on fertilized land were obtained. The samples were from three field-sampling harvests in 1949 and 1951 and from four harvests in 1950. They were tested for their content of total protein.

For all hybrids in each of the three seasons, the protein content of the shelled corn declined markedly from the first to the final harvest (Table 8). In 1950, for example, the protein content of several of the hybrids declined during the 21-day period (August 22 to September 12) to about half that of the level at the first harvest.

Treatment with fertilizers did not bring about an increase in the protein content of the shelled corn during 1949. In fact, the protein content of the unfertilized corn was higher than that of the fertilized

Table 7.—Analyses of Variance for Yields of Dry Matter (in Tons) of Leaf-Stalk Fraction of Corn Forage Grown on Unfertilized and Fertilized Blocks

Source	1947		1948		1949		1950		1951	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Total	119	.....	119	.....	119	.....	119	.....	119	.....
Hybrids	4	.25*	4	.69**	4	.92**	4	.46**	4	1.08**
Harvest dates (stages)	2	.071	2	.46**	2	.16	2	.22	2	.034
Blocks	7	.28	7	.24	7	1.31*	7	1.10**	7	1.68**
Treatments[1]	1	.49	1	.85*	1	4.94*	1	7.01**	1	10.96**
Blocks within treatments	6	.24	6	.14	6	.70	6	.12	6	.13
Hybrids × blocks	28	.067**	28	.11*	28	.083	28	.031	28	.079*
Hybrids × stages	8	.011	8	.062	8	.058	8	.026	8	.0099
Blocks × stages	14	.030	14	.082	14	.088	14	.026	14	.092*
Hybrids × blocks × stages	56	.028	56	.055	56	.059	56	.11	56	.046

* Significant at the 5% level of probability. ** Significant at the 1% level of probability. [1] Unfertilized vs. fertilized.

Table 8. — Protein Content of Shelled Corn From Unfertilized and Fertilized Plots

(Expressed in terms of percentage of protein in air-dry matter in 1949 and 1950 and in dry matter in 1951)

Date of harvest by field sampling	Treatment	Protein content of shelled corn of hybrid No.—				
		1	2	3	4	5
Aug. 16, 1949	Unfertilized	12.86	13.95	12.22	14.90	12.61
	Fertilized	11.64	12.61	11.70	14.29	12.23
Aug. 23, 1949	Unfertilized	10.57	10.68	10.11	11.42	10.67
	Fertilized	10.34	10.19	9.85	10.52	10.17
Aug. 30, 1949	Unfertilized	9.76	9.27	9.32	9.80	9.66
	Fertilized	9.21	8.95	9.49	9.64	9.91
Aug. 22, 1950	Unfertilized	12.90	16.09	12.53	17.66	14.22
	Fertilized	13.64	14.45	13.93	18.82	14.45
Aug. 29, 1950	Unfertilized	10.02	10.79	9.64	11.85	9.63
	Fertilized	11.10	11.56	10.95	12.89	10.92
Sept. 5, 1950	Unfertilized	8.69	8.36	8.48	8.97	8.67
	Fertilized	10.10	10.05	9.50	10.24	9.58
Sept. 12, 1950	Unfertilized	8.00	7.75	7.65	7.78	7.72
	Fertilized	9.73	9.22	9.03	9.19	9.25
Aug. 21, 1951	Unfertilized	14.97	16.87	16.07	19.38	15.05
	Fertilized	14.62	15.38	15.03	17.93	14.77
Aug. 28, 1951	Unfertilized	13.01	13.91	12.93	15.66	13.11
	Fertilized	12.63	13.31	12.66	14.51	12.87
Sept. 4, 1951	Unfertilized	11.04	10.69	10.60	11.65	11.06
	Fertilized	12.08	11.67	11.16	11.35	10.84

corn (Table 8). This finding was confirmed by protein determinations of composite samples of the five hybrids grown in each of the 8 blocks (not reported in the tables). The average protein content of the corn from the four unfertilized blocks was 13.21 percent and that of the four fertilized blocks 12.60 percent. However, the "treatment × harvest date" interaction was significant, indicating that there was a differential effect of the treatment from one harvest date to another. In other words, the differences between unfertilized and fertilized corn at the various harvest dates were not uniform in size.

The 1951 results were similar to those of 1949, for the protein content of the hybrids grown on unfertilized land was higher than that of the same hybrids on fertilized land and the difference caused by treatment was not significant (Table 9). In 1950, on the other hand, the protein content of the corn grown on fertilized land was significantly higher than that of corn grown on unfertilized land (Table 9).

The explanation for the differences observed in protein content does not seem to lie in the character of the soil on which the corn was grown. The 1950 and 1951 crops were grown on the same field, which seems to rule out the likelihood that fertilization was completely responsible for the differences in protein content. A more plausible explanation appears to lie in seasonal effects. Profound differences in the yield of corn forage and of corn grain are known to occur from year to year as the result of differences in rainfall, temperature, relative humidity, days of sunshine, and other environmental effects beyond the control of man. Another possibility is that soil treatment caused a more rapid development of the ears in the fertilized than in the unfertilized blocks, resulting in a lower protein content in the former

Table 9. — Analyses of Variance of Percentage of Protein Content of Shelled-Corn Fraction of Corn Forage From Unfertilized and Fertilized Plots

Source	1949		1950		1951	
	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares
Total	29	......	39	......	29	......
Hybrids	4	1.447	4	4.752	4	4.763*
Treatments[1]	1	1.661	1	11.236**	1	.898
Harvest dates	2	30.770**	3	80.127**	2	57.508**
Hybrid × treatment	4	.092	4	.174	4	.228
Treatment × harvest date	2	.299*	3	.586	2	1.174**
Hybrid × harvest date	8	.611**	12	1.840**	8	1.125**
Hybrid × treatment × harvest date	8	.047	12	.214	8	.109

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.
[1] Unfertilized vs. fertilized.

on a particular harvest date. The data show a rapid decline in protein content during the few weeks covered by the harvest period.

It is evident that fertilizer treatment had little direct effect upon the protein content of the shelled corn.

Protein Content of Leaf-Stalk Fraction

Protein determinations were made of the leaf-stalk fraction of the forage from each hybrid grown in the four unfertilized blocks and the four fertilized blocks (Table 10). In 1949, the protein content of the leaf-stalk fraction of the unfertilized corn was higher than that of the fertilized crop. This difference was significant, as is shown in Table 11. On the other hand, in 1950 and 1951 the protein content of the leaf-stalk fraction of the fertilized crop was higher than that of the leaf-stalk portion of the unfertilized corn. In both years this difference between treatments was found to be highly significant. The fact that the field used in 1949 had a higher productivity than the field on which the 1950 and 1951 crops were grown is believed to be the explanation for the wide difference in response of the leaf-stalk fraction of the forage to fertilizer treatment.

Table 10. — Protein Content of Leaf-Stalk Fraction of Corn Forage From Unfertilized and Fertilized Corn Plots

(Expressed in terms of percentage of protein in air-dry matter)

Date of harvest by field sampling	Treatment	Protein content of leaf-stalk fraction of hybrid No. —				
		1	2	3	4	5
Aug. 23, 1949..........	Unfertilized...........	6.68	6.81	6.81	7.33	6.85
	Fertilized.............	6.30	6.02	5.96	7.04	6.70
Aug. 30, 1949..........	Unfertilized...........	5.73	5.27	5.50	5.52	5.42
	Fertilized.............	5.30	5.23	5.49	5.67	5.37
Aug. 22, 1950..........	Unfertilized...........	6.35	6.15	6.65	5.56	6.20
	Fertilized.............	9.24	7.95	7.84	8.44	8.65
Aug. 29, 1950..........	Unfertilized...........	5.80	5.00	6.18	5.65	6.38
	Fertilized.............	8.24	7.91	8.15	7.87	8.15
Sept. 5, 1950..........	Unfertilized...........	5.54	5.02	5.77	5.84	6.01
	Fertilized.............	7.29	7.33	7.80	7.99	7.64
Sept. 12, 1950.........	Unfertilized...........	4.65	4.27	4.90	5.20	4.34
	Fertilized.............	6.42	6.38	6.15	6.46	6.98
Aug. 21, 1951..........	Unfertilized...........	7.81	6.67	7.31	7.48	6.85
	Fertilized.............	8.34	7.89	8.22	8.41	8.45
Aug. 28, 1951..........	Unfertilized...........	6.97	5.94	6.52	6.44	6.51
	Fertilized.............	7.20	6.89	7.13	8.04	7.23
Sept. 4, 1951..........	Unfertilized...........	6.22	5.74	6.04	6.33	5.70
	Fertilized.............	6.94	6.62	6.78	7.69	7.07

The date of harvest had a marked effect upon the protein content of the leaf-stalk fraction in each of the three years. The values in Table 10 show a fairly consistent decline in protein content for each of the hybrids. For each of the years the difference was highly significant. This decline is not as marked as for the protein content of the shelled-corn fractions of the same samples (Table 8).

Table 11. — Analyses of Variance of Percentage of Protein Content of Leaf-Stalk Fraction of Corn Forage From Unfertilized and Fertilized Plots

Source	1949		1950		1951	
	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares
Total........................	19	......	39	......	29	......
Hybrids......................	4	.178	4	.348	4	.525**
Treatments[1]................	1	.403*	1	42.890**	1	6.883**
Harvest dates................	1	7.200**	3	5.520**	2	3.976**
Hybrid × treatment...........	4	.033	4	.142	4	.169
Hybrid × harvest date........	4	.083	12	.114	8	.026
Treatment × harvest date.....	1	.216	3	.121	2	.035
Hybrid × treatment × harvest date.....................	4	.038	12	.147	8	.046

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.
[1] Unfertilized vs. fertilized.

Crude-Fiber Content of Leaf-Stalk Fraction

In these trials fertilization brought about a highly significant increase in the yield of forage in 1950 and in 1951 (Tables 2 and 3). The extra yield from the fertilized blocks did not lie wholly in the ears, for in only one of the two years was there a significant difference in the proportion of the dry matter formed by the ears (Table 5). Presumably, therefore, the increased yield of forage caused by fertilization was in part brought about by larger plants. Did these larger plants contain more fiber and thus perhaps less feeding value per hundred pounds than the plants from the unfertilized blocks?

To answer this question, samples of the leaf-stalk fraction of the forage of four blocks of unfertilized and four blocks of fertilized corn from three field-sampling harvests and of the forage from the complete harvest of one season were analyzed for their crude-fiber content. The results are shown in Table 12. The differences between the fiber content of the field samples from the unfertilized and fertilized blocks were small and not significant (Table 13). There was, however, a highly significant difference between hybrids and a significant difference between harvest dates.

Table 12. — Crude-Fiber Content of Leaf-Stalk Fraction of Corn Forage and of Entire Forage From Unfertilized and Fertilized Corn Plots, 1950

(Expressed in percentage of dry matter)

Date of harvest	Treatment	Crude fiber of hybrid No. —					Mean
		1	2	3	4	5	
Leaf-stalk fraction (field samples)							
August 22	Unfertilized	28.13	27.50	27.56	30.93	27.94	28.41
	Fertilized	26.81	27.85	28.83	29.33	27.99	28.16
August 29	Unfertilized	27.35	27.16	28.35	29.68	28.22	28.15
	Fertilized	27.33	26.79	27.50	29.08	28.16	27.77
September 5	Unfertilized	27.63	28.09	29.68	30.23	30.48	29.22
	Fertilized	28.27	27.12	29.37	30.51	28.88	28.83
Entire forage (complete harvest)							
September 12	Unfertilized	20.42	21.92	20.40	23.89	18.78	21.08
	Fertilized	18.65	21.77	18.47	22.50	18.94	20.07

The forage obtained from the complete harvest on September 12, showed a much lower fiber content than that of the leaf-stalk fraction (Table 12). This was expected because the fiber content of the shelled corn was lower than that of the stalks and leaves.

The differences in fiber content of the entire forage of the un-

Table 13. — Analysis of Variance of Crude-Fiber Content (Percentage) of Leaf-Stalk Fraction of Corn Forage From Unfertilized and Fertilized Plots, 1950

Source	Degrees of freedom	Mean squares
Total	29	.....
Hybrids	4	6.184**
Treatments[1]	1	.870
Harvest dates	2	2.973*
Hybrid × treatment	4	.106
Hybrid × harvest date	8	.317
Treatment × harvest date	2	.016
Hybrid × treatment × harvest date	8	.544

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.
[1] Unfertilized vs. fertilized.

fertilized and fertilized hybrids were small, and there was no evidence to indicate an increase in fiber content because of fertilization.

SUMMARY

A five-year investigation was conducted to determine the effect of fertilization on the yield and composition of the forage of hybrid corn grown for silage. The hybrids employed had previously been shown to be high yielding for both grain and forage. The yields of forage were obtained by field-sampling harvests at 7- to 10-day intervals over a 3- to 4-week period just prior to the filling of silos, and in three years by complete harvest of the forage remaining after removal of the samples.

Under the conditions of this five-year trial, the application of fertilizers to soils for the production of corn forage resulted in: (1) gains in tonnage of forage as represented by both ear and leaf-stalk fractions; (2) little or no change in the proportion of the forage which consisted of ears; (3) little change in the protein content of the grain (shelled corn) except as influenced by season; (4) an enhanced protein content of the leaf-stalk fraction of the forage when the crop was grown on soils low in available plant food; and (5) little change in the crude-fiber content of the forage.

LITERATURE CITED

1. Blair, A. W., and McLean, H. C. The influence of lime on the yield and nitrogen content of corn. Soil Sci. 1, 489-504. 1916.
2. Duley, F. L., and Miller, M. F. The effect of a varying supply of nutrients upon the character and composition of the maize plant at different periods of growth. Missouri Agr. Exp. Sta. Res. Bul. 42. 1921.

3. HAMILTON, T. S., HAMILTON, BARBARA C., JOHNSON, B. C., and MITCHELL, H. H. The dependence of the physical and chemical composition of the corn kernel on soil fertility and cropping system. Cereal Chem. **28**, 163-176. 1951.

4. HARRIS, F. S., and PITTMAN, D. W. Irrigation and manuring studies. II. The effect of varying quantities of irrigation water and manure on the growth and yield of corn. Utah Agr. Exp. Sta. Bul. 154. 1917.

5. HOENER, I. R., and DETURK, E. E. The absorption and utilization of nitrate nitrogen during vegetative growth by Illinois high protein and Illinois low protein corn. Jour. Amer. Soc. Agron. **30**, 232-243. 1938.

6. OBENSHAIN, S. S. The effect of different concentrations of nutrient supplies in sand cultures on the elemental composition of the express sap of the corn plant. Va. Acad. Sci. Proc., p. 74, 1944. Exp. Sta. Rec. **94**, 162. 1946.

7. SNYDER, HARRY. Forage crops of high, medium, and low protein content. Minn. Agr. Exp. Sta. Bul. 101, 227-256. 1907.

8. STUBBLEFIELD, F. M., and DETURK, E. E. The composition of corn, oats, and wheat as influenced by soil, soil treatment, seasonal conditions, and growth. Soil Sci. Soc. Amer. Proc. **5**, 120-124. 1940. Chem. Abstr. **36**, 2362. 1942.

9. WEEKS, M. E., FERGUS, E. N., and KARRAKER, P. E. The composition of the corn plant grown under field conditions in relation to the soil and its treatment. Soil Sci. Soc. Amer. Proc. **5**, 140-146. 1940.

10. WHITSON, A. R., and STODDART, C. W. Studies on the influence of the soil on the protein composition of crops. Wis. Agr. Exp. Sta. Ann. Rpt. 21, 193-199. 1904.

11. WHITSON, A. R., WELLS, F. J., and VIVIAN, A. Influence of the soil on the protein content of crops. Wis. Agr. Exp. Sta. Ann. Rpt. 19, 192-209. 1902.

12. WOODS, C. D. Effects of different fertilizers upon the composition of corn. Conn. (Storrs) Agr. Exp. Sta. Ann. Rpt. 2, 127-178. 1889.

OTHER ILLINOIS PUBLICATIONS ON SILAGE

The following Illinois publications give information about silage crops, methods of making silage, and feeding value and money value of the silage. They can be obtained on request from the Information Office, College of Agriculture, Urbana, Illinois.

Grass and Legume Silages for Dairy Cattle. Circular 605. 20 pages.

Making High Quality Silage for Dairy Cattle. Circular 686. 24 pages.

A Method for Estimating the Money Value of Corn Silage. Bulletin 576. 16 pages.

6M—6-54—54937