PROTEIN AND OIL IN CORN: VARIATION BY CROP YEARS FROM 1907 TO 1972[1]

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ABSTRACT

Since 1907, the protein content of commercial corn (as reported by certain individual companies) has varied between 9.1% (1951) and 11.9% (1934). Since 1937, the protein content has been much the same as it was from 1907 to 1929. From 1930 to 1936, protein content was unusually high. A relation between high protein and high July temperature is obvious in the hotter years but not in the cooler ones. A slight inverse relation is suggested between protein and July rainfall and, for the early years, between protein and yield. Oil content since 1917 has varied from 4.0 to 4.9%, but no reason has been found for year-to-year variation.

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Although the great importance of corn as animal feed generates a continuing interest in its protein content, few studies have been made of factors governing composition. These have been limited primarily to effects of variety, nitrogen fertilization, plant population, and yield. Only one study reported protein content of corn for any extended period (1); another reported protein content from many different parts of the U.S. (2).

DATA COLLECTION

Requests to seven commercial corn processors brought usable historical data on protein content from six of them. Some data represented yearly averages; some were monthly averages from which an annual average was calculated for each year beginning in October. For one company, averages were also calculated for years beginning with the January after harvest; the resulting values were essentially the same as those calculated for years beginning in October. Data from the companies are presented in Table I under sources A–F, along with oil data where available. Data from source G (1) are included for comparison.

The pattern of variation is supported by evidence from a noncommercial source, the continuing University of Illinois program of selection for high- and low-protein and high- and low-oil lines of corn. The progressive change in protein content resulting from this selection program prevented direct use of the published data. However, deviations from the fitted trend lines (3) representing the general progress of the program should reflect, among other factors, variations due to climatic conditions. Instead of using the deviation figures directly, a "calculated protein content" for the high- and low-protein lines was created for each year by adding the appropriate deviation to the protein content indicated by the trend line for 1896, when the program began (11.9% for the high-protein series and 9.4% for the low-protein series). An arbitrary line was used in

[1]Presented in part at the 39th Annual Meeting, Denver, Colo., May 1954.

[2]The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

calculations for the oil-selection series. Results from the two protein series were averaged, as were those of the two oil series (source H, Table I).

Temperature and rainfall data were supplied by the U.S. Weather Bureau stations at Davenport-Moline, Rockford, Peoria, Springfield, and Indianapolis. Data from the five stations were averaged for each year (Table I).

Data on corn yield, fertilizer usage, and the introduction of hybrid corn in Illinois (Table I) were obtained from Agricultural Statistics (4) for 1936 and following years. Earlier yield figures were taken from the U.S. Department of Agriculture's Yearbook of Agriculture (5).

DISCUSSION

Data in Table I show good agreement between companies with respect to yearly changes in protein content of corn. There are a few conspicuous divergencies, but they can probably be attributed to differences in the origins of the corn, in local weather conditions, in patterns of processing freshly harvested *vs.* stored grain, or perhaps in other operational procedures. To simplify graphical presentation of compositional variation from year to year (Fig. 1), all

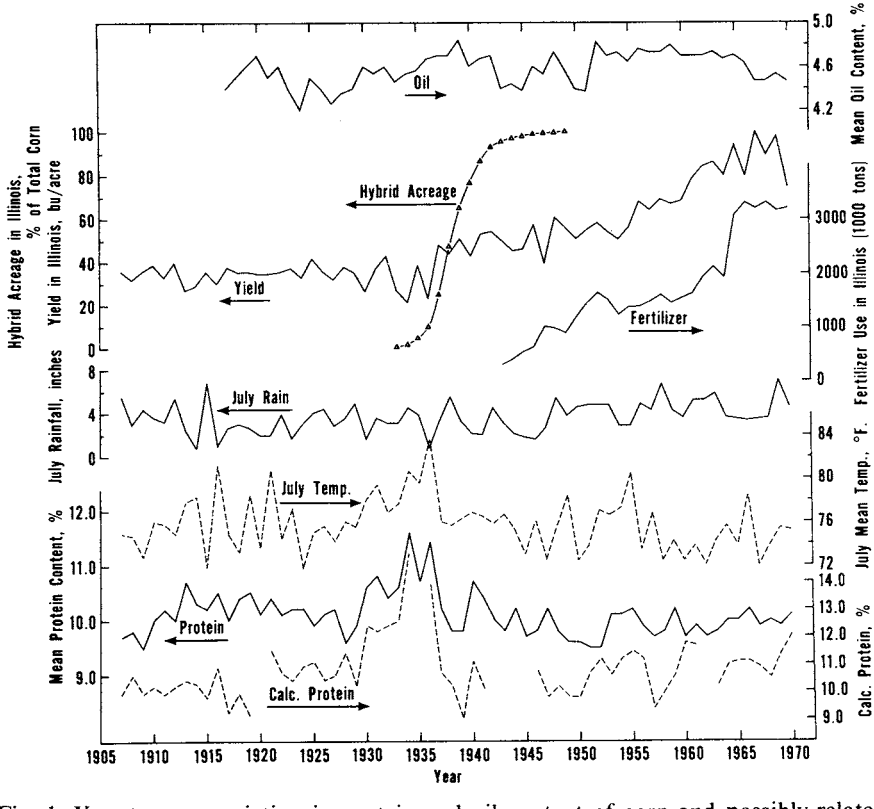

Fig. 1. Year-to-year variation in protein and oil content of corn and possibly related factors.

TABLE I
Protein and Oil Contents of Corn and Some Possibly Related Factors

Crop Year	Source[a] A	B	C	D	E	F	A–F Av.	G	H Calculated Prot. series	H Calculated Oil series	Oil content (% db) B	C	F	B,C,F Av.	July Mean Temp. °F	July Rain in.	Illinois Yield bu/acre	Illinois Corn Acreage Hybrid %	Illinois Fertilizer Use 1000 Tons
	Protein content (% db)																		
1907	9.7	...	...	...	...	...	9.7	...	10.0	9.8	...	...	...	...	74.9	5.55	36.0	...	...
1908	9.8	...	...	...	...	...	9.8	...	10.5	10.8	...	...	...	...	74.7	2.98	31.6	...	...
1909	9.5	...	...	...	...	...	9.5	...	9.8	10.0	...	...	...	...	72.4	4.36	35.9	...	...
1910	10.0	...	...	...	...	...	10.0	...	10.9	9.6	...	...	...	...	76.0	3.63	39.1	...	...
1911	10.2	...	...	...	...	...	10.2	...	10.0	9.8	...	...	...	...	75.8	3.15	33.0	...	...
1912	10.0	...	...	...	...	...	10.0	...	10.5	10.0	...	...	...	...	74.9	5.45	40.0	...	...
1913	10.7	...	...	...	...	...	10.7	...	10.4	10.4	...	...	...	...	77.8	2.41	27.0	...	...
1914	10.3	...	...	...	...	...	10.3	...	10.4	10.2	...	...	...	...	78.4	0.80	29.0	...	...
1915	10.2	...	...	...	...	...	10.2	...	9.9	9.8	...	...	...	...	72.0	6.89	36.0	...	...
1916	10.5	...	...	...	...	...	10.5	...	11.2	9.7	...	...	...	...	81.2	0.97	29.5	...	...
1917	10.0	9.9	...	...	...	...	10.0	...	9.7	8.8	4.4	...	...	4.4	74.8	2.66	38.0	...	...
1918	10.9	10.0	...	...	...	...	10.4	...	10.2	9.7	4.5	...	...	4.5	73.2	2.96	35.5	...	...
1919	10.8	10.2	...	...	...	...	10.5	...	9.4	8.8	4.6	...	...	4.6	78.5	2.65	36.0	...	...
1920	10.0	10.2	...	...	...	...	10.1	...	9.6	...	4.7	...	...	4.7	73.6	2.02	34.6	...	...
1921	10.4	10.4	...	...	...	...	10.4	...	11.6	11.4	4.5	...	...	4.5	80.7	1.99	34.0	...	...
1922	10.2	10.0	...	...	...	...	10.1	...	11.0	10.4	4.6	...	...	4.6	74.5	3.85	35.5	...	...
1923	10.2	10.3	...	...	...	...	10.2	...	10.1	10.8	4.4	...	...	4.4	77.2	1.70	37.5	...	...
1924	10.2	10.1	...	...	...	...	10.2	...	11.0	10.8	4.2	...	...	4.2	71.8	2.98	33.0	...	...
1925	10.2	9.6	...	...	...	...	9.9	...	11.4	10.8	4.5	...	...	4.5	74.9	3.95	42.0	...	...
1926	10.3	9.6	10.4	...	...	...	10.1	...	10.8	10.1	4.5	4.3	...	4.4	75.6	4.40	35.0	...	...
1927	10.7	9.8	10.0	...	...	...	10.2	...	11.2	10.0	4.5	4.0	...	4.2	74.2	2.78	30.0	...	...
1928	9.7	9.4	9.7	...	...	...	9.6	...	10.8	12.0	4.6	4.1	...	4.4	76.0	3.49	38.4	...	...
1929	10.4	9.4	9.8	...	...	...	9.9	...	10.3	10.2	4.6	4.2	4.4	4.4	75.6	4.85	35.0	...	...
1930	10.9	10.4	10.5	...	...	...	10.6	...	12.2	12.6	4.7	4.5	4.6	4.6	77.9	1.58	25.5	...	...
1931	11.1	10.6	10.8	...	...	...	10.8	10.7	12.3	12.2	4.6	4.5	4.5	4.5	79.4	3.56	37.0	...	...

TABLE I, *continued*
Protein and Oil Contents of Corn and Some Possibly Related Factors

Crop Year	Source[a] A	B	C	D	E	F	A–F Av.	G	H Calculated Prot. series	H Calculated Oil series	Oil content (% db) B	C	F	B,C,F Av.	July Mean Temp. °F	July Rain in.	Illinois Yield bu/acre	Illinois Corn Acreage Hybrid %	Illinois Fertilizer Use 1000 Tons
	Protein content (% db)																		
1932	10.3	10.3	10.6	...	...	...	10.4	10.6	12.2	12.6	4.6	4.5	4.7	4.6	76.8	3.07	43.0	...	...
1933	10.4	10.6	10.7	...	...	...	10.6	10.5	13.5	11.6	4.5	4.2	4.6	4.4	77.6	3.08	27.0	0.6	...
1934	...	11.3	11.9	...	...	...	11.6	11.5	15.4	15.3	4.5	4.5	4.6	4.5	80.7	4.49	20.5	1.5	...
1935	...	10.4	11.0	...	...	...	10.7	10.0	9.7	...	4.5	4.6	4.6	4.6	79.4	3.90	38.0	4.1	...
1936	...	11.0	11.7	...	...	...	11.4	10.9	13.5	14.6	4.8	4.6	4.6	4.7	83.5	0.80	23.5	9.9	...
1937	...	10.3	10.2	...	...	...	10.2	10.5	10.2	11.2	4.7	4.6	4.8	4.7	76.0	3.47	48.0	25.2	...
1938	...	9.7	9.9	...	...	...	9.8	10.4	9.5	10.8	4.7	4.6	4.8	4.7	75.7	5.54	45.0	47.5	...
1939	...	9.6	9.9	9.8	...	...	9.8	10.8	8.2	9.8	4.8	4.6	4.9	4.8	76.2	3.14	52.0	65.5	...
1940	...	10.4	11.2	10.6	...	...	10.7	10.3	10.8	11.4	4.8	4.2	4.8	4.6	76.8	2.07	43.0	76.4	...
1941	...	10.1	10.7	10.4	...	...	10.4	10.5	9.4	10.8	4.7	4.6	4.7	4.7	76.4	1.96	53.0	86.9	...
1942	...	10.0	10.4	10.1	9.7	...	10.0	10.1	...	...	4.7	4.6	4.8	4.7	75.9	4.58	54.0	93.3	...
1943	...	9.6	9.8	9.9	9.7	10.0	9.8	9.8	...	...	4.5	4.2	4.5	4.4	76.6	3.14	50.0	96.0	289
1944	...	9.7	10.2	10.3	10.1	10.6	10.2	9.8	...	...	4.4	4.3	4.6	4.4	76.3	2.14	45.0	96.9	410
1945	9.9	9.6	9.8	9.9	9.2	9.9	9.7	...	9.5	...	4.4	4.3	4.4	4.4	73.0	1.84	46.5	98.1	550
1946	9.9	9.7	9.8	9.8	9.3	10.3	9.8	...	10.4	11.2	4.6	4.4	4.8	4.6	76.0	1.66	57.0	99.0	615
1947	10.4	9.9	10.2	10.2	9.8	10.7	10.2	...	9.6	10.9	4.6	4.3	4.7	4.5	72.5	2.60	39.5	99.5	1007
1948	9.9	9.6	9.8	10.0	9.5	10.1	9.8	...	9.8	10.6	4.8	4.6	4.8	4.7	75.6	5.36	61.0	99.5	973
1949	9.7	9.6	9.6	9.8	9.3	9.8	9.6	...	9.6	10.0	4.7	4.3	4.7	4.6	78.4	3.73	56.0	100.0	871
1950	9.6	9.7	9.5	9.8	9.4	9.6	9.6	...	9.6	10.0	4.4	4.1	4.7	4.4	72.4	4.50	51.0	100.0	1177
1951	...	9.2	9.5	9.8	9.1	9.7	9.5	...	10.2	11.2	4.6	4.3	4.2	4.4	73.8	4.72	55.0	...	1434
1952	...	9.5	9.7	9.7	...	9.0	9.5	...	11.6	10.7	4.9	4.7	4.9	4.8	77.0	4.67	58.0	...	1653
1953	...	9.8	10.0	10.5	...	10.1	10.1	...	10.2	11.1	4.7	4.5	4.9	4.7	76.6	4.73	54.0	...	1506
1954	...	10.0	10.6	10.2	9.7	10.2	10.1	...	9.6	12.9	4.8	4.6	4.8	4.7	77.2	2.81	50.5	...	1210
1955	...	10.2	10.3	10.4	9.9	10.4	10.2	...	10.9	12.1	4.6	4.5	4.8	4.6	80.3	2.73	56.0	...	1360
1956	9.6	9.8	9.9	10.3	9.5	10.1	9.9	...	10.6	11.8	4.8	4.6	4.9	4.8	73.3	4.90	68.0	...	1368

TABLE I, *continued*
Protein and Oil Contents of Corn and Some Possibly Related Factors

	Source[a]																		
	A	B	C	D	E	F	A–F	G	H		B	C	F	B,C,F					
	Protein content (% db)																		
									Calculated		Oil content (% db)								
Crop Year							Av.		Prot. series	Oil series				Av.	July Mean Temp. °F	July Rain in.	Illinois Yield bu/acre	Illinois Corn Acreage Hybrid %	Illinois Fertilizer Use 1000 Tons
1957	9.5	9.6	9.6	9.9	9.2	10.4	9.7	...	9.2	9.7	4.8	4.6	4.8	4.7	76.7	4.27	64.0	...	1454
1958	10.0	9.6	9.5	9.7	9.7	10.3	9.8	...	9.6	10.4	4.7	4.7	4.8	4.7	72.4	6.66	69.0	...	1597
1959	10.0	10.1	10.5	10.1	10.1	10.4	10.2	...	10.8	10.5	4.9	4.7	4.8	4.8	74.2	4.30	67.0	...	1452
1960	9.8	9.5	9.8	9.8	9.2	10.2	9.7	...	11.8	11.8	4.7	4.6	4.8	4.7	72.4	3.54	68.0	...	1556
1961	10.0	9.6	10.0	9.8	9.5	10.3	9.9	...	11.4	12.0	4.7	4.6	4.8	4.7	73.8	5.22	78.0	...	1628
1962	9.8	9.4	9.6	9.7	9.5	10.3	9.7	...	11.1	...	4.7	4.6	4.8	4.7	72.0	5.15	84.0	...	1939
1963	9.8	9.7	9.9	9.9	9.3	10.2	9.8	...	10.1	10.2	4.9	4.5	4.8	4.7	74.2	5.83	86.0	...	2123
1964	10.0	9.9	9.7	10.3	9.8	10.1	10.0	...	10.7	11.4	4.8	4.4	4.8	4.7	75.6	3.50	80.0	...	1909
1965	10.1	9.7	9.7	10.2	10.0	10.3	10.0	...	11.2	11.0	4.7	4.6	4.8	4.7	73.7	3.43	94.0	...	3060
1966	10.1	10.1	10.4	10.3	...	10.3	10.2	...	11.4	10.8	4.7	4.4	4.8	4.6	78.3	3.33	80.0	...	3296
1967	10.1	9.6	9.8	10.0	...	10.2	9.9	...	11.0	10.8	4.4	4.4	4.6	4.5	71.9	3.39	100.0	...	3199
1968	10.1	9.8	9.7	10.4	...	10.2	10.0	...	10.4	10.6	4.5	4.3	4.6	4.7	73.7	3.53	89.0	...	3300
1969	10.0	9.5	9.8	10.0	9.6	10.3	9.9	...	11.8	10.9	4.5	4.4	4.7	4.5	75.4	7.06	98.0	...	3142
1970	10.1	9.9	9.9	10.3	10.3	10.3	10.1	...	12.6	11.6	4.4	4.2	4.8	4.5	75.2	4.60	74.0	...	3199
1971	10.2	...	...	10.1	9.9	10.3	10.1	...	12.0	...	...	4.3	4.7	4.5	...	...	106.0	...	2926
1972	...	...	...	10.1	9.8	10.1	10.0	...	12.0	9.8	...	4.4	4.6	4.5	...	...	110.0	...	...

[a]A–F from commercial sources, G from reference (1), and H from reference (2).

protein data for a given year were averaged, as were oil data. Similarly, data were combined from the oil and protein series in the University of Illinois' program. If data were available from all sources for all years, some of the averages would be different but the general picture probably would not be altered seriously.

Temperature

Since the highest levels of protein occurred in 1934 and 1936, high temperature was suspected as a causative factor. In Fig. 1, parallelism between July mean temperature and protein content in the decade 1930-1940 is spectacular for both the commercial corn and the Illinois series. This parallelism is also exhibited in much of the rest of the 1907-1970 period, even though variation in protein content is much smaller. In 1916, 1921, and 1955, temperatures were essentially as high as in 1934, but protein content, while higher than in adjacent years, was much lower than in 1934. There are a few outstanding exceptions in which the change in protein is the reverse of the change in temperature; *e.g.*, 1949 and 1957. The Illinois series shows somewhat less correlation with temperature, perhaps because of variation in degree of success in selecting for specific composition, difference in fertility of plots used in different years, and deviations in Urbana weather from the mean of the region.

The relation between protein content and temperature is shown more specifically in Fig. 2; again, the correlation at higher temperatures is obvious. When the July mean temperature was above 77° F, protein content was below 10% in only 1 (1949) of the 16 years. In cooler years, the protein level exceeded 10% in only 16 of the 48 years. If there is any relation between temperature and protein content in these cooler years, it is obscured by other factors. The present data cover too few factors to permit meaningful multiple correlation.

When mean temperature for July-August is considered, the pattern is much

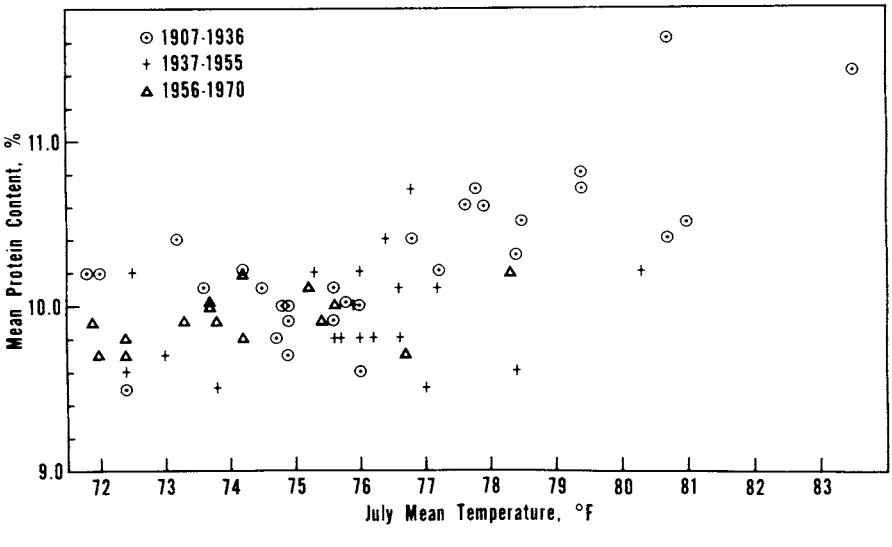

Fig. 2. Relation between protein content of commercial corn and July mean temperature.

like that for July (Fig. 2). Considering only August temperature, no relation with protein is apparent.

Rainfall

There appears to be an inverse relation between July rainfall and protein content (Fig. 3). It seems definite in the period 1907-1936, especially if 1934 and 1915 are disregarded. Similarly, in the 1937-1955 period, eliminating 1945 and 1946 would improve the pattern. In the latest period the relation is not evident. For the entire 64 years, July-August rainfall shows less relation with protein content than July rainfall, and May-September rainfall shows none.

Temperature and Rainfall

Combining the effects of temperature and rainfall modifies the picture (Fig. 4). Although the general impression is one of high protein (large circles) in the hotter, drier years, within these years (above 77° F) there seems to be no relation to rainfall, and in the cooler years the relation is minimal. The highest protein content occurred in 1934 when, surprisingly, the July rainfall was above average. However, May 1934 was the driest May in the 64 years and the developing corn plants may have been seriously affected. Similarly, the high protein in 1936 may have resulted from another unusually dry May (the third driest), although an unusually dry July (one of the two driest) may well have been a contributing factor. The 2 years with the lowest July rainfall in cooler years (below 77° F) produced corn with such low protein content that the data deviate from the expected pattern. June in these years had above average rainfall, which may be responsible for the low-protein figures; a heavy rain in the last days of June should have essentially the same effect as one early in July.

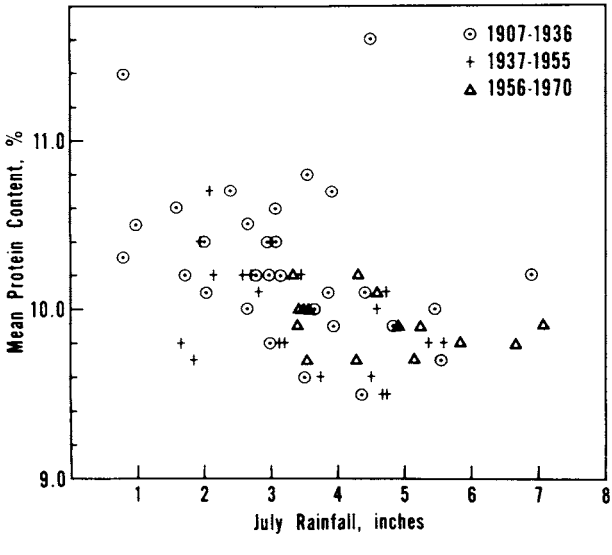

Fig. 3. Relation between protein content of commercial corn and July rainfall.

Hybrid *vs.* Protein

For a number of years there were frequent claims that the introduction of hybrid corn caused a reduction in the protein content of the crop. However, research data soon refuted such claims. The basis for these erroneous claims is

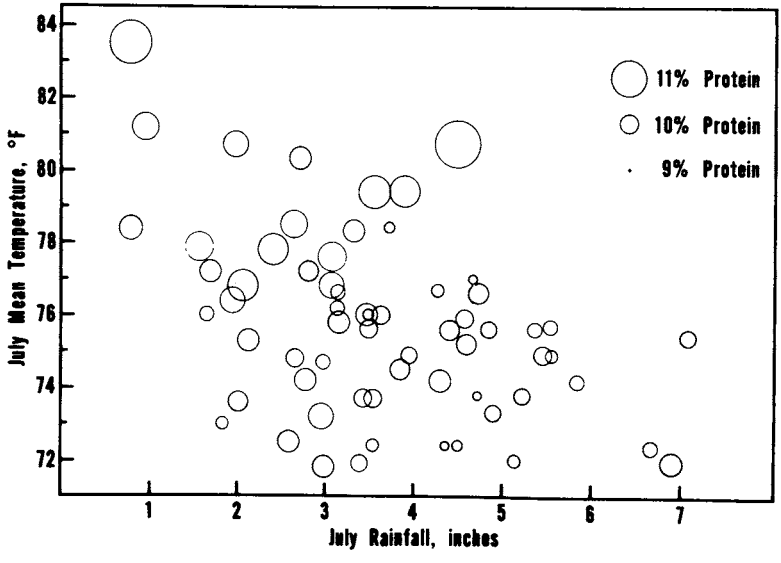

Fig. 4. Relation between protein content of commercial corn, July rainfall, and July mean temperature.

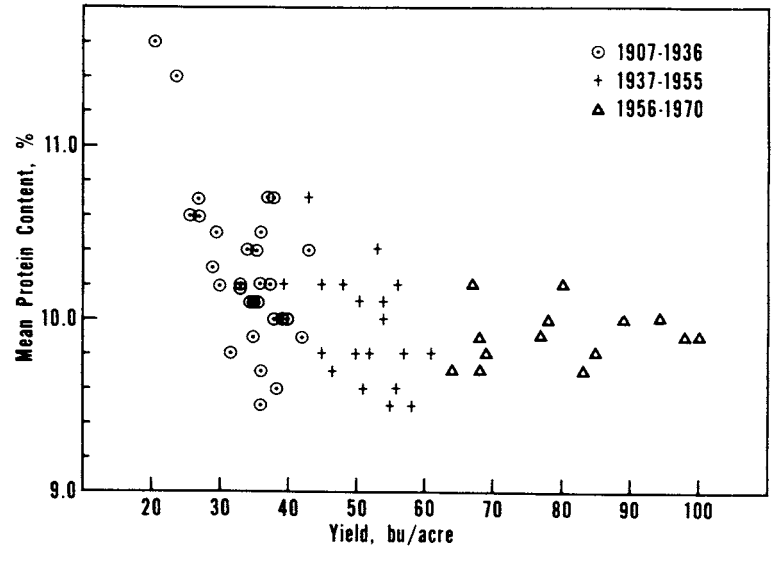

Fig. 5. Relation between protein content of commercial corn and crop yield.

now obvious (Fig. 1); the marked decrease in protein following 1934 coincided closely with the introduction of hybrids. It is perhaps only human that people in the period about 1945-1950 would remember the undesirable decrease in protein in the years after 1934 and fail to remember the earlier desirable change from 1928 to 1934. Present-day hybrid corn is not much different in protein content from the open-pollinated corn before 1930.

Yield Effect

Increased yields have sometimes been blamed for low protein content. In research plots, high yield sometimes results in low protein; however, protein level can be maintained if sufficient fertilizer is used. Yields of commercial corn were fairly uniform from 1907 to 1936, were at a somewhat higher level between 1937 and 1955, and have progressively increased since then (Fig. 1). (The grouping is more obvious if 3-year running averages are considered.) In the first two periods, there is some slight inverse relation between yield and protein content (Fig. 5), but in the third period there is none. Increased fertilizer usage on corn, presumably accompanying the increase in total usage (Fig. 1), has apparently been enough to maintain protein levels during increasingly high yields.

Oil Content

With respect to variation in oil content, data from the three companies providing information are in good agreement (Table I); data from one company are lower than those from the other two because a different solvent (petroleum ether) was used for extracting the oil. Again, 3-year running averages show the parallelism between results of the three companies better than do the data from individual years. This parallelism between companies is so close that the variation shown (Fig. 1) must be real, but no causative factors have been identified.

CONCLUSION

The data collected provide a historical record of the oil and protein contents of corn and of some factors presumed to bear on the composition. They show some interesting relations with protein content but are too limited, too simple, to be definitive. Many other factors must be involved, perhaps day- and night-time temperature, hours and brightness of sunshine, soil moisture, relative humidity, rainfall pattern, date of planting, plant population, and fertilization rate. The effect of any specific factor probably varies in different periods of the growing season, and the interaction between factors must be quite complex. Relations shown for corn primarily of the Illinois-Iowa area do not hold for all areas of the country, but perhaps may be modified to apply to other specific areas.

Acknowledgments

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