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Selecting and Breeding Corn for Protein and Oil in South Dakota

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SELECTING AND BREEDING CORN FOR PROTEIN AND OIL IN SOUTH DAKOTA

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SELECTING AND BREEDING CORN FOR PROTEIN AND OIL IN SOUTH DAKOTA

By A. N. Hume, Agronomist and Superintendent of Sub-Stations; Manley Champlin, Assistant Agronomist, and Collaborator, and Howard Loomis, Analyst.

Since the year 1910, the South Dakota Experiment Station, Agronomy Department, has been developing four separate strains of Minnesota 13 corn. These may be grouped into two pairs of strains, the first pair being *high protein* and *low protein,* and the second pair *high oil* and *low oil.*

The selection and breeding of these several strains has been carried out in pursuance of a project which was started previous to the organization of the present Agronomy Department, by the then Agronomists, Mr. C. Willis and Mr. W. L. Burlison. The object of the project as originated, according to the records, was in large part to secure corn which should have, for instance a high amount of protein, or a high amount of oil, which apparently would increase the value of the corn for manufacturing oil.

Since the present Agronomy Department began to conduct the project, it has been conducted with slight modifications, largely with a view to accomplishing, or at least of demonstrating the practicability of accomplishing, the production of the strains of corn involved. The writers believe that some information has been acquired, which points somewhat conclusively toward an apparent fact that it is easily possible in South Dakota to secure, by chemical and mechanical selection, strains of corn that are either high or low in protein, or either high or low in oil. Accordingly we are making the present report as a report of progress, and more especially in view of the fact that it is the plan somewhat to modify the manner of the investigation.

PLAN OF PROJECT

The plan of the corn breeding project under discussion as inaugurated, has been similar to the plan pursued by some other experiment stations in making similar selections.

The general nature of the plan has been to select ears of corn known as "mother ears", which should contain, first, as high a percentage of protein as it is possible to secure, and similarly, but in the opposite direction, to select other "mother" ears of the same variety and containing the lowest percentages of protein that could possibly be found.

Mother ears thus selected were recorded in order, upon a corn breeding register sheet. The several mother ears were shelled and the kernels from each were planted in a row by itself. The mother ears of each strain were planted in adjoining rows, the total number of rows of each strain thus making up what is called "the high protein plot" or "the low protein plot," or "the high oil" or the "low oil plot," as the case might be.

At the close of the season, when the rows of corn from the mother ears had matured, they were harvested, each row by itself and the yield of corn taken. Moreover, seed ears were selected from each row and retained for possible planting the following year. At least as many as ten such seed ears have been usually selected from each field row. The ears thus selected from the several rows have been inspected mechanically. Each year the rows from whence seed ears for the following year were to be taken have been thus tentatively determined.

Before finally determining the rows from which seed ears for the following year should be taken, however, a chemical analysis was made of a composite sample of corn from the rows thus tentatively selected by chemical examination. These chemical determinations were made by the Agronomy Analyst, whether for protein or for oil, according to the strain of corn desired in making the given selection.

The details of selecting corn mechanically for high or low protein, or for high or low oil content, are described more in detail on page 67.

In short, in breeding corn for protein, high protein mother ears were planted separately in rows. Low protein mother ears were also planted separately in rows. For the following year of breeding, the process was continued with seed secured from the individual rows of corn grown in the previous year's breeding plot. Selections of seed ears were made mechanically, and the accuracy of the selections was checked by chemical analyses. The details of making selections have been varied slightly in the several years. Moreover, changes in personnel of the Agronomy Department have probably interfered with the continuity of results. The results as attained indicate that what was attempted by this project has been accomplished, so far as securing a strain of corn having a high percentage of protein and another strain having a low percentage of protein is concerned.

SELECTION FOR HIGH PROTEIN AND LOW PROTEIN

In the Annual Report of the Agronomist to the Director, June 30, 1913, the following was given as a summary of work done in the direction of securing high protein and low protein strains of corn, with results added for 1914.

"In 1909, selections of seed corn for low protein were apparently lost. Therefore, seed used for planting the high protein corn for 1910, and for planting the low protein corn of the same year, appears from the records to have been the same. In other words, seed for planting the 1911 low protein plot was selected from the high protein plot of 1910."

The following table shows composite analyses of high and low protein seed planted for the year indicated.

Composite Per Cents of Protein in Seed Planted in High and Low Protein Plots, With Respective Differences.

Year	Percent protein in seed planted in high protein plots	Percent protein in seed planted in low protein plots	Difference
1910	13.14	13.14	0.00
1911	13.09	11.11	1.98
1912	13.91	11.07	2.84
1913	13.48	11.98	1.50
1914	12.83	11.22	1.61

It is apparent that two strains of the same variety of corn are being secured, by combined mechanical and chemical selection, one having a constantly higher percentage of protein than the other. The difference in protein is not constant.

This apparent fact that it is possible to develop separate strains of corn having a similar origin, one with a high percentage of protein and the other a comparatively low percentage, is of interest to South Dakota farmers. This is for the reason that it may be possible to employ such knowledge in making selections when conducting practical corn breeding. So far as the writers are informed, no previous attempt has been made to develop such strains of corn in our state. It is considered, therefore, that the present results have added something to our knowledge of corn breeding in South Dakota.

The apparent fact that it is possible to secure results such as are put down in this bulletin accords with results in other states, notably those secured in Illinois, and reported in Bulletin No. 100 of the Experiment Station of that state. (See also Illinois Experiment Sta. Bu. 87).

THE TOTAL YIELD OF PROTEIN PER ACRE IS IMPORTANT

Assuming that the present results with securing strains of corn are in substantial accord with those previously acquired, there is still information of more importance to acquire. The total amount of protein per acre which may be harvested by use of a given strain of corn is apparently of as much importance as the per cent of protein in the corn harvested. The writers have, therefore, sought to determine whether results thus far acquired might give any indications. One might ask a direct question—Will a high protein strain of corn produce more protein per acre than a low protein strain, other things equal? The following Table I is constructed from data of our corn breeding records.

In securing the pounds of protein per acre, bushels of corn are computed by taking eighty pounds of ears for one bushel, then using eighty-one as the percentage of grain per ear, then deducting the computed amount for moisture in the grain, as based upon the laboratory determinations, then computing the amount of protein per acre with using the percentage of protein as put down in Table I.

In the above table, it may be noted that the first digit of the row-numbers given both under the heading of High Protein and Low Protein, indicates the year of the breeding plot, whether it be first, second, third or fourth. The following digits indicate the number of the row involved. Thus in the year 1910, the row number 106 indicates Row No. 6 in the first year of the breeding plot. In the year 1913, No. 401 indicates Row No. 1 of the fourth year of the breeding plot. In the second column under high protein, and also in the second column under low protein are given the yields of corn of the rows in question. These are computed by using the weights of corn produced per row as a basis for computing the yield of ear corn per acre, and assuming a weight of eighty pounds per bushel of ear corn.

The yields put down are thus produced by the rows of the numbers preceding. The per cents of protein put down in Column 3, under High Protein, and under Column 3, under Low Protein, are averages of all analyses made of ears taken from the row in question. In nearly every case as many as three ears from each row were analyzed chemically for the purpose of securing seed ears for the breeding plot of the following year. Frequently a greater num-

TABLE I.

Yields in Bushels Per Acre of High Protein and Low Protein Rows, With Per Cent of Protein Contained in the Corn, and Yields of Protein in Pounds Per Acre.

Year	Row No.	HIGH PROTEIN				LOW PROTEIN		
		Yield in bushels per acre	Per cent protein in corn harvested	Yield pounds protein per acre	Row No.	Yield in bushels per acre	Per cent protein in corn harvested	Yield pounds protein per acre
1910	106	44.4	13.07	376.04	117	40.0	11.54	299.14
	107	44.4	13.33	383.49	118	40.6	11.92	313.60
	110	45.0	12.96	377.88	120	36.9	10.13	242.22
Average		44.6	13.11	379.13		39.2	11.20	284.98
1911	213	30.6	13.47	241.85	201	33.8	11.76	233.21
	215	21.3	14.31	178.84	206	35.0	9.95	204.38
	223	26.3	13.97	215.58	222	34.4	11.52	232.46
Average		26.1	13.91	212.09		34.4	11.07	223.35
1912	302	58.5	12.83	446.14	302	52.8	13.41	420.87
	306	55.0	13.62	445.27	306	33.6	12.26	244.86
	308	48.6	11.81	341.17	307	45.7	13.01	353.41
	311	62.8	12.91	481.91	309	48.0	12.93	368.91
	314	55.0	12.78	417.81	314	44.3	11.99	315.73
	316	66.4	13.08	516.25	315	50.7	12.29	370.38
	317	44.3	13.35	351.54	319	45.0	11.91	320.18
	320	50.7	13.22	398.40	322	50.7	12.21	367.97
	323	49.3	12.77	374.21	323	51.4	12.10	369.69
	325	46.4	12.53	345.58	324	40.7	12.43	300.71
Average		53.7	12.89	411.83		46.3	12.46	343.27
1913	401	53.6			401	44.8	11.05	298.21
	402	67.8			402	53.4	11.69	376.00
	403	63.3			403	58.4		
	404	58.4			404	39.8		
	405	60.6			405	62.8		
	406	53.8	13.41	434.93	406	48.7	10.93	320.65
	407	62.8			407	60.6		
	408	47.4			408	52.1		
	409	63.4	12.15	464.42	409	48.6		
	410	53.8	12.92	419.16	410	46.3		
Average		58.5	12.83	439.50		51.5	11.22	331.62

ber than three from a given row were analyzed. The per cents of protein put down in the Table are averages of these analyses. In the last column under High Protein, and also in the last column under Low Protein, are put down the yields of protein figured to pounds per acre for each of the several rows. These totals in each case are computed with assuming eighty pounds of ear corn per bushel and assuming further, that there was 81 per cent of shelled corn on the ears harvested. This latter per cent is in accord with some data which have been acquired by shelling Minnesota 13 ears of corn.

COMPARISON OF YIELDS OF PROTEIN FROM HIGH PROTEIN AND LOW PROTEIN ROWS

A casual examination of the two columns of yields of protein in pounds per acre as put down in Table I, will strongly indicate that the higher yields of protein per acre have been secured from high protein corn. In order, however, to make comparison easier the averages are abstracted from Table I and recompiled in Table II, which follows:

TABLE II.

Comparative Average Yields of High Protein and of Low Protein Corn, 1910-1913, in Bushels Per Acre, and Pounds of Protein Per Acre—From Table I.

YEAR	HIGH PROTEIN			LOW PROTEIN		
	Yield in bushels per acre	Per cent protein in corn harvested	Pounds yield of protein per acre	Yield in bushels per acre	Per cent protein in corn harvested	Pounds yield of protein per acre
1910	44.6	13.11	379.13	39.2	11.20	284.98
1911	26.1	13.91	212.09	34.4	11.07	223.35
1912	53.7	12.89	411.83	46.3	12.46	343.27
1913	58.5	12.83	439.50	51.5	11.22	331.62
Average	45.7	13.18	360.64	42.8	11.49	295.80

From this Table, it may readily be discovered:

(1) In three of the four years 1910-13, high protein ears produced a higher average yield of corn in bushels per acre than low protein.

(2) The general average yield of high protein corn for the four years was 2.9 bushels greater than the yield of low protein.

(3) The computed yield of protein per acre from high protein ears was also greater in three of the four years recorded than the corresponding yield of protein from low protein ears.

(4) The general average yield of protein in pounds per acre from high protein corn for the four years was 64.84 pounds higher than the yield from low protein corn. The difference is 21.9 per cent in favor of high protein corn, using low protein corn as a basis.

It is believed by the writers that the chances for error in the conclusions above based on Table I, are as few as would usually be found in an experiment of similar nature. The natural type of soil of both high protein and low protein plots was similar. The soil treatment of the two pieces of land was not widely different. If one piece of land is "richer" than the other, and if either kind of corn has the advantage over the other on that account, it would be difficult to determine which.

PROTEIN SELECTION

In selection of high protein corn, advantage is taken of the fact that the corn kernel is not homogeneous in structure. This is well known by all corn growers and may be noted in detail by anyone who wishes to examine kernels of corn.

Corn kernels may be said to roughly consist of three parts:

(1) The germ, which is readily visible in outline from one side of the kernel.

(2) The corneous, semi-transparent part of the endosperm. This part may be distinguished when holding up the kernel before the light by the fact that it appears glassy and smooth, and permits the light to pass thru to some little extent.

(3) The starchy endosperm. This portion is opaque. When the kernel is held up before the light the starch of the kernel does not permit the light to pass thru.

The corneous, glassy portion of the endosperm is found mainly at each side of the germ and occupying the main central portion of the sides of the kernel. The starchy portion of the endosperm forms the "cap" of the kernel and moreover, extends down and more or less completely surrounds the germ in direct contact with the latter.

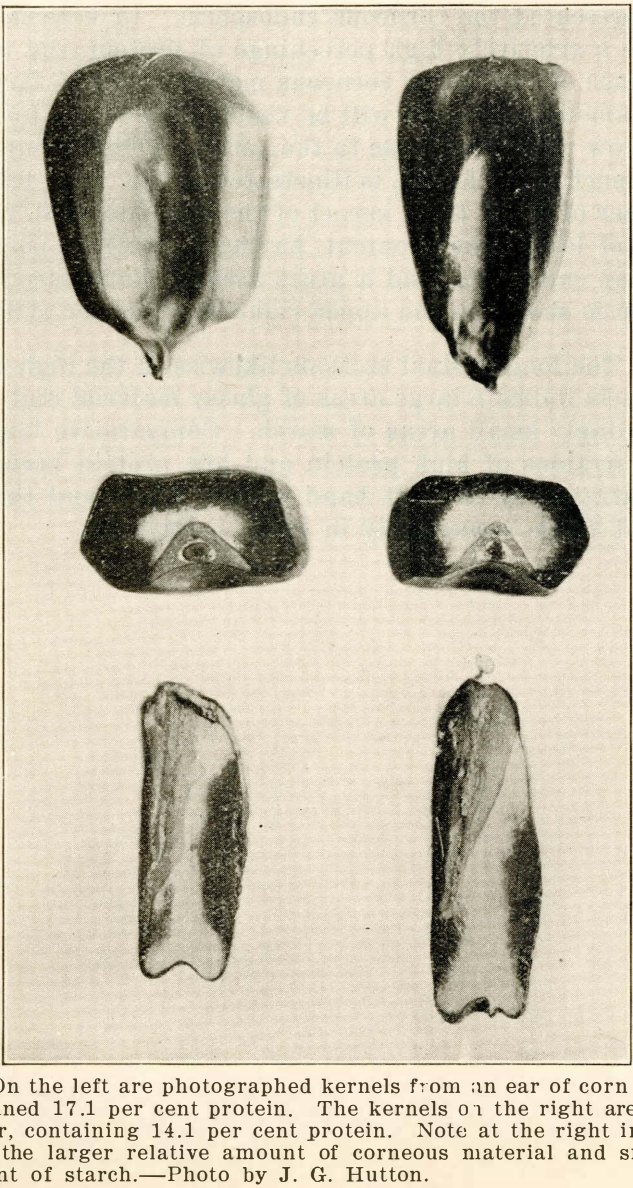
The facts that the proportion of each of these three main portions of corn kernels which may vary in size in different kernels, and that the various kernels of individual ears, are consistent in kernel composition throughout, make it possible to mechanically select those kernels that have, for instance, a large portion of corneous endosperm, and therefore, a correspondingly large proportoin of protein. The additional fact that the content of the various kernels of individual ears of corn is consistent thruout, makes it possible to select high or low protein ears, and therefrom to secure high or low protein "strains."

In selecting corn having high percentage of protein, it is well to first make a casual examination of ears and of kernels. High protein kernels consisting largely, as they do, of corneous endosperm, appear glassy. In South Dakota they may have a smooth, some even a "flinty" appearance. It is possible to make a preliminary selection of a number of ears of corn which have kernels that appear glassy as compared with the kernels of other ears that have a more starchy, opaque appearance.

It may be well in selecting the high protein ears from out of a given amount of corn, thus to make a preliminary division upon the basis of the quality indicated. In order to better observe the relative portions of the corn kernels from individual ears, several kernels should be removed from each ear with the use of a strong knife, preferably sharp. Different kernels should be cross sectioned, a number of them laterally and a number longitudinally. The cross sections of the kernels will present somewhat the appearance of those shown in Plate I, Page 69.

HIGH PROTEIN AND LOW PROTEIN KERNELS

PLATE I.



On the left are photographed kernels from an ear of corn which contained 17.1 per cent protein. The kernels on the right are from an ear, containing 14.1 per cent protein. Note at the right in each case, the larger relative amount of corneous material and smaller amount of starch.—Photo by J. G. Hutton.

In kernels sectioned laterally, one may observe the severed end of the germ. Immediately surrounding this will be a certain amount of starch outside of which will be presented the corneous endosperm. In kernels which have a relatively high percentage of protein, the relative surface of this latter corneous material will be large and the amount of starch will be visible only in the form of a narrow white line close to the germ. A high protein kernel, such as indicated, is illustrated in the upper left hand corner of Plate I. A kernel of the opposite kind, namely, one of low protein content, having a small proportion of glassy endosperm and a great area of starch around the germ is shown in the upper right hand corner of Plate I.

The longitudinal sections likewise in the high protein kernels indicate large areas of glassy material and correspondingly small areas of starch. Comparative longitudinal sections of high protein and low protein kernels are illustrated by the left hand middle figure and the right hand figure respectively in Plate I, Page 69.

PRACTICAL CORN BREEDING FOR HIGH PROTEIN OR LOW PROTEIN CONTENT

It is of interest to practical farmers of South Dakota to know whether the selection of corn for chemical content as was described, is or is not so difficult as to make it of practical interest. The question may properly be asked whether such selection may be carried out by South Dakota farmers on their own farms. As evidence that such selection is quite possible, results may again be cited from Illinois Experiment Station Bulletin No. 100. This bulletin tabulates results from nine different selections made by six different farmers and two experiment stations. After these selections were made mechanically, the corn selected was subjected to chemical analysis. The average protein content of the nine different trials for selecting high protein was 11.85. The average of ears rejected as not high in protein was 10.80. Apparently in these instances, with the exception of one case, the ears rejected as not high in protein were not necessarily selected as low in protein, thus the difference represented of 1.05 per cent would not be the extreme difference in percentage of protein which it would have been possible to secure.

At South Dakota State College, spring semester, 1914, one of the laboratory exercises for advanced students in farm crops, was the mechanical selection of ears of corn which should be high in protein content and likewise the selection of other ears which should be low in protein content. After each one of the twelve members of the class had selected one high protein ear and one low protein ear of corn, the class as a unit were asked to select from the total twelve high protein ears the one which would be deemed highest in this respect and likewise from the low protein ears the one which would be deemed lowest in this respect. The class was unanimous in the choice of the high protein ear. The low protein ear was chosen by a majority of the twelve members of the class. After the two ears were thus selected, they were submitted for analysis for raw protein.

It was determined that the protein content of the high protein ear was 17.1 per cent and the low protein was 14.13 per cent, a difference of 2.97 per cent. This incident of corn selection by students is an example of what may be accomplished in this direction by skillful persons who, however, had not previously had much experience.

The experience of the various corn breeders of the country, such as is quoted from Illinois, and of students of South Dakota State College, given above, as well as the several years' results of the South Dakota Experiment Station as cited in this bulletin, all indicate that it is well within possibility for practical corn breeders to obtain excellent results by selecting strains of corn mechanically for certain constituents, especially protein. Obviously considerable experience in such selection will be necessary to secure maximum results.

It has been indicated that where strains of corn have been successfully selected for chemical composition, a number of chemical analyses have entered into the selection. It might be immediately urged that any necessity for chemical analyses would render any method of corn breeding for chemical composition impractical. As a matter of fact, few are necessary.

One state experiment station was in a position to offer to analyze for any farmer "who wishes to improve the quality of his corn by breeding according to these directions, and who agrees to make the best selection of seed possible, two composite samples representing each of the two lots of ears, that is, the selected lot and the rejected lot." Such an offer makes it possible for certain corn breeders, who desire to select corn for chemical composition, namely protein or oil, to have the accuracy of their selection "checked" annually. Such checking is sufficient to enable such corn breeders to find whether their method of selection is actually securing the kind of corn desired.

SELECTING AND BREEDING CORN FOR OIL CONTENT

It is not only possible to select corn for a high or a low protein content by mechanical means, corn kernels may be also selected mechanically that are either high or low in content of oil. This possibility is based upon the fact that approximately 80 per cent of the entire oil content of any corn kernel is to be found within the germ of the kernel. Accordingly corn kernels having relatively the largest germs are sure to be highest in content of oil.

The oil content of the various kernels of ears of corn is likewise found to be consistent. This means that all kernels on the same ear may be depended upon to have approximately the same composition of oil. Thus ears of corn may be selected and may be planted in an ear to row system, giving rise to strains of corn that have varying percentages of oil content.

The South Dakota Experiment Station has accomplished certain results with selection of a strain of corn for high oil and another strain for low oil. The original stock of corn from which these strains were taken was the same Minnesota 13 corn as has been used in breeding for high and low protein.

The selections for oil content have not been continued for many years. The following short table summarizes the results of making composite analyses of ears of corn for oil content in 1911 and 1912.

TABLE III.

Composite Per Cents of Oil in Seed Planted in High and Low Oil Plots, with Respective Differences.

Year	Per cent oil in corn planted in high oil plots	Per cent oil in corn planted in low oil plots	Difference
1911	3.474	3.147	0.327
1912	6.103	5.66	0.443

The differences in oil content of the two years for which results are available indicate that they are in general accord with what would be expected and with results that have been secured elsewhere in breeding corn for oil content.

That which has been said about the practicability of making mechanical selections of strains of corn for high protein and low protein by corn breeders on their own farms might apparently be repeated with reference to high oil and low oil.

It is apparently quite possible to secure strains of these latter kinds by means of mechanical selection, providing it seems desirable to do so.

When breeding strains of corn for content of oil, as for content of protein, a question of much interest is total yield of oil per acre. In other words, is a high oil strain of corn capable of yielding more pounds of oil per acre than a low oil strain?

The following table, constructed from data secured from the high oil and low oil breeding plots gives some information relative to such a question.

TABLE IV.

Comparative Yields of Oil in Pounds Per Acre From High Oil and Low Oil Strains.

Year	Row No.	Composite per cent oil in corn harvested	Yield in bushels per acre	Pounds of oil yield per acre	Row No.	Composite per cent oil in corn harvested	Yield in bushels per acre	Pounds of oil yield per acre
	High Oil				Low Oil			
1911	103	3.68	40.6	86.87	109	2.82	39.4	64.69
	115	3.22	39.4	73.76	119	3.07	28.1	50.23
	121	3.52	48.8	99.87	123	3.55	33.8	69.86
Average		3.47	42.93	86.83		3.15	33.77	61.59
1912	201	6.18	38.6	141.75	202	5.67	40.0	135.40
	202	5.69	69.3	234.31	203	5.48	54.3	177.64
	203	5.91	64.3	225.81	206	5.02	56.4	168.97
	207	6.20	68.6	252.73	208	5.24	55.0	172.05
	208	6.31	55.0	206.23	210	5.94	51.4	182.27
	209	6.37	57.8	218.78	211	6.24	52.8	196.70
	213	5.72	60.0	203.93	212	5.45	55.7	181.23
	217	5.96	57.1	202.22	216	5.64	46.4	156.23
	220	6.36	62.1	234.69	221	6.25	48.6	181.34
	221	6.32	66.4	249.36	223	5.67	45.7	154.69
Average		6.10	59.92	216.97		5.66	50.63	170.66
1913	301		55.7		301		62.7	
	302		56.7		302		55.3	
	303		57.7		303		61.4	
	304		57.7		304		36.0	
	305		56.7		305		47.4	
	306		60.4		306		44.7	
	307		53.7		307		64.6	
	308		60.8		308		50.3	
	309		53.3		309		60.1	
	310		57.7		310		43.0	
Average			57.04				52.55	

The data of the above table are offered as tentative until more data are available. In the meantime it may be noted that in three years, 1911, '12, '13, the average yield in bushels per acre of the high oil strain of corn has been greater than for average yield of bushels per acre of the low oil strain of corn. Moreover, for the years 1911 and 1912, the data indicate that the yield of oil in pounds per acre, as computed was greater from high oil corn than from low oil corn.

Providing further experiment shall substantiate these data concerning oil, they are in agreement with similar data concerning protein in the general respect *that the highest yields of protein per acre are secured from high protein strains of corn, and the highest yields of oil per acre are secured from high oil strains of corn.*

THE PERCENTAGE OF OIL CONTENT IN CORN AS AFFECTED BY THE DEGREE OF MATURITY

From the lines marked Average in Table IV, in the columns headed Composite Per cent of Oil in Corn Harvested, it may be noted that the figures for 1912 are noticeably higher both for high oil and for low oil than for figures for 1911. This considerable variation in oil content of the corn crop for the two years was remarked upon immediately by Mr. Howard Loomis, Analyst of the Agronomy Department. Steps were taken to ascertain a reason for variation.

It was thought that an explanation might be found in some difference of degree of maturity of the corn harvested in the two seasons.

Accordingly a small project was undertaken with harvesting similar ears of corn at three different stages of maturity, and later analyzing the several ears for oil content. On August 15, 1913, Mr. Loomis harvested five separate ears of corn, on September 4th, five additional ears were harvested, and again on September 19th, five ears were harvested. These three lots of five ears each were hung for airing under similar conditions and permitted to become air dry.

In addition to these three lots of five ears each, composite samples of corn were taken for analysis on each of the three dates given above. On August 15, 1913, a composite sample was taken from forty ears of corn, on September 4th, 1913, another composite sample of forty ears was taken, and on September 19th, another such composite sample was taken. The following table summarizes the results of the analysis of single ears and of composite samples as described.

TABLE IV.

Oil Content of Corn Ears and Samples Harvested at Different Degrees of Maturity (1913)

Date of Harvesting	August 15	September 4	September 19
Ear Number	Percent of oil		
1	3.279	5.628	5.697
2	3.209	5.392	5.633
3	2.605	5.861	5.862
4	3.011	5.198	5.747
5	3.199	4.289	6.568
Average	3.0606	5.273	5.901
Average percent of oil composite sample 40 ears each)	3.272	4.982	5.523

The results of the above table indicate that the percentage of oil in the dry matter of corn increases very appreciably from a very early date of harvesting up to a date of complete maturity.

Every one of the five ears harvested August 15th possessed a lower percentage of oil than any ear harvested September 4th, and every ear harvested September 4th possessed a lower percentage than any ear harvested September 19th.

The average percentage of oil in the ears harvested August 15th, was 3.06 per cent and of those harvested September 19th was 5.88 per cent, a difference of 2.82 per cent. The corresponding composite analysis, while showing slightly less difference, confirmed the conclusion that *with increasing maturity, the percentage of oil in the dry matter of corn increases.*

RAINFALL AT THE SEVERAL STATIONS

	Brookings									Cottonwood				Eureka					Highmore					
	1905	1906	1907	1908	1909	1910	1911	1912	1913	1910	1911	1912	1913	1909	1910	1911	1912	1913	1908	1909	1910	1911	1912	1913
Jan.	0.22	0.17	1.06	0.20	1.20	1.07	0.61	0.28	0.20	0.66	T	0.17	0.16	0.10	0.60	0.50	0.25	0.10	T	0.26	0.82	0.11	0.13	0.05
Feb.	1.00	0.02	0.28	1.80	1.57	0.40	0.53	0.24	0.09	0.97	0.15	0.05	0.10	0.45	1.70	0.73	0.40	0.03	0.53	0.34	0.19	0.39	0.11	0.30
Mch.	0.68	0.58	0.55	1.16	0.37	0.35	0.53	0.26	0.45	0.76	T	3.00	0.43	0.14	1.23	0.62	1.05	0.09	0.00	0.13	0.58	2.54	0.27	0.87
Apr.	1.01	1.40	1.67	2.10	1.16	2.34	1.62	3.36	2.24	1.06	0.85	3.32	1.15	0.50	0.82	2.24	1.29	0.68	1.35	0.30	1.40	0.32	1.05	1.27
May	6.14	3.51	2.36	6.46	4.85	0.87	1.90	6.98	3.60	2.54	1.10	1.18	2.95	2.65	0.42	0.97	3.37	1.97	2.68	4.72	0.94	2.31	2.20	4.56
June	6.09	4.89	5.65	6.35	2.29	1.85	3.78	2.09	1.96	1.30	0.64	0.95	0.59	3.35	3.80	1.29	1.50	2.91	5.78	1.69	3.74	0.09	1.31	0.97
July	0.98	1.86	3.77	4.69	2.44	1.68	3.32	2.52	2.99	1.11	0.59	2.42	0.81	2.21	0.53	0.43	2.19	2.16	2.49	1.81	0.85	2.69	1.44	1.79
Aug.	4.54	4.28	1.41	2.37	3.39	2.46	3.81	4.68	1.33	0.48	2.41	3.42	1.84	1.39	2.60	3.57	3.27	1.53	3.53	3.74	0.66	2.52	3.39	1.20
Sept.	2.16	5.13	1.28	3.89	1.67	0.96	3.08	1.61	1.55	0.82	3.59	1.30	1.15	1.25	3.65	1.15	1.43	0.54	0.62	1.70	0.89	3.06	0.71	0.53
Oct.	1.50	3.01	0.96	1.43	1.71	0.38	5.12	0.96	1.18	0.32	1.15	0.11	0.76	0.17	0.18	0.61	0.07	1.52	2.19	1.04	0.24	1.05	0.20	0.61
Nov.	2.45	0.89	0.10	1.30	0.65	0.17	0.23	0.00	0.81	0.53	0.20	T	0.14	0.60	T	0.88	T	0.06	1.39	0.71	0.40	0.35	0.00	0.03
Dec.	T	0.52	1.12	0.42	1.14	0.10	0.42	0.20	0.09	3.00	0.42	0.12	0.38	2.40	0.25	0.80	0.11	0.52	0.31	1.41	0.44	0.44	0.35	0.28
Total	22.77	26.26	20.21	32.17	22.44	12.63	24.95	23.18	16.49	12.65	11.10	16.04	10.46	15.21	15.78	13.79	14.93	12.11	20.87	17.85	9.05	15.87	12.06	12.46

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97. Speltz and Millet for the Production of Baby Beef.
99. Macaroni and Durum Wheats. A continuation of Bulletin 92.
105. Stock Food for Pigs.
106. Sugar Beets in South Dakota.
107. Sheep Scab.
108. New Hybrid Fruits.
109. Rusts of Cereals and other Plants.
110. Progress in Variety Tests of Oats.
111. A Study of South Dakota Butter with Suggestions for Improvement.
112. The Killing of Mustard and other Noxious Weeds in Grain Fields by the use of Iron Sulphate.
113. Progress in Variety Tests of Barley.
114. Digestion Coefficients of Grains and Fodders for South Dakota.
115. Report of Work for 1907 and 1908 at Highmore Sub-Station.
116. Acidity of Creamery Butter and its Relation to Quality.
117. Sugar Beets in South Dakota.
123. Milk Powder Starters in Creameries.
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126. Alkali Soils.
127. Breeding and Feeding Sheep.
128. Progress in Wheat Investigations.

129. Growing Pedigreed Sugar Beet Seed in South Dakota.

130. Some New Fruits.

131. Scabies (Mange) in Cattle.

132. Effects of Alkali Water on Dairy Products.

134. More Winter Dairying in South Dakota.

135. Trials with Millets and Sorghums for Grain and Hay in South Dakota.

136. Fattening Pigs.

137. Wintering Steers.

138. Hog Cholera.

139. Soil and Crop and Their Relation to State Building.

140. Selection and Preparation of Seed Potatoes in the Season of 1912.

141. Co-Operative Tests of Alfalfa from Siberia and European Russia.

142. Sugar Beets in South Dakota—Results to Date.

143. Roughage for Fattening Lambs.

144. Preliminary Report on the Milking Machine.

145. A Report of Progress in Soil Fertility Investigations.

146. Some Varieties and Strains of Wheat and their Yields in South Dakota.

147. Effect of Alkali Water on Dairy Cows.

148. Corn Silage and Mill Products for Steers.

149. Some Varieties and Strains of Oats and their Yields in South Dakota.

150. Weeds.

151. Trials with Sweet Clover in South Dakota.

152. Testing and Handling Dairy Products.