TABLE 1.—*Results of rainfall measurements in Guatemala and Salvaaor.*

[Means for given periods in mm.]

Station	San Luis.	La Concepcion.	La Candelaria.	El Sororro.	El Reposo.	San Francisco, Miramar.	Santa Amalia.	El Rosario, Bola de Oro.	Bolivar.
Department	San Marcos.	San Marcos.	San Marcos.	San Marcos.	Quezaltenango, Costa Cuca.	Quezaltenango, Costa Cuca.	Quezaltenango, Costa Cuca.	Quezaltenango, Costa Cuca.	Quezaltenango, Costa Cuca.
Altitude	650 meters.	820 meters.	860 meters.	(?)	180 meters.	740 meters.	800 meters.	900 meters.	1,000 meters.
Period	1909–1919	1909–1919	1909–1919	1916–1919	May, 1913–Dec., 1919.	1908–1919	1909–1919	1911–1919	1909–1919
January	49.9	35.5	41.9	58.9	30.6	30.9	29.0	43.8	44.5
February	92.8	51.9	49.0	102.1	31.7	35.7	27.8	31.4	42.3
March	123.6	114.2	107.1	166.9	51.5	69.0	63.2	70.3	86.3
April	311.5	266.8	261.5	270.1	164.0	242.9	232.5	195.9	241.9
May	608.8	514.7	508.9	708.2	267.8	495.0	421.7	448.0	511.1
June	712.2	639.2	650.4	780.1	496.1	647.5	639.3	608.4	692.5
July	539.7	463.7	448.9	640.8	319.4	440.3	513.8	476.3	557.2
August	658.0	519.1	545.6	643.0	390.5	591.5	630.3	539.1	647.0
September	792.0	691.0	672.4	821.1	428.3	753.3	822.6	657.9	812.6
October	697.4	600.2	630.7	527.6	522.5	689.3	709.3	560.4	651.7
November	250.5	138.5	111.9	256.2	105.0	144.7	173.4	151.0	187.7
December	58.7	89.7	87.5	82.3	2.7	55.2	46.0	50.1	66.0
Year	4,895.1	4,124.5	4,115.8	5,057.5	2,741.6	4,194.4	4,308.9	3,832.8	4,540.8
Max. in month	Sept. 16: 1,031.6	Sept. 9: 1,113.4	Sept. 9: 1,126.2	Sept. 18: 969.6	Oct. 17: 1,013.0	Sept. 9: 1,244.6	Sept. 19: 1,055.9	Sept. 18: 1,018.6	Sept. 18: 1,235.3
Min. in month	Dec. 12: 0	Jan., Feb. 10: 0 Feb. 12: 0	Jan., Feb. 10: 0 Feb. 12: 0	Jan. 19: 1.3	Dec. 13, 14, 16–19: 0 Feb. 15, Mar. 16, Feb. 18: 0	Jan. 10, Feb. 19, Mar. 9, Dec. 10: 0	Jan. 12: 0	Dec. 18: 4.9	Dec. 18: 0
Max. in year	1909: 5,946.1	1909: 5,352.5	1916: 5,554.0	1916: 5,355.0	1917: 3,487.4	1909: 6,065.0	1916: 5,880.7	1916: 5,179.3	1916: 6,745.0
Min. in year	1912: 3,966.4	1914: 3,025.1	1912: 3,204.8	1919: 4,834.0	1919: 2,704.4	1913: 2,850.6	1914: 2,760.2	1914: 2,689.0	1912: 3,405.9

Station	El Pensamiento.	Santa Sofia.	Morella.	Magdalena.	Setal.	Chinasayub.	Chimax.	Samac.	Seritquiché.	San Salvador.
Department	Quezaltenango. (Chuvá.)	Chimaltenango.	Chimaltenango.	El Quiché.	Alta Verapaz.	Alta Verapaz.	Alta Verapaz.	Alta Verapaz.	Alta Verapaz.	Republic of Salvador.
Altitude	1,200 meters.	760 meters.	980 meters.	2,200 meters.	730 meters.	950 meters.	1,306 meters.	1,300 meters.	....	657 meters.
Period	1909–1919	1912–1919	1909–1919	1913–1919	1914–1920 except 1918.	1914–1920	1912–1920	1920	1920	1912–1920
January	36.4	47.0	51.0	6.5	314.9	313.7	146.2	189.0	201.0	13.7
February	44.2	58.0	74.0	3.0	334.7	256.4	101.6	245.2	119.0	13.5
March	102.2	100.0	105.4	30.9	283.3	222.1	131.7	172.0	64.0	24.7
April	213.1	256.4	190.7	34.1	286.7	288.3	143.7	132.1	77.0	72.8
May	411.8	641.3	581.9	80.7	311.9	335.3	199.2	354.0	474.0	167.8
June	668.4	816.4	763.8	170.6	462.6	519.0	285.5	651.3	818.0	298.0
July	488.5	693.5	559.4	139.5	405.9	512.3	250.4	228.5	690.0	306.8
August	547.8	680.9	708.3	137.7	402.7	396.4	234.7	195.0	417.0	298.9
September	621.7	941.4	901.7	181.3	576.1	588.5	263.7	743.4	781.5	260.0
October[1]	531.3	785.4	788.4	109.6	728.5	812.5	317.5	651.2	405.5	281.5
November[1]	144.7	186.4	183.3	29.2	773.6	653.4	308.2	941.2	396.0	42.3
December[1]	61.0	46.6	46.4	5.9	498.0	514.4	184.5	400.8	69.0	20.3
Year[1]	3,862.4	5,253.3	4,954.3	979.0	5,378.9	5,412.3	2,566.9	4,903.7	4,512.0	1,800.3
Max. in month	June 10: 1,138.5	July 16: 1,182.2	Oct. 9: 1,220.8	June 17: 286.5	Nov. 14: 1,182.5	Oct. 17: 1,257.0	Oct. 17: 545.0	Nov. 20: 941.2	Mar. 20: 64	....
Min. in month	Feb. 15: 3.0	Dec. 19: 0	Jan. 10, Dec. 11, Feb. 14: 0	5 times Jan., 4 times Feb. & Mar. 1 time May 3 times Dec.: 0	May 15: 129.0	Mar. 17: 85.0	Feb. 13: 26.0	Apr. 20: 132.1	June 20: 818	....
Max. in year	1916: 4,512.0	1916: 6,084.5	1919: 5,545.3	1916: 1,312.1	1920: 6,603.5	1920: 6,452.0	1920: 2,996.2	....	....	1918: 2,119.0
Min. in year	1912: 3,002.0	1914: 3,588.5	1914: 3,704.5	1914: 458.0	1916: 4,199.5	1919: 4,645.0	1919: 1,877.0	....	....	1912: 1,478.5

[1] 10-year mean: Break in record, Oct. to Dec., 1918.

RELATION BETWEEN THE RAINFALL, THE TEMPERATURE, AND THE YIELD OF CORN IN ARGENTINA.[1]

551.578.1 : 551.524 : 633 (82)

By N. A. HESSLING.

[Translated from the Spanish by G. B. Diehl.]

Among the diverse factors that determine the variations in the yield of crops, the fluctuations of the meteorological elements are, without doubt, the most important, and among these precipitation must occupy the principal place. We know, naturally, that if the rainfall is insufficient, the crops fail or diminish; also that excessive rains are prejudicial. But we need to know more exactly what conditions are more favorable for crops, what is the minimum of rain for a normal crop, and when the rains turn to excessive or prejudicial.

A study of these relations has interest, not alone from the scientific point of view, but also from the practical side. In fact, J. Warren Smith and H. A. Wallace have demonstrated that, knowing the rainfall and the mean temperature during the critical period of growth, it is possible to forecast the crop of corn in the United States with more or less certainty. (Mo. WEATHER REV., February, 1914, and August, 1920.) This, like other practical applications that these studies can have, depends naturally upon the degrees of connection between the determining factors and the yields. That connection is more apparent for certain cultivations than for others, and for similar cereals it is more marked in certain regions than in others, according to the greater or lesser presence of other factors that complicate the result.

In general, the connection is not so intimate that one can utilize it in forecasting, as indicated above, but whatever the method, it is of interest to determine scientifically what the relations are for each cereal.

We begin with corn, for it is the cereal that appears to be most affected by meteorological variations. The yield data are taken from the *Statistical Agriculturist*, published annually under the direction of the Office of Statistics and Agriculture. On page 53 of that publication

[1] Relaciones entre la lluvia, la temperatura y el rendimiento del maiz. *Boletin Mensual*, Oficina Meteorologica Nacional, Oct., 1918, pp. 487–492.

are given the areas sown and the yield in tons of the different cereals, since 1898 for corn, flax, and oats, and since 1890 for wheat. These data refer to the country as a whole, and with regard to corn they are the only ones that we have. It is not possible, therefore, to study the relations with this cereal for each Province or region.

In order to correlate these yields with the precipitation and temperature, it is necessary to have data that represent the conditions in conjunction with the corn-growing zone, formed by averages from a number of well-located stations. In order to attain this object, a map was made (map not reproduced); it was prepared with the data given in the publication before cited, respecting the area sown with corn in each Province. The rainfall data utilized in this study represent the average of 24 rainfall stations of which a proportionate majority are found within the area where the cultivation of corn is carried on more intensively. The full meteorological stations are not so numerous as the rainfall stations; neither is this necessary, because the temperature is an element much less variable than the rainfall; the average of six stations was employed.

TABLE 1.

Year.	Yield (in tons per 100 acres).	Rainfall (in millimeters).						
		October.	November.	December.	January.	February.	March.	October to January.
1898-9	2,000	74	113	143	109	78	180	439
1899-1900	1,400	58	82	89	68	112	220	297
1900-1901	2,000	72	110	49	81	52	86	312
1901-2	1,518	78	108	67	68	95	86	321
1902-3	2,100	73	86	103	69	98	142	331
1903-4	2,119	49	74	79	83	106	110	285
1904-5	1,563	93	122	51	68	69	93	334
1905-6	1,822	195	36	117	71	30	42	419
1906-7	639	49	75	67	39	55	185	230
1907-8	1,271	72	56	95	33	43	99	256
1908-9	1,513	74	128	78	62	75	22	342
1909-10	1,481	76	85	79	75	69	121	315
1910-11	219	50	45	26	49	101	21	170
1911-12	3,196	152	122	208	116	75	88	598
1912-13	1,304	98	139	111	17	75	146	365
1913-14	1,610	80	120	59	80	61	66	339
1914-15	1,965	107	155	141	112	152	77	515
1915-16	1,019	96	95	86	70	55	56	347
1916-17	412	21	52	95	57	108	73	225
1917-18	1,229	45	22	64	167	64	61	298
1918-19	1,706	75	105	85	107	92	148	372
1919-20	1,984	71	95	171	110	82	139	447
Average	1,503	80	92	94	78	79	103	344

Year.	Yield (in tons per 100 acres).	Temperature (° C.).						
		October.	November.	December.	January.	February.	March.	October to January.
1899-9	2,000	15.5	18.8	23.7	24.0	23.2	22.3	20.5
1899-1900	1,400	16.5	20.2	24.2	26.1	25.8	21.7	21.7
1900-1901	2,000	17.4	21.5	23.5	23.6	24.0	22.5	21.5
1901-2	1,518	20.2	21.0	23.7	26.3	26.4	23.0	22.8
1902-3	2,100	18.6	21.8	24.0	24.5	21.2	23.5	22.2
1903-4	2,119	17.4	21.6	23.8	24.3	22.2	21.1	21.8
1904-5	1,563	18.0	20.6	22.4	24.1	22.8	22.6	21.3
1905-6	1,822	17.5	20.9	23.3	25.3	25.5	24.3	21.8
1906-7	639	19.4	21.7	23.3	26.4	25.5	21.6	22.7
1907-8	1,271	17.1	21.0	24.2	25.2	24.5	22.9	21.9
1908-9	1,513	18.2	21.2	24.2	26.2	24.0	22.0	22.4
1909-10	1,481	16.9	18.9	23.0	25.4	23.4	19.7	21.0
1910-11	219	17.8	22.0	25.5	26.3	23.6	20.4	22.9
1911-12	2,196	16.8	21.0	22.6	25.4	24.3	22.6	21.4
1912-13	1,304	18.6	20.7	24.9	26.1	26.8	21.3	22.6
1913-14	1,610	17.5	21.5	23.5	26.6	24.6	21.0	22.3
1914-15	1,965	17.3	19.2	21.9	24.2	24.3	20.2	20.6
1915-16	1,019	18.5	22.3	24.6	26.0	25.2	21.8	22.8
1916-17	412	20.3	23.5	24.4	27.9	25.2	21.8	24.0
1917-18	1,229	17.8	22.6	26.6	26.0	24.7	22.4	23.2
1918-19	1,706	17.9	21.9	25.0	27.2	24.3	22.3	23.0
1919-20	1,984	17.7	20.6	24.4	26.4	24.2	22.8	22.3
Average	1,503	17.9	21.1	23.9	25.6	24.5	22.0	22.1

Those who have made similar studies in England—Hooker, and in the United States—J. Warren Smith, Blair, and others, have generally determined the degree of connection between the determining factors and the yields by means of the correlation coefficient. This formula presupposes the correlation between the different factors to be a straight line, the variations of the one factor always being proportionate to the other, that is to say, or would be in this particular case, that the yield always would increase with the same amount of precipitation. Logically, this is not the case, but one must have a point at which the increase in yield is stopped, and where it will presently diminish if the precipitation increases much more. We see, for example, when studying the relations in connection with wheat, that this cereal in our country suffers with more or less frequency from excessive as well as from lack of moisture. As the growth of corn takes place more or less in summer, when evaporation is more active, and the necessity for moisture is consequently greater, and, moreover, the plant for physiological reasons needs more water, this cereal does not suffer generally from excessive precipitation, although the relation is not a straight line; nevertheless it approximates to that condition, and as the correlation coefficient is a convenient method for expressing different degrees of connection, it can be utilized in order to see in what months the correlation is more marked. These coefficients are given in Table 2.

TABLE 2.—*Correlation coefficients of the yield of corn with the precipitation and temperature of different months.*

	Precipitation.	Temperature.
October	0.46	−0.49
November	0.45	−0.47
December	0.52	−0.35
January	0.46	−0.61
February	0.04	−0.28
October to January	0.71	−0.64

The coefficients can vary between 1.0 and −1.0, expressing these two extreme correlation values perfectly in a direct sense and in an inverse sense, respectively. Zero or values near zero indicate that there is no correlation, or that, if there is, it is not a straight line.

The values obtained in this case indicate that the yield of corn depends, to a great extent, on the rainfall during the months October to January, and in a negative sense on the mean temperature in the same months. Nevertheless, in February the temperature influenced somewhat, but the precipitation had no influence. In the individual months the influence is nearly equal with respect to precipitation for each of the four months, while temperature shows its greatest influence in January. This diminution of the coefficient for December is not well explained, which must probably be attributed to accidental causes. The correlation is greater for the two elements when we consider the four months in conjunction than for any individual month, which explains itself, because, if the conditions are unfavorable one month this can be compensated for in part in other months. The difference between the correlation of the individual months and that of the four months will no doubt be great, if not out of place, for the reason that the meteorological elements have certain passive or permanent principles, that if one month is rainy, or dry, cold or hot, it is probable that the following month will be of the same character, a principle which generally does not affect the compensation from one month to the other. In order to know this degree of permanence between the months in question, the correlation coefficient between one month and another has been calculated with respect to the precipitation and to the temperature, the following result being obtained:

Precipitation:

October-November, 0.22; October-December, 0.48; October-January, 0.07.
November-December, 0.29; November-January, 0.03; December-January, 0.33.

Temperature:

October-November, 0.63; October-December, 0.18; October-January, 0.53.
November-December, 0.56; November-January, 0.51; December-January, 0.50.

As is seen, there is always more probability that the general character of a month will be like the months

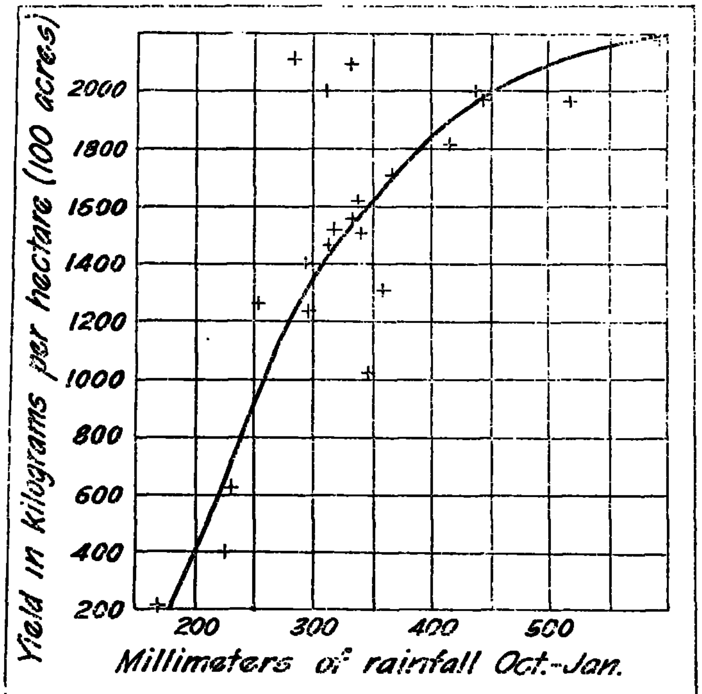

Fig. 1.—Relation between the rainfall and the yield of corn.

preceding, and also that the various months will preserve this character, which proves that the causes that determine this character are not transitory phenomena, but that they must be phenomena that alter slowly. Of the two elements, the temperature is the more stable with respect to time, as well as geographically.

The correlation coefficients of Table 2, as has already been said, give a relative measurement, but as an absolute measurement of the correlation will be incorrect, it must be that the relation is not a straight line. In the diagrams, figures 1 and 2, the natural verity of the correlation can be seen. The year of greatest yield corresponds to the year of greatest rainfall, and the minimum yield to the least rainfall, but it is easy to see that the increase in yield with the rainfall is not constant, being greater for the first 300 millimeters, diminishing gradually thereafter, as shown by the points of intersection between precipitation and yield grouped around the curved line, such as is traced on the figure. Except five or six, the points generally remain close to this line. In taking the relation with the temperature, we can very well express it by means of a straight line, but in this case there is more dispersion of the points indicating a lesser degree of correlation.

The influence of temperature, as has been seen, is negative, that is to say, when the temperature is low it is much more favorable for corn. The question occurs, is this fact true, or only apparent because the temperatures are much lower precisely in the periods of most rainfall, and higher in times of dryness. In fact, the correlation coefficient between these two elements is -0.52 (this is for the months of October to January, therefore in the winter it does not happen the same), which indicates that none of the factors are completely independent. Therefore, it is necessary to ascertain the effect of each one of these independent of the other, or what would be the effect of the rainfall, supposing the temperature constant, and the effect of the temperature with the precipitation constant. If the correlations were rectilinear, this could be done by the method of partial correlation. As the relation with the precipitation does not satisfy this condition, I utilized for this object a new method, invented by George F. MacEwen and Ellis L. Michael, described in the *Proceedings of the American Academy of Arts and Sciences*, December, 1919, vol. 55, No. II. Applying it to the present case, the method consists in obtaining a series of averages of yield, corresponding to a series of averages of precipitation, corrected to a temperature constant, and a similar series of averages of yield, corresponding to average temperatures corrected to a precipitation constant. These corrections are found by a method of successive approximations. The computations are too long to give in detail, but as a new method is employed, it will be well to give the proceedings succintly.

The first step consists in arranging the precipitation and temperature data in the order of ascending magnitude with the corresponding yield data; then making up

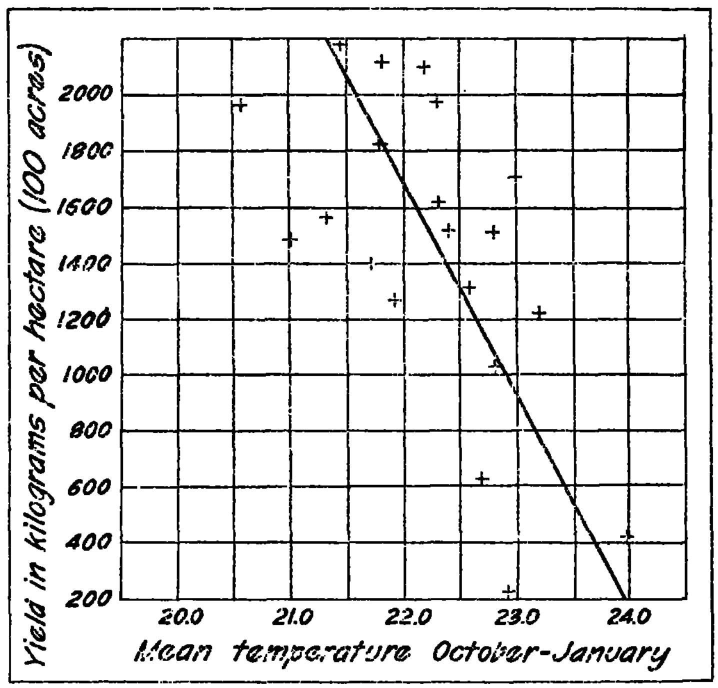

Fig. 2.—Relation between the temperature and the yield of corn.

two series of averages of a number of suitable yield groups corresponding to the precipitation and temperature. Each individual yield fact will then be represented in some group of each series, and according as they occur in respective groups, the corrections are applied in order to reduce them to a precipitation and temperature constant. The number of groups employed in this case is five for rain and four for temperature. These numbers have been adopted with the idea that each group should remain within definite limits; for example, join in one group the precipitation of 200 to 300 millimeters, in another 300 to 400, etc. It would be advantageous also to have each group contain the same approximate number of data, but it is not possible to satisfy these two conditions, for when values near the normal are more frequent than those which deviate greatly, this last condition has been sacrificed in favor of the first.

In Table 3 are given the averages corresponding to each group, the number that form the data N of each group, and the number of times that the individual n data of the group are found in each group of the opposite series.

TABLE 3.

Group.	N	Average rainfall (millimeters).	Average yield (in tons per 100 acres).	$n6$	$n7$	$n8$	$n9$	Group.	N	Average temperature (centigrade).	Average yield (in tons per 100 acres).	$n1$	$n2$	$n3$	$n4$	$n5$
1	1	170	A_1 219	....	....	1	....	6	2	20.5	F_1 1,982	....	....	....	1	1
2	6	265	B_1 1,178	....	3	1	2	7	8	21.5	G_1 1,732	....	3	3	1	1
3	10	338	C_1 1,581	....	3	6	1	8	9	22.6	H_1 1,323	1	1	6	1	....
4	3	435	D_1 1,935	1	1	1	....	9	3	23.4	I_1 1,116	....	2	1	....	....
5	2	556	E_1 2,080	1	1	....	....	....	....	....	....	....	....	....	....	....

We take as base yields the averages of groups 3 and 8, *that is to say, to correct the rainfall by the effect of the* temperature, supposing it to be constant in this value, or to be 22.6°, and correct the temperature by the rainfall; this will remain at the constant reduced value of 33.8 mm. The equations in order to find the correct values take, then, this form:

$$
\begin{array}{lll}
A = 219 & & (1) \\
B = 1178 + 1/6 & (3g + 2i) & (2) \\
C = 1581 + 1/10 & (3g + i) & (3) \\
D = 1935 + 1/3 & (f + g) & (4) \\
E = 2080 + 1/2 & (f + g) & (5) \\
F = 1982 + 1/2 & (d + e) & (6) \\
G = 1732 + 1/8 & (3b + d + e) & (7) \\
H = 1323 + 1/9 & (a + b + d) & (8) \\
I = 1115 + 1/3 & (2b) & (9)
\end{array}
$$

in that

$$
\begin{array}{l}
a = C - A \\
b = C - B \\
d = C - D \\
e = C - E \\
f = H - F \\
g = H - G \\
i = H - I
\end{array}
$$

The correction of the average A is zero, because the one datum that forms it is found in group 8, is elected base. To the average B is applied the correction 3g by the three data that are found in group 7, or for that that is in group 8, and 2i by the two data that are found in group 9, all divided by 6, because there are six data that form the average.

Considering these averages as the first approximation of A, in order to find the values looked for, the second approximation of A, B, C, D, and E is obtained by substituting in the equations (1) to (5) the first approximations to f, g, and i, that is:

$$
\begin{array}{l}
f_1 = H_1 - F_1 = -659 \\
g_1 = H_1 - G_1 = -409 \\
i_1 = H_1 - I_1 = 208
\end{array}
$$

Summing up said equations we would have:

$$
\begin{array}{ll}
A_2 = 219.0 & a_2 = 1260.1 \\
B_2 = 1,042.8 & b_2 = 436.3 \\
C_2 = 1,479.1 & \\
D_2 = 1,579.0 & d_2 = -99.9 \\
E_2 = 1,546.0 & e_2 = -66.9
\end{array}
$$

Now substituting the values a_2, b_2, d_2, and e_2, in the equations (6) to (9), we obtain the second approximation F_2, G_2, H_2, and I_2; and f_2, g_2, and i_2, that were substituted *in the equations (1) to (5), will give the third approximation* of A, B, etc.

If we continue these successive approximations, the values converge, that is to say, the difference between one approximation and the following will be diminishing until zero, when the two base averages will also be equal. This result has been obtained in the present case in the 9a, approximation, when the respective averages and differences are

$$
\begin{array}{ll}
A = 219 & a = 1,265 \\
B = 1,027 & b = 457 \\
C = 1,484 & \\
D = 1,753 & d = -269 \\
E = 1,806 & e = -322 \\
F = 1,686 & f = -202 \\
G = 1,829 & g = -345 \\
H = 1,484 & \\
I = 1,420 & i = 64
\end{array}
$$

In figure 3 the original relation between precipitation and yield is graphically shown, and with the broken line

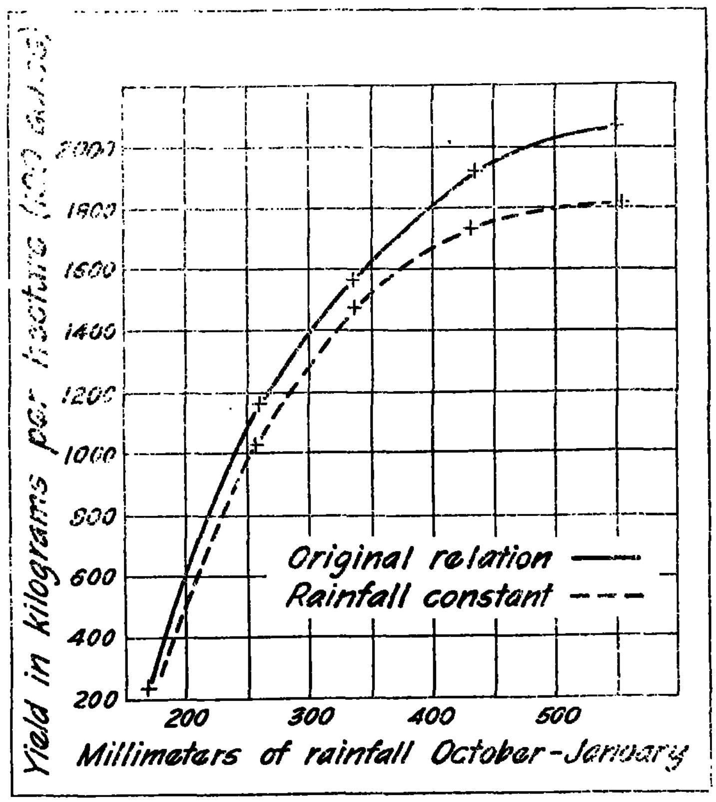

FIG. 3.—Relation between the rainfall and the yield reduced to five averages.

the same relation supposing the temperature to be constant. As is seen, this last line has a curve more pronounced, that is to say, the effect of the rainfall diminishes more rapidly. The explanation of this is, evidently, that favorable rainfall conditions are generally accompanied by favorable temperature conditions, and if this should be constant, the effect of the precipitation only, naturally would be less.

In the diagram, figure 4, it is seen by the lesser amplitude of the curve that the effect of temperature over yield is much less than the effect of rainfall, and when the effect of the rainfall is simultaneously subtracted this amplitude is reduced still more. Moreover, in its original form, this correlation is a straight line diminishing the yield with the rising of the temperature, but correcting by the effect of the rainfall, it is seen that too low temperatures are also prejudicial. Logically, it could be expected that it would be so, and if we could have yield data for Provinces, probably we should see that, in the south of the corn zone, this dimunition by too low temperatures follows with more frequency than in the north. The most favorable temperature is around 21.0 to 21.5° C., for the months of October to January, higher tem-

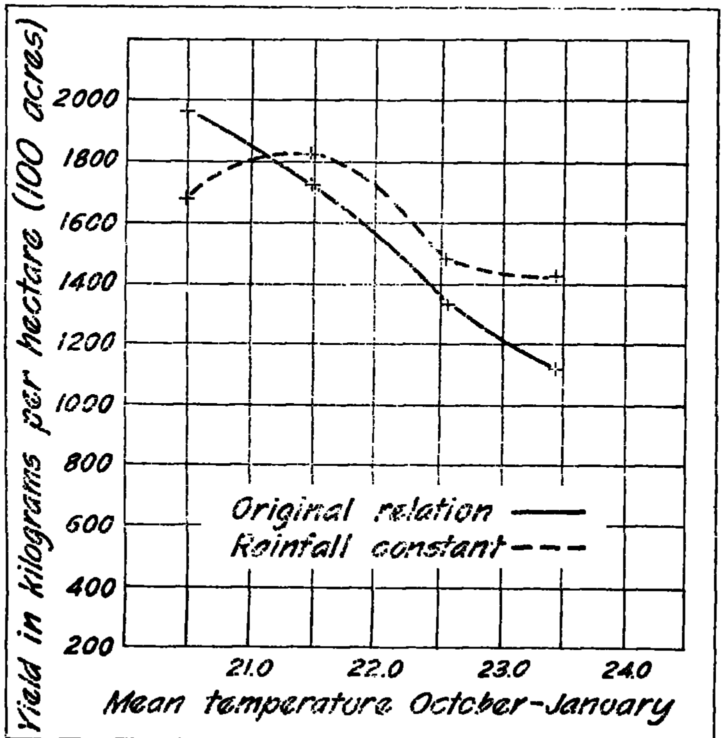

FIG. 4.—Relation between the temperature and the yield of corn reduced to four averages.

perature being prejudicial. This inverse effect of temperature probably must be attributed to the increase of evaporation with temperature, although the curve is not parabolic, as would be expected if this supposition was correct, in virtue of the more rapid increase of evaporation than temperature. Nevertheless, as very little part of these data are disposable, much depends on the method of forming the groups. In the year of least yield; that is to say, the temperature was 22.9° C., higher than included in group 8. If this year had been included in the last group, the result would have been different. There are also certain limitations to solving these questions by purely statistical methods, which should be examined closely; and the most that we can hope for is to arrive at some approximation.

With the differences a, b, d, etc., we can determine the correction applicable to the base yield (1,484 kilograms), in order to calculate the yield, knowing the rainfall and temperature. As in all cases, the result will only be approximate, it will be sufficiently correct to do the interpolations between said values graphically, as has been done in figure 5.

Calculating by means of this graph, the yield for the year 1898–99, for example, we have: Rainfall from October to January, 439 mm.; correction given by the perpendicular line (ordinate) corresponding to this quantity of rainfall, +270; temperature, 20.5°; correction, +202; that is to say, 1,484+270+202=1,956. In Table 4 are given the yields calculated by this method for all the years from 1898 to 1919, and the difference that resulted subtracting this calculated yield from the actual yield.

TABLE 4.—*Yield of corn calculated for the rainfall and the temperature October to January.*

Year.	Calculated yield (tons per 100 acres).	Difference between calculated and actual yields.	Year.	Calculated yield (tons per 100 acres).	Difference between calculated and actual yields.
1898–99	1,956	44	1909–10	1,714	−233
1899–1900	1,579	−179	1910–11	174	45
1900–1901	1,699	301	1911–12	2,154	42
1901–2	1,379	139	1912–13	1,559	−255
1902–3	1,584	516	1913–14	1,584	36
1903–4	1,484	635	1914–15	2,014	− 49
1904–5	1,794	−231	1915–16	1,479	−460
1905–6	2,014	−192	1916–17	644	−232
1906–7	734	− 95	1917–18	1,209	20
1907–8	1,209	62	1918–19	1,539	167
1908–9	1,519	− 6	1919–20	1,854	130

In three cases the differences amounted to 30 per cent of the normal, but in the rest of the years the differences are not more than 20 per cent, although the differences are considered, and are considerable, compared with the usual variations from year to year, they are really small as is seen by the graph, fig. 6.

The low yields of crops obtained in 1904–5 and 1912-13 are explained, without doubt, because the rainfall of

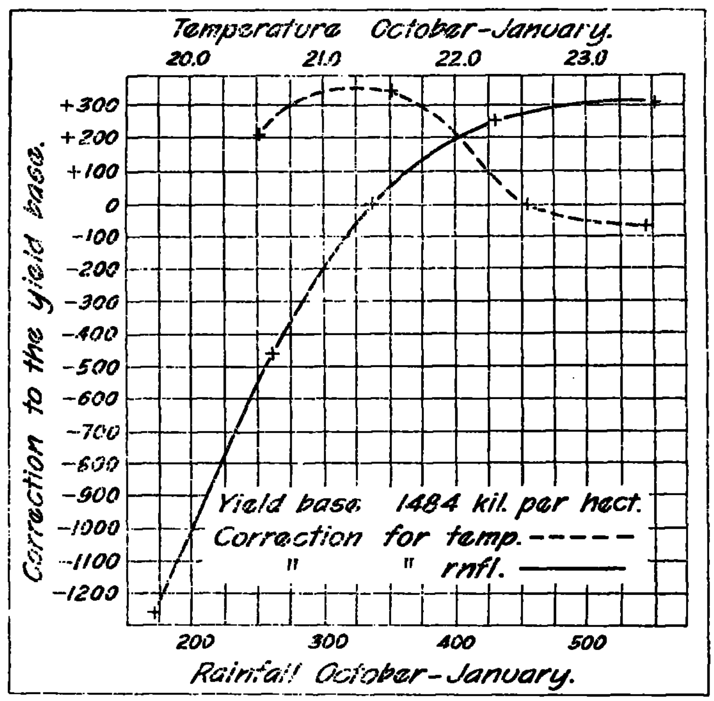

FIG. 5.—Corrections corresponding to different temperatures and rainfall for calculating the yield of corn.

December in the first place, and of January in the second, was very much below the normal, although the total rainfall for the four months was more or less normal. In consequence of this, the differences will probably be reduced somewhat if the effect of each month is considered separately. Nevertheless, some large differences remain, and in order to make the calculations more dependable, and to strengthen them, it would be necessary to so consider the rainfall, likewise temperature under other aspects, principally the distribution of the rainfall, or, this being so, to make the periods less than a month. The low yield of 1915–16, for example, is explained, because, although the total rainfall of each month was more or less normal, it occured in small, vigorous showers, with long intervals of dryness. The rainfall of January practically all fell on the 15–16th, not having rained before since the middle of December. This appeared to be exceeded in 1909–10, when there was an absolutely dry spell to the north of Buenos Aires from November 25 until December 18, only interrupted in localities by small falls that, in reality, only intensified the dryness, because instead of penetrating to the roots they formed a crust on the surface that facilitated evaporation.

It is natural that these long periods of dryness caused injury to the plants, which can be compensated for only partially by later rains. It would evidently be of interest to find out which is the critical period of growth of the plants, that is to say, in which period was the lack of rainfall more harmful; but, in order to do this, it would be necessary to have yield data over all of the Provinces, and also over all of the periods of seedtime and harvest, although these vary according to the Provinces, and also from one year to the other. The period of ab-

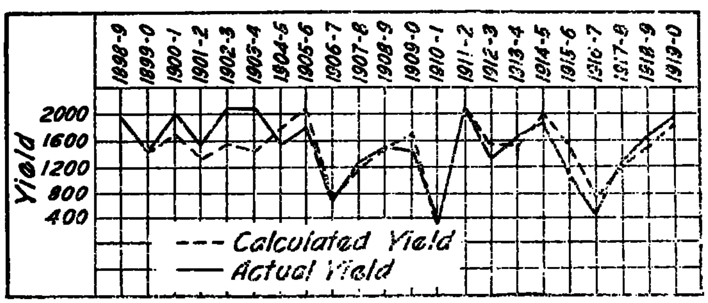

Fig. 6.—Comparison between calculated and actual yields.

solute dryness in 1909, for example, was only experienced in part of the corn zone, having been interrupted in others by regular rains the beginning of December.

Another cause of diminution of yield, and this is a factor that can not be taken into account in the calculation, must be when rainfall is excessive during the period of harvest, and without doubt the loss in yield in 1899–1900 must be attributed to this cause.

It is more difficult to explain the positive differences when the yield has been more than calculated, as in 1902–3 and 1903–4, although it is possible they are influenced somewhat in these cases by the relatively low temperatures in January that, according to the correlation coefficient, being the month when temperatures have their major effect. Nevertheless, the same explanation can not obtain in 1918–19 and 1919–20, although it was in these years that the January temperature was very high. For the rest, the distribution of the rainfall, although in some years it can be unfavorable, in others has been favorable and worked toward the making of a yield superior to the mean conditions.

In résumé, the factor most important in the yield of corn in our country is the rainfall from October to January, inclusive, and in the second place, the temperature during the same time. With these two factors it is possible to calculate the yield with sufficient accuracy, and therefore, knowing the area sown, the amount of the total crop of the country at the end of the month of January, which is of evident interest, as the harvest in general does not begin until March.

The calculation, as has been seen, would probably perfect itself considering these elements by periods; for example, for weeks or decades, although much complication of the question would result and, moreover, in order to estimate each one of these elements correctly for the lesser periods, it would be necessary, as has already been said, to arrange the yield data by Provinces or lesser areas.

Still, perfecting the calculation all that is possible, it is evident that differences remain between the calculations and the yields, because, although the temperature and the rainfall can be considered the principal factors in determining the yield of corn, they are not, naturally, the only ones. Of other factors that influence in a negative sense, some are meteorological, as hail and frost, others not so, principally the invasion of locusts and other plagues. Hail generally only causes injury in limited areas, and for that reason has no great influence on the total production of the country. Frost influence can also be considered negligible with respect to corn, because conditions which produce frost occur too late to injure the cereal, or it is generally possible to sow new seed. A more important factor is, no doubt, locusts, and in the low yields of 1915–16 and 1916–17, the poor distribution of the rainfall must have further influenced, in great part, the ravages caused by the insects, these years being those of worst punishment by this plague.

Before we finish, we will turn a moment to figure 5. The yield corresponding to 200 mm. is 550 kilograms per hectare (100 acres) (the temperature being constant); at 300 mm. it is 1,300; at 400 1,680, and at 500 mm. 1,820 kilograms per hectare. Between 200 and 300 mm., therefore, the yield increases $1,300-550=750$ kilograms, or should be 7.5 kilograms for each millimeter of rain; from 200 to 400 increases 3.8 kilograms per millimeter, and from 400 to 500 mm. 1.4 kilograms. As, notwithstanding, the rainfall generally comes accompanied by favorable temperature conditions, according to an approximate calculation, and in order to have a computation of the two elements, we can take the expressed yields by the continuous line. This we do for rainfall until 300 mm., 8 kilograms, more or less, per 100 acres for each millimeter; for 300 to 400 mm. four kilograms for each millimeter, and above 400 mm. 2.4 kilograms per millimeter.

In the last year of those that enter into this study, 1919–20, the area sown was 3,312,200 hectares. A millimeter of rainfall, until 300 mm. for the four months is reached, would equal, then, 26,500 tons, or at the price $10 a hundredweight, two millions and a half of dollars, more or less. In proportion as the rainfall increases, its value will be diminishing, but as respects corn its value will always increase, except during harvest, or at least in the 22 years that are used in this study there is no evidence that corn has suffered from excessive rainfall during growth. The calculated values, as are drawn by a mean curve, refer to mean conditions of distribution, and if the distribution of rainfall should be poor its value will be less, as also it will be greater if the distribution is especially good.

If the rainfall observers would say to themselves that each millimeter of rainfall can be worth millions of dollars to the country, perhaps they would have more interest in the observations, which are not always made with the care that could be wished for.