RELATION OF GERMINATION TO EARLINESS IN CORN

(Minor Subject)

Thesis Presented to the Graduate Committee
of the Virginia Polytechnic Institute,
in Application for the Degree of
Master of Science in Agriculture.

By

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April, 1916.

Acknowledgement.

The writer expresses his appreciation to Professor
, who suggested the work and whose advice was of value during the experiment.

The writer is also indebted to for assistance in obtaining the data presented in this paper.

Introduction.

This is a subject of great importance to farmers and corn breeders of many sections of the United States. Even a few days' difference in time of maturity of varieties of corn will determine the success or failure of the corn crop. If there exists any relation between time of germination and earliness of maturity, work of this nature is of the utmost importance, and would enable the farmer or breeder to select varieties adapted to their particular section or length of season. It is a well known fact that the latest variety which will mature in a given section of the country is the one which produces the largest yield per acre. Farmers living in sections where the season is too short for the late maturing varieties to ripen, have been lured into planting late maturing varieties in the hope of obtaining a larger yield than is commonly produced by early maturing varieties, and the result is usually a failure, or a large amount of soft, immature corn which has little feeding value. On the other hand, farmers living in sections where the season of growth is long, are not planting the varieties which utilize the full growing season and give larger yields.

In making this study of the relation of germination to earliness, we are taking up other points of interest, so it is well to give an outline of work to be studied.

Statement of Problem.

1. A study of the minimum, optimum and maximum temperature of germination for Boone County White corn.

2. A study of the relation between size of kernel and time of germination for Boone County White corn under optimum conditions.

3. A study of the relation between time of germination and earliness. A number of varieties of corn of which the relative time for maturity is known will be germinated at the same temperatures (optimum) in an attempt to find whether any relation exists between time of germination and subsequent growth and maturity.

Review of Literature.

There is no available literature at the present time on the relation of germination to earliness in corn, but there have been many determinations for the minimum, optimum and maximum temperatures of germination, and also a number of unit characters have been found to be mutually related in significance, i.e., a correlation exists between certain unit characters in corn.

Haberlandt[1] found the minimum temperature for corn germination to range between 4.44° and 10.55° C.

Howard[2] found the minimum temperature for corn germination to range between 8° and 10° C.; optimum between 32° and 35° C., and maximum between 40° and 44° C.

Wilson and Warburton[3] state that the optimum temperature for corn germination varies around 35° C.

Many correlations between unit characters have been found in the corn plant. Davenport[4] finds a correlation coefficient of

0.87 ± 0.005 between weight of ears, in ounces, and length of ears, in inches. He also finds a coefficient of 0.49 ± 0.02 for correlation between circumference and length of ears, in inches.

Ewing[5] finds the following correlations: Between weight of grain, in grams, and diameter of stalk, in cm.; r = .393 ± .02 (r = correlation coefficient); between weight of grain, in grams, and length of leaf, in cm.; r = .292 ± .021. Between weight of grain, in grams, and breadth of leaf, in cm.; r = .314 ± .021. Between weight of grain, in grams, and height of mature plants, in d.m.; r = .203 ± .025. Between weight of grain and number of internodes; r = .228 ± .023.

Leighty[6] finds the following correlations in oats characters: Between height of culms per plant, in c.m., and total yield of plant, in grams; r = .6886 ± .0159. Between number of culms per plant, and total yield of plant, in grams; r = .8496 ± 0.0084 Between number of culms per plant and average number of kernels per culm per plant; r = 0.4226 ± 0.248.

Myers[7] finds the following correlations in wheat characters; Between the average height of culms per plant and average weight of kernels per plant; r = 0.509 ± 0.0221. Between gross weight of culms, in grams, and weight of grain, in grams; r = .925 ± .004

These correlations found by Ewing in corn, by Leighty in oats, and by Myers in wheat, do not bear directly on the correlation taken up in this paper, but are of interest to know that certain

relations do exist between different characters in plants. Many other characters were taken up by these men, which are not mentioned a bove. Other men have mentioned correlations between certain unit characters in corn, but few of them followed statistical methods. Brigham, Hopkins, Smith, East, DeVries, and others cite correlations between characters in corn.

Material Used.

1. A Standard Germinator, adopted by the Association of Official Seed Analysts of North America, and manufactured by the Kny-Scheerer Company of New York City.
2. A Thermostat for regulating temperature of germinator.
3. Chemical balance for weighing corn.
4. A quantity of white blotting paper.
5. A number of varieties of corn.
6. Ice, water and salt.
7. Bunsen burners, tubing and all other necessary equipment.

Procedure and Results.

Before attempting to determine the minimum temperature of germination, we selected eight average ears and ran a germination test at a temperature around 32° C., or 89.6°F., to determine the vitality of each individual ear. Fifty grains were taken from each ear, selecting about one-third of this number from butt, middle and tip, respectively. All these ears germinated fairly well, showing a variation in percent of germination from 80 to 100, as shown in Table I.

In determining the minimum temperature of germination it was found impossible to keep the germinator in a warm room and lower the temperature sufficiently, so we moved it to a basement room of the Agricultural Hall where the temperature was fairly low (ranging between 50° and 60° F., being kept at this temperature by the passage of ammonia pipes to the Cold Storage Room), and by the use of crushed ice and salt in the ice box we were able to hold the temperature of the brine in the jacket of the germinator at a temperature ranging from 6° to 9° C. (42.8° to 48.2° F.) By the nature of the germination at this temperature, it was evident that we were within the range of the minimum temperature of germination for Boone County White corn.

The percentage of germination at this temperature is shown in Table II. It should be noted that ears Number 6 and 7 gave a slightly larger percent germination than in Table I. The germination at this low temperature took place very slowly and was low in vitality. Two weeks elapsed before any signs of germination could be detected, and at the end of eighteen and twenty-three days, all grains which showed their plumules bursting through the skin were counted as germinated. The plumules grew very little after breaking through the skin, although some radicles grew to a length of 1/4 to 1/2 inch.

Germination Test of Ears (Nos. 1 to 8) at 32° C. (89.6°F.) to Determine Percent of Germination for Individual Ears, prior to Tests for Minimum Temperature of Germination.

Table I.

Ear Number	Total Number of Grains.	Number of Grains Germinated.	Percent of Germination.
1	50	40	80
2	50	50	100
3	50	40	80
4	50	43	86
5	50	50	100
6	50	48	96
7	50	46	92
8	50	45	90

Determination of Minimum Temperature of Germination for Boone County White Corn. Range of Temperature, 6°-9° C., (42.8°-48.2°F

Table II.

Ear Number	Total Number of Grains	Number of grains germinated.	Days in Germinator	Percent of Germination.
1	50	25	23	50
2	50	42	23	84
3	50	24	18	48
4	50	35	18	70
5	50	46	18	92
6	50	49	18	98
7	50	48	18	96
8	50	42	18	84

Taking the above temperature (6°-9°C.) as the minimum temperature of germination for Boone County White corn, this compares very favorably with the results of others. Haberlandt[1] found the minimum temperature for corn germination to range between 40° and 51° F. (4.44° and 10.55°C.). He also states that it requires 11½ days for corn germination at a temperature of 50° F. Howard[2] found the minimum temperature to range between 8° and 10°C.

Optimum and Maximum Temperature of Germination for Boone County White Corn.

A series of thirteen tests were run on eight different ears, twenty five grains from different portions of each ear being used in each series. The temperature at which the germinator was kept varied for each series, temperature for Series I being held somewhat below the expected optimum and for each succeeding series it was raised until a temperature sufficiently high to allow little or no germination was reached.

The following tables show the results for each series. Table No. 1 shows the percent of germination, and also the number of grains germinating within twelve hour periods for each individual ear. Table No. 2 shows the total percent germinated at the close of each period for each individual ear, and also the average for all ears.

Note: Grains were not considered germinated until the plumules broke through the skin.

Series I.

Table 1.

Temperature 25° to 30° C. (77°-86°F)

Ear No.	No. of Grains Tested	Germinated.	%Germination.	Number Grains Germinated at 12 hr. periods. 24	36	48	60	72	84	96	108	120	132
1	Thrown out.												
2	25	25	100	0	2	12	5	4	1	1	0	0	0
3	25	24	96	0	5	6	6	3	4	0	0	0	0
4	25	24	96	0	1	10	7	5	0	0	1	0	0
5	25	24	96	0	0	4	12	6	1	0	1	0	0
6	25	25	100	0	0	8	6	4	5	1	0	1	0
7	25	25	100	0	3	12	5	5	0	0	0	0	0
8	25	25	100	2	0	7	6	5	1	1	1	1	1

Table 2.

Total Percent Germinated at 12 hour period.

Ear No.	24	36	48	60	72	84	96	108	120	132
2	0	8	56.	76	92	96	100*	100	100	100
3	0	20.83	45.83	70.83	83.33*	100	100	100	100	100
4	0	4.17	45.84	79.17	95.83	95.83	95.83*	100	100	100
5	0	0	16.67	66.67	91.67	95.83	95.83	100*	100	100
6	0	0	32.	56.	72.	92.	96.	96	100*	100
7	0	12	60	80	100*	100	100	100	100	100
8	8	8	36	60	80	84	88	92	96	100*
verage	1.14	7.57	41.76	69.81	78.83	94.81	96.52	98.28	99.43	100

Note: *indicates period at which ear completed germination. The variable temperatures for each series indicate the minimum and maximum temperature recorded. Temperature was recorded or read every twelve hours.

Series II.

Table 1.

Temperature 29-35° C. (84.2-95°F.)

Ear No.	Number of Grains Tested	Germinated.	% of Germination	No. Grains germinated at 12 hr. period 24	36	48	60	72	84	96
1	25	25	100	0	5	9	9	2	0	0
2	25	25	100	0	0	5	10	9	1	0
3	25	25	100	0	0	5	8	6	5	1
4	25	25	100	0	4	6	4	7	4	0
5	25	25	100	0	0	4	17	4	0	0
6	25	23	92	0	0	3	17	2	1	0
7	25	24	96	2	1	14	7	0	0	0
8	25	25	100	0	4	8	10	2	1	0

Table 2.

Total percent germinated at 12 hour periods.

Ear No.	24	36	48	60	72	84	96
1	0	20	56	92	100*	100	100
2	0	0	20	60	96	100*	100
3	0	0	20	52	76	96	100*
4	0	16	40	56	84	100*	100
5	0	0	16	84	100*	100	100
6	0	0	13.04	86.96	95.65	100*	100
7	8.33	12.5	70.83	100*	100	100	100
8	0	16	48.	88	96	100*	100
Average	1.04	8.06	35.48	77.37	93.46	99.5	100

Series III

Table 1.

Temperature 32.5° to 36° C (90.5° - 96.8°F.)

Ear No.	Number of Grains Tested	Number of Grains Germinated	% of Germination.	Number Grains Germinated at 12 hrs. 36	48	60	72	84	96
1	24	24	100	17	6	1	0	0	0
2	25	25	100	2	18	5	0	0	0
3	25	24	96	1	12	4	7	0	0
4	25	23	92	1	8	12	2	0	0
5	25	24	96	0	14	7	2	0	1
6	25	25	100	0	15	10	0	0	0
7	25	25	100	10	9	3	2	0	1
8	25	25	100	7	10	4	1	3	0

Table 2.

Total percent germinated at 12 hour periods.

Ear No.	36	48	60	72	84	96
1	70.83	96.83	100*	100	100	100
2	8	80	100*	100	100	100
3	4.17	54.17	70.83	100*	100	100
4	4.35	39.13	91.30	100*	100	100
5	0	58.33	87.5	95.83	95.83	100*
6	0	60	100*	100	100	100
7	40	76	88	96	96	100*
8	28	68	84	88	100*	100
Average	19.42	66.43	90.20	97.48	98.98	100

Series IV.

Table 1.

Temperature 34° to 40.75°C. (93.2° to 105.35° F.)

Ear No.	No. Grains Tested	No. Grains Germinated	%Germination.	No. grains germinated at 12 hr. periods 36	48	60	72	84	96	108	120	132
1	25	25	100	0	12	10	3	0	0	0	0	0
2	25	25	100	0	4	12	8	1	0	0	0	0
3	25	19	76	0	2	7	7	2	0	1	0	0
4	25	25	100	0	5	3	16	0	0	0	1	0
5	25	24	96	0	1	10	8	3	1	1	0	0
6	25	25	100	0	5	14	5	1	0	0	0	0
7	25	25	100	1	12	9	3	0	0	0	0	0
8	25	24	96	0	1	10	6	4	1	1	0	0

Table 2.

Total percent germinated at 12 hour periods.

Ear No.	36	48	60	72	84	96	108	120	132
1	0	48	88	100*	100	100	100	100	100
2	0	16	64	96	100*	100	100	100	100
3	0	10.53	47.36	84.21	94.74	94.74	100*	100	100
4	0	20	32	96	96	96	96	100*	100
5	0	4.17	45.83	79.16	91.66	95.87*	100	100	100
6	0	20	76	96	100*	100	100	100	100
7	4	52	88	100*	100	100	100	100	100
8	0	4.17	45.83	70.83	87.49	91.66	95.83	95.83	100*
Average	.5	21.86	60.88	90.27	96.24	97.28	98.98	99.48	100

Series V.

Table 1.

Temperature 36° to 44.5° C. (96.8 to 112.1° F.)

Ear No.	No. Grains Tested	No. Grains Germinated	%Germination	No. grains germinated at 12 hour periods. 36	48	60	72	84	96	108	120	132	144	156	168	180
1	25	25	100	2	1	3	1	11	4	2	0	1	0	0	0	0
2	25	24	96	0	0	1	4	6	9	3	1	0	0	0	0	0
3	25	20	80	0	0	0	0	4	4	1	0	6	3	2	0	0
4	25	23	92	0	0	0	4	5	4	4	1	5	0	0	0	0
5	25	17	68	0	0	3	0	2	2	6	0	2	1	0	0	1
6	25	23	92	0	0	1	2	7	4	6	1	1	1	0	0	0
7	25	23	92	0	3	6	4	2	3	1	2	1	1	0	0	0
8	25	23	96	0	6	6	3	6	1	0	0	1	0	1	00	0

Table 2.

Total percent germinated at 12 hour periods.

Ear No.	36	48	60	72	84	96	108	120	132	144	156	168	180
1	8	12	24	28	72	88	96	96	100*	100	100	100	100
2	0	0	4.17	20.83	45.83	83.33	95.83	100*	100	100	100	100	100
3	0	0	0	0	20	40	45	45	75	90	100*	100	100
4	0	0	17.39	39.13	56.52	73.91	78.26	100*	100	100	100	100	100
5	0	0	17.65	17.65	29.41	41.17	76.47	76147	88.24	94.12	94.12	94.12	10
6	0	0	4.35	13.04	43.47	60.86	86.95	91.30	95.35	100*	100	100	100
7	0	13.04	39.13	56.52	65.21	78.25	82.60	91.30	95.35	100*	100	100	100
8	0	26.09	52.17	65.21	91.30	95.65	95.65	95.65	100*	100	100	100	100
Avg.	1	6.39	17.68	27.33	50.79	67.97	81.53	84.24	94.24	98.01	99.26	99.26	100

Series VI.

Table 1.

Temperature 39.25° - 45° C. (102.6° - 113° F.)

Ear No.	Number of Grains Tested	Germinated	% of germination.	No. grains germinated at 12 hour periods. 72	84
1	25	1	4	1	0
2	25	1	4	0	1
3	25	0	0	0	0
4	25	0	0	0	0
5	25	3	12	3	0
6	25	0	0	0	0
7	25	0	0	0	0
8	25	1	4	1	0

Series VII.

Table 1.

Temperature 39.25° to 47° C. (102.6° to 116.6° F.)

Ear No.	Number of Grains Tested	Germinated	%Germination.	No. grains germinated at 12 hr. pds 60	72	84	96	108	120	132	144	156
1	25	6	24	4	1	1	0	0	0	0	0	0
2	25	2	8	0	1	1	0	0	0	0	0	0
3	25	0	0	0	0	0	0	0	0	0	0	0
4	25	2	8	0	0	0	0	0	1	0	1	0
5	25	0	0	0	0	0	0	0	0	0	0	0
6	25	1	4	1	0	0	0	0	0	0	0	0
7	25	4	16	0	2	0	1	0	1	0	0	0
8	25	0	0	0	0	0	0	0	0	0	0	0

Series VIII.

Temperature 41.75° to 46° C. (107.15° to 114.8° F.)

Same number of grains (25) were used from ears 1 to 8, as were used in all previous series. No germination took place at this temperature. Grains split open, and only a limited number exhibited signs of germination. At the end of 96 hours all germs were soft and of a watery nature.

Series IX.

Table 1.

Temperature 39.25° to 47° C. (102.6° to 116.6° F.)

Ear No.	No. of Grains Tested	Germinated	%of germination.	No. grains germinated at 12 hours. 60	72	84	96	108
1	25	3	12	0	2	1	0	0
2	25	0	0	0	0	0	0	0
3	25	1	4	0	1	0	0	0
4	25	0	0	0	0	0	0	0
5	25	8	32	5	1	1	1	0
6	25	5	20	0	1	2	2	0
7	25	2	8	1	0	1	0	0
8	25	8	32	1	0	5	1	1

Series X.

Temperature 41.25° to 47° C. (106.2° - 116.6° F.)

Same results as for Series VIII. (No germination).

Series XI.

Temperature 41.75° to 46.75° C. (107.15-116.15° F.)

Same results as in Series VIII & X. (No germination).

Series XII.

Temperature 42.5°-49° C. (107.6° - 120.2° F.)

Same results as in Series VII, X, & XI. (No germination).

Series XIII.

Table 1.

Temperature 8.5° to 47.5° C. (47.3° to 117.5° F.)

Ear No.	Number Grains Tested	Germinated	%Germination.	No. grains germinated at 12 hr. periods 60	72	84	96	108	120	132	144
1	25	25	100	0	2	3	9	10	1	0	0
2	25	24	96	1	3	0	7	12	1	0	0
3	25	18	72	0	0	0	1	4	3	7	3
4	25	22	88	0	0	0	4	13	3	1	1
5	25	24	96	2	5	0	7	6	4	0	0
6	25	24	96	0	2	0	15	4	2	0	1
7	25	21	84	0	1	2	7	5	4	0	2
8	25	25	100	1	2	0	11	8	3	0	0

Table 2.

Total Percent of Germination at 12 hour periods.

Ear No.	60	72	84	96	108	120	132	144
1	0	8	20	56	96	100*	100	100
2	4.17	16.67	16.67	45.83	95.83	100*	100	100
3	0	0	0	5.55	27.77	44.44	83.33)	100*
4	0	0	0	18.18	77.27	90.90	95.45	100*
5	8.33	29.17	29.17	58.33	83.33	100*	100	100
6	0	8.33	8.33	70.83	87.50	95.83	95.83	100*
7	0	4.76	14.29	47.62	71.43	90.48	90.48	100*
8	4	12	12	56	88	100*	100	100
Average	2.06	9.87	12.56	44.79	78.39	90.21	95.64	100

The optimum temperature of germination may be defined as the temperature at which maximum germination takes place within minimum time.

By glancing over tables in the above series, it is evident that the optimum temperature was reached in Series III, where the temperature varied from 32.5° to 36° C. (90.5° to 96.8° F.) Suppose we consider the total percent germinated at the end of seventy two hours. The high percent of 97.48 (average for 8 ears) germinated at this period is higher than for the corresponding period in any of the other series. Another point which gives this temperature preference over the temperatures of other series is the large percent of ears which had completed their germination at seventy two hours. At the close of this period, five ears show complete germination. The nearest approach to this is three ears in Series II where the temperature varied from 29° to 35° C. (84.2° to 95° F.)

The maximum temperature of germination may be defined as the highest temperature at which some germination will take place regardless of time.

The maximum temperature is found to vary from 39° to 42° C. (102.2° to 107.6° F.) We select this as the maximum temperature because Series VI, VII, and IX show slight germination, although the maximum temperature ran as high as 47°C. in the latter series. The minimum temperature for each of these series was 39.25° C. In the case of Series VIII, X, and XI, where the temperature ranged from 41.75° to 46° C. (Series VII), 41.25° to 47° C. (Series X), and 41.75° to 46.75° C. (Series XI), we fail to get any germination. It then seems logical that the maximum temperature occurs somewhere between 39.25° and 41.75° C., although a temperature of 47° C. does

not prevent germination, provided it is allowed to drop, or vary, to a temperature as low as 39.25° C. This fact is again shown in Series XIII, where the temperature varied from 8.5° to 47.5° C. No germination took place in this series until sixty hours, and the time for total germination was much longer, due to the temperature being kept above 42° C. for the first thirty six hours, then gradually lowered until it reached 8.5° C. at eighty four hours, and then again raised until it reached 40.5° C. at 144 hours. In this series, fairly good germination was obtained, as shown in the tables.

These results, 32.5° to 36° C. for the optimum and 39° to 42° C. for the maximum, check very closely with those given by Howard[2], and Wilson and Warburton[3]. Howard gives the optimum temperature of germination for corn at 32° to 35° C., and the maximum at 40° to 44° C., while Wilson and Warburton state that the optimum varies around 35° C.

Relation Between Size of Kernel and Time of Germination for Boone County White Corn.

For this work we selected two ears of good quality, one large ear, (#1), and one much smaller, (#2). Each individual grain from these ears were weighed (grams) and correlated with time of germination to determine if there exists any relation between these factors. All grains from the same ear were placed in the germinator at the same time and subjected to exactly the same conditions, the temperature being kept around the optimum, (32.5° to 36° C.). The results are shown in correlation tables below.

Table I.

Correlation between weight of grains and time of germination. Time subject, weight of grain relative; $r = .259 \pm .0227$.

Ear I.

Hrs.	.15-.20	.2-.25	.25-.30	.30-.35	.35-.40	.40-.45	.45-.50	.50-.55	Gms.
24			3	11					14
30			4	48	24				76
36		2	21	126	93	12	1		255
42		2	13	110	115	17	3		260
48		1	6	55	52	21	2		137
54			2	12	35	13	3		65
60		1	1	17	9	9	4		41
66				5	7	1	1		14
72	1				2	2			5
78					2	1		1	4
	1	6	50	384	339	76	14	1	871

Table II.

Correlation between weight of grain and time of germination; time subject, weight of grain relative; $r = .0115 \pm .0269$

Ear II.

Hrs.	25-30	30-35	35-40	40-45	45-50	50-55	Gms.
24				3			3
30		2	6	15	3		26
38	2	31	68	111	24	2	238
42	1	7	29	38	12		87
48	1	19	44	50	26	1	141
54		6	17	25	13	1	62
60	2	12	13	21	7		55
66	1	1	2	5	8		17
72		1	1	3	2		7
78			1				1
	7	79	181	271	95	4	637

In the case of Ear No. 1, Table I, we find a fair degree of correlation, the coefficient being 0.259 $\pm$ 0.0227.

In the case of Ear No. 2, Table II, we find the coefficient of correlation to be 0.0115 $\pm$ 0.0269, which shows very little, if any, relation between the size of kernels and time of germination.

There seems to be a slight positive correlation between the size of grain and time of germination, as our results show that the smaller the grain the more rapid the germination. We do not state this as a conclusion, because the data obtained is meagre and the individuality of ears might have a decided effect upon the results. The results of these two ears necessitate more work along this line before a definite conclusion is drawn.

Relation of Germination to Earliness in Corn.

Twenty varieties, of which the relative number of days from planting to maturity (for this section) is known, were used in this work. Four series of germination tests were run (temperature kept around the optimum), and the results shown in tables below. No definite number of grains were used, but the percentage of germination for each variety is taken as a basis. The total percent germinated at the end of 72 hours is used as the basis for determining the rank of varieties as to maturity.

Varieties of Corn Named in order of Earliness of Maturity.

Rank	Variety	Days from planting to maturity.
1	Shenandoah White	142
2	Fulford's Yellow Dent	146
2	Hickory King	146
2	Collier's Excelsior	146
2	Improved Leaming	146
2	Virginia Yellow Dent	146
3	Boone County White	150
4	Westwood Royal	151
5	Virginia White Dent	152
5	Improved Southern White Snowflake	152
5	Improved Golden Dent	152
6	Gold Standard	155
7	Columbian Beauty	156
7	Casey's Purebred	156
7	Blount's Prolific	156
8	Cooke's Prolific	159
8	Bigg's 7 Ear	159
8	Pamunkey Ensilage	159
9	Eureka	160
9	Virginia Ensilage	160

Series I. (Temperature 31° to 36° C.)

Number	Variety	Number grains planed in the germinator.	Number grains germinated.	Percent of germination.
1	Casey's Purebred	716	716	100.00
2	Shenandoah White	640	638	99.97
3	Gold Standard	597	595	99.67
4	Va. White Dent	483	480	99.38
5	Cooke's Prolific	570	566	99.93
6	Va. Yellow Dent	544	412	75.74
7	Boone County White	446	441	98.88
8	Westwood Royal	616	615	99.84
9	Pamunkey Ensilage	566	556	98.23
10	Improved Golden Dent	451	422	93.57
11	Hickory King	351	349	99.43
12	Eureka	517	509	93.45
13	Improved Leaming	532	528	99.25
14	Fulford's Yellow Dent	719	716	99.58

Note : Kernels used above were taken from individual ears, grown in alternate rows on the same plot, and are therefore hybrid to a more or less extent.

Series I.

Number Grains Germinated at 8 Hour Periods.

Variety Number.	32	40	48	56	64	72	80	88	96	104	112	120	128
1	14	82	102	198	182	90	42	4	0	2	0	0	0
2	1	4	71	96	163	160	110	30	2	1	0	0	0
3	2	37	143	157	115	119	16	3	2	1	0	0	0
4	1	36	53	94	108	85	65	23	8	7	0	0	0
5	4	132	107	219	70	30	2	1	0	0	1	0	0
6	4	82	42	87	68	71	30	13	3	5	4	3	0
7	2	14	70	86	117	109	29	10	1	1	0	2	0
8	0	9	33	144	121	132	113	55	5	1	2	0	0
9	0	7	122	216	100	71	23	11	1	1	1	3	0
10	0	16	19	48	44	57	65	47	49	40	20	14	3
11	0	15	18	72	58	79	48	36	12	7	1	3	0
12	0	50	81	141	105	81	40	7	4	0	0	0	0
13	0	32	39	91	118	156	66	18	6	1	1	0	0
14	0	0	5	19	63	96	156	238	108	27	4	0	0

1 - Casey's Purebred.

2 - Shenandoah White.

3 - Gold Standard.

4 - Virginia White Dent.

5 - Cooke's Prolific.

6 - Virginia Yellow Dent.

7 - Boone County White.

8 - Westwood Royal.

9 - Pamunkey Ensilage.

10 - Improved Golden Dent.

11 - Hickory King.

12 - Eureka.

13 - Improved Leaming.

14 - Fulford's Yellow Dent.

Series I.

Percent germinated at 8 hour periods & total percent of germination at 72 hours.

Variety No.	32	40	48	56	64	72	80	88	96	104	112	120	128
1	1.96	11.45	14.25	27.66	25.42	12.57 93.31	5.87	.558	0	.279	0	0	0
2	.156	.627	11.13	15.04	25.55	25.08 77.59	17.24	4.70	.313	.156	0	0	0
3	.336	6.22	24.02	26.39	19.33	20.00 96.30	2.69	.504	.336	.168	0	0	0
4	.708	7.50	11.04	19.58	22.50	17.71 79.04	13.54	4.79	1.67	1.46	0	0	0
5	.706	23.32	18.90	38.69	12.37	5.30 99.29	.353	.177	0	0	.176	0	0
6	.971	19.90	10.19	21.12	16.50	17.23 85.91	7.28	3.16	.728	1.21	.971	.728	0
7	.454	3.17	15.87	19.50	26.53	24.72 89.89	6.58	2.27	.227	.227	0	.453	0
8	0	1.46	5.37	23.41	19.67	21.46 71.37	18.37	8.94	.813	.163	.325	0	0
9	0	1.26	21.94	38.85	17.99	12.77 92.81	4.14	1.98	.179	.180	.180	.539	0
10	0	3.79	4.50	11.37	10.43	13.51 43.60	15.40	11.14	11.61	9.48	4.74	3.32	.711
11	0	4.30	5.16	20.63	16.62	22.63 69.34	13.75	10.32	3.44	2.01	2.86	.859	0
12	0	9.82	15.91	27.70	20.63	15.91 89.97	7.86	1.40	.786	0	0	0	0
13	0	6.06	7.39	17.23	22.35	29.55 82.58	12.50	3.41	1.14	.189	.189	0	0
14	0	0	.698	2.66	8.80	13.41 25.57	21.79	33.21	15.08	3.78	.559	0	0

Series I

Varieties of Corn Named in Order of Earliness of Germination and Maturity.

Germination	Maturity
1 - Cocke's Prolific.	1 - Shenandoah White.
2 - Gold Standard.	2 - Fulford's Yellow Dent.
3 - Casey's Purebred.	2 - Hickory King.
4 - Pamunkey Ensilage.	2 - Improved Leaming.
5 - Eureka.	2 - Virginia Yellow Dent.
6 - Boone County White.	3 - Boone County White.
7 - Virginia Yellow Dent.	4 - Westwood Royal.
8 - Improved Leaming.	5 - Virginia White Dent.
9 - Virginia White Dent.	5 - Improved Golden Dent.
10 - Shenandoah White.	6 - Gold Standard.
11 - Westwood Royal.	7 - Casey's Purebred.
12 - Hickory King.	8 - Cocke's Prolific.
13 - Improved Golden Dent.	8 - Pamunkey Ensilage.
14 - Fulford's Yellow Dent.	9 - Eureka.

Series II.

(Temperature 28°-35°C.)

Number	Variety	Number kernels in germinator.	Number kernels germinated.	Percent germination.
1	Improved Golden Dent	367	364	99.18
2	Columbian Beauty	362	359	99.17
3	Casey's Purebred	406	404	99.51
4	Boone County White	544	543	99.82
5	Gold Standard	517	517	100.00
6	Blount's Prolific	405	403	99.51
8	Virginia White Dent	416	378	90.87
7	Virginia Yellow Dent	434	429	98.85
9	Collier's Excelsior	473	459	97.04
10	Shenandoah White	478	444	92.89
11	Westwood Royal	430	412	95.81
12	Eureka	396	395	99.75
13	Fulford's Yellow Dent	511	485	94.91
14	Cooke's Prolific	468	441	94.23

Note: Kernels used above were taken from individual ears, grown in alternate rows on the same plot, and are therefore hybrid to a more or less extent.

Series II.

Number of grains germinated at 8 hour periods.

Variety Number.	32	40	48	56	64	72	80	88	96	104	112	120
1	0	15	78	79	93	61	25	13	0	0	0	0
2	0	23	50	92	100	49	24	15	2	4	0	0
3	0	47	45	61	80	64	70	30	6	1	0	0
4	1	84	50	114	141	107	34	11	0	0	0	1
5	0	5	21	101	118	125	87	54	5	0	1	0
6	0	3	7	68	107	120	57	37	3	1	0	0
7	0	30	57	86	76	115	54	9	2	0	0	0
8	0	21	66	72	126	61	26	4	0	0	0	0
9	0	63	43	103	104	95	27	21	3	0	0	0
10	0	5	9	82	122	120	62	39	2	3	0	0
11	0	1	9	70	66	95	96	46	21	6	2	0
12	3	84	57	109	88	49	3	1	1	0	0	0
13	0	1	4	52	109	143	84	64	21	6	1	0
14	0	18	53	102	151	81	30	5	1	0	0	0

1 - Improved Golden Dent.

2 - Columbian Beauty.

3 - Casey's Purebred.

4 - Boone County White.

5 - Gold Standard.

6 - Blount's Prolific.

7 - Virginia Yellow Dent.

8 - Virginia White Dent.

9 - Collier's Excelsior.

10 - Shenandoah White.

11 - Westwood Royal.

12 - Eureka.

13 - Fulford's Yellow Dent.

14 - Cooke's Prolific.

Series II.

Percent Germination at 8 hour periods.

Variety No.	32	40	48	56	64	72	80	88	96	104	112	120
1	0	4.12	21.43	21.70	25.55	16.76 89.56	6.87	3.57	0	0	0	0
2	0	6.41	13.93	25.63	27.86	13.65 87.47	6.69	4.18	.56	1.11	0	0
3	0	11.63	11.14	15.10	19.80	15.84 73.51	17.33	7.43	1.49	.25	0	0
4	.18	15.47	9.21	20.99	25.97	19.71 91.53	6.26	2.03	0	0	0	.18
5	0	.97	4.06	19.54	22.82	24.18 71.57	16.83	10.44	.97	0	.19	0
6	0	.74	1.74	16.87	26.55	29.78 75.68	14.14	9.18	.74	.25	0	0
7	0	6.99	13.29	20.05	17.72	26.81 84.86	12.59	2.10	.47	0	0	0
8	0	5.56	17.99	19.05	33.33	16.14 92.07	6.88	1.06	0	0	0	0
9	0	13.72	9.37	22.44	22.66	20.70 88.89	5.88	4.58	.65	0	0	0
10	0	1.13	2.03	18.47	27.48	27.03 76.14	13.96	8.78	.45	.68	0	0
11	0	.24	2.18	16.99	16.02	23.06 58.49	23.30	11.17	5.10	1.46	.48	0
12	.76	21.27	14.43	27.59	22.28	12.41 98.74	.76	.25	.25	0	0	0
13	0	.21	.82	10.72	22.47	29.48 63.70	17.32	13.20	4.31	1.24	.21	0
14	0	4.08	12.02	23.12	34.24	18.37 91.83	6.80	1.13	.23	0	0	0

1-Improved Golden Dent.
2 - Columbian Beauty.
3 - Casey's Purebred.
4 - Boone County White.
5 - Gold Standard.
6 - Blount's Prolific.
7 - Virginia Yellow Dent.
8 - Virginia White Dent.
9 - Collier's Excelsior.
10 - Shenandoah White.
11 - Westwood Royal.
12 - Eureka.
13 - Fulford's Yellow Dent.
14 - Cooke's Prolific.

Series II.

Varieties of corn named in order of earliness of

Germination.	Maturity.
1 - Eureka.	1 - Shenandoah White.
2 - Virginia White Dent.	2 - Pulford's Yellow Dent.
3 - Cocke's Prolific.	2 - Collier's Excelsior.
4 - Boone County White.	2 - Virginia Yellow Dent.
5 - Improved Golden Dent.	3 - Boone County White.
6 - Collier's Excelsior.	4 - Westwood Royal.
7 - Columbian Beauty.	5 - Improved Golden Dent.
8 - Virginia Yellow Dent.	5 - Virginia White Dent.
9 - Shenandoah White.	6 - Gold Standard.
10 - Blount's Prolific.	7 - Casey's Purebred.
11 - Casey's Purebred.	7 - Blount's Prolific.
12 - Gold Standard.	7 - Columbian Beauty.
13 - Pulford's Yellow Dent.	8 - Cocke's Prolific.
14 - Westwood Royal.	9 - Eureka.

Series III.

(Temperature 31° to 37° C.)

No.	Variety	Number of kernels.	Number of kernels germinated.	Percent of germination.
1	Columbian Beauty	485	484	99.79
2	Collier's Excelsior	544	543	99.82
3	Imp. So. White Snowflake	578	576	99.65
4	Bigg's Seven Ear II	473	473	100.00
5	Bigg's Seven Ear	463	460	99.35
6	Improved Leaming (Woods)	476	448	94.12
7	Cooke's prolific "	388	364	93.56
8	Virginia Ensilage "	395	379	95.95
9	Blount's Prolific	383	380	99.22
10	Hickory King (Woods)	401	380	94.76
11	Collier's Excelsior (Wds)	559	500	89.45
12	Shenandoah White (Woods)	418	327	78.23
13	Imp. Golden Dent "	472	445	94.28

Note: Kernels of varieties marked (Wood's) came from seed samples grown in Virginia. Kernels of all other varieties used above came from individual ears, grown in alternate rows on same plat, and are therefore hybrid to a more or less extent.

Series III.

Number of Grains germinated at 8 hour periods.

Var. No.	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128
1	0	0	0	1	15	48	133	119	70	57	24	7	3	7	0
2	0	0	0	33	112	85	140	135	23	10	3	0	2	0	0
3	0	0	5	47	100	132	129	111	34	16	2	0	0	0	0
4	0	0	3	33	108	143	123	46	12	2	3	0	0	0	0
5	0	0	0	1	20	57	111	119	81	45	15	7	4	0	0
6	2	22	79	167	137	33	6	2	0	0	0	0	0	0	0
7	0	5	30	131	136	44	12	5	1	0	0	0	0	0	0
8	0	0	2	13	60	55	85	82	49	18	6	4	4	1	0
9	0	0	0	3	16	65	108	41	64	53	21	5	3	1	0
10	0	1	7	33	33	69	68	58	31	39	16	15	4	5	1
11	1	23	75	110	107	59	98	8	15	4	0	0	0	0	0
12	0	3	47	100	104	38	21	10	2	2	0	0	0	0	0
13	0	0	17	65	168	78	83	23	9	1	1	0	0	0	0

1 - Columbian Beauty.

2 - Collier's Excelsior.

3 - Improved Southern White Snowflake.

4 - Bigg's Seven Ear II.

5 - Bigg's Seven Ear.

6 - Improved Leaming. (Wood's).

7 - Cooke's Prolific (Wood's).

8 - Virginia Ensilage. (Wood's)

9 - Blount's Prolific.

10 - Hickory King. (Wood's)

11 - Collier's Excelsior (Wood's)

12 - Shenandoah White (Woods).

13 - Improved Golden Dent. "

Series III.

Percent of Germination at 8 hour periods.

Var. No.	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128
1	0	0	0	.21	3.10	9.92	27.48	24.59 65.30	14.46	11.78	4.96	1.45	.62	1.45	0
2	0	0	0	6.08	20.63	15.65	25.78	24.86 93.00	4.24	1.84	.55	0	.37	0	0
3	0	0	.87	8.16	17.36	22.92	22.40	19.27 90.98	5.90	2.78	.34	0	0	0	0
4	0	0	.63	6.98	22.83	30.23	26.00	9.73 96.40	2.54	.42	.63	0	0	0	0
5	0	0	0	.22	43.5	12.39	24.13	25.87 66.96	17.61	9.78	3.26	1.52	.87	0	0
6	.45	4.91	17.63	37.28	30.58	7.37	1.34	.45 100.00	0	0	0	0	0	0	0
7	0	1.37	8.24	35.99	37	.36	12.09	3.30 1.37 99.72	.27	0	0	0	0	0	0
8	0	0	.53	3.43	15.83	14.51	22.43	21.64 78.37	12.93	4.75	1.58	1.06	.05	.26	0
9	0	0	0	.79	4.21	17.11	28.42	10.79 61.32	16.84	13.95	5.53	1.32	.79	.26	0
10	0	.26	1.84	8.68	8.68	18.16	17.89	15.26 70.77	8.16	10.26	4.21	3.95	1.05	1.32	.26
11	0	.2	4.6	15.00	22.00	21.4	11.8	19.6 94.6	1.6	3	.8	0	0	0	0
12	0	.92	14.37	30.58	31.80	11.62	6.42	3.06 98.77	.61	.61	0	0	0	0	0
13	0	0	3.82	14.61	37.75	17.53	18.65	5.17 97.53	2.02	.22	.22	0	0	0	0

1 - Columbian Beauty.
2 - Collier's Excelsior.
3 - Improved Southern White Snowflake.
4 - Bigg's Seven Ear II.
5 - Bigg's Seven Ear.
6 - Improved Leaming (Wood's).
7 - Cooke's Prolific "
8 - Virginia Ensilage (Wood's)
9 - Blount's Prolific.
10 - Hickory King (Wood's).
11 - Collier's Excelsior (Wood's)
12 - Shenandoah White (Wood's).
13 - Improved Golden Dent ".

Series III.

Varieties of Corn named in Order of Earliness of

Germination	Maturity.
1 - Improved Leaming.	1 - Shenandoah White.
2 - Cocke's Prolific.	2 - Improved Leaming.
3 - Shenandoah White.	2 - Collier's Excelsior.
4 - Improved Golden Dent.	2 - Hickory King.
5 - Bigg's Seven Ear II.	3 - Improved So. Wh. Snowflake.
6 - Collier Excelsior. (Wood's).	3 - Improved Golden Dent.
7 - Collier's Excelsior.	4 - Blount's Prolific.
8 - Improved Southern White Snowflake.	5 - Columbian Beauty.
9 - Virginia Ensilage.	6 - Cocke's Prolific.
10 - Hickory King.	6 - Bigg's Seven Ear.
11 - Bigg's Seven Ear.	7 - Virginia Ensilage.
12 - Columbian Beauty.	
13 - Blount's Prolific.	

Series IV.

(Temperature 31.5° to 38° C.)

No.	Variety	Number kernels placed in germinator.	Number kernels germinated.	Percent of germination.
1	Boone County White	491	479	97.56
2	Shenandoah White	479	403	84.13
3.	Improved Leaming	479	463	96.66
4	Cooke's Prolific	688	630	91.57
5	Hickory King	388	363	93.56
6	Collier's Excelsior	523	481	91.97
7	Improved Golden Dent	452	432	95.58

Note : Kernels used above came from seed samples grown in Virginia.

Number kernels germinated at 8 hour periods.

Var. No.	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136
1	1	1	13	59	114	172	64	22	23	8	2	0	0	0	0
2	2	16	75	136	84	56	15	10	4	4	1	0	0	0	0
3	7	40	164	153	88	9	1	0	0	1	0	0	0	0	0
4	0	3	48	133	166	139	62	47	21	7	4	0	0	0	0
5	0	7	30	51	63	77	53	13	23	18	12	8	5	2	1
6	0	19	91	138	124	75	20	8	2	4	0	0	0	0	0
7	0	8	94	132	81	74	21	14	5	2	1	0	0	0	0

Percent of Germination at 8 hour Periods, and Total percent of Germination at 72 hours.

Var. No.	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136
1	.21	.21	2.71	12.32	23.80	35.91	13.36 87.52	4.59	4.80	1.67	.42	0	0	0	0
2	.49	3.97	18.61	33.74	20.84	13.89	3.72 95.26	2.48	.99	.99	.25	0	0	0	0
3	1.51	8.64	35.42	33.05	19.01	1.94	.22 99.79	0	0	.22	0	0	0	0	0
4	0	.47	7.62	21.11	26.35	22.06	9.84 87.45	7.46	3.33	1.11	.63	0	0	0	0
5	0	1.93	8.26	14.05	17.36	21.21	14.60 77.41	3.58	6.34	4.96	3.30	2.20	1.38	.55	27
6	0	3.95	18.92	28.69	25.78	15.59	4.16 97.09	1.66	.41	.83	0	0	0	0	0
7	0	1.85	21.76	30.56	18.75	17.15	4.86 94.71	3.24	1.16	.46	.23	0	0	0	0

Series IV.

Varieties of Corn Named in order of earliness of

Germination.

1 - Improved Leaming.
2 - Collier's Excelsior.
3 - Shenandoah White.
4 - Improved Golden Dent.
5 - Boone County White.
6 - Cocke's Prolific.
7 - Hickory King.

Maturity.

1 - Boone County White.
2 - Shenandoah White.
3 - Improved Leaming.
4 - Cocke's Prolific.
5 - Hickory King.
6 - Collier's Excelsior.
7 - Improved Golden Dent.

Summation of Series I, II, III, and IV.

The following table shows the rank of all varieties used as to maturity, percent germination at end of 72 hours for each series, average of these percentages, and rank of varieties as to earliness of germination.

Maturity Rank	Variety	Percent germination for each series at end of 72 hours. I	II	III	IV	Avg.	Numerical rank as to germination	
1	Shenandoah White	77.59	76.14	98.77	95.26	86.94	8	
2	Fulford's Yellow Dent	25.57	63.70	-----	-----	44.63	20	
2	Hickory King	69.34	-----	70.77	77.41	72.51	17	
2	Collier's Excelsior	-----	88.89	94.06	97.09	93.26	4	
2	Improved Leaming	82.58	-----	100.00	99.79	94.12	3	
2	Va. Yellow Dent	85.91	84.86	-----	-----	85.38	10	
3	Boone County White	89.89	91.53	-----	87.52	89.65	7	
4	Westwood Royal	71.37	58.49	-----	-----	64.93	19	
5	Va. White Dent	79.04	92.07	-----	-----	85.55	9	
5	Improved So. Snowflake	-----	-----	90.98	-----	90.98	6	
5	Improved Golden Dent	43.60	89.56	97.53	94.71	81.35	14	
6	Gold Standard	96.30	71.57	-----	-----	83.93	11	
7	Columbian Beauty	-----	87.47	65.30	-----	76.38	16	
7	Casey's Purebred	93.31	73.51	-----	-----	83.41	12	
7	Blount's Prolific	-----	75.68	61.32	-----	68.50	18	
8	Cocke's Prolific	99.29	91.83	99.72	87.45	94.57	1	(flint)
8	Bigg's 7 Ear	-----	-----	96.40	-----	81.68	13	
8	Pamunkey Ensilage	92.81	-----	-----	-----	92.81	5	(flint)
9	Eureka	89.97	98.74	-----	-----	94.35	2	"
9	Virginia Ensilage	-----	-----	78.37	-----	78.37	15	

From the above summation, which combines the results of the four series, there exists a marked earliness of germination among the flinty varieties, although they are later maturing. Considering only the dent varieties, one would draw the conclusion that there exists no relation between earliness and time of germination, but that some varieties germinate earlier than others, regardless of length of time required for maturity. Improved Leaming germinates more rapidly than other dent varieties, although Fulford's Yellow Dent and Hickory King (having the same number of days for maturity) are among the latest in respect to germination.

Conclusions.

1 - The minimum, optimum, and maximum temperatures of germination determined for Boone County White corn corresponds very closely to that found by other men, who have done work along this line.

2 - There is a slight positive correlation between size of kernels and time of germination for Boone County White corn, but we do not state this as a conclusion, because our work has not been duplicated enough for a final conclusion.

3 - a. Flint varieties germinate more rapidly than dent varieties.

b. No relation exists between time of germination and earliness of varieties.

Remarks: 1 - The varieties used in this work do not have enough variation in time of maturity.

2 - A definite number of varieties should have been selected which possess the desired variation, as to time of maturity, and each of these varieties should have been tested in each series.

Bibliography.

1 - Haberlandt. Landw. Versuchs. Stat., 17, p. 104.

2 - Howard, W. L. Plant Propagation. p. 24; U. of M. 1914.

3 - Wilson, A. D., and Warburton, C. W. Field Crops. p. 25; 1912.

4 - Davenport, E. Principles of Breeding. pp. 460 - 467; 1907. Ginn & Co., Boston.

5 - Ewing, E. C. Cornell Univ. Exp. Sta. Bul. 287; 1910.

6 - Leighty, C. E. Paper No. 22. Dept. of Plant Breeding, Cornell University. Ithaca, N. Y.

7 - Myers, C. H. Paper No. 18. Dept. of Plant Breeding, Cornell University. Ithaca, N. Y.