THE CORRELATION BETWEEN EGG PRODUCTION DURING
VARIOUS PERIODS OF THE YEAR IN
THE DOMESTIC FOWL

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INTRODUCTION

As a basis for economic procedure, our knowledge of the interrelationships of the various characteristics and functions of domesticated plants and animals can hardly be too precise. Indeed, it is hardly too much to say that had pure scientific research received more attention, even at the expense of the so-called practical studies, the economic ends attained would have been greater.

The present paper embodies the results of an attempt to analyze by the application of quantitative methods certain of the problems of egg production in the domestic fowl. The work falls, therefore, in the general field opened and extensively developed by PEARL and his associates at the MAINE AGRICULTURAL EXPERIMENT STATION. The particular

methods of analysis which we have used are somewhat different from those chiefly employed in the Biological Laboratory of the MAINE STATION, where most of the really quantitative work on egg production has been done.

Our materials also differ from those chiefly used at the MAINE STATION. The work of PEARL and his associates has been largely based on the Maine flock of Barred Plymouth Rocks. The present paper deals with White Leghorn fowl. The Maine flock represents one of the most homogeneous series of birds available for scientific study. Our materials are drawn from a general egg-laying competition.¹

The present study, while in the same general field as those already published by PEARL, SURFACE, CURTIS and others, does not, therefore, overlap—either in material or method—work already done. The problem of egg production is one as broad and complex biologically as it is important economically. Data can hardly be secured from too many sources or analyzed by too many different methods. Upon a comparison of the results of such work, broad scientific generalizations and specific practical recommendations must ultimately be based.

We have already considered (GENETICS 2: 38) in some detail the question of the value of the series of birds submitted in egg-laying competitions for biological work. Such series must undoubtedly lack the uniformity of particular closely bred experiment station flocks. They are, therefore, unsuited for certain types of pure scientific research. They represent, on the other hand, the kind of poultry which yields an annual revenue of about half a billion dollars to the practical breeders of the United States. Such materials must, sooner or later, receive the careful attention of biological investigators.

The general purpose of the present paper is to consider the correlation between the egg production of different periods of the year in such series of birds as are submitted in egg-laying contests. The specific problems will be stated and explained in detail under the captions below.

The materials upon which the constants here presented are based com-

¹ In such a competition, it is not possible to know with accuracy the exact date of hatching and the consequent age of all the birds represented, as can be known in dealing with experimental flocks. Our material is more homogeneous, however, than one might infer. All the birds represented in the present study were in their pullet year. From the advice of experiment stations and from their own experience, breeders have learned that, in order to insure the maximum egg production in the pullet year, the time of hatching must be kept within rather narrow limits. As a general statement, it may be said that the birds entering the contest on November first had been hatched the previous March or April, or rarely as late as May, and were, therefore, not very heterogeneous in regard to age.

prise 309 and 375 White Leghorn birds for which a record of egg production throughout a contest year at Storrs, Connecticut, is available. These have been discussed by KIRKPATRICK and CARD (1915, 1916) and by HARRIS, BLAKESLEE, WARNER and KIRKPATRICK (1917) in papers to which the reader may refer for information as to origin and treatment of birds, methods and possible sources of error in records, and other details.

PRESENTATION OF RESULTS

The correlation between monthly egg record and annual egg production

The correlation between the egg production of a minor period and that of a major period of which it is a part has material economic importance as well as biological interest. If the correlation of the production of a first period with the production of a later period be high, it is clear, from the biological side, that the flock under investigation is composed of birds innately differentiated in their capacity for egg production. From the practical side, it is evident that when the correlation is of a substantial order of magnitude, the culling of a flock can be undertaken at the economically most profitable time if the egg production of the individual birds be known or can be estimated by dependable criteria (HARRIS, BLAKESLEE, WARNER and KIRKPATRICK 1917).

The correlation between the production for the individual months of the year and the annual egg production is biologically at least, and possibly also economically, of greater importance than that between any group of months and annual egg production. This is due to the following facts: First, the determination of the correlations for individual months and annual totals permits the selection of the best months for trap nesting operations for those breeders with whom trap nesting must necessarily be a purely commercial matter. Second, if the correlation between the production of individual months and annual totals is close enough to furnish criteria of value for the selection of birds, the culling of the flock may be begun at any time that economic conditions may demand. Third, from the physiological side, the determination of the correlations for the individual months has the value of throwing light upon the problem of the existence of major cycles of egg production in the fowl.

Since the correlations between the records of the individual months and of the annual totals seem of considerable economic as well as of biological importance, it is desirable to publish tables of data from which these correlations may be verified. Such tables will also be made use of later in this paper.

Fortunately the coefficient of correlation may be determined by a method already extensively used (HARRIS 1910) if the total value of the y variable associated with given values of the x variable are known in addition to the means and standard deviations of the two characters.

The actual frequency distributions of number of eggs laid per month in each month of the two years have been given in tables 1 and 2 of our former paper (GENETICS 2: 43-44). The means and standard deviations of number of eggs were also given in tables 3 and 4² of that paper.

Since the total egg record of the year is so extensively used in this paper, the distribution of number of eggs laid per year is given in table 1. The constants for annual egg production have already been published (GENETICS 2: 42).

In tables 2 and 3 the number of eggs laid per month, the number of birds by which each (monthly) fecundity class is represented and the total eggs laid in the year are given.

The correlations between the egg production of the twelve individual months and the annual total egg production for 309 and 375 White Leghorns in the years 1913-'14 and 1914-'15 are shown side by side in

DIAGRAM I.—Magnitudes of correlation between the egg record of the individual months and the egg record of the whole year (solid dots) and of the correlations between the egg record of the individual months and the total egg production of the remaining eleven months of the year (circles). The shaded area indicates the magnitude of the difference between these values.

² In the calculations of the correlations in this paper a larger number of decimal places were of course retained than are given in the tables.

TABLE I
Total number of eggs laid per year by each bird in the two contest years.

Eggs laid	Birds		Eggs laid	Birds		Eggs laid	Birds		Eggs laid	Birds		Eggs laid	Birds		Eggs laid	Birds		Eggs laid	Birds	
	1913 and 1914	1914 and 1915		1913 and 1914	1914 and 1915		1913 and 1914	1914 and 1915		1913 and 1914	1914 and 1915		1913 and 1914	1914 and 1915		1913 and 1914	1914 and 1915		1913 and 1914	1914 and 1915
0	—	1	92	1	—	121	2	3	151	3	7	180	2	5	209	2	4	209	2	4
1	—	1	93	2	1	122	5	2	152	6	4	181	1	3	210	1	1	210	1	1
4	—	1	94	1	2	123	3	1	153	1	7	182	—	1	211	—	—	211	—	—
13	—	1	95	1	—	125	3	2	154	1	7	183	1	4	212	1	—	212	1	—
16	—	1	96	—	1	126	—	3	155	2	2	184	1	2	213	—	4	213	—	4
17	—	1	97	1	2	127	1	2	156	4	1	185	4	5	214	1	2	214	1	2
33	—	1	98	1	—	128	5	2	157	3	2	186	—	1	215	2	2	215	2	2
40	—	1	99	1	2	129	3	4	158	3	6	187	—	3	216	1	3	216	1	3
50	—	1	100	3	3	130	5	2	159	1	3	188	—	4	217	2	—	217	2	—
51	—	1	101	—	1	131	4	2	160	3	6	189	2	2	218	—	3	218	—	3
60	—	1	102	2	—	132	1	2	161	4	3	190	3	4	219	2	—	219	2	—
65	—	1	103	2	—	133	7	1	162	2	1	191	2	3	220	—	2	220	—	2
66	—	1	104	2	2	134	2	3	163	1	3	192	1	2	221	1	—	221	1	—
70	2	1	105	2	—	135	2	4	164	2	2	193	1	3	222	1	—	222	1	—
72	1	1	106	2	—	136	6	2	165	1	2	194	1	5	223	1	—	223	1	—
73	1	1	107	—	1	137	1	1	166	3	—	195	1	3	224	2	—	224	2	—
77	1	1	108	—	1	138	2	2	167	1	4	196	1	4	225	—	1	225	—	1
78	—	2	109	2	3	139	2	4	168	3	4	197	3	3	226	—	1	226	—	1
79	1	1	110	4	2	140	2	2	169	4	3	198	5	3	227	—	1	227	—	1
80	1	1	111	2	7	141	1	3	170	6	2	199	—	4	228	—	1	228	—	1
81	—	1	112	2	2	142	4	3	171	2	2	200	—	2	229	1	1	229	1	1
82	—	1	113	2	2	143	5	2	172	1	2	201	2	3	230	1	1	230	1	1
83	1	1	114	2	4	144	4	2	173	3	4	202	2	2	231	1	1	231	1	1
84	2	4	115	—	1	145	2	4	174	2	6	203	1	2	232	1	1	232	1	1
85	—	1	116	5	3	146	7	5	175	4	5	204	—	4	233	2	—	233	2	—
87	—	2	117	3	2	147	4	4	176	4	5	205	1	2	234	1	1	234	1	1
88	—	2	118	—	2	148	4	4	177	2	5	206	—	2	235	—	—	235	—	—
89	—	1	119	3	4	149	4	3	178	2	1	207	3	1	236	—	—	236	—	—
91	—	2	120	1	1	150	7	—	179	4	5	208	4	3	237	—	—	237	—	—

table 4. The coefficients are also represented by the solid dots in diagram 1.

The comparisons between the results of the two years by means of the difference column and the probable errors of the differences, in the column showing the ratio of the differences to their probable errors, show a remarkable degree of consistency between the results for the two years. In only a single instance is the difference between the correlations obtained from the two sets of experiments over twice as large as its probable error. Closer agreement could not be expected under the most ideal conditions for biological work.

Cursory inspection of the table or the graph shows that the constants have a very material value. They are of the order $r = .40$ to $r = .70$ with an average value of .550 in 1913-'14 and .562 in 1914-'15. Thus prediction of annual total from the results of individual months' production should be a matter of a relatively high degree of precision.

TABLE 4
Correlation between the egg production of the twelve individual months and total annual egg production.

Month	Correlation			Diff./E. Diff.
	1913-1914	1914-1915	Difference	
November	.433 ± .031	.372 ± .030	— .061 ± .043	1.42
December	.561 ± .026	.503 ± .026	— .058 ± .037	1.57
January	.463 ± .030	.483 ± .026	+ .020 ± .040	.50
February	.495 ± .029	.495 ± .026	.000 ± .039	.00
March	.463 ± .030	.522 ± .025	+ .059 ± .039	1.51
April	.381 ± .033	.544 ± .025	+ .163 ± .041	.40
May	.539 ± .038	.596 ± .022	+ .057 ± .044	1.30
June	.563 ± .026	.629 ± .021	+ .066 ± .033	2.00
July	.667 ± .021	.663 ± .019	— .004 ± .028	.14
August	.672 ± .021	.684 ± .019	+ .012 ± .028	.43
September	.691 ± .020	.695 ± .018	+ .004 ± .027	.15
October	.676 ± .021	.558 ± .024	— .118 ± .032	3.69

The straight line equation for the prediction of annual production from the record of any month is given by

$$E = (\bar{E} - r_{eE} \frac{\sigma_E}{\sigma_e} \bar{e}) + r_{eE} \frac{\sigma_E}{\sigma_e} e$$

where e = egg production for any given month and E the production for the year.

The results given by the substitution of the actual constants in this equation are given in table 5.

TABLE 2

Total annual egg production for birds of different grades in each individual month. 1913-1914.

Eggs laid per month	November		December		January		February		March		April		May		June		July		August		September		October	
	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs
0	126	16968	157	21250	158	22084	21	2713	—	—	—	—	—	—	2	135	4	347	9	780	88	10778	184	24466
1	26	4025	9	1219	23	3332	12	1497	—	—	1	16	—	—	2	143	—	—	5	519	26	3444	14	2162
2	9	1379	5	895	6	849	12	1378	—	—	1	65	1	16	—	—	2	100	4	356	14	1870	10	1487
3	21	3300	7	1143	16	2334	12	1485	1	16	—	—	—	—	—	—	1	70	4	469	6	822	4	685
4	13	1842	3	403	15	2225	3	222	2	178	—	—	1	65	1	98	3	310	—	—	6	891	6	1020
5	9	1327	9	1420	10	1470	11	1501	1	72	—	—	—	—	1	65	2	216	5	681	4	593	4	559
6	13	2134	14	2022	9	1487	21	2791	4	462	1	79	—	—	2	234	1	128	3	376	6	935	3	488
7	10	1507	9	1431	14	2379	19	2718	1	113	—	—	—	—	2	209	3	388	3	271	8	1056	2	320
8	12	1956	14	2071	5	919	18	2758	1	116	—	—	—	—	2	207	2	200	2	163	6	919	7	1058
9	9	1490	5	765	15	2692	24	3728	3	551	2	240	—	—	2	181	3	256	4	449	3	519	8	1409
10	10	1712	7	1092	8	1392	17	2781	2	200	3	420	—	—	4	582	10	1153	8	902	4	578	5	893
11	9	1419	7	1217	5	957	22	3529	7	833	4	543	4	354	8	977	8	1011	9	1134	5	755	8	1611
12	12	2206	7	1163	4	681	16	2462	7	886	6	706	3	273	8	911	6	602	4	463	5	714	2	344
13	6	1053	5	791	5	881	17	2511	14	1786	4	586	2	194	6	880	5	592	6	851	6	943	5	900
14	4	703	5	967	7	1261	17	2969	17	2349	8	975	5	493	8	940	9	1188	6	854	5	649	3	553
15	10	1874	7	1248	1	160	22	3776	16	2246	8	1065	3	359	7	933	5	582	8	1066	7	1212	3	551
16	7	1347	6	1147	3	617	15	2462	26	3502	17	2324	5	625	7	976	10	1269	16	2130	11	1659	5	989
17	1	237	6	1140	2	400	17	3096	25	3870	15	2155	9	1254	7	893	11	1599	9	1219	12	2017	10	1986
18	1	219	5	996	2	393	8	1491	33	5144	22	3111	15	2066	17	2515	13	1751	17	2375	16	2772	9	1793
19	—	—	7	1394	1	243	3	539	32	4896	32	4997	16	2073	19	2477	17	2403	11	1704	18	3536	5	1101
20	1	157	7	1462	—	—	1	193	40	6354	47	7341	22	3075	27	4128	27	3795	30	4581	19	3500	8	1639
21	—	—	—	—	—	—	1	255	26	4090	44	6868	27	3986	32	4575	21	3252	24	3908	17	3287	2	388
22	—	—	5	944	—	—	—	—	27	4878	43	6618	48	7285	31	4673	35	5704	32	5495	11	2148	2	453
23	—	—	3	675	—	—	—	—	15	2655	31	5347	50	8117	47	8060	38	6602	36	6146	3	610	—	—
24	—	—	—	—	—	—	—	—	7	1324	16	2744	41	6854	25	4640	31	5413	36	6562	2	438	—	—
25	—	—	—	—	—	—	—	—	1	133	3	512	24	3966	24	4210	13	2398	9	1594	1	201	—	—
26	—	—	—	—	—	—	—	—	1	201	1	143	18	2989	10	1651	21	3852	7	1351	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—	10	1034	6	1167	6	1253	1	255	—	—	—	—
28	—	—	—	—	—	—	—	—	—	—	—	—	5	877	2	390	1	146	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	185	1	201	—	—	—	—

TABLE 3

Total annual egg production for birds of different grades in each individual month. 1914-1915.

Eggs laid per month	November		December		January		February		March		April		May		June		July		August		September		October	
	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs	f	Total eggs
0	152	21068	103	13485	133	17620	47	5350	8	308	4	92	3	5	11	606	12	809	25	2275	69	7271	190	24870
1	20	2924	14	1876	12	1573	18	2233	1	78	1	4	2	100	2	117	5	384	9	602	16	1693	23	3601
2	10	1353	12	1802	16	2215	16	2043	1	82	—	—	—	—	—	—	1	139	5	519	6	833	14	2415
3	16	2769	17	2483	22	3464	15	2438	2	193	1	94	1	13	4	393	6	539	3	389	3	432	12	1982
4	13	1851	13	1833	13	2252	19	2740	2	171	1	17	1	84	—	—	2	206	4	528	5	721	12	2017
5	7	1149	18	2346	15	2398	24	3399	5	599	4	339	2	290	3	298	2	154	9	1029	5	670	13	2024
6	18	2750	23	3612	11	1719	21	3248	5	663	—	—	1	33	6	771	2	230	1	113	3	446	10	1743
7	9	1518	17	2450	14	1845	18	2789	8	1041	3	402	3	394	4	433	2	224	4	564	4	604	7	1364
8	14	2370	13	2185	15	2560	30	4518	10	1252	2	235	6	720	—	—	3	368	4	478	2	313	8	1290
9	14	2297	10	1669	10	1561	18	2920	3	484	5	517	8	955	4	397	6	725	8	1030	5	772	7	1363
10	15	2487	15	2442	14	2293	21	3296	13	1746	9	1232	3	286	5	564	5	562	1	145	6	832	7	1339
11	12	1968	16	2415	11	1931	12	2181	14	2049	7	946	3	327	5	632	5	600	5	575	10	1430	4	678
12	18	2935	8	1359	16	2794	20	3495	8	1153	5	807	2	236	7	924	9	1176	7	979	6	904	6	1080
13	10	1874	11	1976	12	2057	12	2077	16	2335	10	1390	7	858	7	924	7	895	8	1238	12	1870	6	1018
14	7	1168	7	1348	8	1515	17	3082	21	3181	25	3659	9	1226	4	509	9	1343	11	1482	11	1797	7	1398
15	13	2360	16	2614	8	1398	21	3626	27	4044	19	2603	6	611	5	591	9	1316	8	1205	17	2505	7	1378
16	6	1114	12	2352	5	922	14	2532	23	3250	26	3732	10	1317	4	646	6	748	10	1484	20	3181	8	1388
17	3	567	17	3234	14	2787	12	2248	22	3593	30	4363	7	1023	4	399	11	1491	17	2401	23	3817	8	1768
18	4	776	9	1878	8	1481	12	2132	29	4652	32	4409	13	1893	12	1848	16	2312	24	3590	24	4179	7	1333
19	5	809	12	2169	8	1525	2	359	39	6331	43	7256	25	3514	12	1791	17	2527	14	2074	25	4295	7	1404
20	1	199	5	1022	6	1140	5	1005	42	7305	39	6624	22	3412	17	2404	22	3274	29	4949	29	5134	6	1278
21	6	1172	5	900	3	672	1	218	33	5659	40	6944	45	6664	45	7068	23	3443	36	6001	32	5873	4	825
22	—	—	1	255	1	207	—	—	15	2665	23	3593	39	6313	41	6030	41	6843	50	8621	16	3146	1	218
23	1	216	—	—	—	—	—	—	18	3251	25	4509	50	8444	50	8403	36	6151	40	7357	13	2443	1	155
24	—	—	1	224	—	—	—	—	8	1459	13	2520	42	7115	53	9162	39	6807	25	4634	6	1282	—	—
25	1	235	—	—	—	—	—	—	1	157	5	1127	29	5330	33	6037	41	7518	10	2005	6	1278	—	—
26	—	—	—	—	—	—	—	—	1	228	2	358	23	4169	23	4313	25	4479	5	1068	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	1	157	10	1961	11	2059	10	2053	3	594	—	—	—	—
28	—	—	—	—	—	—	—	—	—	—	—	—	2	399	2	427	2	464	—	—	1	208	—	—
29	—	—	—	—	—	—	—	—	—	—	—	—	1	237	1	183	1	149	—	—	—	—	—	—

Since the egg productions for the several months are given in units, the second constant of these equations shows at a glance the difference in average annual egg production which will result by choosing groups of birds differing by one egg in their production for any month. This amount is seen to be a very material one ranging from about 3 to about 5.5 eggs.

The problem of the prediction of mean annual production from the actually determined record of any individual month is a question of such real practical importance that it has seemed worth while to represent each of these regression equations and the empirical means graphically.

The comparison between the empirical and the theoretical mean annual egg production for birds of different productions in the individual months is made in diagrams 2 to 5.

The first thing which impresses one about these diagrams is the closeness of agreement of the straight lines for the two years. Around these lines, which mark off on the ordinates for monthly egg production the theoretical mean number of eggs laid during the year as a whole, the

TABLE 5

Regression equations for the prediction of annual total egg production from monthly egg records.

Month		1913-1914	1914-1915
		Regression equation	Regression equation
November,	e_1	$E = 137.971 + 3.191 e_1$	$E = 140.437 + 2.615 e_1$
December,	e_2	$E = 135.382 + 3.115 e_2$	$E = 130.858 + 3.271 e_2$
January,	e_3	$E = 139.181 + 3.780 e_3$	$E = 134.742 + 3.258 e_3$
February,	e_4	$E = 118.332 + 3.522 e_4$	$E = 124.009 + 3.759 e_4$
March,	e_5	$E = 74.552 + 4.354 e_5$	$E = 87.041 + 4.181 e_5$
April,	e_6	$E = 74.727 + 3.963 e_6$	$E = 65.162 + 5.045 e_6$
May,	e_7	$E = 30.904 + 5.561 e_7$	$E = 56.691 + 4.807 e_7$
June,	e_8	$E = 69.403 + 4.138 e_8$	$E = 69.094 + 4.252 e_8$
July,	e_9	$E = 67.919 + 4.320 e_9$	$E = 74.056 + 4.174 e_9$
August,	e_{10}	$E = 84.132 + 3.767 e_{10}$	$E = 88.506 + 3.915 e_{10}$
September,	e_{11}	$E = 123.868 + 3.040 e_{11}$	$E = 108.134 + 3.591 e_{11}$
October,	e_{12}	$E = 135.292 + 3.834 e_{12}$	$E = 137.631 + 3.771 e_{12}$

actual means are scattered with the irregularity which one would expect when the two following facts are taken into consideration.

a. In neither year is the number of individual birds large. Considerable variation would, therefore, be expected in the empirical means in any series of biological data giving correlations no larger than those characteristic of the materials here under investigation.

b. In these data sometimes one and sometimes the other end of the range of variation is represented by very low frequencies. Thus in November and October—the first and the last months of the competition—about 40-60 percent of the birds are laying no eggs. This means that those laying from 1 to 25 or more eggs are both relatively few in

DIAGRAM 2

number and distributed among a large number of classes. In April and May, on the other hand, the zero and the single egg birds are scarcely represented at all. If the distribution were less irregular it would be possible to group into classes of three or five eggs each, but because of the wide differences in the egg production during different months of the year this procedure can hardly be resorted to without seriously impairing the value of the work.

In view of these facts, the irregularities which are certainly conspicuous in the empirical means lose much of their purely apparent significance. Taking the results as a whole, the scatter of the means on either side of the straight lines given by the equations seems to be such

as would result from errors of sampling in dealing with a relatively small number of individuals measured for a highly variable character.

There are, however, apparently certain cases of non-linearity. Thus in October the mean annual egg production seems to increase fairly uniformly from birds which have laid no eggs to those which laid 23 eggs during the month. Closer examination will show, however, that the

DIAGRAM 3

annual average for the birds which laid no eggs in October is distinctly lower than the annual average for the birds which laid 1, 2, 3, 4, . . . eggs in that month. Since the number of birds which are not laying

in October is very great (about 50-60 percent of the entire flock) the difference between this and the following means cannot be looked upon as a chance result merely. To this point we shall return later. The exceptions do not invalidate the general rule of approximate linearity of regression of annual production upon monthly egg record.

Since mean annual egg production changes at a practically uniform

DIAGRAM 4

rate with monthly egg production for each of the 12 months of the year, the prediction of the average annual yield of birds of any specified grade of monthly egg production is a relatively easy matter.

This is not at all equivalent to saying that all twelve months are equally good for the practical purposes of prediction.

From the purely formal side, that month is the best for purposes of prediction which has the greatest slope of the regression line, i.e., in which the second constant of the regression equation as given in table 5 is the largest. But from the practical standpoint other considerations may outweigh this. For example, prediction from earlier months is of greatest value if it is desired to eliminate poor layers from the flock at the earliest possible date.

The relationships between the production of the later months and the annual total have quite as much *biological* value as the relationship between the production of the earlier months of the contest and the annual total. Economically, they have the value of furnishing criteria for the selection of breeders at the time when the flock is being reduced after the first year of laying. They are obviously of no value for the elimination of poor layers, unless the flock is to be kept over to the second year for egg production.

Furthermore, a factor of very real practical importance is the range and distribution of the number of eggs laid in the various months. The second constant of the regression equation shows the difference in mean annual egg production which will be secured by selecting groups of birds differing by a single egg in their monthly egg record. But the practical breeder will not, of course, select groups of birds which differ by a single egg in their production for any given month, but groups which differ by as many eggs as possible. This will be determined by the range of variation in egg production and the total number of birds available in the several classes in the different months. The distribution of the frequency of different numbers of eggs varies greatly from month to month, as may be easily seen from tables 1 and 2 of our earlier paper (GENETICS 2: 43-44).

A detailed discussion of the practical aspects of the problem of the prediction of annual production from trap nest records for a single month lies outside the scope of this paper. We cannot, however, forego the presentation of certain concrete illustrations of the practicability of either eliminating early in the year, birds which will probably prove to be poor layers, instead of retaining them at a possible economic loss, or of the selection at the end of the first egg-laying year of the best birds for breeders. Such practical illustrations may serve to make clear by concrete illustrations the meaning of the equations. The constants derived from the two contests differ slightly. The use of the equations

given here in practical operations with flocks of birds of about the kind with which we have dealt would probably be attended by errors of about the magnitude of the differences between the results of the two years.³

There are, as has been indicated above, two chief uses of estimation

DIAGRAM 5

of annual egg production from monthly egg record: the culling of the flock to secure a high average egg record during the egg producing year, and the selection of the best birds for use as breeders in the second year.

³ In suggesting the use of correlations and prediction equations of the kind which we have given, we must lay great stress upon the fact that the birds upon which our conclusions are based are apparently uniform in breed but are derived from a very wide range of sources. It is possible that quite different results would be secured by the analysis of data from a highly selected or closely bred flock.

We would greatly appreciate the use of records, if sufficiently extensive, of flocks of this kind for the purpose of ascertaining how the results obtained from such series of birds compare with those derived from contest series.

In such culling or selecting, a given proportion of the flock will be divided off from the rest. For purposes of illustration merely we have assumed that from one to three quarters of the flock will be so segregated. One may work with groups of any size he chooses.

One of the simplest methods of doing this is to reduce the actual frequencies of birds laying given numbers of eggs to percentages, and to sum these percentage frequencies by adding each frequency to the sum of all that have preceded it. The summation may be done from either end of the range of variations. Thus, for example, the results for April are given in table 6.

Reading the summed percentage frequencies in the fifth column one may say that about a quarter of the birds lay 16 eggs, or fewer, about

TABLE 6

Illustration of method of the divisions of flock into groups on the basis of monthly egg production.

Eggs laid in April	Number of birds	Percent of flock	Sum of percentages	Sum of percentages	Total eggs for year
0	4	.585	100.000	.585	92
1	2	.292	99.415	.877	20
2	1	.146	99.123	1.023	65
3	1	.146	98.977	1.169	94
4	1	.146	98.831	1.315	17
5	4	.585	98.685	1.900	339
6	1	.146	98.100	2.046	79
7	3	.439	97.954	2.485	402
8	2	.292	97.515	2.777	235
9	7	1.023	97.223	3.800	757
10	12	1.754	96.200	5.554	1652
11	11	1.608	94.446	7.162	1489
12	11	1.608	92.838	8.770	1513
13	14	2.047	91.230	10.817	1976
14	33	4.825	89.183	15.642	4634
15	27	3.947	84.358	19.589	3668
16	43	6.287	80.411	25.876	6056
17	45	6.579	74.124	32.455	6518
18	54	7.895	67.545	40.350	7520
19	75	10.905	59.650	51.315	12253
20	86	12.573	48.685	63.888	13905
21	84	12.281	36.112	76.169	13812
22	66	9.649	23.831	85.818	10211
23	56	8.187	14.182	94.005	9856
24	29	4.240	5.995	98.245	5264
25	8	1.170	1.755	99.415	1639
26	3	.439	.585	99.854	501
27	1	.146	.146	100.000	157
Totals	684	100.000	(100.000)	(100.000)	104784

50 percent (51.3%) lay 19 eggs or less and about 75 percent lay 21 eggs or less. Or, reading from the other end of the scale from the fourth column, one notes that about 25 percent of the birds lay 22 eggs or more, about 50 percent (48.6%) lay 20 eggs or more, and about 75 percent (74.1%) lay 17 eggs or more.

From such a table one may conveniently divide off any portion of the flock. The frequency column and the column showing the total eggs per year enable one to determine the mean production for the year of groups of birds of any size.⁴

The actual results of such divisions of the flock into as nearly as possible equal quarters are shown in the accompanying table 7.

During the first three months of the contest the number of birds which lay no eggs is so great that they comprise roughly 40 percent of the flock. The actual percentages for this one class are 40.6, 38.0, and 42.5. It is impossible to divide the lower frequencies in a way to obtain two groups containing approximately a quarter of the flock each. We have, therefore, considered the influence of culling one half of the flock at this time. The averages show that this would eliminate from the flock birds with an annual average of from 136 to 139 eggs, leaving 50 percent of the birds in two groups, one belonging to the third quarter of the flock with average annual productions of from 153 to 159 eggs, and a highest quarter comprising birds with an annual average of 177 to 187 eggs. If the flock be considered approximately halved in either of these three early months, two nearly equal groups of birds will be secured, one of which would lay on the average 136 to 139 eggs per year as compared with another which would lay on the average 167 to 170 eggs per year.

It is perhaps superfluous to suggest *which* half of the flock should be sent to the commission house!

An even more stringent elimination of poor birds may be made in February, March or April⁵ when it is possible to discard the poorest quarter instead of the poorest half of the flock. A group of birds which lay from 126 to 131 eggs a year may be withdrawn from the flock, leaving 75 percent of the flock with an annual average production of about 167 eggs per year.

⁴ The validity of using the correlations found in this paper for practical selection operations must depend upon the flock having approximately the characteristics of the White Leghorn group submitted in the two years in the Storrs competitions.

⁵ In case some of the birds have been removed from the flock in November, December or January the percentage relations indicated in our tables will be disturbed. The whole subject requires special treatment which we hope to give it later.

TABLE 7A

Annual average egg production of quarters of the flock selected on the basis of egg records for the several months.

Quarter of flock selected	November		December		January	
	Record for month	Annual average	Record for month	Annual average	Record for month	Annual average
Lowest quarter	0-2	139.1	0-4	136.4	0-2	137.0
Second quarter	3-9	158.8	5-11	153.3	3-8	157.6
Third quarter	10-25	176.7	12-24	187.1	9-22	181.1
Highest quarter						

TABLE 7B

Quarter of flock selected	February		March		April	
	Record for month	Annual average	Record for month	Annual average	Record for month	Annual average
Lowest quarter	0-4	126.3	0-14	129.4	0-16	130.4
Second quarter	5-8	146.4	15-17	147.5	17-19	151.1
Third quarter	9-13	161.9	18-20	161.3	20-21	163.4
Highest quarter	14-21	178.5	21-26	174.5	22-27	169.5

TABLE 7C

Quarter of flock selected	May		June		July	
	Record for month	Annual average	Record for month	Annual average	Record for month	Annual average
Lowest quarter	0-19	123.1	0-18	121.0	0-16	114.7
Second quarter	20-21	147.7	19-21	147.7	17-21	145.2
Third quarter	22-23	161.3	22-23	160.8	22-23	168.7
Highest quarter	24-29	174.8	24-29	180.2	24-29	181.8

TABLE 7D

Quarter of flock selected	August		September		October	
	Record for month	Annual average	Record for month	Annual average	Record for month	Annual average
Lowest quarter	0-14	114.9	0-1	116.5	} 0	
Second quarter	15-20	149.1	2-13	145.9		131.9
Third quarter	21-22	169.2	14-19	167.3		163.2
Highest quarter	23-29	183.6	20-28	189.5	8-23	190.8

Quite similar results may be secured by culling in May, June, July, August or September. The average annual productions of the poorest quarter of the flock are seen to be even lower in these months than in any other. The averages of such birds range from about 115 to about 123 eggs.

In the autumn the requirement is the selection of the best birds to be held over to the following year to be used as breeders.

This may be done by selecting the highest quarter. Thus the selection of the quarter of the flock with the highest September or October egg record will give a group of birds with an average for the year of about 190 eggs as compared with an average of about 140 to 142 eggs in the poorer 75 percent of the flock.

It is most interesting to determine the result of separating the birds at certain favorable periods into two groups, *laying* and *not laying*.

The subject may be illustrated on the basis of the combined series of data for 1913-'14 and 1914-'15.

For months in which a considerable proportion of the birds are not laying, the mean annual egg productions are:

For November,	40.6 percent not laying,	136.8 eggs
	59.4 percent laying,	164.2 eggs
	Difference	27.4 eggs
For December,	38.0 percent not laying,	133.6 eggs
	62.0 percent laying,	165.2 eggs
	Difference	31.6 eggs
For January,	42.5 percent not laying,	136.4 eggs
	57.5 percent laying,	165.6 eggs
	Difference	29.2 eggs
For September,	23.0 percent not laying,	115.0 eggs
	77.0 percent laying,	164.6 eggs
	Difference	49.6 eggs
For October,	54.7 percent not laying,	131.9 eggs
	45.3 percent laying,	178.9 eggs
	Difference	47.0 eggs

From these figures it is clear that by culling the flock in November, December or January a group of about 40 percent of birds averaging about 135 eggs each may be removed, leaving the remainder of the flock with an average of about 164 eggs per year.

In the autumn months at the close of the first egg-producing year, the elimination of birds which have ceased to lay before the first of September removes about 23 percent of the flock with an annual average of about 115 eggs, leaving a group of about 77 percent of the birds with an average of about 165 eggs per year from which birds to be used for breeding purposes may be chosen.

In October a larger number of birds have ceased laying, and this larger number naturally includes birds of a higher average annual production. Thus the average number of eggs per year for the 55 percent which are not laying in October is 131.9 eggs per year, as compared with an annual average of 115.0 for the 23 percent of the flock which *did not* lay in September.

It seems at first rather paradoxical that the birds which did lay is also higher in October than in September. This is due to the fact that only the relatively good layers are continuing to lay in October. Thus the average for the year of birds which are laying in September is 164.6 eggs, whereas in October it is 178.9 eggs.

To further consideration of this point we shall return presently. For the moment it is important to note that the conclusions concerning the influence of the early cessation of laying in the relatively poor layers is fully borne out by an examination of the annual egg production of the few birds which did not lay in August. The annual averages are:

5 percent not laying in August,	89.9 eggs
95 percent laying in August,	156.5 eggs
Difference	66.6 eggs

Note that this, in connection with the records for September and October, indicates a steady increase in the mean annual egg production of birds recorded as not laying. Thus the annual means for birds not laying in the three months are:

For August	89.9 eggs
For September	115.0 eggs
For October	131.9 eggs

If the annual averages for the birds which did lay in these months be placed side by side the results are as follows:

For August	156.5 eggs
For September	164.6 eggs
For October	178.9 eggs

Again the means show an increase from the earlier to the later month.

Now, while from the practical standpoint the thing which one wants to know is the value of the record of each month in predicting egg production for the year as a whole, it is quite apparent that as a measure of a physiological relationship such a constant has the disadvantage that it involves a comparison between the egg production for a particular month and for a whole year in which that month is included. For the purposes of a physiological investigation it is important to eliminate this source of spurious correlation.

We have attempted to do this in two ways.

First, we have determined the correlation between the egg production of each month and that of the remaining eleven months.

Second, we have applied a special coefficient measuring the relationship between total fecundity and relative fecundity in the individual months.

The correlation between monthly egg record and the total production of the remaining eleven months

The first method consists simply in determining directly the correlation between the production of any given month and that of the remaining 11 months of the year.

This we have done for each of the 12 months of the year, that is, we have determined the correlation between November production and the total egg record of the year *less the number of eggs laid in November*, the correlation between December production and the egg record of the year *less the number of eggs laid in December*, and so on for each month of the contest year.

This method of procedure involves the labor of determining a series of 12 additional sets of physical constants and 12 additional rough product moments,—that is, the numerical values for the 12 possible sets of 11 months each to be used in combination with the twelve individual months.

Number of eggs per year ranges from 16 to 255 in 1913-'14, and from 0 to 255 in 1914-'15. While for any 11 month period the range would be narrower, it is clear that the labor of forming tables would be excessive. Fortunately the correlations may be determined indirectly by the use of proper formulae which will be published later.

The results of the correlation between the egg production of each individual month of the year and the productions of the 11 other months of the year are shown for the two series of White Leghorns in tables 8 and 9 in comparison with the coefficients measuring the correlations between the production of each of the twelve months with the production of the whole year. They are also represented graphically in diagram 1 in which the circles denote the correlations between the production of an individual month and the production of the eleven remaining months of the year. The shaded area shows the difference between these correlations and those for monthly and annual egg production (solid dots).

As might have been expected on *a priori* grounds, the exclusion of the eggs laid during the month used as the first variable in the correlation formula has in all cases resulted in a reduction in the closeness of correlation of the yield of minimum and maximum periods. The percentage reduction is shown in a special column. The point of particular biological interest (and the point which could not have been foretold on any *a priori* ground) is that the correlation which remains after the elimination of this source of spurious correlation is still relatively large. The reduction has been from about 14 to 35 percent, with an average reduction of 20.45 percent in each year.

The fact that the correlations between the egg production of any month and the total egg production of the remaining eleven months of the year have such substantial positive values is ample proof that the birds submitted in competitions are distinctly differentiated organisms, such that the average performance of a group of individuals may be satisfactorily predicted from a relatively limited known period.

To somewhat different lines of evidence bearing upon this question we shall return presently.

The correlation between the annual egg production and the deviation of the monthly records from their probable values

Consider now the relationship between the magnitude of the annual egg production and that of the contributions of the individual months.

We have already shown that the correlations between the monthly egg records and both the annual total and the totals of the remaining eleven months are positive in sign and of a substantial magnitude throughout. A moment's consideration will, however, convince one that this condition might exist in a group of birds in which the egg produc-

TABLE 8

Comparison of correlation between monthly egg production and annual egg production, and monthly egg production and the record of the remaining eleven months of the year.

1913-1914

Month	Correlation with total production	r/E_r	Correlation with other eleven months production	r/E_r	Difference	Percentage reduction
November	.433 $\pm$.031	13.97	.313 $\pm$.035	8.94	— .120	27.71
December	.561 $\pm$.026	21.58	.418 $\pm$.032	13.06	— .143	25.49
January	.463 $\pm$.030	15.43	.358 $\pm$.033	10.85	— .105	22.68
February	.495 $\pm$.029	17.07	.377 $\pm$.033	11.42	— .118	23.84
March	.463 $\pm$.030	15.43	.373 $\pm$.033	11.30	— .090	19.44
April	.381 $\pm$.033	11.55	.295 $\pm$.035	8.43	— .086	22.57
May	.539 $\pm$.038	14.18	.465 $\pm$.030	15.50	— .074	13.73
June	.563 $\pm$.026	21.65	.459 $\pm$.030	15.30	— .104	18.47
July	.667 $\pm$.021	31.76	.567 $\pm$.026	21.81	— .100	14.99
August	.672 $\pm$.021	32.00	.554 $\pm$.027	20.52	— .118	17.56
September	.691 $\pm$.020	34.55	.539 $\pm$.027	19.96	— .152	22.00
October	.676 $\pm$.021	32.19	.562 $\pm$.026	21.62	— .114	16.86

TABLE 9

Comparison of correlation between monthly egg production and annual egg production, and monthly egg production and the record of the remaining eleven months of the year.

1914-1915

Month	Correlation with total production	r/E_r	Correlation with other eleven months production	r/E_r	Difference	Percentage reduction
November	.372 $\pm$.030	12.40	.240 $\pm$.033	7.27	— .132	35.48
December	.503 $\pm$.026	19.35	.375 $\pm$.030	12.50	— .128	25.45
January	.483 $\pm$.027	17.89	.357 $\pm$.030	11.90	— .126	26.09
February	.495 $\pm$.026	19.04	.385 $\pm$.030	12.83	— .110	22.22
March	.522 $\pm$.025	20.88	.422 $\pm$.029	14.55	— .100	19.16
April	.544 $\pm$.025	21.76	.461 $\pm$.027	17.07	— .083	15.26
May	.596 $\pm$.022	27.09	.507 $\pm$.026	19.50	— .089	14.93
June	.629 $\pm$.021	29.95	.526 $\pm$.025	21.04	— .103	16.38
July	.664 $\pm$.019	34.95	.559 $\pm$.024	23.29	— .105	15.81
August	.685 $\pm$.019	36.05	.573 $\pm$.023	24.91	— .112	16.35
September	.695 $\pm$.018	38.61	.572 $\pm$.023	24.87	— .123	17.70
October	.558 $\pm$.024	23.25	.443 $\pm$.028	15.82	— .115	20.61

tion of the months made very different *relative* contributions to the annual record.

Consider the problem as follows. In the flock as a whole the total production for the year $\Sigma(E)$ is composed of a number of sub-produc-

tions $\Sigma(e_1), \Sigma(e_2), \Sigma(e_3) \dots \Sigma(e_{12})$ for the several months, where E is the total egg production of the individual bird for the year and $e_1, e_2, e_3, \dots e_{12}$, her record for the several months. Then the relative contribution of the record of each month to the record of the year is

$$\begin{aligned}\Sigma(e_1)/\Sigma(E) &= \bar{e}_1/\bar{E} = p_1, \\ \Sigma(e_2)/\Sigma(E) &= \bar{e}_2/\bar{E} = p_2, \\ \Sigma(e_3)/\Sigma(E) &= \bar{e}_3/\bar{E} = p_3, \\ &\vdots \\ &\vdots \\ &\vdots \\ \Sigma(e_{12})/\Sigma(E) &= \bar{e}_{12}/\bar{E} = p_{12},\end{aligned}$$

where the bars denote monthly and annual means and p is to be read as the probable contribution of any month to the annual egg record, considered as unity.

The problem to be solved is whether in the case of individual birds the relative contribution of the individual months is independent of or correlated with the magnitude of the total annual production.

This can be done in a quantitative way by determining the correlation between the total eggs laid by the individual birds (E) and the deviation of the number of eggs laid by them in the individual months from their probable value, i.e., between E and $e_1 - p_1\bar{E}$, between E and $e_2 - p_2\bar{E}$, between E and $e_3 - p_3\bar{E}$ and so on.

The results calculated by the formula due to PEARSON and HARRIS (HARRIS 1909) are given for two years in table 10 and compared with the direct correlations between annual egg production and the actual monthly egg productions in diagram 6.

The agreement between the results of the two years is not so good as has been found in the case of some of the direct correlations. Nevertheless, the constants for the two experiments are in accord so far as fundamentals are concerned. In both years, the winter months, November, December, January and February, and the following autumn months, September and October, show an increase over their theoretical quota of eggs when the annual total egg production rises above the normal. The spring and summer months, March, April, May, June and July, in both years, show a lower relative contribution to the annual total than might be expected when this total varies in the direction of an increase above the normal egg production of the flock as a whole.

In other words, the good layers owe their superiority to increased egg production during the autumn and winter months.

DIAGRAM 6.—Comparison between magnitudes of the correlation between total eggs laid per year and number of eggs laid per month, and magnitudes of correlations between total eggs laid per year and the deviations of the monthly egg records from their probable value.

The essential agreement between the results of the two years is splendidly brought out by the distribution of the circles which represent these correlations between the total production and the deviations of the sub-productions from their probable values in diagram 6. In both years

TABLE 10

Correlation between annual egg production and the deviation of the monthly records from their probable values.

Month	Correlation			Diff./ $E_{Diff.}$
	1913-1914	1914-1915	Difference	
November	+ .242 $\pm$.036	+ .135 $\pm$.034	— .107 $\pm$.050	2.14
December	+ .408 $\pm$.032	+ .224 $\pm$.033	— .184 $\pm$.046	4.00
January	+ .307 $\pm$.035	+ .242 $\pm$.033	— .065 $\pm$.048	1.35
February	+ .058 $\pm$.038	+ .110 $\pm$.034	+ .052 $\pm$.051	1.02
March	— .581 $\pm$.025	— .344 $\pm$.031	— .237 $\pm$.040	5.93
April	— .716 $\pm$.019	— .526 $\pm$.025	— .190 $\pm$.031	6.13
May	— .684 $\pm$.020	— .516 $\pm$.026	— .168 $\pm$.033	5.09
June	— .436 $\pm$.031	— .306 $\pm$.032	— .130 $\pm$.045	2.89
July	— .210 $\pm$.037	— .159 $\pm$.034	— .051 $\pm$.050	1.02
August	+ .012 $\pm$.038	+ .083 $\pm$.035	+ .071 $\pm$.052	1.37
September	+ .507 $\pm$.029	+ .344 $\pm$.031	— .163 $\pm$.042	3.88
October	+ .574 $\pm$.025	+ .401 $\pm$.029	— .173 $\pm$.038	4.55

the coefficients increase from November to December or January, then drop to the first negative value of the year in March and reach the numerically largest negative value in April, after which they rise to become slightly positive in August, and attain their maximum positive values in October.

The use of supplementary criteria in the classification of birds with regard to fecundity

A peculiarity of the distribution of fecundity in certain months lies in the fact that a very high proportion of the birds are grouped in a single class, especially in the class of zero egg production.

The question now arises: Is the group of birds which have laid no eggs in October really a homogeneous class with respect to capacity for egg production? The question is really one of continuity or discontinuity of variation, or at least of categories of classification. Those who perpetually emphasize discontinuity may assert that a bird is either laying or not laying and that no intermediate stage is possible. Physiologically such an attitude can hardly be justified. Calendar months are quite arbitrary periods of time. A bird which laid during September and did not lay during October is surely a quite different organism from one which laid neither in September nor in October. Yet the two groups are quite indistinguishable on the basis of the October egg record only.

It is quite reasonable to assume, therefore, that the large zero class, which comprises about half of the whole flock in the first and in the final

months of the contest is not in reality homogeneous, and is not in reality one member of a discontinuous series. The problem now before us is to discover criteria by which such an apparently homogeneous group may be subdivided.

One of the simplest ways of showing the real heterogeneity in capacity for total annual egg production of the birds which lay no eggs in October is to subdivide them into groups which did not and which did lay in September.

The results are given in the accompanying table II.

The results are self explanatory and most convincing. Birds which did not lay in September nor in October have a materially lower annual egg production than those which did lay in September but did not lay in October.

TABLE II

Status of birds	1913-1914		1914-1915	
	Number of birds	Mean annual production	Number of birds	Mean annual production
Not laying in October and Not laying in September	82	120.5	68	104.7
Laying in September	102	143.0	122	145.5
Both groups	184	133.0	190	130.9
Laying in October and Laying in September	119	180.6	184	178.9

As a basis of comparison the table shows that if one selects birds which laid in both September and October, a group with an annual egg record of about 180 eggs will be secured.

Thus the mere condition of laying or non-laying in individual months may furnish highly valuable criteria for the selection of the birds with the best annual records.

From the theoretical, as contrasted with the practical, standpoint, the reader will have noticed a possible fallacy in the arguments of the immediately preceding paragraphs. For the practical purpose of selecting birds with a high annual egg record it is immaterial whether the superiority in annual egg production of birds which did lay in September but did not lay in October over those which did not lay in either September or October is due solely to the September records of the birds

laying during that month or in part to September record and in part to superiority in one or more of the ten preceding months. Similarly, it is quite immaterial from the practical standpoint⁶ whether the high value of the annual record of the birds which laid in both September and October is due solely to the eggs laid in these months or whether such birds also show superior egg-laying capacity in the first ten months of the contest year.

Biologically, it is important to differentiate the two sources of increased annual egg production just noted and to obtain some concrete measure of the relative weight of the two.

Among the birds which laid in September but did not lay in October the average annual egg production for the two years is 143.0 and 145.5 eggs as compared with 120.5 and 104.7 for those which laid in neither of these two months. Thus the birds which laid in September show an average annual production of 22.5 and 40.8 eggs over that of those which did not lay in September. Note that this is for birds which did not lay in October. Such great differences cannot possibly be due to September egg production only, for *in the flock as a whole* the September average is only 9.1 and 12.9 eggs in the two years. For the birds which did lay in September and did not lay in October the September egg production averaged 6.9 and 11.2 eggs in the two years.

Similarly we note that birds which laid in both September and October laid 60.1 and 74.2 eggs more than those which laid in neither of these months. It is quite impossible that these results should be due solely to eggs laid during the final two months of the contest, although it is quite obvious that they are in part due to these monthly productions. The actual average records for the two final months of the contest of birds which did lay are 28.5 and 28.0 eggs.

Deducting the values for September production from the annual average production in the case of birds which laid in September but did not lay in October to obtain the mean production for the first ten months of the contest, and deducting the mean production for the two final months of the contest for the birds which laid in both September and October from the annual average productions of these birds to obtain average productions for the first ten months of the contest we have the following results:

⁶ We are, of course, arbitrarily neglecting for the moment the purely economic factors of cost of maintenance and of the value of the eggs produced under the varying market conditions of different months.

Laying activity		Mean production	
<i>September</i>	<i>October</i>	<i>November to August</i>	
		<i>1913-14</i>	<i>1914-15</i>
Not laying	Not laying	120.5	104.7
Laying	Not laying	136.1	134.3
Laying	Laying	152.1	150.9

These average productions for a ten months test show conclusively that birds which continue laying into September are distinctly superior *in the earlier months of the contest* to those which cease laying in August, and that those which continue laying into October are distinctly superior *in the earlier months of the contest* to those which cease laying in either August or September.

Returning to certain more immediately practical considerations it is important to note that in selecting for breeders in the autumn it is not necessary to trap nest in September to obtain birds which are laying in both September and October, because birds which are laying in October have almost without exception laid in September. The converse is of course quite untrue.

The actual relationship between the occurrence or the non-occurrence of oviposition in the two months is as shown in tables 12 and 13.

These tables show that in 1913-'14 there were only 6 out of 309 birds which are recorded as having laid in October if they did not lay in September, while in 1914-'15 there is only 1 out of 375 birds which is recorded as laying in October but not in September.

Another line of attack upon the problem of the sub-classification of birds which are indistinguishable on the basis of trap nest records of egg production is possible. Using the percentage of yellow pigment in the ear lobe in October as a basis of prediction of annual egg production as in our earlier paper (1917), we may determine the correlation between the percent of yellow in the ear lobe in October and annual egg production in birds which are and in birds which are not laying in the final month of the contest. If the large class of birds which have no eggs to their credit in the October records be really homogeneous in respect of capacity for egg production, one might expect the correlation between pigmentation and annual egg production in birds of this class to be sensibly zero.

The actual correlations are as follows:

TABLE 12
October 1914

September 1914		Laid	Did not lay	Totals
	Laid	119	102	221
	Did not lay	6	82	88
	Totals	125	184	309

TABLE 13
October 1915

September 1915		Laid	Did not lay	Totals
	Laid	184	122	306
	Did not lay	1	68	69
	Totals	185	190	375

Relationship between percent yellow in ear lobes and annual egg production in birds which did not lay in October.

For 1913-'14, $N = 184$

$$r = -.120 \pm .049, r/E_r = 2.45$$

For 1914-'15, $N = 190$

$$r = -.217 \pm .047, r/E_r = 4.62$$

Relationship between percent yellow in ear lobes and annual egg production in birds which did lay in October.

For 1913-'14, $N = 125$

$$r = -.430 \pm .049, r/E_r = 9.19$$

For 1914-'15, $N = 185$

$$r = -.294 \pm .045, r/E_r = 6.53$$

Remembering that the values of the correlation between October pigmentation and annual egg production in the whole flock were (HARRIS, BLAKESLEE, WARNER and KIRKPATRICK 1917)

$$\text{For 1913-'14, } r = -.582 \pm .026$$

$$\text{For 1914-'15, } r = -.527 \pm .025$$

we note that the separation of the data for each year into two groups on the basis of egg-laying in October has resulted in a material reduction of the correlation in each case. This is precisely the result to be expected if egg production be the cause of differences in pigmentation, for each group is rendered more homogeneous with respect of egg production.

Furthermore it is to be noted that notwithstanding the reduction in the magnitude of the correlation coefficients which has resulted from a division of the records on the basis of October egg production, the constants all indicate negative, and, with one possible exception, significantly negative, correlation. Thus it is clear that October egg production is not the sole factor in the determination of the concentration of yellow pigment. On the other hand, it is also evident that a group of birds which cannot be segregated on the basis of October egg record alone, since all are in an inactive condition, can be further subdivided by the use of an accessory physical character.

It will be interesting, and possibly not without economic value to ascertain the result of a division of the materials with regard to September as well as October egg-laying activity.

The same three groups of birds that are represented in table II may be recognized. Birds which are recorded as laying in October but not in September are too few in number to be considered.

The correlation between October pigmentation and egg production during the year are as follows for the three groups of birds.

Birds not laying in September and not laying in October :

$$\text{For 1913-'14, } N = 82$$

$$r = -.102 \pm .074, r/E_r = 1.38$$

$$\text{For 1914-'15, } N = 68$$

$$r = +.175 \pm .079, r/E_r = 2.22$$

Birds laying in September but not laying in October :

$$\text{For 1913-'14, } N = 102$$

$$r = -.084 \pm .066, r/E_r = 1.27$$

$$\text{For 1914-'15, } N = 122$$

$$r = -.258 \pm .057, r/E_r = 4.53$$

Birds laying in September and laying in October:

For 1913-'14, $N = 119$

$$r = -.397 \pm .052, r/E_r = 7.63$$

For 1914-'15, $N = 184$

$$r = -.286 \pm .046, r/E_r = 6.22.$$

In the group of birds which were inactive in both September and October, the correlation is insignificant. In one year the sign of the correlation coefficient is negative, in the other it is positive. In neither year is it as much as two and one half times as large as its probable error.

In the group of birds which laid in September but did not lay in October, the sign of the correlation is negative in both years, and one of the coefficients may be reasonably regarded as significant in comparison with its probable error.

Finally, when the birds have laid in both September and October, the correlation coefficients have moderately large and statistically significant values. These are only slightly smaller than those found for the whole group of birds which are laying in October.

Thus October ear lobe pigmentation is of no value for the subdivision of a group of birds which have not laid in either September or October. It is of some value for birds which have laid in September but have not laid in October. It is of greater value for the subdivision of birds which have not laid in October, but concerning which no record of September activity is available. Finally it is most useful in the sorting of birds which have laid in October.

Looking at these results from the purely physiological standpoint rather than as a means of segregating groups formally regarded as alternative, we must conclude:

a. That *within a group of birds which have not laid for the two months September and October*, the total egg production of the year has no demonstrable influence upon the concentration of ear-lobe pigment recorded in October.

b. That *within a group of birds which have not laid in October but which have laid in September*, the annual record of the bird does have a sensible influence upon her October ear-lobe pigmentation.

c. That *within a group of birds which have laid in both September and October*, the annual egg record of a bird materially influences her October ear-lobe pigmentation.

It must be understood that this influence is not a simple or a direct one, but is in the main a resultant of the correlation between September

and October egg production and the egg production of the whole year on the one hand and with October pigmentation on the other.

Further analysis is of course quite possible but does not seem to be worth while at this time.

Correlation between the egg production of individual months

In the preceding sections we have shown that the egg production of major periods of the contest year are correlated with the egg production of minor periods. Specifically, the points established are as follows:

a. That the egg production of the contest year is significantly and fairly closely correlated with the record of the individual months.

b. That the total egg production of any eleven months is correlated with the production of the remaining month of the contest. This correlation is lower than that between the production of the individual months and the annual total. Thus the correlation between the production of the entire year and that of the single month is in part, but only in part, due to the influence of the month used as the first variable in the correlation formula. Conversely, one must conclude that the correlation between the eleven months' production and the production of the single remaining month of the contest year is due in large part to a permanent differentiation (at least for the duration of the contest year) of the birds in their capacity for egg production.

c. That the relative influence of the individual months upon variation in the annual egg production is very different. When the total egg production of the year rises above the average annual production this is generally due to a proportionately higher contribution of the winter period of November, December, January and February and the following autumn period of August, September and October.

Further light will, we believe, be thrown upon these and other problems by the determination of the correlations between the egg productions of the several individual months.

The importance of such studies was recognized in 1911 by PEARL and SURFACE who wrote (1911, p. 84):

"It is of the greatest importance, practically as well as theoretically, to know just how closely each month's production is, on the average, associated or correlated with the production in every other month in the year."

The correlations which may be determined are:

$$\begin{array}{c}
 \text{---}, r_{e_1 e_2}, r_{e_1 e_3}, \dots r_{e_1 e_{12}}, \\
 r_{e_2 e_1}, \text{---}, r_{e_2 e_3}, \dots r_{e_2 e_{12}}, \\
 r_{e_3 e_1}, r_{e_3 e_2}, \text{---}, \dots r_{e_3 e_{12}}, \\
 \vdots \\
 \vdots \\
 \vdots \\
 r_{e_{12} e_1}, r_{e_{12} e_2}, r_{e_{12} e_3}, \dots \text{---},
 \end{array}$$

or $n(n-1) = 12 \times 11 = 132$ in number for the year.

So far as we are aware, there is no method of determining these correlations except to actually form a condensed correlation table for each coefficient, or to go through some indirect processes equally laborious. We have, therefore, contented ourselves with determining 110 of the 264 possible relationships for the two series of data at our disposal.

The months to be used for these constants were selected with some care.

The two end months of the contest year of course afforded the widest possible separation of egg records, and were accordingly employed. They also represent two of the months of lowest egg production. April and May are the months most nearly midway between the first month, November, and the final month, October, of the contest. May has the advantage of being the month with the highest egg record of any. April, however, has the distinction of being the month with the lowest correlation with the total annual production, and the numerically highest negative correlation for its deviation from the probable production. April was chosen.

In addition to these three months which represent as nearly as possible the extreme and the central periods of the contest year, it seemed desirable to have constants for two other months intermediate in time between the central and the two end periods. January and August were chosen.

The coefficients for the correlation between November egg production and the production of every other individual month of the year is shown for both the 1913-'14 and the 1914-'15 series in table 14. The coefficients for April egg production and the egg production of the earlier and later months of the year are given in table 15. Those for October egg production and the production of the eleven preceding months of the contest year are set forth in table 16. The results for January are given in table 17 and those for August in table 18.

TABLE 14

Correlation between November egg production and production in other months.

Month	1913-1914 correlation	r/E_r	1914-1915 correlation	r/E_r	Differences 1914-'15—1913-'14	Diff./E _{Diff.}
November						
December	.3992 ± .0322	12.40	.3671 ± .0301	12.20	— .0321 ± .0441	.73
January	.2323 ± .0363	6.40	.0990 ± .0345	2.87	— .1333 ± .0501	2.66
February	.0778 ± .0381	2.04	.1657 ± .0339	4.89	+ .0879 ± .0510	1.72
March	.1502 ± .0375	4.01	.0509 ± .0347	1.47	— .0993 ± .0511	1.94
April	.0530 ± .0375	1.41	.0807 ± .0346	2.33	+ .0277 ± .0510	.54
May	.1006 ± .0380	2.65	.0500 ± .0347	1.44	— .0506 ± .0515	.98
June	.1267 ± .0378	3.35	.0759 ± .0346	2.19	— .0508 ± .0512	.99
July	.1809 ± .0371	4.88	.0995 ± .0345	2.88	— .0814 ± .0507	1.61
August	.2044 ± .0368	5.55	.1551 ± .0340	4.56	— .0493 ± .0501	.98
September	.1526 ± .0375	4.07	.2097 ± .0333	6.30	+ .0571 ± .0501	1.14
October	.2193 ± .0365	6.01	.1389 ± .0342	4.06	— .0804 ± .0500	1.61

TABLE 15

Correlation between April egg production and production in other months.

Month	1913-1914 correlation	r/E_r	1914-1915 correlation	r/E_r	Differences 1914-'15—1913-'14	Diff./E _{Diff.}
November	.0530 ± .0383	1.38	.0807 ± .0346	2.33	+ .0277 ± .0516	.54
December	.0721 ± .0382	1.89	.1006 ± .0345	2.92	+ .0285 ± .0515	.55
January	.0970 ± .0380	2.55	.0739 ± .0346	2.14	— .0231 ± .0514	.45
February	.2691 ± .0356	7.56	.2837 ± .0320	8.87	+ .0146 ± .0479	.30
March	.4942 ± .0289	17.10	.5065 ± .0259	19.56	+ .0123 ± .0388	.32
April						
May	.5309 ± .0276	19.24	.5863 ± .0229	25.60	+ .0554 ± .0359	1.54
June	.3008 ± .0349	8.62	.4565 ± .0276	16.54	+ .1557 ± .0445	3.50
July	.2130 ± .0366	5.82	.3419 ± .0308	11.10	+ .1289 ± .0478	2.69
August	.1222 ± .0378	3.23	.2545 ± .0326	7.81	+ .1323 ± .0499	2.65
September	.0344 ± .0383	.90	.2143 ± .0332	6.45	+ .1799 ± .0507	3.55
October	.0432 ± .0383	1.13	.1160 ± .0344	3.37	+ .0728 ± .0515	1.41

These coefficients merit close scrutiny.

The 110 constants are without exception positive in sign. They are sometimes low, but are frequently of a very substantial order of magnitude. They are not statistically significant throughout in comparison with their probable errors, but 96 out of the 110 may be reasonably regarded as statistically trustworthy. A high proportion of these are many times as large as their probable errors, and so unquestionably significant.

Leaving out of account entirely the differences in the magnitudes of the correlations from month to month, a problem to which we shall return later, the fact that these 110 coefficients are without exception

positive in sign seems to us a matter of considerable biological interest. The result indicates that if abnormally high laying at one period tends to result in abnormally low production during a subsequent period, the reduction is not sufficient to outweigh the influence of the initial differentiation of the birds in their capacity for egg production.

Before considering the variation in the magnitude of the correlation from month to month, it is desirable to examine the tables with a view to ascertaining the closeness of agreement of the results for the two years. If this agreement be fairly close, it will furnish strong evidence for the biological significance of the constants.

For the November correlations, there is only one difference between

TABLE 16

Correlation between October egg production and production in other months.

Month	1913-1914 correlation	r/E_r	1914-1915 correlation	r/E_r	Differences 1914-'15—1913-'14	Diff./ $E_{Diff.}$
November	.2193 ± .0365	6.01	.1389 ± .0341	4.07	— .0804 ± .0499	1.61
December	.3331 ± .0341	9.76	.2527 ± .0326	7.75	— .0804 ± .0472	1.70
January	.2553 ± .0359	7.11	.2363 ± .0329	7.18	— .0190 ± .0487	.39
February	.2192 ± .0365	6.01	.2070 ± .0333	6.22	— .0122 ± .0494	.25
March	.1390 ± .0376	3.70	.1305 ± .0342	3.82	— .0085 ± .0508	.17
April	.0432 ± .0383	1.13	.1160 ± .0344	3.37	+ .0728 ± .0515	1.41
May	.2067 ± .0367	5.63	.2167 ± .0332	6.53	+ .0100 ± .0495	.20
June	.2650 ± .0357	7.42	.1698 ± .0338	5.02	— .0952 ± .0492	1.93
July	.3264 ± .0343	9.52	.2714 ± .0323	8.40	— .0550 ± .0471	1.17
August	.3647 ± .0333	10.95	.3048 ± .0316	9.64	— .0599 ± .0459	1.31
September	.6943 ± .0199	34.89	.5791 ± .0232	24.96	— .1152 ± .0305	3.78
October						

TABLE 17

Correlation between January egg production and production in other months.

Month	1913-1914 correlation	r/E_r	1914-1915 correlation	r/E_r	Differences 1914-'15—1913-'14	Diff./ $E_{Diff.}$
November	.2323 ± .0363	6.40	.0990 ± .0345	2.87	— .1333 ± .0501	2.66
December	.5426 ± .0271	20.02	.4251 ± .0285	14.92	— .1175 ± .0393	2.99
January						
February	.3374 ± .0340	9.92	.3573 ± .0304	11.75	+ .0199 ± .0456	.44
March	.0972 ± .0380	2.56	.2348 ± .0329	7.14	+ .1376 ± .0503	2.74
April	.0970 ± .0380	2.55	.0739 ± .0346	2.14	— .0231 ± .0514	.45
May	.0588 ± .0382	1.54	.1611 ± .0339	4.75	+ .1023 ± .0511	2.00
June	.1039 ± .0380	2.73	.1425 ± .0341	4.18	+ .0386 ± .0510	.76
July	.1284 ± .0377	3.41	.1597 ± .0339	4.71	+ .0313 ± .0507	.62
August	.1581 ± .0374	4.23	.1454 ± .0341	4.26	— .0127 ± .0506	.25
September	.1383 ± .0376	3.68	.2290 ± .0330	6.94	+ .0907 ± .0500	1.81
October	.2553 ± .0359	7.11	.2363 ± .0329	7.18	— .0190 ± .0487	.39

TABLE 18

Correlation between August egg production and production in other months.

Month	1913-1914 correlation	r/E_r	1914-1915 correlation	r/E_r	Differences 1914-'15—1913-'14	Diff./ $E_{Diff.}$
November	.2044 ± .0368	5.55	.1551 ± .0340	4.56	— .0493 ± .0501	.98
December	.2078 ± .0367	5.66	.1654 ± .0339	4.88	— .0424 ± .0500	.85
January	.1581 ± .0374	4.23	.1454 ± .0341	4.26	— .0127 ± .0506	.25
February	.2190 ± .0365	6.00	.1151 ± .0344	3.35	— .1039 ± .0501	2.07
March	.1798 ± .0371	4.85	.2224 ± .0331	6.72	+ .0426 ± .0497	.86
April	.1222 ± .0378	3.23	.2545 ± .0326	7.81	+ .1323 ± .0499	2.65
May	.2887 ± .0352	8.20	.3510 ± .0305	11.51	+ .0623 ± .0466	1.34
June	.3623 ± .0333	10.88	.4495 ± .0278	16.17	+ .0872 ± .0434	2.01
July	.5656 ± .0261	21.67	.6114 ± .0218	28.05	+ .0458 ± .0340	1.35
August						
September	.5207 ± .0280	18.60	.6098 ± .0219	27.84	+ .0891 ± .0355	2.51
October	.3647 ± .0333	10.95	.3048 ± .0316	9.65	— .0599 ± .0459	1.31

the constants for 1913-'14 and 1914-'15 which is over 2.5 times as large as its probable error. This is, indeed, the only difference which is as much as twice as large as its probable error.

For January egg production and the production of the other months there are only three months out of the eleven in which the differences between the constants for the two years are over 2.5 times as large as their probable errors. For the April correlations, there are four out of the eleven coefficients which differ by amounts over 2.5 times as large as the probable errors of the differences. These fall on the months June to September inclusive, which show materially larger correlations in 1914-'15 than in 1913-'14.

In the series of correlations for August, the values for only one or two months may be considered to differ significantly in the two years.

In the October series of correlations there is but a single case in which the difference between the coefficients for the two years is as much as twice as large as its probable error. This is the value for October and September, when the correlation is .69 in 1913-'14 and .58 in 1914-'15. The coefficient for these two months is of particular interest and will be treated in some detail later.

Taking the 55 comparisons, irrespective of the time at which the correlation was determined, 24 of the constants differ by less than the probable error of the difference, 17 differ by from 1 to 2 times the probable error of the difference, 11 differ by from 2 to 3 times the probable error of the difference, and 3 differ by more than three times the probable error of their difference.

Thus while it is clear that certain of the results for 1913-'14 and 1914-'15 are statistically different, neither the trained biologist nor the trained statistician will, we believe, be inclined to deny that there is a remarkably good agreement between the results of the two years considered as a whole.

If this be true, there can be no objection to combining the data derived from the two contests for the purpose of securing smoother results. If this combination be made by the determination of averages of the correlations, there will be a distinct advantage in that any effect of conditions prevailing in either year will tend to be minimized by the combinations of results of two years experiments.

The averages of the correlations for the two years appear in table 19. These are represented graphically in diagram 7.

These diagrams bring out forcibly the essential nature of the relationship between the egg production of the different months. Two laws governing the intensity of these measures of interdependence are apparent.

These laws tend to some extent to obscure each other. They must be considered in their mutual relations, but for the sake of simplicity they may first be formulated independently. This tentative statement has the advantage of arranging the materials for a more thorough study of the constants.

1. The correlation between minor periods of time (months) in the year tends to decrease as these periods become more widely separated.
2. There is a more intimate correlation between the egg production of the autumn and winter months at the beginning and end of the contest year than between the egg production of these months and the productions of the spring and summer months.

The relationship between the intensity of correlation and the extent of separation of the two periods compared is most clearly shown by the relationship between April production and that of the five preceding and six following months. The intensity of the correlation decreases with fair regularity in both directions. The distribution of the correlations forms a fairly regular monomodal polygon.

In the case of both November and October egg production the regularity of the decrease is somewhat obscured by the obvious tendency for a higher correlation between the production of the autumn and winter months, even when separated by the maximum possible period of time. Thus in the correlations between the number of eggs laid in November and the number laid subsequently, the coefficient decreases

DIAGRAM 7.—Magnitudes of the correlations between the egg records of individual months. The subject months are entered on the blank areas, and the correlations between these months and the remaining months are indicated by the height of the bars over the initial letters of the relative month. One space on the scale = .050.

TABLE 19

Averages of the correlation between various pairs of individual months in the two years.

Month	November and the other months	January and the other months	April and the other months	August and the other months	October and the other months
November	—	.1657	.0669	.1798	.1791
December	.3832	.4839	.0864	.1866	.2929
January	.1657	—	.0855	.1518	.2458
February	.1218	.3474	.2764	.1671	.2131
March	.1006	.1660	.5004	.2011	.1348
April	.0669	.0855	—	.1884	.0796
May	.0753	.1100	.5586	.3199	.2117
June	.1013	.1232	.3787	.4059	.2174
July	.1402	.1441	.2775	.5885	.2989
August	.1798	.1518	.1884	—	.3348
September	.1812	.1837	.1244	.5653	.6367
October	.1791	.2458	.0796	.3348	—

steadily from the value for November and December to that for November and April, after which it rises again to about equal values in August, September and October.

In working from the other extreme of the series, practically the same condition is found to prevail. September production is very closely correlated with October production, August production is less closely correlated with October productions than is that of September and so on. The decrease continues to April which gives the lowest correlation with the following October, just as it gave the lowest correlation with the preceding November. The correlation between October egg production and that of the preceding months then begins to rise, and reaches its maximum value for the preceding autumn-winter period in December.

The distributions of the correlations between the production of January and of August and the productions of the remaining months of the year are very similar indeed to those represented in the polygons for November and October. The relationship for January shows a drop in intensity from December to November, on the one side and from February to April on the other. Beyond April, the intensity of the relationship increases to its highest autumn value in October.

In the case of the August relationships, the intensity decreases from September to October on the one hand, and from July to the earlier months of the year on the other, but from May to November (of the preceding calendar year) the correlation remains practically the same.

One cannot, we believe, study these diagrams without the conviction that the two laws formulated above hold for the egg production of the group of organisms investigated. The first law is best exemplified by the interrelationships of April egg production. The second appears most clearly in the constants for the two autumn months, November and October, of the two years. The distribution of the correlations for the intermediate months, January and August, is clearly intermediate in certain regards between that of November and April on the one hand and April and October on the other.

The first step in the further analyses of these data is the determination of the regression of the production of one month upon the production of another month.

It is obviously quite out of the question to illustrate each of the 110 regressions.

Since the records are more numerous in 1914-'15 than in 1913-'14, the data of that year have been chosen to illustrate the nature of the interrelationship. The months selected, with the straight line equations, are the following.

For regression of December egg production, e_2 , on November egg production, e_1 ,

$$e_2 = 5.086 + 0.397 e_1$$

For regression of April egg production, e_6 , on November egg production, e_1 ,

$$e_6 = 17.372 + 0.061 e_1$$

For regression of October egg production, e_{12} , on November egg production, e_1 ,

$$e_{12} = 3.690 + 0.145 e_1$$

For regression of February egg production, e_4 , on April egg production, e_6 ,

$$e_4 = 1.976 + 0.346 e_6$$

For the regression of May egg production, e_7 , on April egg production, e_6 ,

$$e_7 = 8.403 + 0.674 e_6$$

For the regression of August egg production, e_{10} , on April egg production, e_6 ,

$$e_{10} = 9.543 + 0.413 e_6$$

For the regression of October egg production, e_{12} , on April egg production, e_6 ,

$$e_{12} = 1.647 + 0.159 e_6$$

For regression of December egg production, e_2 , on October egg production, e_{12} ,

$$e_2 = 6.047 + 0.262 e_{12}$$

For regression of April egg production, e_6 , on October egg production, e_{12} ,

$$e_6 = 17.324 + 0.085 e_{12}$$

For regression of August egg production, e_{10} , on October egg production, e_{12} ,

$$e_{10} = 15.240 + 0.360 e_{12}$$

For regression of October egg production, e_{12} , on September egg production, e_{11} ,

$$1913\text{'14}, e_{12} = -0.663 + 0.539 e_{11}$$

$$1914\text{'15}, e_{12} = -1.247 + 0.443 e_{11}$$

The lines for the prediction of December, April and October production from November egg records appear in diagram 8.⁷

The differences in the mean egg production of these three months are clearly shown by the relative position of the three lines. December shows a decidedly higher average than October. April has of course the highest average of the three. The differences in the closeness of correlation of the three months with November egg production are also evident. December, the month immediately following November, is represented by a line showing a distinctly steeper slope than either October or April. The means are scattered about these lines in a most irregular fashion, but this is to be expected from the fact that 152 of the 375 birds fall in the zero class, leaving only 223 to be distributed among the twenty-five groups of birds actually laying. So far as we are able to judge from the position of these means, no curve would give a better description of the change in egg production in December, April and October associated with variations in egg production in November, than a straight line. In short, egg production in December, April and October increases

⁷ In this and the three following diagrams the following rules have been followed:

In cases in which there are one or more birds laying the specified number of eggs in the first month, but laying no eggs in the second month, the average is given as 0. When there are no birds of a specified egg production in the subject month, no average is represented.

The means of number of eggs laid by all classes represented by only 5 birds or fewer have been connected by broken lines with the means of adjoining classes, whatever the number of birds in these classes. All those represented by 6 birds or more have been connected by solid lines with the adjoining classes, when these also contain 6 or more birds.

DIAGRAM 8.—Regression of December, April and October egg production on November egg production.

at a somewhat different, but in each case a uniform, rate with November egg production.

Turning to the lines representing the February, May, August and October egg production of birds producing given numbers of eggs in April, we see (diagram 9) conditions very similar to these in diagram 8 showing the relationship between December, April and October production and November production. May production, closely associated in time and in intensity of correlation with April production, shows a steeper slope of the regression line than does October which is separated by the maximum period of time from April and least closely correlated with it in egg production. The line for February is intermediate in

DIAGRAM 9.—Regression of February, May, August and October egg production on April egg production.

slope between those for October and August. Furthermore, the means while highly irregular in their distribution—especially near the extremes where the number of birds is very small—are apparently quite as well represented by straight lines as by equations of a higher order.

Diagram 10 shows the regression of the preceding months of December, April and August on the egg production of October, the final month of the contest year. Again the empirical means show great irregularity, but on the whole a straight line serves practically as well to smooth them as would any curve of a higher order.

In all the preceding cases the slope of a straight line represents the rate of egg production of an associated month apparently quite as well

DIAGRAM 10.—Regression of December, April and August egg production on October egg production.

as a curve of a higher order would do. This is not, however, the case universally.

The relationship between October and September production is the best illustration we have found among the series tested.

The results for the two years are laid side by side in diagram 11, which shows the average number of eggs laid by birds ranging from 0 eggs to 25 and 28 eggs in the two years. The straight lines are clearly quite inadequate to describe the change in egg production, which must be represented by a curve. Birds show practically no better egg production in October if they have laid up to about eight eggs in September

than if they have laid no eggs in September. Birds which have laid about 9 or more eggs in September seem to belong to a quite different

DIAGRAM 11.—Regression of October egg production in the two years on September egg production.

class. Beyond this point, October egg production increases rapidly with increased September egg production.

Apparently the factor involved is the cessation of laying in the fall.

The foregoing graphs apparently justify the conclusion that in general the relationship between the production of two months is a linear one. In cases in which production is rapidly decreasing, the relationship may be a distinctly non-linear one.

RECAPITULATION

The purpose of this paper is to present the results of a biometric study of the relationship between egg-laying in different periods of the year in White Leghorns.

The constants are based upon the data of two annual international egg-laying competitions at Storrs, Connecticut. The constants for the two years are in remarkably close agreement.

There is a significant positive correlation between the number of eggs laid by a bird in any month of the year and the number of eggs laid in the whole year. The correlation coefficients range from $r = .38$ to $r = .69$ in 1913-'14 and from $r = .37$ to $r = .70$ in 1914-'15, with an average value of $\bar{r} = .550$ in the first contest considered and $\bar{r} = .562$ in the second.

The correlation between the record of the individual month and the egg production of the year, serving as it does as a basis for regression formulae by which the annual yield may be predicted from shorter periods, is a relationship of the greatest practical importance. As a biological constant, it has the disadvantage that it is in some degree spurious, due to the fact that the egg record for each individual month is included in the annual total which is correlated with each month's production. The correlations between each month's record and the production of the remaining eleven months of the year have, therefore, been worked out.

These, like the correlations for monthly and annual egg production, are positive and statistically significant throughout, ranging from $r = .30$ to $r = .57$ in 1913-'14 and from $r = .24$ to $r = .57$ in 1914-'15. The constants are on an average about 21 percent smaller than those for monthly and total annual egg record.

Thus the superior egg record of an individual does not in general depend to a great extent upon a high record for an individual month, but upon a permanent differentiation (at least during the first egg-laying year) of the birds in capacity for egg production.

This conclusion is fully substantiated by the correlations between the egg records of the individual months. The correlations between November, January, April, August and October egg production and that of each of the other months have been determined for the two years. The 110 constants are positive throughout, generally statistically significant, and of a substantial order of magnitude.

The correlations between the monthly productions are by no means uniform in magnitude. Two laws governing the intensities of these relationships are discernible, although these laws tend to be to some extent mutually obscurant.

First, the correlation between the egg production of the individual months tends to become smaller as the months considered are more widely separated in time.

Second, there is a more intimate correlation between the egg production of the autumn and winter months at the beginning and end of the

contest year than between the egg production of these months and the productions of the spring and summer months.

The relative influence of the several months of the year upon variations in the annual egg production differs greatly. By a method of analysis for which the body of this paper must be examined, it has been shown that the winter months, November, December, January and February, and the following autumn months, August, September and October, show an increase over their theoretical quota of eggs when the annual total egg production rises above the normal. The spring and summer months, March, April, May, June and July, show a lower relative contribution to the annual total than might be expected when this total varies in the direction of an increase above the normal egg production of the flock as a whole.

From the practical standpoint the result of greatest importance is the demonstration that in commercial work with the class of birds entered in these egg-laying competitions, trap-nesting need not be carried on during the entire year to secure results of very material value.

Because of the closeness of the correlation between the egg production of individual months and the total production of the year, trap-nest records for a period of one month only make possible the distinction of groups of birds differing very materially in annual egg production. Thus in November, at the time the birds are just beginning to lay, or in the two subsequent months, December or January, it is possible to divide a flock approximately into two halves, one of which will average from 136-139 eggs per year and the other of which will average from 167 to 170 eggs. Or if it seems desirable to retain only a quarter of the flock for egg production, a group averaging from 176 to 187 eggs per year may be secured.

In selecting birds in the autumn to be kept over for breeding purposes, differences in annual egg record quite as material may be secured by trap-nesting for one month only. Thus by trap-nesting in September or October, the flock may be divided into two groups, one comprising seventy-five percent of the birds with an average annual production of from 140 to 142 eggs, the other comprising a quarter of the flock with an annual average of about 190 eggs.

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