A quantitative study of the factors influencing the weight of the bean seed. — I. Intra-ovarial correlations.

By

J. Arthur Harris,

Carnegie Institution of Washington, U. S. A.

With plate I to IV (figures 1—4).

I. Introductory remarks.

It is one of the functions of the science of vegetable physiology to discover and record the factors which influence the size, form, rate of development, etc., of the individual or its parts. Various names have been applied to this field of research and the most diverse methods have been called into use for the solution of the problems with which it abounds. No apology is needed, therefore, for considering any problem of the factors which underlie the form or magnitude of the structural elements of the organism. Nor should a defense of any method of attack, involving accurately determined facts and logically sound methods of analysis, be necessary. The general problem set in the present paper is, „What factors determine the weight of the seed in the garden bean, *Phaseolus vulgaris,* and what, quantitatively, is the significance of each?"

This question has the interest of any problem in „Entwicklungsmechanik". In addition, it has a very real pertinence in evolutionary studies. The size of the bean seed is the character dealt with in some of the most discussed evolutionary questions of the present time; some writers have been most dogmatic concerning the physiological factors to which the variation curve in the weight of the bean seed is due. The results of this study show, if we may anticipate, that however probable they may seem on the surface such statements as have been made require checking against actual data.

The analytical methods employed are those of the modern higher statistics, which are steadily gaining ground as tools of research. No other technique known to me is capable of attacking the kind of problem with which we have to deal.

The present section deals solely with the interrelationships between the characters of the pod and the weight of the seed. It touches on no factors except those peculiar to the fruits in which the seeds are borne — the pods drawn from a „general population“ produced by the cultivation under ordinary garden or field conditions of a reasonably homogeneous variety. Thus the material has no experimental artificiality. We are, in fact, studying the physiology of seed development as it normally goes forward. Factors which for the present are left entirely out of account will be taken up in detail later.

II. Presentation and analysis of data.

The portion of the data discussed here consists of five series derived from several hundreds of plants, and comprising altogether 23,312 individually weighed seeds. These will be referred to hereafter by key letters. They are:

L. Golden Wax. Grown at Lawrence, Kansas, 1906. 2861 seeds.

LL. Golden Wax. Plants the offspring of the L. series. Grown at Lawrence, Kansas, 1907. 3947 seeds.

GG. Burpee's Stringless. Grown at the Missouri Botanical Garden, 1907. 8364 seeds.

NH. Navy. Grown near Sharpsburg, Ohio, 1907. 5778 seeds.

ND. Navy. Another series, grown, under very different conditions, near Sharpsburg, Ohio, 1907. 2362 seeds.

The characteristics of these varieties and the cultural conditions under which they were grown have been or will be described for other purposes elsewhere. The most exact description of the pods and of the seeds is furnished by the physical constants derivable from the tables of data.

The Influence of Number of Ovules and of Number of Seeds per Pod.

The data may be best shown in a series of condensed tables, in Table I. Here, the first column shows the number of ovules formed (the denominator) and the number of seeds developing (the numerator) in the pods considered. The number of seeds weighed and the total weight (in working units of .025 grams) of seeds produced for each class of pods is given in the 5 pairs of columns.[1])

[1]) From the data in this table, the physical constants (means, standard deviations and coefficients of variation) for ovules per pod, seeds per pod, ovules failing to develop per pod, and seed/ovule index can be calculated, as well as the rough moments for the correlations between these characters and seed weight. The correlations are completed by a knowledge of the variation constants for seed weight by a method explained elsewhere (Amer. Nat. Vol. 44. 1910. p. 693–699.)

The seriations of weights of seed, which are essential for completing the correlation coefficients, form Table II.

Table I.

Seed/Ovule Fraction	Series L		Series LL		Series GG		Series NH		Series ND	
	F	Total Weight	F	Total Weight	F	Total Weight	F	Total Weight	F	Total Weight
1/1	—	—	4	46	—	—	—	—	—	—
1/2	5	80	11	158	5	76	4	41	1	8
2/2	10	165	10	137	2	37	—	—	4	30
1/3	16	265	32	455	14	220	1	12	24	172
2/3	30	495	39	549	18	331	4	47	90	673
3/3	24	361	16	205	11	160	9	100	173	1355
1/4	49	831	96	1371	57	1032	9	87	25	196
2/4	198	3202	206	2911	121	2095	37	375	177	1320
3/4	228	3478	161	2179	168	2851	74	746	446	3307
4/4	108	1721	64	870	75	1315	97	972	911	6971
1/5	57	1022	153	2232	168	3174	20	172	3	26
2/5	252	4135	476	6843	462	8451	90	865	15	116
3/5	411	6421	566	8004	594	10401	261	2486	66	448
4/5	424	6622	504	6866	460	8112	468	4571	158	1114
5/5	300	4396	274	3638	274	4617	758	7255	244	1799
1/6	14	245	52	766	190	3570	14	130	—	—
2/6	108	1859	197	2913	666	12090	111	1021	—	—
3/6	126	2013	386	5711	922	16224	322	3062	—	—
4/6	192	2965	357	4988	810	14064	590	5649	9	61
5/6	210	3051	213	2919	541	9270	990	9355	6	33
6/6	90	1354	59	845	264	4475	1121	10558	10	76
1/7	2	38	5	70	108	1958	5	47	—	—
2/7	2	28	8	133	300	5328	24	217	—	—
3/7	—	—	14	202	483	8408	38	359	—	—
4/7	—	—	20	270	471	8151	82	774	—	—
5/7	5	75	15	208	317	5484	218	1907	—	—
6/7	—	—	4	47	246	4213	189	1727	—	—
7/7	—	—	—	—	71	1251	220	2029	—	—
1/8	—	—	—	—	25	463	—	—	—	—
2/8	—	—	2	34	61	1089	—	—	—	—
3/8	—	—	—	—	113	2095	—	—	—	—
4/8	—	—	—	—	109	1959	4	40	—	—
5/8	—	—	—	—	90	1558	5	33	—	—
6/8	—	—	3	47	66	1222	6	49	—	—
7/8	—	—	—	—	26	477	7	57	—	—
8/8	—	—	—	—	20	339	—	—	—	—
1/9	—	—	—	—	1	17	—	—	—	—
2/9	—	—	—	—	5	90	—	—	—	—
3/9	—	—	—	—	11	190	—	—	—	—
4/9	—	—	—	—	9	184	—	—	—	—
5/9	—	—	—	—	2	30	—	—	—	—
6/9	—	—	—	—	6	112	—	—	—	—
7/10	—	—	—	—	2	34	—	—	—	—
	2861	44822	3947	55617	8364	147217	5778	54743	2362	17705

The variation constants do not concern us at present. We pass at once to the correlations, given with their probable errors in Table III.

1*

All are of a low order of magnitude. Of the 20,16 would ordinarily be considered statistically significant in comparison with

Table II.

Weight	Series L	Series LL	Series GG	Series NH	Series ND
3	—	—	—	2	1
4	1	—	—	2	28
5	5	1	1	14	108
6	8	13	3	87	339
7	15	24	4	361	733
8	32	47	25	1049	681
9	38	146	36	1507	317
10	81	191	74	1369	126
11	96	321	137	879	24
12	144	401	220	363	5
13	217	499	383	101	—
14	336	547	523	33	—
15	339	520	689	11	—
16	401	431	919	—	—
17	305	343	1073	—	—
18	304	216	1016	—	—
19	232	150	923	—	—
20	184	53	784	—	—
21	69	24	612	—	—
22	28	12	390	—	—
23	15	7	250	—	—
24	9	1	161	—	—
25	1	—	80	—	—
26	1	—	38	—	—
27	—	—	14	—	—
28	—	—	5	—	—
29	—	—	3	—	—
30	—	—	1	—	—

Table III.[1])

Series	Ovules and Weight	Seeds and Weight	Ovules Failing and Weight	Seed/ovule Index and Weight
L	— .0401	— .2051	+ .1905	— .1991
	± .0126	± .0121	± .0122	± .0121
LL	+ .0586	— .1068	+ .1473	— .1388
	± .0107	± .0095	± .0084	± .0087
D	— .1227	— .0069	— .0859	+ .0745
	± .0118	± .0139	± .0138	± .0131
H	— .1410	— .0599	— .0273	+ .0094
	± .0087	± .0088	± .0089	± .0088
GG	+ .0109	— .1007	+ .1016	— .1126
	± .0073	± .0073	± .0073	± .0073
Average	— .0469	— .0959	+ .0652	— .0732

their probable errors. But it must be remembered that when correlation is low the probable error calculated by the ordinary formula

[1]) Sheppard's Correction was applied to Seed Weight.

is not to be given the same weight as in the case of coefficients of moderate values. Again, the N used in the calculation of the probable errors is the number of seeds weighed, not the number of pods involved, many of the pods furnishing two or more seeds. Possibly, the number of pods rather than the number of seeds weighed should bave been employed. This would give higher probable errors. In view of these facts, much stress cannot be laid upon the ratio of the constants to their probable errors. Deductions must be drawn rather from the general run of the constants.

Consider, first, the relationships for the number of ovules per pod. Three of the constants are negative and two are positive. The highest is only —.123, while the average of the five is —.047. Thus the influence of the number of ovules upon seed weight is very slender indeed. Expressing it in terms of regression as has already been done,[1]) we find:

Series of Plants	Regression Straight Line Equation	Rate of Change in Grams
L	W = 16.4645 — .1597 o	.0040
LL	W = 13.0281 + .2060 o	.0052
GG	W = 17.3881 + .0354 o	.0009
NH	W = 11.0961 — .2806 o	.0070
ND	W = 8.5554 — .2853 o	.0071

Thus the highest absolute change in seed weight for a variation of one ovule per pod is .28 units. or 70/10,000th gram! The mean value, regarding signs, is but 24/10,000th gram.

When one takes into consideration that the number of ovules and the number of seeds per pod are correlated,[2]) one can hardly assert on the basis of the present materials, extensive though they may be, whether there is any relationship at all between the number of ovules in a pod and the weight of the seeds which it matures.[3])

For number of seeds per pod, the results are steadier. In all, the sign of the correlation is negative. In 4 of the 5 cases, the constant is nominally significant in comparison with its probable error. The mean correlation is —.096.

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[1]) Harris, J. Arthur, On the Relationship between the Bilateral Asymmetry of the Unilocular Fruit and the Weight of the Seed which it Produces. (Science. N. S. 36. 1912, p. 414—415.)

[2]) For actual constants in many series see "On the Relationship between Bilateral Asymmetry and Fertility and Fecundity." (Arch. f. Entwicklungsmech. d. Organ. Bd. 35. 1912. S. 500—522.)

[3]) Apparently, the numercial smallness of these correlations and their diversity in sign cannot be attributed to regression of a higher order than linear. Diagram 1 shows these lines and the empirical means which they smooth. Dr. Roxana H. Vivian of Wellesley College has kindly worked out the correlation ratios and applied Blakeman's test for linearity of regression in four of the cases, and (bearing in mind the difficulties involved in testing for linearity when r is low) there is no clear evidence that a curve of a higher order would be better than a straight line for expressing the change in seed weight due to variation in number of ovules.

Apparently, therefore, the pods, in which the number of seeds is above the average, produce lighter seeds than those of average (or lower) fertility. But the difference is not large. The influence of seed number is shown by the second term of the regression equations, which are:

Series of Plants	Regression Straight Line Equation	Rate of Change in Grams
L	$W = 17.4473 - .5241\ s$	.0131
LL	$W = 14.8753 - .2508\ s$	.0063
GG	$W = 18.4166 - .2356\ s$	.0059
NH	$W = 9.8102 - .0719\ s$	.0018
ND	$W = 7.5299 - .0097\ s$	.0002

These straight line equations are also represented in Diagram 1. The absolute change in seed weight as one passes through a range of one seed per pod is clearly very slight, amounting in the extreme case to only 13/1000th of a gram, and averaging only 55/10,000th gram.

These results are in agreement with those already announced for *Staphylea* and *Cladastris*.[1])

If the correlations between number of seeds developing per pod and seed weight be negative, then one might expect those for number of ovules failing to develop per pod and seed weight to be positive. But since both the number of ovules and the number of seeds are concerned in determining the number of ovules which fail to develop, one might expect these results to be more irregular than those for number of seeds. This is, as a matter of fact, the case. Three of the constants are positive and two are negative. The two negative constants taken alone are the least probably significant of the five. The mean value for the five series is + .065.

A priori, one might suppose that the closest of all the interdependences would be that between the relative number of seeds which develop per pod and weight. The actual correlations between the ratio $\frac{\text{seeds per pod}}{\text{ovules per pod}}$ are shown in the final column of the table. Three are positive, two negative. The two positive constants cannot be considered significant with regard to their probable errors. The largest is —.199. The average is —.073. Thus, the correlations for relative number of seeds per pod substantiate those for actual number of seeds per pod, although they are more irregular and on the average lower.

The thing which impresses one about these constants is this: there is but a very slight correlation between the fertility characters of the pod and the weight of the seed which it produces. These results are in direct contradiction to the kind of statements which are sometimes made by biologists. They show what caution must

[1]) Harris, J. Arthur, Seed Weight in *Staphylea* and *Cladastris*. (Torreya. Vol. XI. 1911. p. 165—169.)

be exercised in discussing, except upon a groundwork of extensive quantitative data, questions of the physiology of nutrition or of the "causes" of the so-called "fluctutating variability".

The influence of position in the pod.

The possibility of an influence of the position of the seed in the pod upon the weight that it attains is suggested by the general belief that the ovules near the ends show a higher mortality. The causes of this failure are quite unknown. There seems little ground for the assumption that the end seeds have not room to develop. The fact that development is not equally frequent at both ends of the ovary evidences strongly against this view. More probably, the factors are opportunity for fertilization and variation in plastic materials. If distance from the stigma affects time of fertilization, or if distance from the pedicel influences the chances of obtaining seed-building substances, these factors should theoretically be recorded in the weights of the seeds as well as in the relative numbers developing in each of the several positions.

For the series here considered records of the position of all seeds developing as well as of those weighed have been kept. It seems worth while to consider the data. It is idle to ascertain the percentage of development or weight at maturity of ovules in any position in a sample of pods of various numbers of ovules. The pods must be sorted into sub-groups according to the number of ovules which they contain. It might be desirable to sub-sort the ovule classes according to the number of seeds matured per pod, but for our present purposes and on the basis of the available data this extra refinement is out of place.

The relationship between the position of the ovule in the pod[1]) and its chances of development is shown in the most condensed manner by a graph, Figure 2.[2])

From this diagram, it is perfectly clear that:

a) The chances of development are much better for ovules situated towards the distal than those towards the proximal end of the pod.

b) For pods with a small number of ovules (three), the position of maximum development is generally at the tip. In pods with a larger number of ovules the rate of increase in percentage of development is not linear, and there may be a decided falling off at the distal end of the pod.

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[1]) By "position in the pod", we understand the serial order from the proximal to the distal end — the firwt ovule being numbered 1.

[2]) In the five diagrams, the percentage of the total ovules formed which develop into mature seeds in any position in the pod is shown by the heights of the circles on the scale indicated in part at the side of the graph. The position of the ovule in the pod is indicated by the shift from left to right on the base line. Thus, the reader, with a little trouble (unavoidable, if the data are to be presented in a very condensed form) may determine with moderate accuracy the percentage frequency of development for any position in any of the chief classes of pods.

Turn now to the relationship between the position of the seed in the pod and its weight. Condensed tables are presented for the five series, Table IV.[1])

Table IV.

	Position	3 Ovules		4 Ovules		5 Ovules		6 Ovules		7 Ovules		8 Ovules	
		f	Total Weight	f	Total Weight	f	Total Weight	f	Total Weight	f	Total Weight	f	Total Weight
Series L	1	16	248	108	1646	164	2374	50	723	—	—	—	—
	2	28	433	151	2358	275	4208	108	1566	—	—	—	—
	3	26	440	168	2728	308	4789	126	1936	—	—	—	—
	4	—	—	156	2500	360	5759	148	2328	—	—	—	—
	5	—	—	—	—	337	5466	153	2494	—	—	—	—
	6	—	—	—	—	—	—	155	2440	—	—	—	—
Series LL	1	23	285	89	1180	206	2679	61	791	—	—	—	—
	2	31	445	139	1875	354	4841	180	2489	6	81	—	—
	3	33	479	148	2093	469	6495	240	3396	8	100	—	—
	4	—	—	151	2183	518	7434	275	3967	14	203	—	—
	5	—	—	—	—	426	6134	300	4440	11	160	1	14
	6	—	—	—	—	—	—	208	3059	9	127	1	17
	7	—	—	—	—	—	—	—	—	18	259	1	17
	8	—	—	—	—	—	—	—	—	—	—	2	33
Series NH	1	4	42	34	330	244	2207	327	2839	70	596	1	7
	2	6	71	50	513	298	2827	447	4144	81	716	1	8
	3	4	46	63	641	340	3323	529	5125	109	984	2	15
	4	—	—	70	696	371	3668	594	5753	120	1113	3	23
	5	—	—	—	—	344	3324	625	6089	136	1268	4	34
	6	—	—	—	—	—	—	616	5825	131	1224	3	26
	7	—	—	—	—	—	—	—	—	129	1159	4	34
	8	—	—	—	—	—	—	—	—	—	—	4	32
Series ND	1	64	469	269	1925	57	383	2	11	—	—	—	—
	2	98	761	380	2872	95	667	3	20	—	—	—	—
	3	125	970	454	3503	107	778	5	34	—	—	—	—
	4	—	—	456	3494	112	836	5	35	—	—	—	—
	5	—	—	—	—	115	839	6	43	—	—	—	—
	6	—	—	—	—	—	—	4	27	—	—	—	—
Series GG	1	12	214	70	1189	215	3638	271	4604	111	1869	19	337
	2	13	203	115	1945	354	6174	461	7972	211	3551	37	689
	3	18	294	119	2046	426	7592	618	10698	285	4889	74	1297
	4	—	—	117	2113	485	8699	701	12376	347	6054	70	1247
	5	—	—	—	—	478	8652	686	12258	346	6113	98	1733
	6	—	—	—	—	—	—	656	11785	362	6388	79	1447
	7	—	—	—	—	—	—	—	—	334	5929	72	1298
	8	—	—	—	—	—	—	—	—	—	—	61	1154

[1]) From these, the means and standard deviations of position can be obtained. The physical constants for weight of the series of seeds associated with each number of ovules must be sought outside these tables. These constants have been carefully calculated and verified, hence, it does not seem necessary to publish the rather voluminous data upon which they are based.

We pass at once to the end results — the correlations[1]) between the distance which a seed is from the insertion of the pod (in units of the interval between ovules) and the weight of the seeds. As seen in Table V, the correlations are uniformly low, but all 20 are positive and the most of them may be looked upon as statistically significant in comparison with their probable errors. Biologically, this means that from the proximal end to the distal end of the pod, the seeds become slightly heavier. The rate of this change throughout the whole material is shown by

Table V.

Series and Ovules per Pod	Number of Seeds	Correlation Coefficient r	Correlation Ratio η	Difference	Blakeman's Criterion
Series L					
3	70	$.214 \pm .077$	$.250 \pm .076$	.036	.82
4	583	$.099 \pm .028$	$.118 \pm .028$	.019	1.15
5	1444	$.166 \pm .017$	$.171 \pm .017$	.005	1.15
6	740	$.155 \pm .024$	$.192 \pm .024$	.037	2.34
Series LL					
3	87	$.238 \pm .068$	$.270 \pm .067$	.032	.90
4	527	$.157 \pm .029$	$.161 \pm .029$	.004	.54
5	1973	$.147 \pm .015$	$.155 \pm .015$	.008	1.53
6	1264	$.151 \pm .019$	$.163 \pm .018$	.012	1.62
Series NH					
4	217	$.014 \pm .046$	$.116 \pm .045$	.102	1.28
5	1597	$.136 \pm .017$	$.181 \pm .016$	.045	3.57
6	3148	$.176 \pm .012$	$.213 \pm .011$	.037	5.03
7	776	$.108 \pm .024$	$.181 \pm .023$	.073	3.05
Series ND					
3	287	$.109 \pm .039$	$.132 \pm .039$	.023	.95
4	1559	$.121 \pm .017$	$.148 \pm .017$	.027	2.47
5	486	$.159 \pm .030$	$.193 \pm .029$	.034	1.80
Series GG					
4	421	$.114 \pm .032$	$.131 \pm .032$	.017	1.00
5	1958	$.105 \pm .015$	$.111 \pm .015$	.006	1.14
6	3393	$.093 \pm .011$	$.095 \pm .011$	.002	.83
7	1996	$.096 \pm .015$	$.102 \pm .015$	.006	1.09
8	510	$.073 \pm .030$	$.140 \pm .029$	.067	2.03

the magnitude of the correlation coefficient. Whether or not the rate of change in weight is uniform throughout the whole range of proximal to distal may be tested graphically by the fitting of a straight line equation to the means of seed weight for each position. Using the conventional formula

$$W = (\overline{W} - r \frac{\sigma_w}{\sigma_p} \overline{p}) + r \frac{\sigma_w}{\sigma_p} p,$$

where w = weight, p = position or units of distance from the

[1]) Here calculated without the application of Sheppard's correction to the second moment for seed weight. The uncorrected value is used in obtaining the standard deviations in order that r and η, to be discussed later, may be compared.

base of the pod, the sigmas denoting the standard deviations and the bars the means, we find for the two lots:

NH Series

4 ovules.	$w = 9.456 + .212\,p$
5 ovules.	$w = 9.131 + .152\,p$
6 ovules.	$w = 8.840 + .162\,p$
7 ovules.	$w = 8,743 + .081\,p$

GG Series

4 ovules.	$w = 16.289 + .387\,p$
5 ovules.	$w = 16.873 + .263\,p$
6 ovules.	$w = 16.821 + .198\,p$
7 ovules.	$w = 16.658 + .171\,p$
8 ovules.	$w = 17.441 + .120\,p$

These lines and the empirical means are shown graphically in Diagrams 3 and 4. For both series the increase in weight from the base towards the tip of the pod is unmistakeable. It would be hazardous to say that any curve of a higher order would describe the rate of change for the GG series better than a straight line. For the NH series, the straight line is clearly inadequate — the empirical means forming beautifully regular curves. At first, the rate of increase is more rapid than is indicated by the straight line, later, it falls off and finally may actually decrease. The mean distal weight is in all four cases greater than the mean proximal.

To test this matter of the form of the regression line somewhat more critically, the correlation ratio, η, which measures the intensity of interdependence between the magnitude of two characters when the y character (seed weight) does not increase at a linear rate with the x character (position in the pod).

From the table it appears that the correlation ratio is sometimes materially larger than the coefficient of correlation, but in general there is not much choice between them as descriptions of the interrelationship between the two characters. Blakeman's test for linearity of regression[1])

$$\frac{\frac{1}{2}\sqrt{\xi}\,.\,\dfrac{1}{\sqrt{1+(1-\eta^2)^2-(1-r^2)^2}}}{\chi_1}$$

where $\xi = \eta^2 - r^2$ and $\chi_1 = .67449 / \sqrt{N}$, applied to these individual values of r and η enables us to say whether or not the ratio of change may be regarded as uniform (within the limits of the errors of sampling) from the base to the tip of the pod. Apparently, in most cases (*e. g.*, in GG where the conclusion from Blakeman's test is amply substantiated by the diagram) the straight line may

[1]) Blakeman, J., Biometrika. Vol. 4. 1905. p. 332—350.

be regarded as fairly smoothing the observed means, but in NH there is clear evidence of non-linearity. This is also, as already noted, especially conspicuous in the diagram.

III. Discussion and Summary.

This paper, which is one of a series dealing with the physiology of seed production, embodies data bearing on the problem of the factors determining the weight of the bean seed.

This first part based upon a series of weighings of about 23,000 seeds drawn from five cultures of three different varieties, deals solely with the problem of the dependence of seed weight upon the characteristics of the pod. Other factors will be discussed later. All general discussion of literature and of observations is reserved. The present summary deals only with the findings as to facts in the phase of the problem under consideration.

The influence of the characteristics of the pod upon the weight of the seed is easily measured in terms of the correlation between the two variables. That between number of ovules per pod and weight is low. Indeed, both positive and negative values of the coefficient occur, and the rate of change in weight associated with a variation of one ovule in number of ovules per pod ranges only from —.0071 to + .0052 grams. Thus number of ovules formed is practically negligible as a factor influencing seed weight.

For the relatioship between number of seeds matured per pod and seed weight the results are more consistent. In all cases, the weight of the seeds decreases as the number of seeds per pod increases; but the correlations are low throughout, averaging only —.096. The change in absolute seed weight for an increase or decrease of one seed is only .0055 grams.

For the relative number of seeds, $\frac{\text{seeds per pod,}}{\text{ovules per pod,}}$ the correlations are even lower than for absolute number, averaging only —.073.

The chances of an ovule developing into a seed are correlated with the position which it occupies in the pod — the percentage of development increasing from the base towards the stigmatic end. In small pods, the rate of increase may be fairly regular, but in larger pods it falls off towards the distal end, where the fecundity may be even lower than in less distal regions.

The weight of the seed is also postively, but not highly, correlated with its distance from the proximal end of the pods. That is, seed weight increases towards the stigma. The change seems in some cases to be sensibly linear. In other cases, however, the mean weight increases fairly rapidly at first, then the rate of increase falls off and finally the seeds become lighter towards the distal end of the pod.

Cold Spring Harbor, N. Y., U. S. A.
Oct. 23, 1912.

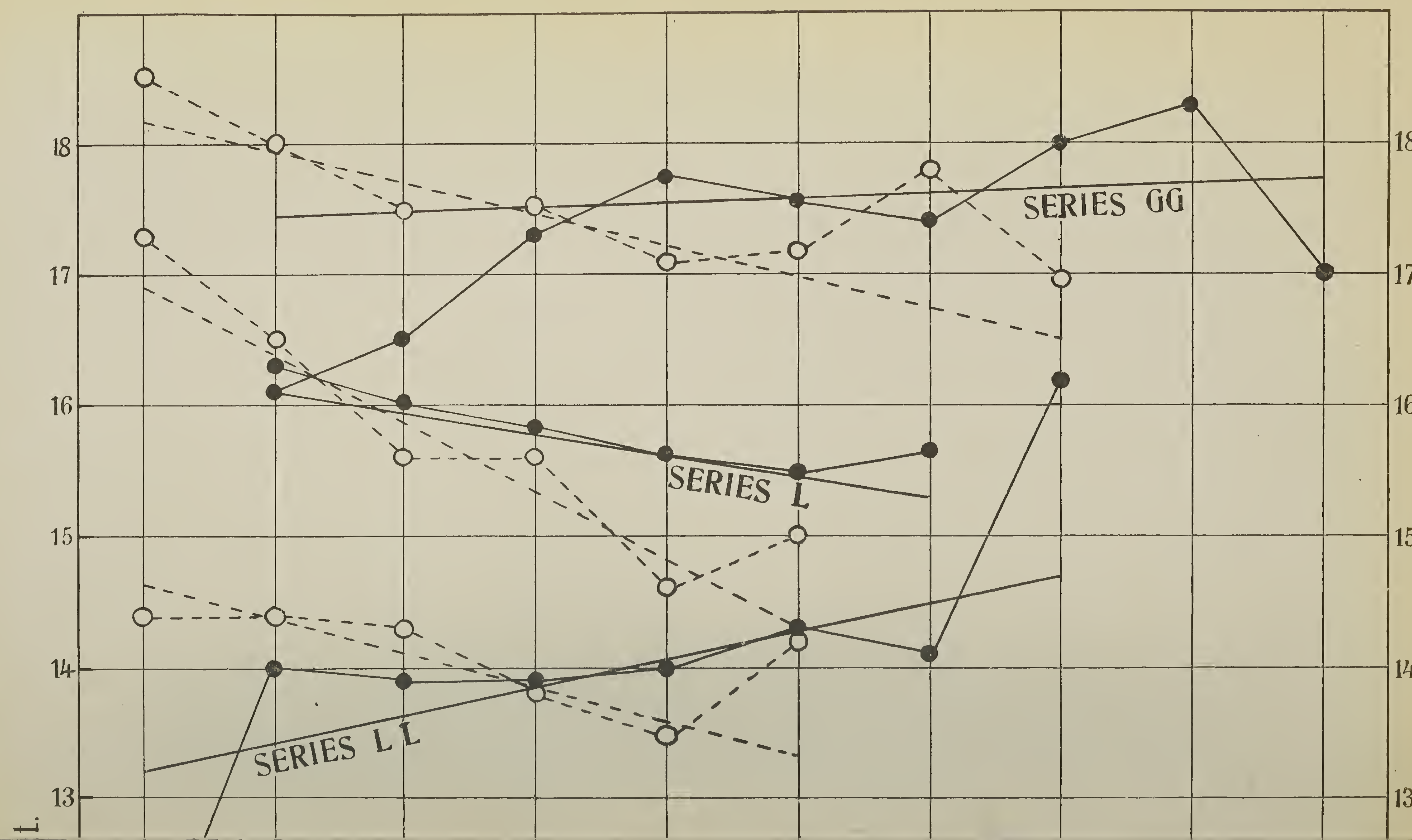
Explanations of Diagrams.

Figure 1. Regression straight lines and their empirical means for the relationship between ovules per pod and weight of seeds, and for seeds per pod and weight of seed. Relationships for ovules represented by solid dots and firm lines; mean weight for seeds represented by circles and broken lines. Note the small slope of the lines and the great irregularity of the means.

Figure 2. Percentage of ovules developing into seeds in various positions in the pod.

Figure 3. Regression straight lines and observed means showing change in weight from the base to the tip of the pod in the NH series. Note that regression is clearly non-linear.

Figure 4. Regression lines for the GG series. Regression is apparently linear within the limits of the errors of sampling.



18
17
16
15
14
13
SERIES GG
SERIES L
SERIES L L
18
17
16
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14
13

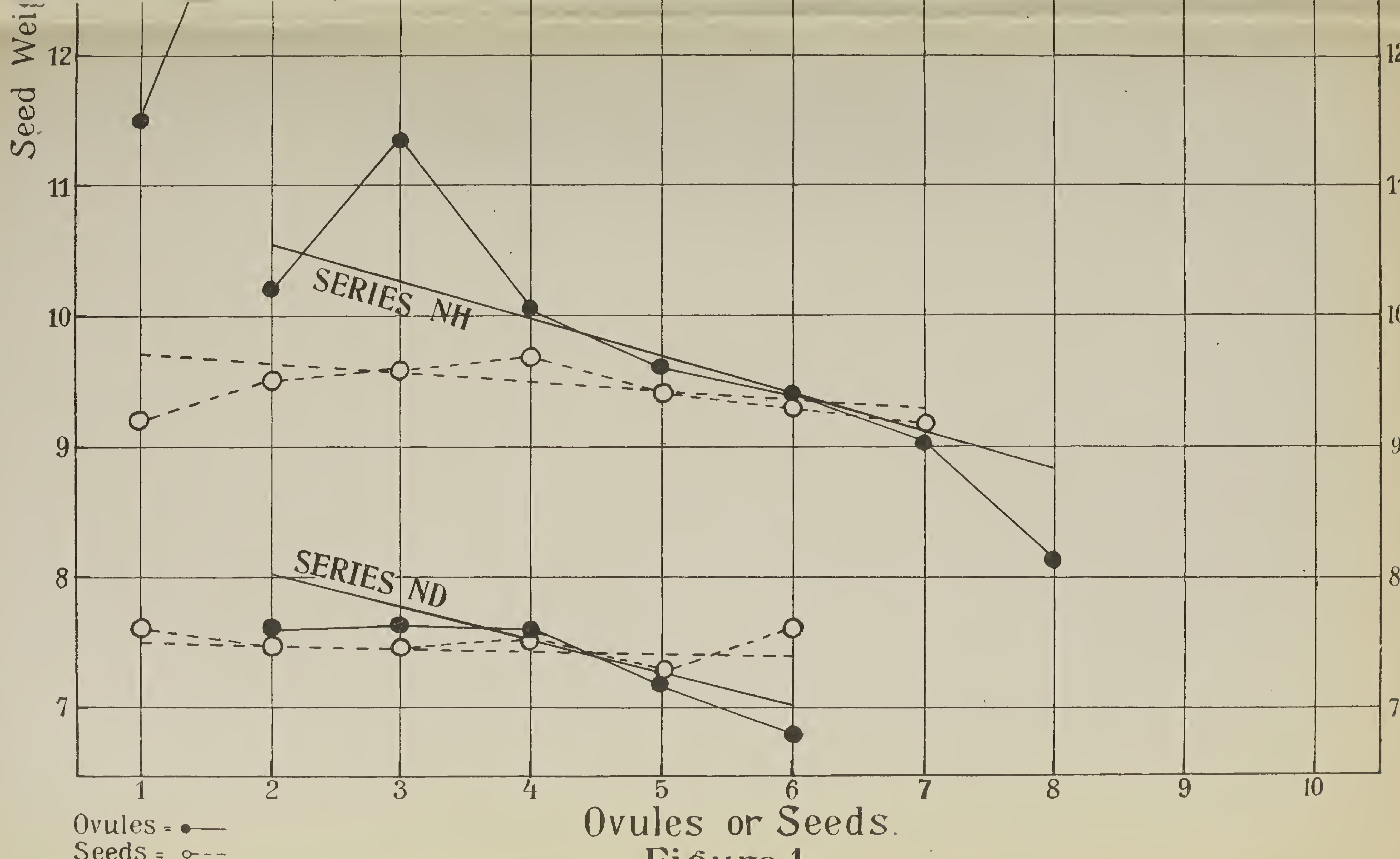

Figure 1.

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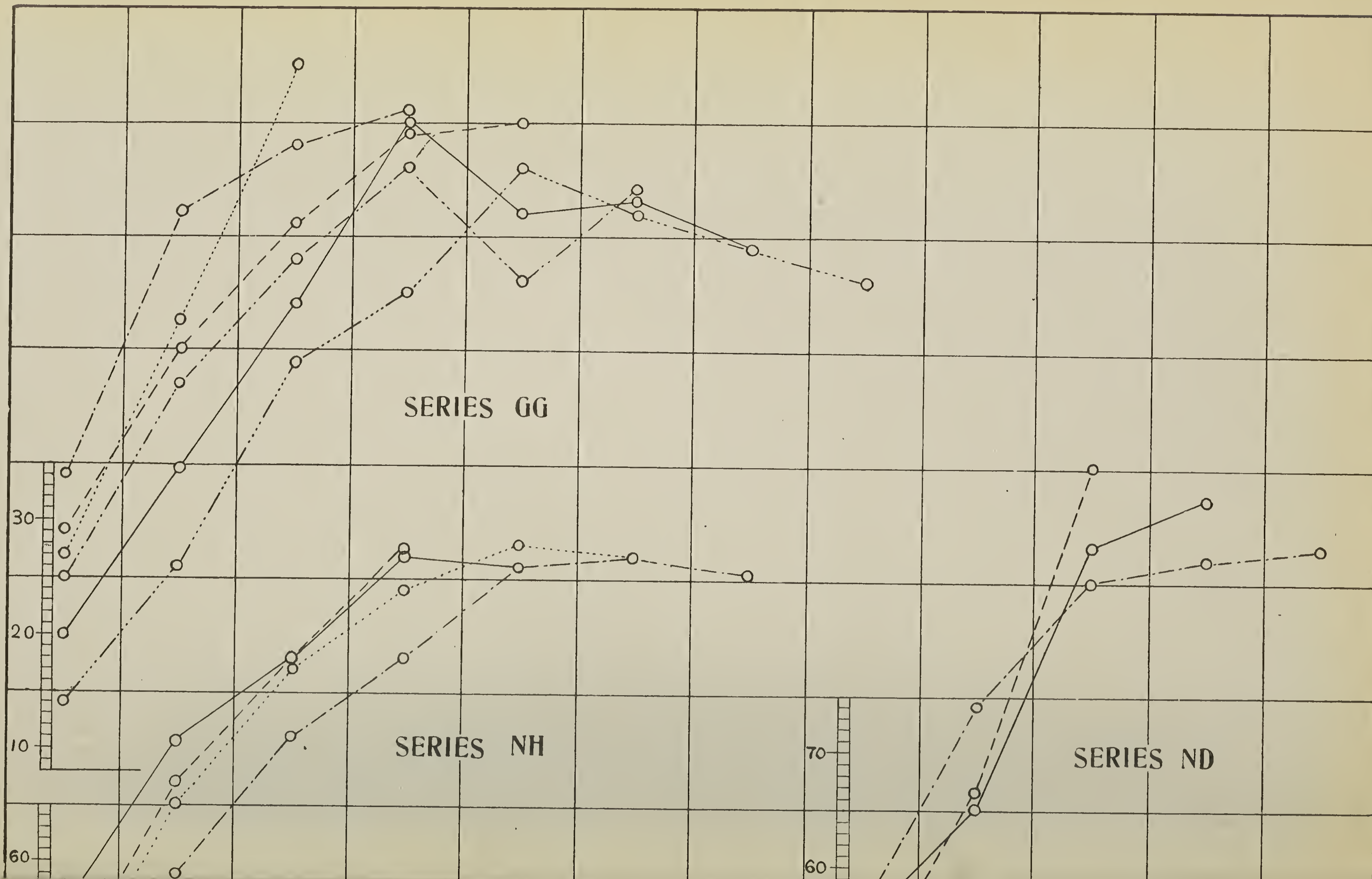
SERIES GG
SERIES NH
SERIES ND
30
20
10
60
70
60

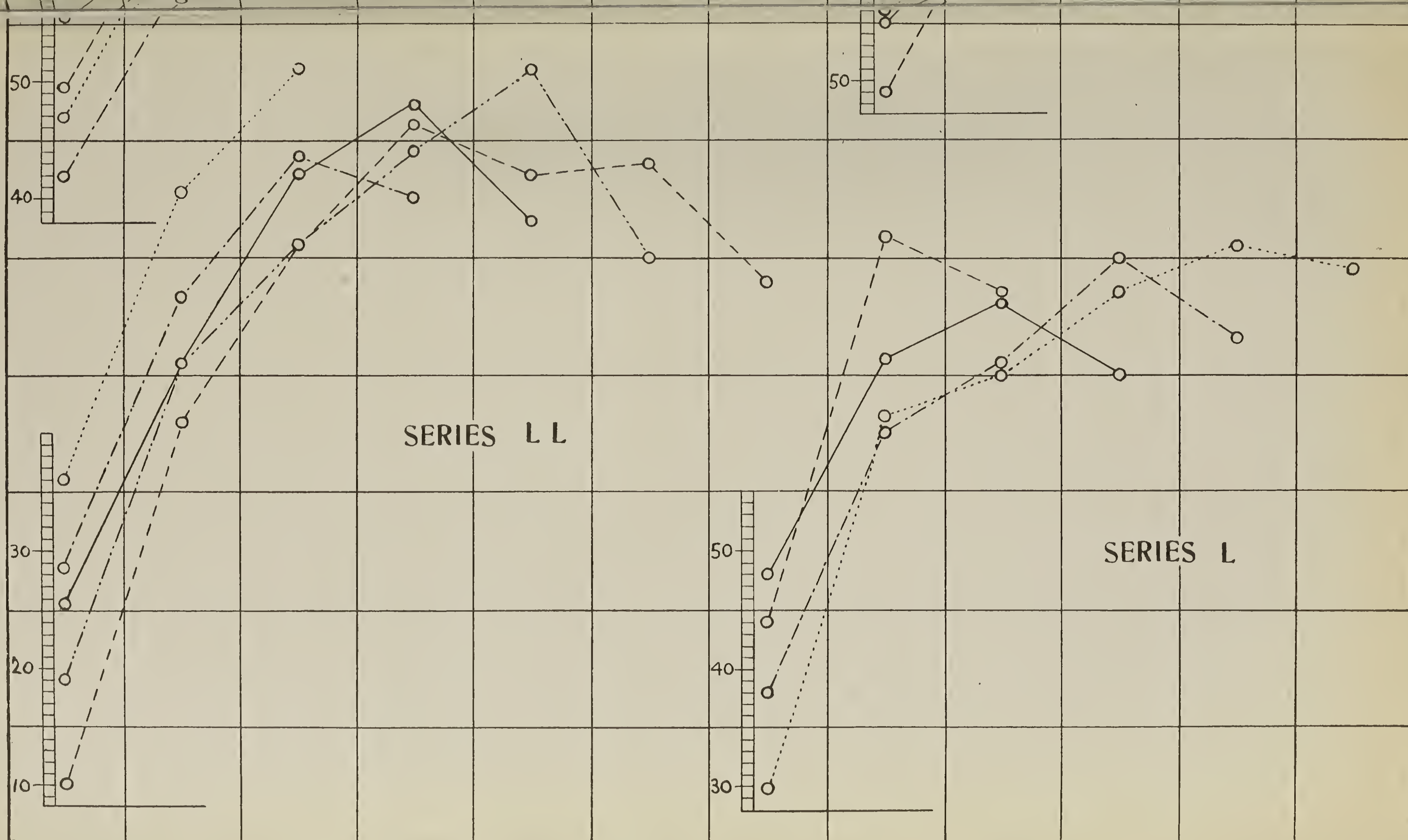

Figure 2.

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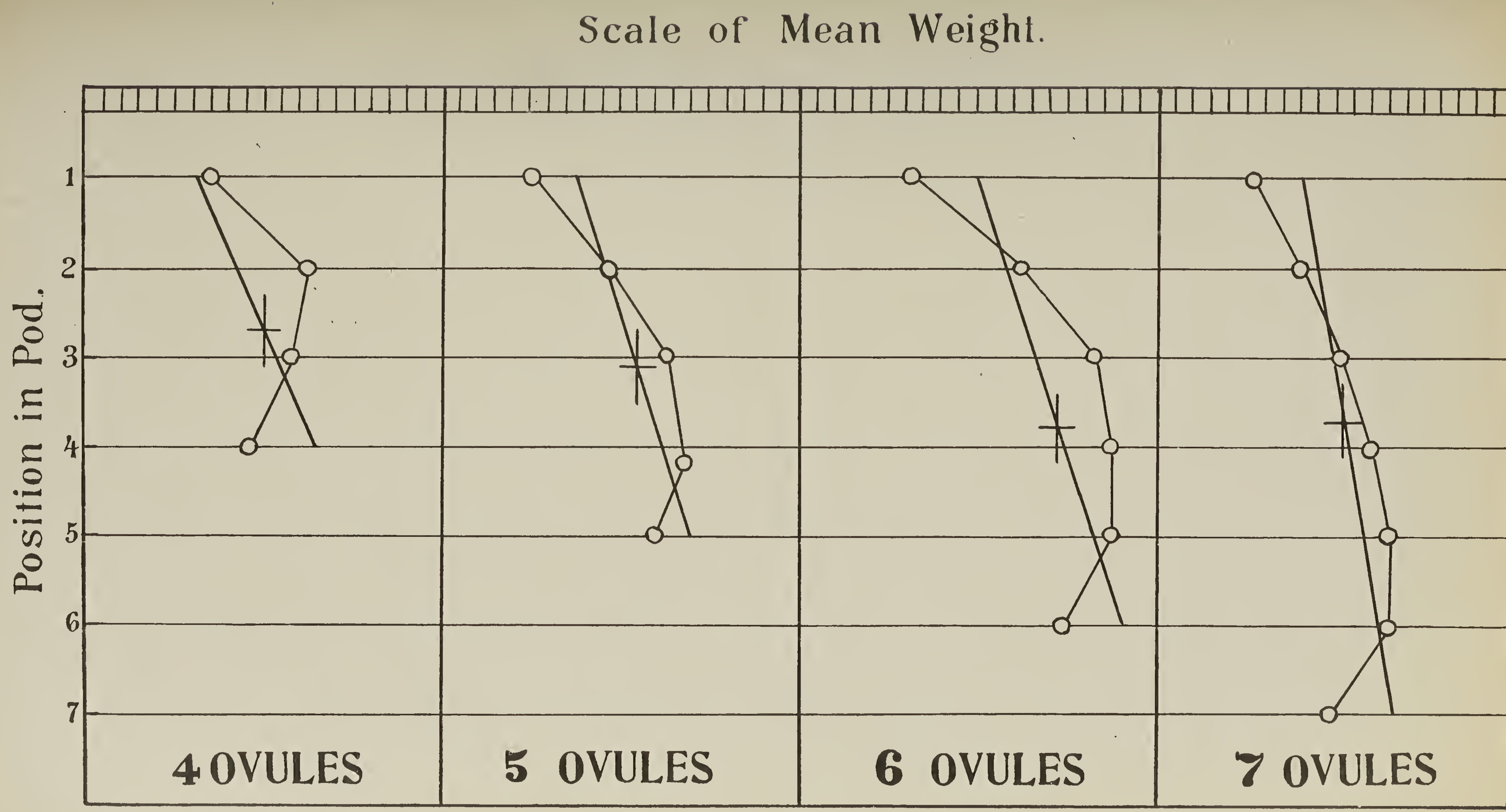
Scale of Mean Weight.
Position in Pod.
1
2
3
4
5
6
7
4 OVULES
5 OVULES
6 OVULES
7 OVULES

Figure 3.

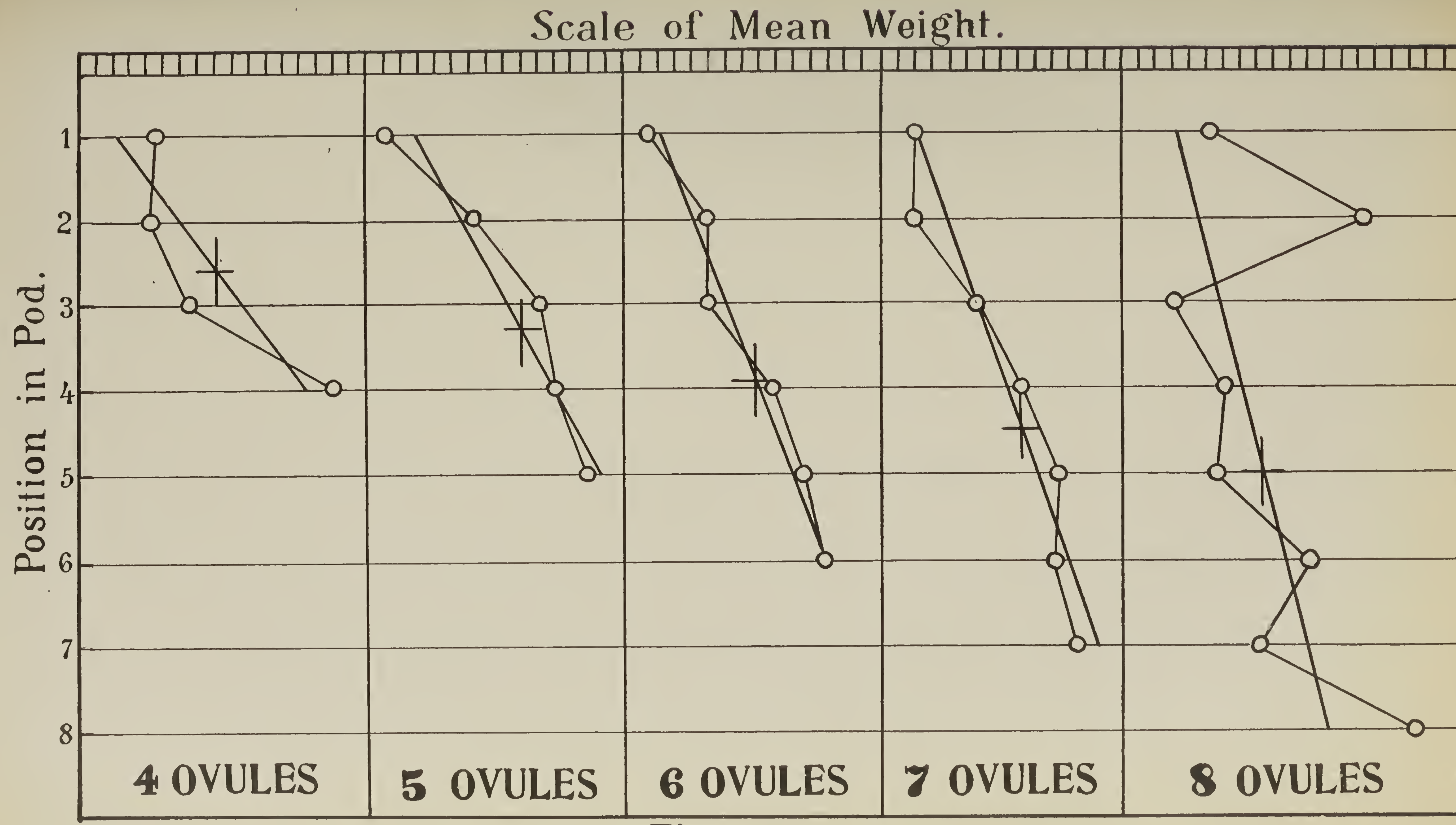

Figure 4.

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