On the influence of nutrition on the fluctuating variability of some plants

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That nutrition has an influence on the development of
plants has long been known. Also that some parts are
much more sensitive in this respect than others and that,
for example, the size of the stem and leaf is much more
affected by good or bad nutrition than the number of
stamens. As yet our knowledge on this point, especially
our quantitative knowledge, is very superficial. The intro-
duction of the statistical method, however, into botany has
enabled us to formulate more sharply the formerly vague
and insufficiently defined question of the influence of nu-
trition and also to interpret the results obtained easily
and accurately.

Although the number of statistical investigations on plant
characteristics, carried out in recent years, is fairly nume-
rous, yet the influence of nutrition on the value of these
characteristics has not often been studied.

De Vries [1] carried out an extensive investigation in
this direction with *Othonna crassifolia.* He compared plants
that had been grown in a greenhouse in pots with very

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1) Hugo de Vries, *Othonna crassifolia*, Bot. Jaarb. Dodo-
naea, 1900, p. 20.

dry ground with garden-cultures, and found that with the plants from the greenhouse the median of the length of the leaves was only about half that of the plants that had grown in full ground, the average number of ray-flowers per head being 12 with the former, 13 with the latter. In his work „die Mutationstheorie" de Vries [1]) describes experiments and observations, the chief object of which has been the comparison of the influence of nutrition with that of selection, but which at te same time increase our knowledge about the influence of nutritive conditions as such. He investigated the influence of these two factors on the length of the fruit of *Oenothera Lamarckiana* and *Oenothera rubrinervis*, on the number of umbel-rays of *Anethum graveolens* and *Coriandrum sativum* and on the number of ray-flowers of *Chrysanthemum segetum*, *Coreopsis tinctoria*, *Bidens grandiflora* and *Madia elegans*. From his observations de Vries concludes that nutrition and selection act in the same direction and that by stronger nutrition as well as by positive selection the median value of a character is increased. Moreover he generally observes that the variability of the characters is increased when nutrition and selection act in opposite directions, i. e. when, as in his experiments, strong nutrition goes together with negative selection.

Also the experiments by Reinöhl [2]) on the variability of the number of stamens of *Stellaria media* show that with good nutrition the median of this character possesses a higher value than with bad nutrition. Besides Reinöhl finds that the index of variability, which is a measure for the variability, becomes smaller under unfavourable nutritive conditions.

1) Hugo de Vries, Die Mutationstheorie. Bd. I. p. 368.

2) Friedrich Reinöhl, Die Variation im Andröceum der *Stellaria media Cyr.* Bot. Zeit. 1903, p. 159.

Weisse [1]) investigated the influence of nutrition on various characters of *Helianthus annuus* and found that the arithmetical mean for all the characters studied is smaller with plants cultivated on a sandy soil than with well-fed plants. His numbers, (for each culture about forty) are too small, however, to allow us to calculate the constants for median and variability from them and to draw conclusions from these.

Mac Leod [2]) made experiments in order to determine the influence of nutrition on the number of ray- and disk-flowers of *Centaurea Cyanus* and found that this number is the smaller the more the nutitrive conditions are unfavourable. Besides he investigated the influence of good and bad nutrition on the number of stigmatic-rays of *Papaver Rhoeas coccineum aureum*. He arrived at the result that with the badly-fed plants the median is considerably smaller, but that the variability of the character is increased by the bad nutrition.

From this short summary it will appear that in very few cases only the quantitative change, caused in the median by varying nutrition, has been determined. It is desirable to extend the number of observations on this point, but it is especially important to learn the influence of nutrition on the variability for several characters and plants. Two questions here arise, in the first place whether this influence is different for different parts of the same plant, in agreement with Verschaffelt's [3]) result that the va-

1) Arthur Weisse, Die Zahl der Randblüthen an Compositenköpfchen in ihrer Beziehung zur Blattstellung und Ernährung. Jahrb. f. wiss. Bot. Bd. 30, 1897, p. 453.

2) J. Mac Leod, On the variability of the disk- and ray-flowers in the cornflower (*Centaurea Cyanus*). Hand. v. h. 3de Vlaamsch Nat. en Geneesk. Congres, Sept. 1899, p. 61 (in Dutch) and On the variability of the number of stigmatic-rays in *Papaver*. Hand. v. h. 4de Vlaamsch Nat. en Geneesk. Congres, Sept. 1900, p. 11 (in Dutch).

3) Ed. Verschaffelt, Ueber graduelle Variabilität von pflanzlichen Eigenschaften. Ber. d. d. bot. Gesellsch. Bd. XII, 1894, p. 350.

riability itself of different parts differs considerably, and secondly whether bad nutrition causes either an increase or a decrease of the variability for all characters, or an increase for some and a decrease for others.

With the object of answering these questions, I made some culture experiments in the botanical garden at Groningen in the summer of 1903. The description and results of these experiments will be found in what follows.

For the cultures four beds of 2 metres breadth and 6 metres length were prepared in April. Two of them were manured with hornmeal, about half a kilogram per square metre. The other two beds were dug out to a depth of about half a metre and filled with a very meagre loamy sandsoil, originating from Harendermolen, a sandy region in the neighbourhood of Groningen. In the middle of April on one of the manured beds and on one of sandy soil equal quantities of seed were sown of *Iberis amara Linn.*, obtained from H a a g e and S c h m i d t at Erfurt, *Ranunculus arvensis Linn.*, obtained from various botanical gardens and mixed, and of *Malva vulgaris Fr. (Malva rotundifolia Linn.)*, obtained from the botanical garden at Leiden. The seeds of three other species, which were sown at the same time on the remaining two beds, did not germinate in sufficient numbers, so that about the middle of June we resolved to weed them all out and to sow afresh. This time *Anethum graveolens Linn.*, from the trade, *Scandix Pecten-Veneris Linn.* and *Cardamine hirsuta Linn.*, both obtained from various botanical gardens were chosen, three species of which it might be expected that, although sown so late in the summer, they might still fully develop. This seed was sown in germinating dishes, each species partly in meagre and partly in fertile earth taken from the beds in the garden. In the course of the following days part of the germplants were placed into small pots with meagre as well as with manured earth, special care being taken

that no selection from the germplants should be made. At the middle of July the young plants were placed in the beds at such distances from each other that each could freely develop.

Already at the beginning a considerable difference between the two cultures could be observed in all three species sown in the garden. The seed in the bed that had been manured with hornmeal came up sooner and the plantlets developed much more vigorously. With *Malva vulgaris* the difference between the plants of the two beds was at first very great. Those on the fertile soil showed already abundant leaves and flowers when the plants on the sandy soil had only formed few and small leaves. This difference remained till the beginning of July, when suddenly also the plants on the meagre soil began to develop vigorously, so that in the autumn scarcely any difference could be observed. The reason of this late, very rapid development appeared when the plants were dug out. It turned out, namely, that some of the strongest roots had reached the underlying earth through the layer of sand. As long as the plants only obtained their food from the sand, they remained tiny and backward, but when the roots had penetrated into the fertile earth they still developed vigorously and with great rapidity. Also with *Iberis amara* the roots appeared to have reached the earth underneath, but in a much less degree. It was difficult here to trace the fine terminals of the principal roots as far as the underlying earth, whereas the roots of *Malva vulgaris*, where they passed from the sand into the earth below, were strong and penetrated at least a few decimetres. Of *Ranunculus arvensis* only few roots had reached the underground with their tips, the same being the case with *Scandix Pecten-Veneris* and *Anethum graveolens*; the roots of *Cardamine hirsuta* were restricted to the sand, as far as I could see.

Although with most of the species studied the nutrient

material was not entirely derived from the sandy soil, yet all these plants were in less favourable nutritive conditions than the plants on the manured soil. So the experiments will show us the consequences of the difference in nutrition.

For investigation I chose some characters that are easily expressed quantitatively and numerically and took care that the determination was made at the same time for both cultures and that the same parts of both were always taken.

In this way I determined in the first place the length ōf the leaf of *Iberis amara*. In July the length of the five oldest leaves, which were already adult then, was measured. Besides, in the autumn, after the plants had been dug out, the length of the plant was determined from the base to the top of the inflorescence of the principal stem; at the same time were counted the number of branches of the second order, the number of branches of the third order and the number of fruits on the inflorescence of the principal stem.

Of *Malva vulgaris* the number of akenes of the schizocarp, the length of the leaf-blade and the length of the leaf-stalk were determined. These countings and measurements were made in the beginning of July, when a very distinct difference in the development between the two cultures was visible, hence probably before the roots of the plants on the meagre soil had penetrated the layer of sand and in any case before a better nutrition had any perceptible effect.

In the case of *Anethum graveolens* and *Scandix Pecten-Veneris* the number of lobes of the first leaf was counted in the plants that had survived in germinating dishes. Besides I determined in adult plants of *Scandix Pecten-Veneris* the number of umbel-rays and with *Anethum graveolens* also the number of umbel-rays and at the same time the number of flowers of the umbellet. For the

determination of this latter character only the umbellets of the oldest umbel of each plant were taken. Of *Ranunculus arvensis* the number of fruits per flower was determined and of *Cardamine hirsuta* the length of the silique, of each plant the siliques of the principal stem being measured.

For each of the characters mentioned I took of each of the cultures on fertile soil and on sandy soil 300 measurements or countings, a number which, according to the calculations of Prof. Kapteyn, gives in investigations of this kind a sufficient guarantee of accuracy. For certain characters I had to be contented with a smaller number since the material in these cases was deficient. For those cases in which the variability concerns the number, the numbers were noted increasing by unity; for those characters that vary in length, the length was determined in fractions of a millimetre, in milimetres or in centimetres, depending on the absolute size of the parts. By means of the numbers obtained, curves were plotted in order to have a general survey of the observations and to facilitate a comparison of the observations of the culture on fertile soil with that on sandy soil. In most cases the observations were combined into groups, so that from seven to seventeen intervals were obtained. In this way curves are obtained that admit of easy inspection and in which the smaller irregularities have disappeared. Only for the number of branches of the third order of *Iberis amara*, fig. V, the observations of the plants on the fertile soil had to be combined to 28 groups, since only then a comparison with the plants from the sandy soil was possible.

The curves for the various characters are reproduced on the accompanying plate. Since for all cases the frequencies have been calculated, all the curves have the same area and can be mutually compared. For each character the curve of the well-fed plants has been drawn as a continuous line and that of the badly-fed plants as a

dotted one, both having the same absciss. Of both the observations have been combined to groups with the same interval. In all the figures the size or the number of the part in question increases from left to right.

These curves now show us the way in which the studied characters vary and the limits of this variation.

Looking at the various figures we notice that the studied characters generally give fairly symmetrical curves, disregarding smaller irregularities. Only in a few cases, as with *Anethum graveolens* for the number of umbel-rays of plants on the sandy soil, fig. VI, for the number of lobes of the leaves of the well-fed plants, fig. VIII, and besides for the number of lobes of the leaves of *Scandix Pecten-Veneris* of the fertile soil, fig. IX, the curve is markedly oblique. Only for the number of branches of the third order of *Iberis amara* from the sandy soil, fig. V, a semi-curve has been obtained.

Examining in the various figures the position of the two curves with respect to each other, it appears that they partly coincide. This means that in the two corresponding cultures plants are found in which the organ under consideration is as large or occurs in equal number in the well-fed and in the badly-fed plants. But at the same time they show that in one culture individuals occur, in which a definite part is so strongly or feebly developed, as are not to be found in the other culture. The figures further show that in all cases except of the number of akenes of *Malva vulgaris*, fig. XIII, the curve of the plants on sandy soil has been shifted to the left with respect to that of the well-fed plants.

The observations now enable us to determine how great the influence of the nutritive conditions is in the various cases and whether this difference in development between the two cultures is the same for various parts of the same plant.

Examining the figs. I—V, relating to the characters of *Iberis amara*, figs. VI—VIII of *Anethum graveolens* and XI—XIII of *Malva vulgaris* it appears that, whereas with the two former plants the shifting of the curve is very different in the various cases, it is about the same for the three characters of *Malva vulgaris* and for all three of them relatively small. So the curves enable us to form an approximate idea of the influence of various nutritive conditions, but a clear insight is only obtained when the curves are defined by definite constants and these are mutually compared. In this way it is possible to determine what influence feeding has not only on the median value of the character, but also on its variability. In order to obtain these values, the median value M and the quartile Q were deduced from the observations. From these the coefficient of variability $\frac{M}{Q}$, which is a measure of the variability and enables us to mutually compare the varia-bility of different characters, was calculated by the method introduced by Verschaffelt[1]). Also for the somewhat skew curves these values have been determined, since these curves do not considerably deviate from the symmetrical ones, and besides, in all cases the average of both quartiles has been taken. Only from the semi-curve for the branches of the third order of *Iberis amara*, fig. V, no constants were calculated. This curve will be dealt with later on.

I give here the values found for the various characters in the plants studied in the same order as that of the curves of the plate. In the table, W means the constants of the well-fed, B those of the badly-fed plants. For each character are given: the median value, the quartile, the variability-coefficient and the minimum and maximum value. Besides the differences of these values in the well-fed

1) Ed. Verschaffelt, l. c.

and the badly-fed plants have been calculated as well for the median as for the variability-coefficient. This difference, divided by the value for the well-fed plants and consequently expressed as a fraction of this value, I will call the *sensibility-coefficient* of the median or the variability. This coefficient is given in the table under the two values. A + sign for the sensibility-coefficient means that the value is greatest with the well-fed plants, a — sign that with these the value is smallest.

		M	Q	$\dfrac{Q}{M}$	Minimum.	Maximum.
Iberis amara.						
I. Length of the plant	W	41.1 cM.	4.65 cM.	0.114	26 cM.	56 cM.
	B	31.3 „	3.25 „	0.103	12 „	51.8 „
	sensibility-coefficient . . .	+ 0.24		+ 0.09		
II. Length of the leaf	W	7.9 cM.	1.085 cM.	0.137	4.5 cM.	14.2 cM.
	B	5.18 „	0.825 „	0.160	2.3 „	8.5 „
	sensibility-coefficient . . .	+ 0.28		− 0.17		
III. Number of silicles	W	55.4	7.5	0.13	29	91
	B	47	6.8	0.14	11	118
	sensibility-coefficient . . .	+ 0.15		− 0.08		
IV. Number of branches of the 2d order	W	22.4	3.35	0.15	5	35
	B	10.3	3.75	0.36	0	22
	sensibility-coefficient . . .	+ 0.54		− 1.40		
Anethum graveolens.						
VI. Number of umbel-rays	W	32.8	6.40	0.19	15	59
	B	18.4	6.45	0.35	7	41
	sensibility-coefficient . . .	+ 0.44		− 0.74		

		M	Q	$\dfrac{Q}{M}$	Minimum.	Maximum.
VII. Number of flowers in the umbellet.	W	33.3	6.55	0.19	1	67
	B	26.5	5.7	0.21	4	45
	sensibility-coefficient . . .	+ 0.20		− 0.105		
VIII. Number of lobes of the first leaf.	W	18	3 25	0.18	9	40
	B	16,5	2.1	0.127	7	28
	sensibility-coefficient . . .	+ 0.08		+ 0.29		
Scandix Pecten-Veneris.						
IX. Number of lobes of the first leaf. .	W	27.2	3.85	0.14	16	56
	B	25.1	2.6	0.104	11	43
	sensibility-coefficient . . .	+ 0.08		+ 0.26		
X. Number of umbel-rays.	W	6.05	0.7	0.101	3	10
	B	5.03	0.55	0.100	4	7
	sensibility-coefficient . . .	+ 0.17		+ 0.01		
Malva vulgaris.						
XI. Length of the blade	W	53.8 mM.	3.85 mM.	0.071	40 mM.	65 mM.
	B	51.9 „	3.95 „	0.075	30 „	70 „
	sensibility-coefficient . . .	+ 0.03		− 0.055		
XII. Length of the leaf-stalk	W	172.4 mM.	15.4 mM.	0.089	128 mM.	289 mM.
	B	167 „	13.65 „	0.081	115 „	244 „
	sensibility-coefficient . . .	+ 0.03		+ 0.09		
XIII. Number of akenes	W	13.38	0.7	0.05	9	17
	B	13.6	0.6	0.044	11	17
	sensibility-coefficient . . .	− 0.015		+ 0.12		
Ranunculus arvensis.						
XIV. Number of akenes	W	8.5	0.75	0.09	5	12
	B	6.9	0.775	0.11	4	11
	sensibility-coefficient . . .	+ 0.19		− 0.22		
Cardamine hirsuta.						
XV. Length of the silique.	W	17.5 mM.	2.75 mM.	0.15	4 m.M	24.1 mM.
	B	14.7 „	2.75 „	0.19	3.2 „	23.2 „
	sensibility-coefficient . . .	+ 0.16		− 0.27		

It appears from this table as well as from the curves that in general the median value of the characters of the badly-fed plants is smaller than of the well-fed ones. Only with *Malva vulgaris* the median value of the number of akenes of the plants from the sandy soil is slightly larger, the difference being very small, however. The sensibility-coefficient is only — 0.015. With the remaining characters the sensibility-coefficient of the median is positive and differs very much; on the whole it varies between — 0.015 and + 0.54.

Let us now see from the table whether nutrition has the same influence on the median value of the different characters of the same species. We shall leave *Malva vulgaris* out of account here since, as was mentioned above, its roots had in the bed of unfertile earth penetrated into the fertile underground and possibly on this account the differences were very slight for all the characters conside-red. Comparing the sensibility-coefficients of the median of the various characters of one species, we find that they diverge largely.

While the sensibility-coefficient of the median of the number of branches of the second order of *Iberis amara* is + 0.54, it is + 0.15 for the number of silicles of the principal stem; the sensibility-coefficients of M for the length of the plant and the length of the leaf lie between these values and amount to + 0.24 and + 0.28. With *Anethum graveolens* the sensibility-coefficient of the median of the number of umbel-rays is + 0.44, that of the number of lobes of the first leaf only + 0.08. To some extent this may be explained by the circumstance that the influence of nutrition on the first leaf is not so great as on charac-ters which appear later, since the food, stored in the seed, is the same for both cultures and possibly has not been entirely used when the first leaf develops. In agreement with this the sensibility-coefficient of the median of the

number of lobes of the first leaf of *Scandix Pecten-Veneris* is + 0.08, whereas it is + 0.17 for the number of umbel-rays of the same plant.

From what precedes it will be seen that the influence of nutrition on the median value of different characters of the same plant varies greatly, some organs being very sensitive for differences in nutrition, others experiencing little difference in their development on this account.

Concerning the value of the quartile the table shows that we do not obtain in all the cases studied, a variation in the same sense by bad nutrition, as was the case with the median value. In some cases Q is greater in the plants from the fertile soil, in other cases it is smaller, as great or nearly as great as with the plants from meagre soil. In order to be able to compare the variability of the characters in both cultures, however, and to draw conclusions from this comparison about the influence of nutrition on the degree of variability, we must not take the quartile but the variability-coefficient $\frac{Q}{M}$.

If, to begin with, we consider the value of this variability-coefficient in the various cases, we see from the table that it varies between wide limits 0.044 and 0.36. Also Verschaffelt [1]) found equally divergent values of $\frac{Q}{M}$ for the characters of different plants studied by him. The smallest variability is found with the different characters of *Malva vulgaris*, as well in the well-fed as in the badly-fed plants. Hence this plant appears to be little variable. Comparing the variability of the different characters of the same species with each other, we see that they diverge relatively little with the well-fed plants, as well with *Iberis amara*, as with *Anethum graveolens* and *Malva vulgaris*.

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1) Verschaffelt l. c. p. 353.

For the different characters of *Iberis amara* $\frac{Q}{M}$ is respectively 0.114, 0.137, 0.13, 0.15; for *Anethum graveolens* 0.19 0.19 and 0.18 and for *Malva vulgaris* 0.071, 0.089 and 0.05.

It will be seen that for the same species these values are nearly the same, while they differ considerably among the three species. Doing the same with the badly-fed plants we find a much greater difference between the variability-coefficients of the various characters of the same plant. For this culture $\frac{Q}{M}$ varies between 0.10 and 0.36 for the characters of *Iberis amara* and between 0.127 and 0.35 for those of *Anethum graveolens*. Hence it follows that the influence of nutrition on the variability of the different properties of a plant is not the same; how much this influence varies will be seen from what follows.

Comparing for each character separately the variability of the well-fed with that of the badly-fed plants, we find that the difference between the variability-coefficients for the two cultures varies greatly in different cases; for some characters it is very considerable, for others small. In order to compare these differences, they were divided by the value of $\frac{Q}{M}$ of the well-fed plants, as stated. The resulting number is the sensibility-coefficient of the variability. This sensibility-coefficient of $\frac{Q}{M}$ appears to vary between — 0.140 and + 0.29. In a comparison of various characters of the same species the fact that the roots of the bad culture had more or less penetrated into the subsoil, obviously is of no consequence, so that the results obtained with *Malva vulgaris* are also available here.

The sensibility-coefficient of $\frac{Q}{M}$ of *Iberis amara* is for the four characters respectively — 1.40, — 0.17, — 0.08 and + 0.09; for the characters of *Anethum graveolens* — 0.74,

— 0.105 and + 0.29; and for those of *Malva vulgaris*
— 0.055, — 0.09 and + 0.12. Especially with the first two
plants these sensibility-coefficients diverge considerably,
which proves how very different the influence of nutrition
is on the variability of the different characters of a plant.
By the same change in nutrition the variability of one
character is hardly modified at all and that of another
character of the same plant very considerably increased
or diminished.

It is very important to know in what direction the
nutrition reacts on the variability, whether under unfa-
vourable nutritive conditions the variability is either always
greater, or generally smaller or whether the two cases are
equally frequent. In this respect the table shows us that
for 6 out of 14 characters the sensibility-coefficient of $\frac{Q}{M}$
is positive which means that the variability of the well-fed
plants is greater than that of the badly-fed ones, whereas
in the other characters the sensibility-coefficient of $\frac{Q}{M}$ is
negative which means that the variability is greatest in
the badly-fed plants.

Even with the same species one character shows a greater,
another a smaller variability when the cultures grown
under favourable and unfavourable nutritive conditions are
compared. With *Iberis amara* the length of the plants from
the fertile earth is more variable than that of the plants
from the sandy soil, other characters, on the other hand,
show greater variability in the badly-fed culture. In the
same way in *Anethum graveolens* the variability is greatest
with the number of lobes of the well-fed plants and with
the number of flowers and umbel-rays of the badly-fed
ones, while with *Malva vulgaris* the length of the leaf-stalk
and the number of akenes of the well-fed plants, but, on
the other hand, the length of the blade of the plants from
the sand, show the greatest variability.

Summarising the results obtained, we see that nutrition influences the median value and the variability of the characters. Besides it appears that the sensibility-coefficient of the median is very different:

1. for different species compared among each other.

2. for different characters of the same species.

And about the variability we saw:

1. that with good nutrition the variability-coefficient $\frac{Q}{M}$ is fairly constant for different characters of the same species, but very divergent for the different species.

2. that with bad nutrition two of the species studied show great differences between the variability-coefficients of the different characters of the same species, while with one species the variability-coefficients of the various characters diverge relatively little.

3. that the sensibility-coefficient of $\frac{Q}{M}$ diverges greatly for different species and characters and varies between — 1.40 and + 0.29.

4. that for some characters the sensibility-coefficient of $\frac{Q}{M}$ is positive and good nutrition results in an increase of the variability; while for other characters, even of the same species, this coefficient is negative.

In what precedes, there has only been question of those characters which show symmetrical or sensibly symmetrical curves and which, when expressed in constants, yielded the results mentioned.

From these the curve of the number of branches of the third order of *Iberis amara*, grown on the sand, deviates entirely, being a semi-curve. For the culture on fertile earth, however, this same character gives a symmetrical curve. In fig. V this latter is very flat and extended in length, as the observations were divided over a great number of intervals in order to allow a comparison of the two

curves. If, however, the observations are arranged to a number of groups equal to that of the other figures, the curve thus obtained is not different from those of the other characters. For this culture the median is 53, the quartile 17.25 and the variability-coefficient $\frac{Q}{M}$ 0.32, the minimum number of side-branches being 1, the maximum 162.

With this character now, bad nutrition does not result in a simple shifting of the curve to the left, accompanied by greater or smaller changes in the values of M, Q and $\frac{Q}{M}$, as in the other cases, but here the symmetrical curve changes into a semi-curve of which the apex lies at zero.

We can explain the origin of this semi-curve in the following way. The lower limit for the number of branches of the third order of *Iberis amara* is 0. Since the plant also blooms on the principal stem and on the branches of the second order, it may exist without branches of the third order. Under favourable nutritive conditions the development of the plant is so vigorous that in all individuals branches of the third order are formed, but in greatly diverging numbers, as is shown by the curve of fig. V for this culture. With unfavourable nutrition, however, also individuals arise in which no branches of the third order are originated and as nutrition becomes worse the number of these individuals will become greater. Hence we see that with the very bad nutrition of the sandy soil, a great number of plants has no branches of the third order and so has reached the lower limit, the other specimens bearing a greater or smaller number of these side-branches, as is shown by fig. V for this culture. This leads us to the conviction that the semi-curve for this character is a necessary consequence of the fact that by the unfavourable nutritive conditions the variation-curve is shifted in such a way that it strikes against the lower limit of the whole range of variation of this character, a

great many of the individuals showing this lower mini-
mum value.

Also with *Anethum graveolens* a great difference is noticed
in the shape of the curves of the number of umbel-rays
in the two cultures, fig. VI. The curve of the well-fed
plants is nearly symmetrical, while that of the plants
from tbe sandy soil is asymmetrical in such a way that
the top of the curve lies nearer the minimum. It can
not be stated with certainty whether in this case we have
the same phenomenon as with *Iberis amara*, i.e. whether
the lack of symmetry of the curve indicates that it has
been shifted to the proximity of the lower limit. But the
fact that the minimum now obtained, viz. 7, is already
very small compared with the maximum 41 and that this
lower limit cannot be zero, renders this view probable.
Yet we must bear in mind in cases like the present, that
the appearance of an asymmetrical curve need not in
general be a proof that the curve is located near one of
the limits of the range of variation, but that the assym-
metry of the curve may also be the consequence of entirely
different causes.

GRONINGEN, July 30, 1904.

EXPLANATION OF THE FIGURES.

The figures are all reproduced at about half size. In the original figures the distances of the intervals, placed along the absciss, are 1 cm., each mm. of the ordinates having a value of 1%. So we can find from the length of the ordinates the percentage number for each interval. In most figures the ordinates are drawn between the two numbers indicating the interval, only in figs. X, XIII and XIV, where the observations are not arranged in groups, the ordinates stand above the number. The curves of the well-fed plants are drawn in continuous lines, those of the badly-fed plants are dotted.

Fig.   I. *Iberis amara.* Length of the plant from the base of the principal stem to the top of the inflorescence of this latter, in cm.

„   II. *Iberis amara.* Length of the leaf, in cm.

„ III. *Iberis amara.* Number of silicles of the inflorescence of the principal stem.

„ IV. *Iberis amara.* Number of branches of the second order.

„   V. *Iberis amara.* Number of branches of the third order.

„ VI. *Anethum graveolens.* Number of umbel-rays.

„ VII. *Anethum graveolens.* Number of flowers in the umbellet.

„ VIII. *Anethum graveolens.* Number of lobes of the first leaf.

„ IX. *Scandix Pecten-Veneris.* Number of lobes of the first leaf.