

selected with many of the qualities already fixed and we could confidently expect to secure a combination of the more important points.

Along with this breeding for type, there should be experiments in crossing for the production of the feeder lamb, for the raising of mutton has become almost, if not quite as important on our ranges as the production of wool. A few years of such work should produce a sheep hardy enough to withstand range conditions better than our present nondescript fine wools, large enough to produce good mutton and better mutton crosses and yielding fifteen pounds or more of wool per head. This would treble the value of the range sheep and make it possible for many more to enter into this industry with smaller flocks which could be better cared for and continually improved. Such breeding would be done with a definite object in view and the sheepman would have the advantage of that stability and certainty which only comes from pure blood through the heredity of improvements which have become fixed. There is no question that a suitable range breed could be produced which would be worth millions of dollars to the industry.

CORRELATION OF CHARACTERS IN PLANT BREEDING.

By HERBERT J. WEBBER, *In charge of Plant Breeding Investigations, U. S. Department of Agriculture.*

WHAT IS CORRELATION?

In the practical work of plant breeding the investigator must handle a large number of plants, and it thus becomes important at as early a date as possible to be able to judge of the probable quality of the product in order to discard some of the numerous individuals. It is doubly important to be able to judge of the nature of the product early, when it is necessary to interbreed different individuals, as is frequently the case in the fixation of variable hybrids. It is well known that certain characters are more or less related to each other in certain plants and are inherited together, acting similar to a unit character in this respect. All practical animal or plant breeders have come to recognize cases of this kind. When they find a certain character present in an individual, they are almost certain to find another character present which is correlated with it. With the introduction of the unit character idea, correlation, which is a well established phenomenon, becomes more interesting and requires interpretation according to our new understanding of character inheritance.

Correlation is used rather loosely by botanists and plant breeders and is frequently used to refer to widely different phenomena. The writer distinguishes four kinds of correlation, which the breeder should recognize. These four correlation groups he has termed Environmental, Morphological, Physiological, and Coherital.

ENVIRONMENTAL CORRELATION.

Correlation is frequently used to indicate relation to physical conditions or environment. It is a well known fact that, if plants of the same race of corn be grown on sterile soil and on soils of varying degrees of fertility, the various members of the plant's body, in each case retain the same relative proportion which is dependent on the environment. In the plants grown on sterile soil the stem will be short, and all other characters, as diameter of stem, size of leaves, size of ear, weight of grain, etc., will be correspondingly reduced. As the fertility of the soil on which the plants are grown increases, the height of the stem increases and all other parts of the plant increase in size in corresponding degree. Such correlations or relations to environmental conditions have been described by Liebenberg in wheat,¹ Proskowetz in barley,² and Fruwirth in field beans,³ etc.

In wheat, according to Liebenberg, with the increase in the length of stem is correlated an increase in strength of stem, length of ear (or head), strength of ear, number of spikelets, number of kernels, total weight of kernels produced, etc. As Fruwirth expresses it, such correlations are merely the expression for equality or conformity to condition of luxuriance. Strictly speaking, these are not correlated characters, and their consideration is of little or no value to the breeder.

MORPHOLOGICAL CORRELATIONS.

What the writer has termed morphological correlations are those cases where a variation in one character is the primary cause for the variation in another character. Under this heading the writer would class those cases of correlated characters where the relationship between the characters is similar to that which exists between the character of size of germ and oil contents of the kernel in corn as pointed out by Dr. A. D. Hopkins.

In the corn kernel, the germ is the portion richest in oil content and, therefore, the larger the germ in proportion to the size of the kernel the higher the oil content. Dr. Hopkins has shown that by selecting ears having large-germed kernels for seed it is possible to secure strains of corn normally producing larger germs, and thus having a higher oil content. A similar case of morphological correlation is also furnished by Dr. Hopkins' discovery that the proteid content of the corn kernel is correlated with the amount of corneous endosperm of the kernel, enabling the breeder to select ears producing kernels with a large amount of corneous endosperm and to know that he is pretty surely securing kernels of high proteid content.

De Vries has described the two groups of correlated characters above referred to. He states that "there are two groups of correlation. In the one belong those phenomena in which two characters react in

¹Mitt. des Vereins zur Forderung 1892 and 1893.

²Landw. Jahr. 1893, p. 129.

³Journ. f. Land. 1900.

the same way, if not also in the same degree, to external conditions. To the other belong those cases where the variation of one character is the causal condition of variation of the other character. For example, all characters on which the capacity of carbonic acid assimilation depends, involves different growth processes with equal inclination to vary."¹

This type of correlation, which at first thought seems similar to coherital correlations described below, is, the writer thinks, of entirely different nature. In these cases the two characters are intimately related in a morphological or physiological sense, and increase in one organ necessarily gives rise to an increase in the other.

PHYSIOLOGICAL CORRELATIONS.

A third group of correlated characters which the writer has termed physiological correlations, are explainable by well recognized physiological principles. As an illustration of such correlations may be cited the relation of number of leaves to seed production in tobacco. Messrs. A. D. Shamel and W. W. Cobey, who have charge of the tobacco breeding work of the U. S. Department of Agriculture, state that, in the Sumatra and Cuban races of tobacco as grown in Connecticut and Florida, excess of leaf production is correlated with a lack of seed production. Where the main strength of the plant goes into leaf production, the seed production is correspondingly decreased. Some plants which were selected in the course of breeding work because of the excessive number of leaves produced, running as high as 40 per plant, were almost sterile. An inverse physiological relationship thus exists between the number of seeds and the amount of leaf production.

Another similar correlation called to my attention by Messrs. Shamel and Cobey is the inverse relationship between shape of leaf and number of suckers. In Sumatra, Cuban and broadleaf races of tobacco, long and narrow leaves are associated with large and numerous suckers, approaching a wild type; while large, broad and rounded leaves are associated with few suckers. Where the main strength of the plant goes into leaf production, fewer branches or suckers are produced. In many varieties of fruit trees, such as apples and oranges, excessive vigor of growth in certain races is correlated with lessened fruit production, and the same is true to some extent in cotton and corn.

COHERITAL CORRELATIONS

In this group of correlated characters the writer includes those characters which are not related to each other in any direct or causal sense but which are inherited as a single unit character. They may be defined as characters related to and dependent on each other in such a way that they are inherited together thus the name *coherital* which the writer has given to this group. In hybridization they are inherited mainly similar to unit characters, though they are known to

¹Mutations Theorie I, p. 113.

be distinct. It would seem as though these different characters which are correlated may be represented in the hereditary apparatus by protoplasmic units which are united together in a relation similar to that which exists in a chemical radical. In the chemical radical two elements are associated so closely that they commonly pass into many different compounds without splitting up, but can, by certain processes, be dissociated. Similarly, characters united in coherital correlations are almost invariably inherited together, but may, at least in some cases, be segregated at rare intervals in hybrids where they are usually inherited together.

The correlations belonging to this group are far the most interesting ones from a scientific standpoint, and may in some cases be of great practical value. An interesting correlation of this kind occurring in sweet corn has been studied by the writer, and is described here in detail.

In 1901 the writer made a number of hybrids of Black Mexican sweet corn (Plate I, ear B. M.), with pollen of Stowells Evergreen sweet corn (Plate I, ear S. E.), having in view the production of a new race that would have the tenderness and sweetness of the Black Mexican, but with the large ear, deep kernel, and adaptability for canning purposes of the Stowells Evergreen. It was also desired in the new race to secure a color intermediate between the two parents to such an extent that the kernels would be white while in the "milk" or eating condition and ripen a light blue color, which would serve to clearly distinguish the new variety from other varieties. It will be noticed that the color desired is intermediate between the two parental colors, *i. e.*, blue black and amber colored or white as it is frequently called; and the fixation of such a color would mean the fixation of a heterozygote type. The splitting up of the hybrids, so far as color is concerned in the second and later generations is in general conformity to Mendelian proportions. Neither one of the colors, however, could be considered to be dominant, as the kernels were amber-colored like Stowells Evergreen, blue black, like the Black Mexican, or some grade of intermediate bluish violet. In the second and third generations good ears of the desired shape and form of kernel were selected, and from these the intermediate light blue kernels were selected for planting. Those taken from a single select ear were kept together and planted together, the "plant to row" system being followed except that only light blue kernels were planted. In the fourth generation it was found that in a few cases, ears were produced which were uniformly of an intermediate blue color though all were somewhat darker blue than was desired (Plate I, ears No. 30 and 386). Some of these ears were selected for planting in the fifth year and also the light blue kernels were selected from some ears which were not uniformly colored but contained again amber-colored, dark blue black, and light blue kernels (Plate I, ears No. 194 and 471). In the fourth year when the plants were in flower every stalk was examined and notes made on the color of silks or pistils, color of stamens, and color of glumes of the tassels. In the pure Black Mexican: the silks are white or light green, the stamens light green, and the glumes light

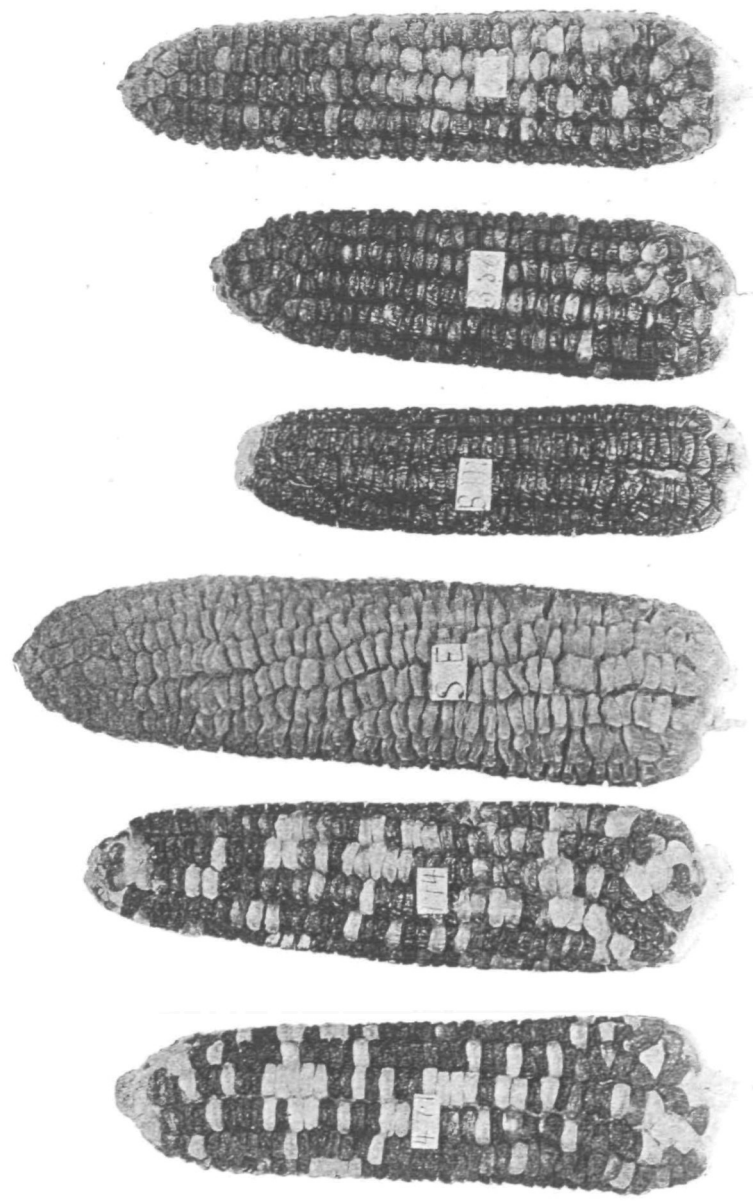


Plate 1. Fourth Generation Hybrids of Sweet Corn, Black Mexican σ \times Stowell's Evergreen σ , with typical ears of parental types.

green, commonly, but occasionally with a few reddish, longitudinal stripes. In the pure Stowells Evergreen the silks range from dark reddish purple to light pink, the stamens are reddish purple and the glumes reddish purple or with marked purplish stripes. It will be noted that the combination of colors here, in comparison with the kernel color, is just the opposite from what would be expected, as the light amber-colored kernels of the Stowells Evergreen would rather be expected to be combined with greenish or light silks, stamens, glumes, etc., and vice versa. It is interesting to note that the cob is white in each case as red-cobbed sorts of sweet corn will not be tolerated in the market, and this character has been bred out of all sweet corn races.

When the mature ears of the fourth generation were harvested and carefully examined, it was found that a peculiar and inexplicable correlation of colors existed. The bluish black kernel color of the Black Mexican was found to be correlated with a green color of silks, glumes and stamens, while the light amber or white color of kernel of the Stowells Evergreen was apparently correlated with the red or purplish color of silks, stamens and glumes. Knowing this correlation, it was possible to examine any one of the 500 ears grown in the fourth generation and tell immediately the general color of the stamens, glumes and silks produced. If an ear had all of the kernels showing a trace of blue from the Black Mexican parent, as in ears 30 and 386, of Plate I, one could be sure that it was developed on a plant having light green silks, stamens and glumes. On the other hand if a portion of the kernels were pure amber or white-colored with no trace of blue as in ears 194 and 471 of Plate I, one could be equally certain that such ears were borne on plants having reddish or purplish silks and purplish stamens and glumes.

In the fourth generation selections of light blue-kerneled ears and light blue kernels from some ears of mixed colors were again made and a fifth generation was grown. In this generation again notes were made of the colors of silks, glumes, and stamens in comparison with color of ear. In the accompanying table (Table I), the results of the counts for the two seasons are given.

The table gives the record of the progeny grown from 19 ears. In the left column is given the pedigree number of the mother ears, seed of which was planted. Following this is the number of the progeny showing the character indicated in the different columns. In the fourth generation progeny each stalk was labeled and followed to the production of the ears, so that the number of stalks and ears correspond. In the fifth generation a count was made in each progeny of the numbers having various colored stamens, glumes and silks, but they were not labeled and traced, so that the numbers of stalks and ears differ slightly owing to the development of more than one ear on a stalk or other cause. The fact of the correlation is, however, plainly evident.

TABLE 1.—*Record of the progeny of 19 ears, showing correlation between color of stamens, glumes, silks and kernels.*

1903 CROP (4th GENERATION).

Pedigree number of mother ear.	Stamens.		Glumes.		Silks.		Kernels.	
	purplish.	light gr.	purplish.	green.	purplish or red.	green.	some am- ber or white.	all with some purple.
36-1	20	0	20	0	20	0	20	0
36-2	50	14	50	14	48	16	50	14
36-3	65	0	65	0	62	3	65	0
36-4	53	15	53	15	51	17	53	15
36-5	48	18	48	18	47	19	49	17
36-6	16	3	17	2	17	2	16	3
36-7	2	2	2	2	2	2	2	2
36-8	23	25	23	25	24	24	24	24
36-9	24	1	24	1	24	1	24	1

1904 CROP (5th GENERATION).

36-1-3	24	3	24	3	24	3	25	5
36-2-30	46	59	46	59	46	59	45	47
36-2-44	57	18	57	18	57	18	73	11
36-3-102	32	7	32	7	31	8	35	4
36-3-1444	72	6	72	6	69	9	69	5
36-4-193	71	14	71	14	71	14	74	15
36-4-194	61	19	61	19	61	19	57	16
36-4-192	61	18	61	18	61	18	67	11
36-5-290	65	27	65	27	65	27	62	27
36-5-313	70	25	70	25	70	25	67	22
Totals	860	274	861	273	850	284	877	239

The most interesting feature of this case is the fact that these characters which are correlated together, hang together, in the splitting up of the hybrids instead of being broken up and inherited separately or in intermediate degree as might be expected. Johannsen states that "crossing is the means of breaking the correlation."¹ At first thought the writer's results would seem to be somewhat at variance with this proposition. However, in about one case out of fifty or a hundred the correlation is broken. In the progeny of ear 36-2, two ears having some amber-colored kernels and purple stamens and glumes, have the silks recorded as green instead of purplish, as would be expected by the correlation. The same is true of three ears in the progeny of 36-3. There is some doubt about these cases as the record of the silk color may have been made very early and the silks when first protruded may be nearly green, and later become markedly purplish or pink. In the progeny of 36-4, fifteen ears have all of the kernels containing some bluish purple color and all of these have light green glumes and stamens. One of them however, has purplish silks, showing pretty clearly a breaking of the correlation. Of the 53 ears of this progeny having some amber kernels, all have purple stamens and glumes but three, which have light green-colored silks instead of purplish as would be required by the correlation. In the progeny of

¹Johannsen W. Sur la variabilité de l'orge considérée au point de vue spécial de la relation du poids des grains à leur teneur en matières azotiques. Cps. Rsd. trav. du Laboratoire de Carlsberg IV, 4 S. 122-192 (1899).

36-5, occurs one of the most interesting cases of splitting. Of the 49 ears having some white kernels, all have purple glumes, purple stamens and purple silks, except three ears. Two of these three have purple stamens, purple glumes and light green silks, while one has light green-colored glumes, light green-colored stamens and purplish silks. In this latter individual the light green color of the Black Mexican glumes and stamens has replaced the purple of the Stowells Evergreen in the correlation. The breaking of the correlation in the majority of cases is in the color of the silks which seems to be less firmly bound in the correlation. In this progeny the 17 ears having purplish kernels, all have light green-colored glumes, stamens and silks. In the progeny of 36-6, the 16 ears having some amber-colored kernels, all have purplish stamens, glumes and silks. Of the three purplish-kerneled ears of this progeny, one has light green glumes, stamens and silks, another light green stamens and glumes but pinkish or purplish silks, while the third has light green stamens and silks but dark purplish glumes. In the latter case the color of the glumes only is broken in the correlation. In the progeny of 36-8 the 24 ears having purplish kernels are all regular in the correlation except one which has purplish silks. Of the 24 ears having some white kernels, all are regular in the correlation except one which has light green glumes, stamens, and silks, the opposite of the rule in all three of these characters.

The above cases which are all of the deviations from the rule which were found in the 477 plants of the fourth generation on which careful notes were made, show that, while the correlated characters are as a rule inherited together, they nevertheless split up occasionally, giving practically all of the possible combinations of the four character pairs.

An interesting practical breeding feature connected with this case of correlation in sweet corn hybrids lies in the fact that it enables the experimenter to determine almost surely the color of the ear when the plants are in flower. If, as in the case of the writer's experiments, it is desired to produce a race having uniformly bluish or light purple kernels, it is possible to select two hybrids which will produce such kernels throughout and breed them together, thus avoiding the crossing in of the strain having amber-colored kernels. By this means the breeder should be able to hasten the fixation of a race of the desired color.

It is a matter of some interest to note that the data included in the above table clearly shows that the various characters concerned are inherited in Mendelian proportions. The hybrids both in the fourth and the fifth generations were open fertilized and we should thus expect the dominant character to show in 75 per cent and the recessive character in 25 per cent. Of the individuals with purple stamens which is the dominant character there are 860, while 274 show the recessive character having light green stamens; 861 have purplish glumes and 273 light green glumes; 850 have purplish or reddish silks and 284 greenish silks. These proportions are near enough to the expected ratio to clearly show that the characters are inherited

in accordance with the law. It will be noted that the individuals showing the recessive character are short of the expected ratio in all cases except in color of silks. As the three characters are bound together so strongly in correlation, we should expect the individuals showing the three characters to be inherited in equal proportions. With reference to the fact that there is a much larger number having green silks than green stamens and glumes, the writer would state that this is doubtless due to the greater ease with which the color of silks is broken in the correlation and in this case the expected ratio is more nearly realized. The notes on kernel color were not made in the right way to show Mendelian inheritance, as the color of the different individual kernels is not recorded. The writer has counts of kernels from a large number of ears, however, which clearly show that the kernel color also follows Mendel's law where no selection is exercised.

Mr. J. B. Norton, one of the writer's associates, has called his attention to an interesting case of coherital correlation in oats. Here the naked character of grain is correlated with a large number of flowers per spikelet, ranging from 3 to 7 and being usually over 4 flowers per spikelet. In ordinary hulled oats the spikelets uniformly have from 1 to 3 flowers, while in naked oat races the spikelets have from 3 to 7 flowers. In hybrids of hulled with naked types, if the spikelets have as high as 4 flowers, one can be practically sure that they have naked grains. One of the desirable improvements in ordinary oats, which are hulled types, is to secure races with spikelets having a larger number of flowers. Apparently the most feasible way of producing such new sorts would be to cross the ordinary oat with the naked oat which has a larger number of flowers per spikelet. In such hybrids, however, where the spikelets have the increased number of flowers, the grains are uniformly naked, the correlation being very hard to break. The Garton Brothers of Newton le Willows, England, the writer is informed, have also had the same difficulty with this correlation in their work. Here the correlation is a very undesirable one for the breeder, but it seems probable that a large number of hybrids would give some exceptions to the rule.

A somewhat similar coherital correlation has been described by Tschermak in his very suggestive paper on a correlation between vegetative and sexual characters in pea hybrids.¹

The following is nearly a literal translation of Tschermak's five paragraphs describing his results:

(1) It was not possible by crossing a white-flowered smooth-seeded *Pisum sativum* with pollen of a red-flowered slightly wrinkled-seeded *Pisum arvense* to produce slightly wrinkled seeds. The first seed generation is in this case smooth. The cotyledon character of smoothness appears to be dominant.

(2) On the contrary a red-flowered wrinkled-seeded *Pisum arvense* by pollination with a smooth-seeded *Pisum sativum* gave wrinkled seeds. The first seed generation showed the *arvense* type. That which in the first case was a recessive character "weak-wrinkled" became through the influence of the mother parent, dominant.

¹Tschermak Erlich. Ueber Correlation zwischen Vegetativen und sexuellen Merkmalen an Erbsenmichlingen. Berich. d. Deut. Bot. Gesell. 20 p. 17 (1902).

(3) The hybrids of the first generation of either combination showed red flowers throughout, showing the dominance of this vegetative character in the first hybrid generation, and gave by self-pollination among themselves only weak-wrinkled seeds. The second seed generation was the same also, in both cases, as the first seed generation of case two.

(4) The pollen of hybrids of the first generation, from a green smooth-seeded *Pisum sativum* and a yellow wrinkled seeded *Pisum arvense*, crossed on a green smooth-seeded *Pisum sativum* produced very differently colored yellow and green seeds which, however, were all smooth (compare case 1.) From the reverse union there resulted, on the contrary, seeds which were differently colored but weak-wrinkled throughout (compare case 2.)

(5) The daughter generation of hybrids of both combinations of a white flowered and smooth-seeded *Pisum sativum*, and a red-flowered wrinkled-seeded *Pisum arvense*, consisted of red-flowered and white-flowered individuals in the numerical relation of 3 : 1; the red-flowered ones again gave throughout weak-wrinkled seeds; the white-flowered ones only smooth seeds.

Tschermak points out that this correlation is evidently sometimes broken as is shown by the existence of constant *arvense* sorts having red flowers, but with smooth seeds.

A somewhat similar case of apparently coherital correlation between color of flower and color of pollen in hybrids of different races of *Epilobium angustifolium* has been described by Correns,¹ but the evidence of true correlation in this case is yet somewhat doubtful.

Dimorphic and trimorphic flowers such as *Primula* and *Lythrum* must probably be considered as cases of coherital correlations, a certain length of stamen being regularly correlated with a certain length of pistil. If such dimorphic and trimorphic species are formed by the the amalgamation of once distinct types, as seems probable, the correlation of the different groups of characters were doubtless inherited from the ancestral types. Space will not permit a further discussion of these interesting cases.

ORIGIN OF COHERITAL CORRELATIONS.

The characters bound together in coherital correlations seem in many cases to be entirely unrelated and to have no reason for existence in the economy of the plant's life processes. Unlike the other forms of correlation, environmental, morphological and physiological, we can assign no probable reason for such a union of diverse characters. It would seem therefore that their origin must be sought in the evolutionary changes that led to the formation of the race or species exhibiting the correlation. Mr. J. B. Norton has suggested to the writer that they may be the characters changed in the mutation that produced the race. The evidence at our command is too meager to allow deductions to be made which are anything more than suggestions. A slight suggestion may be obtained from the action of the characters which are under rigid selection. In careful pedigree breeding if two or three characters, only, are given strict attention, these characters may become very strong in their transmitting power and reproduce themselves true with almost no variation, while other characters which are not considered in the selection show great variation. The

¹Bot. Zeitung. 1900, s. 232 and Bibl. Bot. 1901, Heft 53, s. 146.

constant breeding of these characters to a greater and greater degree of fixity, the writer believes, would tend to increase their hereditary strength and association in inheritance. In the same way the writer is inclined to believe that a mutation affecting only certain characters, would tend to render these characters less variable than other characters in the new race, and thus stronger in transmission. It is to be hoped that further research will throw light on this obscure problem.

HEREDITARY CORRELATION STRENGTHENS THEORY OF UNIT CHARACTERS.

The splitting up and recombination of the four correlated characters in the case of the sweet corn hybrids discussed above, adds strength to the hypothesis of the existence of unit characters and the existence of protoplasmic units representing such characters. If we have definite hereditary granules or protoplasmic units representing unit characters, it is easy to conceive of some of these being closely associated in such a way that they cling together like the elements in a chemical radical as mentioned previously, being transmitted together in the reproduction and splitting up of hybrids. In such a union of different hereditary units, an occasional disjunction would be expected if the characters are distinct. If on the other hand we hold to the theory as some investigators do, that there are no special parts of the protoplasm representing unit characters, but that all of the hereditary tendencies are intricately mixed together in all of the protoplasm, it becomes inconceivable, at least to the writer, how a few characters can be bound together in correlation generally and yet occasionally split apart.

CORRELATIONS VALUABLE TO THE BREEDER.

To the breeder those correlations are valuable, which enable judgment to be passed on the probable character of the product while the plants are still young or in the flowering stage. Such correlations are of special value in biennial plants like sugar beets and perennial plants like various fruit trees. Mr. E. M. East of the Connecticut Agricultural experiment station has called the writer's attention to several cases of correlation which he observed in sugar beets in the course of work conducted at the Illinois experiment station. A quotation from Mr. East's letter follows:

In the course of the work there were a number of things noticed which were easily explainable and which could hardly be called character correlations and others which could.

Among the first may be mentioned the following:

- A large beet indicates low sugar content.
- A small beet indicates high sugar content.
- A regular-shaped beet indicates high sugar content.
- An irregular-shaped beet indicates low sugar content.
- A large-crowned beet indicates low sugar content.
- A small-crowned beet indicates high sugar content.

In the second category, I think, comes the following in varying degrees of correlation, the highest, I give first.

1st. The lightest color of green which might be called a healthy green was highly correlated with high sugar content; that is, this color seemed to indicate the optimum photosynthesis of carbohydrates while dark green probably indicated the use of more energy in the formation of nitrogen compounds although I did not make nitrogen determinations.

2d. The growth of the leaves in such a form of rosette that they seemed to get the maximum amount of sunlight possible, indicated high sugar.

3d. There was an optimum ratio between the weight of beet and leaf surface that was fairly constant.

I might state that I remember that degrees of correlation for any two characters are very variable in different varieties, and I have noticed in corn that two characters may be highly correlated in one blood strain of the same variety and not in another.

Many such cases of valuable correlation have been described by Fruwirth¹, Beach² and others and they do not need to be further discussed here.

CORRELATIONS DETRIMENTAL TO THE BREEDER.

The general opinion prevails among breeders that a correlation of characters is usually valuable in assisting the breeder. This is certainly the case in many instances but in producing new strains by hybridization the writer believes that, in the majority of cases, a correlation of characters will increase the difficulty. Usually in hybridization we desire to combine certain desirable characters of the two parental sorts in a new race. If the characters we have to deal with are unit characters, the breeder by persistence will probably be able to secure a hybrid possessing the desired combination. If, however, some of the desired characters are correlated with undesirable characters which he desires to weed out, the process is liable to be a difficult one. The case cited previously, of hybrids of hulled and naked oats, is an illustration of this kind. A number of such correlations have been discovered by the writer in his experiments in the hybridization and improvement of cotton. In hybrids of upland with Sea Island cotton it is almost impossible to secure a good opening of boll coupled with long lint. Short lint and good opening of boll are correlated in the upland, while long lint and poor opening are characteristic of the Sea Island. In the long list of several hundred thousand hybrids with which the writer has experimented in the last six years, in no single case has he found a perfect opening of boll in a hybrid with long lint. In cotton also, earliness of maturity is usually correlated with small bolls and this is a difficult correlation to overcome. Other cases of similar correlations of characters difficult to break up were described by the writer before this association at its first meeting.³

¹Fruwirth, C. *Die Zuchtung landwirtschaftlichen Kultur-pflanzen*. Berlin, 1906.

²Beach, S. A. Correlation between different parts of the plant in form, color, size and other characteristics. In *Proceedings International Conference on Plant Breeding and Hybridization*, in *Memoirs Hort. Soc. of N. Y.* Vol. I, p. 63, 1904.

³Webber, H. J. *Cotton Breeding*, Am. Breeders' Association, Vol. I, p. 42.