

VARIATION IN WHEAT HYBRIDS.

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The amount of variation in a fixed, long established variety of wheat is confined between rather narrow limits. Possibility of improvement is limited largely by the maximum variation in the number of plants handled. Some investigators even positively assert that the maximum variation in any one variety or species marks the extreme possibility of improvement for that variety or species. It would seem that such a view is too radical for it fails to recognize the possibility of further variation. For instance, one plant of a variety of wheat might have the power of producing progeny which would yield at the rate of eighty bushels per acre under ordinary conditions. This might be the maximum variation occurring at the time the selection was made. If this selection were fixed by rigorous breeding until it could claim the dignity of an established variety, a new maximum variation might arise which would make possible still further improvement. No two plants are ever alike. Variation is always present even in the most uniform and stable varieties. But the variations, ordinarily, are small so that improvement is necessarily slow.

To increase variation wheat breeders have resorted to various expedients such as changing the environment by moving to new climatic conditions, by the heavy use of soil fertilizers and by crossing or hybridization. The latter only will be considered in this paper.

Hybridization is the most potent aid to variation known to the wheat breeder. The hybrid or cross contains within itself the sum of the possibilities for variation lying latent in both its parents and also all possible combinations of those parents. Frequently hybridization brings out some character which has lain dormant for generations. Once in a while an entirely new creation is formed, differing entirely from either parent.

In the past two years, we have worked with something over 200 distinct crosses. Many more crosses were made but were dropped in the first generation from one cause or another. Eleven different varieties of wheat were used and sixteen type crosses were made. These are given below together with the principal variations noted in each case. No particular order of arrangement will be observed as it makes no difference whether I begin in the middle of the list and work both ways or whether one end is attacked before the other.

DESCRIPTION OF VARIETIES USED.

A brief description of the varieties and their chief characteristics is given at this point:

Turkey, Turkey Red, or Turkish Red is at present our most valuable variety. It was brought originally from Russia by a colony of Russian Mennonites who settled near Topeka, Kansas, in 1874. It is bearded, hardy and fairly early-maturing. The straw is rather fine,

of medium length and stiffness. It is our most disease-resistant sort. In the season of 1904, when all Nebraska wheats were more or less affected by blight or scab (*Fusarium culmorum*), it was the only wheat grown on the station farm of marketable quality. When growing, the color is a very deep, dark green. The young stool is very spreading, flattening out close on to the ground. Very numerous stools are produced. The leaves are rather narrow. The head is short and compact. The berry is rather long, red and quite hard.

Big Frame stands second in point of yield among our varieties. It is beardless, slightly less hardy than Turkey and matures from 4 to 7 days earlier. It stools considerably less than Turkey. The young stool is broad, yellow-green-leaved and stands erect. The straw is rather coarse, and slightly longer and stiffer than that of Turkey. The berry is plumper, more nearly round and of lighter color and much softer than that of Turkey. *Big Frame* is quite resistant to rust and smut, but is, with reference to scab, the least resistant variety which we grow.

Russian Winter is a bearded, hard, red wheat imported from Russia. In leaf, color and young stool, it closely resembles Turkey. It makes a greater growth of rather coarser straw than Turkey. It stools rather sparingly, and matures quite late. Hardiness of an extreme degree is its strong point. The berry is of good quality when normal development obtains to maturity. The yield is light.

Yaroslav from St. Petersburg is another late-maturing, hardy, Russian variety. The young stool is more yellow green than the preceding, is somewhat coarser, but has the habit of spreading out upon the ground like Turkey Red. The straw is long, rather coarse and quite stiff. It is a very light yielder.

Yaroslav from Yaroslav resembles Yaroslav from St. Petersburg quite closely. It is later-maturing, being the latest variety we grow, also, the lightest yielder. The chaff in the green, soft-dough stage has a red line along the edges and sometimes up the keel. When ripe the chaff is brown.

Girka is a hardy, medium late, beardless Russian wheat. It rather long, fine straw. The stools resemble Turkey Red very much in habit and appearance but are less abundant. It yields a medium quantity of grain slightly above the average in quality.

Russian Hard resembles Russian Winter very much but does not yield as well.

Nashi is a wheat very similar to Yaroslav in habits of growth and general appearance. The chief difference to be noted, is that Nashi has no chaff markings, and the mature chaff is much lighter in color.

Red Winter closely resembles Russian Winter and is probably of the same origin

Yx is another Russian sort, resembling Red Winter but coarser.

CROSSES MADE AND THE RESULTS.

Turkey Red was crossed with Russian Winter. Reciprocal crosses gave much the same results. By this cross, it was hoped to

get the early maturity, prolific stooling, and high yield of the Turkey wheat and the great hardiness of the Russian Winter. The majority of the first generation of this cross were so late-maturing that chinch bugs and bad weather prevented any seed ripening. In fact only a few grew vigorously. Those surviving were planted to obtain the second generation. The second generation was uniformly quite hardy. Growth was very vigorous and stooling more abundant than with either parent. The centgeners made a height growth fully 10 inches greater than either parent. The leaves were broader. Leaves and culms were considerably coarser. All were uniformly quite late in heading. None reached maturity owing to the attacks of scab (*Fusarium culmorum*). We have since discontinued growing Russian Winter so this cross will not be attempted again.

Yaroslav from St. Petersburg and Yaroslav from Yaroslav by Turkey Red and their reciprocal crosses can be treated together with reference to all characters except chaff markings. The first generation progeny was uniformly poor, less than 25 per cent of the plants maturing seed. The plants maturing resembled the pistillate parent more closely. The second generation was uniformly hardy. In every case in this generation types resembling both parents appeared. Odd combinations representing a large proportion of the gradations between the two types were present in every case. All the plants showed a tendency to coarseness, profuse stooling and larger growth than either parent. Only two plants out of the several hundred of this generation showed early maturity. These early maturing plants have remained early in the third generation, all the progeny having this characteristic. They stool in excess of either parent and show a strong tendency to high yield but are extremely sensitive to diseases—rust and scab. The characteristic of early maturity seems to be fixed in these two strains and late maturity in all others of this cross. One peculiar thing observed, is that while Yaroslav from St. Petersburg has no red lines on its chaff, red lines appear on the chaff of some of the progeny of every cross with Turkey Red. Whether or not the red markings and brown chaff appear in a definite ratio, I am not prepared to say, as careful notes were not taken on this point. In fact we did not care what the color of the chaff was. What we were and are still endeavoring to obtain is a combination of hardiness, early maturity, and yield. Of course we should like to include disease resistance in this combination. But, it looks as if this quality would have to be bred for separately, either by further crossing or by selection.

Big Frame by Girka and the reciprocal cross amounted to what might be termed a freak cross. Only a few plants were obtained in the first generation. The parents are both awnless, yet in the first generation a bearded form, an intermediate between bearded and awnless and an awnless form appeared. In the second generation, all three of the forms with the addition of a club form appeared. No seeds were produced in this generation so I am unable to say what might have happened in the third generation. None of the plants headed until almost the first of August. The failure to produce seed

seemed to be due to faulty fertilization. The plants remained green and continued to grow until about September 1st, when they were cut. When cut they were fully 4 feet in height. This seemed to be a case of incompatibility. We expect to try this cross again and see if we can raise seed instead of forage.

The Turkey Red by Russian Hard cross was a repetition of the Turkey Red by Russian Winter cross. The second generation could not withstand the blight.

Nashi by Turkey Red showed two very important distinctions in the first generation. About half the plants were very low, the other half very tall. The low or dwarf plants stooled very feebly and produced a small amount of seed, none of which germinated, so that there was no second generation of dwarf parentage. The tall types stooled profusely and yielded well. The second generation retained the tall characteristic and all were late in maturity. The stem and leaf type of both parents with about all possible variations between were represented. Some plants would have the characteristic Turkey Red, dark green color combined with the erect, coarse leaves and stems of Nashi. In the third generation those plants which had been distinctly like either parent in the second generation bred true. The other variations appeared also. Variation would be observed in the young stools. The dark rich green of the Turkey and the lighter green of the Nashi were both present combining in different ways with the coarse leaves of Nashi and the slender leaves of Turkey.

Big Frame by Red Winter and its reciprocal cross promised so little that a second generation was not planted. The first generation was all dwarf. This was a cross between an awnless and a bearded variety, and in this characteristic every plant was intermediate, having awns about one half the length of typical Turkey Red awns and the upper half of the head only awned.

Big Frame by Yx and its reciprocal produced dwarf and tall forms all intermediate in the beard character. The second generation gave bearded, awnless, intermediate, dwarf and tall forms. A third form appeared having a very broad, bright green leaf, coarse stem and sparse stool. The heads of this form were very large and coarse, with wide distances between the joints of the rachis. When planted this form failed to produce progeny. The awnless forms gave a third generation, all awnless, the bearded forms all bearded. The intermediate broke up into awnless, bearded, and intermediate. A fourth generation was not planted.

Turkey Red by Girka is another case of a bearded by an awnless wheat. In these characters they behave as the cross just mentioned. All the progeny have, so far, shown a strong tendency to late maturity. The offspring all stool more than either parent, and appear very hardy. These two wheats are very much alike in all their characteristics except in maturity and awns. Turkey is early and bearded; Girka late and awnless.

The Yx by Turkey Red and the reciprocal cross produced progeny so coarse and rank, with such loose heads that it was not carried beyond the second generation.

The Big Frame by Turkey Red and its reciprocal cross have given the most promise so far and have been studied more in detail than the rest of our crosses. They present several characters contrasting sufficiently to produce variations capable of statistical study. Turkey Red is bearded, fine-stemmed, narrow-leaved and is a dark rich green in color. The stool is abundant and spreads close to the ground when young. Big Frame is awnless, rather coarse-stemmed, broad-leaved, and is a yellow green in color. It produces scantier stool than Turkey. The young stool is very erect. Big Frame is from 4 to 7 days earlier in maturity than Turkey. In only one character could a definite form be noticed the first generation. In respect to awns all first generation progeny has been intermediate. The second generation shows various combinations of the various contrasting characters. Some plants are awnless but in other respects show Turkey Red characters. The broad leaf, erect growth, and yellow green color frequently appear in bearded forms. Some of the young stools will have such combinations as broad yellow-green leaf and creeping stool, or erect stool with narrow dark green or yellow green leaves. Although both the parents are early in maturity, a very large majority of the progeny are late-maturing. The few exceptions have bred true in this respect. And all these early forms have had the Turkey Red type of straw, *i. e.*, fine and of medium length. Neither of these wheats is very tall, but nearly all the progeny is considerably above either parent in height. The variation of the progeny in the beard character was made the subject of statistical study. It was found that the first generation of the cross was in every case intermediate between the two parents in this character. In the second generation three forms appear—awnless, intermediate and bearded. The awnless and bearded breed true in the next generation and the intermediate form breaks up into the three forms, awnless, intermediate and bearded. The proportion in which they break up is very close to awnless 25 per cent, bearded 25 per cent and intermediate 50 per cent. These results are shown in the following table:

Heredity in Wheat Hybrids.

1905 Centgener No.	Bearded	Awnless	Intermediate
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
101	27.91	16.28	55.81
301	29.41	11.77	58.82
501	20.51	29.49	50.00
801	29.81	23.08	47.11
1001	19.15	21.28	59.57
2601	25.00	25.00	50.00
2701	30.51	17.80	51.69
3001	45.24	52.38	2.38
3401	34.88	16.18	48.84
3601	18.49	34.25	47.26
4201	23.39	14.04	62.57
Average <i>a</i>	25.906	20.927	53.167

The parents were both second and third generation, but were intermediate in every case.

a In making the average No. 3001 was omitted.

Mendel in his study of pea hybrids said that certain characters were dominant; *i. e.*, if a tall and dwarf form were crossed the first generation progeny would all be tall. In this case tallness is dominant. In the second generation 25 per cent would be dwarf and 75 per cent tall. All the dwarf forms would breed true and one-third of the tall forms. The other two-thirds of the tall forms, 50 per cent of the total progeny, would again break up according to the above law. There were then 25 per cent dwarf (true recessive) 25 per cent true tall (dominant), and 50 per cent false dominant. These false dominant were considered as true hybrids.

Now with reference to the transmission of the bearded character, we find that the first generation is intermediate. The progeny of this intermediate form breaks up into the three forms, awnless, intermediate and bearded. The awnless and bearded forms breed true in every case so far as observed. The intermediate forms so obtained, again breaks up into the three forms and more or less closely in conformity to the following ratio, awnless 25 per cent, bearded 25 per cent, intermediate 50 per cent. According then to the nomenclature of Mendel and his followers, the intermediate form may be considered as a true hybrid, a false dominant which carries its own brand upon its face.

PRACTICAL CORN BREEDING ON A LARGE SCALE.

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To convey a clear and definite understanding of our breeding methods it is necessary to describe fully each successive step, some of which are undoubtedly familiar to you all.

The successful breeder of plants will make as exhaustive a research for the proper environment for the individual as possible. He must always bear in mind that in the growth and development of an individual there are two influences or principles at work. These may be called inherent and external influences. The inherent influence is transmitted through generation after generation of ancestors and displays its force in anticipated characteristics.

Hardly less important is the external influence which is more apparently under the control of man. The environment must be such that it will give full play for the development of all inherent tendencies in the plant.

The selection of the plats of ground used for breeding purposes is thus made important. A fertile, well cultivated plat of some 3 or 4 acres, should be found where plant food and opportunity for growth are equal throughout. These plats may be called breeding blocks.

It is however, with the inherited tendencies and characters that the corn breeder must deal. It is within the scope of every corn grower to better the immediate conditions for growth of the corn plants.