17. EVALUATION OF SYNTHETIC VARIETIES IN THE BREEDING OF HYBRID MAIZE IN JAPAN

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In the Kikyogahara station the breeding of hybrid maize was started in 1938. The first step of the work was raising of varietal crossing hybrids in various combinations and examination of them. Many excellent F_1 hybrids, as Choko No. 161 and Choko No. 202 by varietal crossing and Ko No. 3 which was obtained by top crossing, were selected in this way and brought into practical use. All those varieties were F_1 hybrids between Japanese local flint and American dent varieties, and they surpassed many F_1 hybrids introduced from U.S.A. after the World War II.

Together with this work, breeding of inbred lines derived from the parental varieties of those excellent hybrids were carried out, and many double crossing hybrids superior to the varietal crossing hybrids were selected through examinations of single and then double crossings between the inbreds. The practical use of those double crossing hybrids, however, had to be given up because of difficulties in seed production as follows.

1) As the four parental lines used for double crossing are inbreds, they are poor in seed production and so sensitive to various environmental conditions that the maintenance of breeder's seed are difficult.

2) As it takes two years for the production of double crossing seed, it is difficult to make an exact plan for seed production in Japan where field crop is often damaged by typhoon, drought and others.

3) The production of hybrid seed must be practised by farmers in Japan, while in U.S.A. it is carried out by seed companies with excellent technicians. For instance, the practice of varietal crossing has been placed in farmer's care in this country. However it is very difficult to produce double cross seed under such a system, because the work requires an advanced technique.

4) Furthermore, the production of hybrid seed which requires much labor for detasseling etc. has been confronted with a difficulty even in varietal crossing because of a shortage of farm labor owing to the change in social situation. And it has reflected on the price of seed.

To save the situation, breeding of synthetic varieties superior to varietal crossing hybrids and equal to double crossing hybrids has been undertaken by means of varietal crossing with synthetic varieties which were bred from flint and dent inbred lines, respectively. The inbred lines used as materials for the synthetic variety were the ones which had been raised by discarding undesirable genes and accumulating desirable genes. Their high combining ability had been already evidenced by the double crossing. The examination of about 150 synthetic varieties thus obtained, however, showed that there was none superior to the recommended hybrid, Ko No. 3 regarding produc-

tivity.

In the process of the breeding, we had an intention to raise synthetic varieties by crossing inbred lines originated from Japanese local flint varieties with those from American dent ones on the basis of the experience of breeding for varietal hybrids. There was, however, wide difference between the two kinds of inbred lines in their characteristics, and while heterosis was remarkable in the F_1 generation, segregation of characters was very extensive in the later generation. Accordingly, we selected a large number of plants in the process of breeding of the synthetic varieties, and such intensive sive selection has probably resulted in loss of desirable genes and inbreeding depression. We suppose this is the reason why the productivity of the synthetic varieties has not reached the level of productivity of varietal crossing. In the families originated from flint and dent varieties respectively, the members in each family are rather alike in many characters, so high vigor is not remarkable in the F_1 generation of crosses between them. The breeding of synthetic varieties from each family, however, can quickly bring about good results because of the less segregation of characters in their progenies. The F_1 hybrids, between two synthetic varieties originated from different families were raised in this way. And it has been observed that they show high combining ability and are superior to the varietal hybrids in their productivity. Since 1961, we raised a large number of hybrids between synthetic varieties and also between open-pollinated variety and synthetic variety. We have carried out yield trials on them, obtaining satisfactory results as follows.

For breeding of hybrid maize, we started yield trials on the varietal crossing (including top crossing) in 1938, on the double crossing in 1954 and on the crossing between synthetic varieties in 1961, raising many new F_1 hybrids every year based on the results of each year's experiments. We had a slightly different aim of breeding each year and the three methods of crossing were adopted. The results are shown by the data for four years during which the main part of yield trial was continued (refer Fig. 1 and Table 1).

The varieties used as basic materials were; dent type—Wood's Imp. Golden, Reid's Early Yellow, Jarirs Golden Prolific, Golden, Reld's Yellow Dent, Wisconsin No. 690 and Wis. 531; flint type—local varieties, such as Ehime-otomorokoshi No. 1, Otomorokoshi and Okuzuruwase, etc.; and inbreds originated from those varieties mentioned above.

In the varietal hybrids, the yield per "Are" (1/100 hectare) ranges from 30 to 70 kg, showing an increase of about 20 per cent on an average over the check variety, Nagano No. 1. More than 80 per cent of the varietal hybrids tried out are superior to the check variety, and their yield shows such a remarkable increase as 26 per cent on an average. The superiority of the F_1 hybrids is clearly seen in these results.

For the double crossing hybrids, Choko No. 202 (varietal hybrid) was used as the check variety. It is an excellent F_1 hybrid selected by yield trials of varietal crossing mentioned above, showing a yield-increase of about 20 per cent over Nagano No. 1. In the double crossing hybrids, the yield per "Are" is 35–75 kg, and shows an increase of about 6 per cent on an average over Choko No. 202. Sixty-eight per cent of the hybrids tried out are superior to the check variety, and their yield shows an increase of 16 per cent on an average. The frequency of sterile plants are considerably lower in these hybrids as in the hybrids between synthetics owing to the selection during the process of the breeding of inbred lines.

For the hybrids between synthetics, Ko No. 3 was the check variety. It is an early and high yield top crossing hybrid raised after Choko No. 202, showing an increase of about 20 per cent over the latter in the yield. The hybrids between synthetics tried out

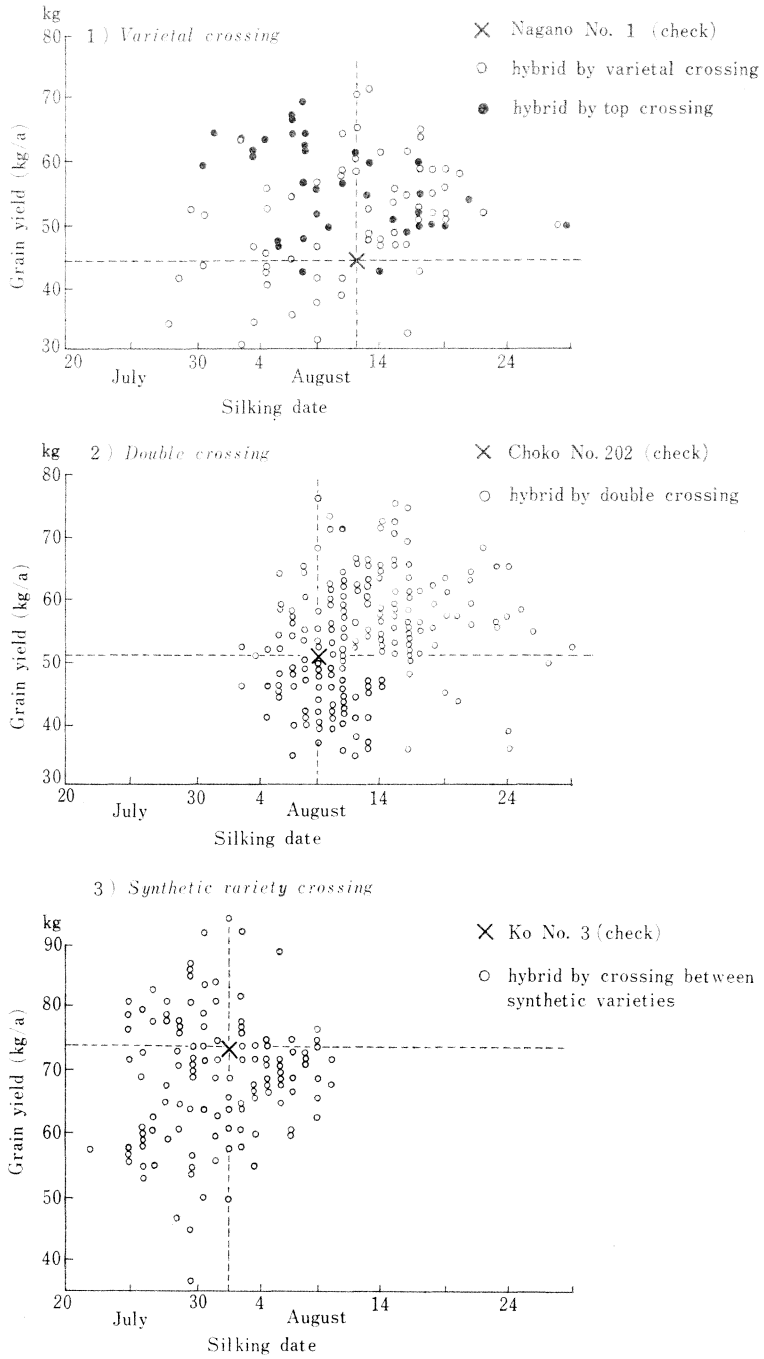

Fig. 1. Relationships between grain yield and silking date in cases of varietal crossing, double crossing and synthetic variety crossing.

Table 1. Results of yield trials obtained on hybrids of three methods of crossing.

Method of crossing	Year	Means of characteristics of all hybrid combinations							Means of characteristics of hydrid combinations over the check yield							
		Number of hybrid combinations	Silking date	Freq. of sterile plant	Grain yield per "Are"	Yield ratio to check	Weight of 1,000 grains	Number of grain per hill	Number of hybrid combinations	Percentage of combinations over check yield	Silking date	Freq. of sterile plant	Grain yield per "Are"	Yield ratio to check	Weight of 1,000 grains	Number of grain per hill
Varietal crossing	1952	23	Aug. 13	1.30%	56.6kg	126%	345g	445	19	82.6%	Aug. 15	1.43%	59.8kg	134%	357g	456
	1953	33	Aug. 13	2.30	45.7	120	285	435	26	78.8	Aug. 14	2.03	49.6	131	289	466
	1954	23	Aug. 16	0.73	50.0	116	279	487	21	91.3	Aug. 16	0.67	51.0	118	281	493
	1955	35	Aug. 6	3.97	54.8	114	347	432	26	74.3	Aug. 6	2.32	59.2	124	351	461
	Mean	(114)*	Aug. 11	2.30	51.6	119	315	446	(92)*	81.8	Aug. 12	1.68	54.8	126	319	469
(check) Nagano No. 1	Mean	—	Aug. 11	3.85	43.5	100	303	391	—	—	Aug. 11	3.85	43.5	100	303	391
Double crossing	1956	79	Aug. 9	1.22	44.3	99	361	333	42	53.2	Aug. 8	0.57	49.3	110	366	366
	1957	57	Aug. 13	0.63	61.0	95	356	465	22	38.6	Aug. 13	0.64	68.5	106	368	507
	1959	61	Aug. 12	2.36	53.7	122	380	384	58	95.1	Aug. 12	2.07	54.2	123	380	388
	1960	46	Aug. 17	1.57	56.6	112	369	417	40	87.0	Aug. 17	0.95	58.8	117	372	430
	Mean	(243)*	Aug. 12	1.43	52.9	106	366	393	(162)*	68.5	Aug. 13	1.21	56.0	116	373	409
(check) Choko No. 202	Mean	—	Aug. 9	6.00	50.8	100	343	402	—	—	Aug. 9	6.00	50.8	100	343	402
Synthetic variety crossing	1964	66	July 31	1.36	69.1	96	351	533	25	37.9	Aug. 2	0.66	77.8	108	360	585
	1965	37	Aug. 3	2.23	61.4	91	317	524	10	27.0	Aug. 5	0.75	70.6	104	316	607
	1966	27	Aug. 6	0.75	69.6	97	336	563	10	37.0	Aug. 7	1.00	73.6	102	334	597
	1967	26	July 29	1.06	79.5	95	361	598	6	23.1	July 31	1.88	87.3	105	372	634
	Mean	(156)*	Aug. 2	1.41	69.1	95	342	547	(51)*	31.3	Aug. 3	0.89	76.7	106	348	598
(check) Ko No. 3	Mean	—	Aug. 2	0	73.7	100	314	635	—	—	Aug. 2	0	73.7	100	314	635

Note: *The figure in parenthesis shows the total number of hybrid combinations for four years.

are 95 per cent on an average in the yield ratio to the check variety. As the level of check varieties goes up, the efficiency of breeding is reduced comparatively. The average yield per "Are", however, is very high in the hybrids between synthetics being near to 70 kg, while it is in the region of 50 kg in the varietal and double crossing hybrids. Thirty per cent of the hybrids between synthetics tried out are superior to the check variety, and their yield shows an increase of 6 per cent on an average over the check variety. We have several hybrids between synthetics which yield more than 90 kg per "Are" in addition to being superior to the varietal and double crossing hybrids. Furthermore, the silking date is earlier by 10 days or so in the hybrids between synthetics than in the other two. This is a result of breeding with the aim of obtaining early and high yield hybrids in recent years.

The yield of maize can be shown by the product of three components of yield: number of hills per unit area × number of grains per hill × average weight of a single grain. Among these three components the number of hills per unit area is fixed, so the yield components are the frequency of sterile plants which has an effect on the number of hills, the number of grains per hill and the average weight of a single grain.

The comparison of these yield components among the three kinds of hybrids (Table 1) is as follows. The frequency of sterile plants is especially higher in the varietal crossing hybrids than in the other two. The number of grains per hill is: hybrids between synthetics>varietal hybrids>double crossing hybrids. The weight of 1,000 grains is: double crossing hybrids>hybrids between synthetics>varietal hybrids.

The correlations between the yield and the yield components are shown in Table 2. The correlation between the yield and the frequency of sterile plants is negative in each of the three kinds of hybrids. The coefficient of correlation is fairly high, −0.43, in the varietal hybrids, showing that the occurrence of sterile plants has a considerable effect on the yield. The correlation, however, is not so remarkable in the other two kinds of hybrids, showing a decrease in the effect in these hybrids.

The correlation between the yield and the number of grains per hill is remarkably high as shown by the coefficient of 0.7 or so in each of the three kinds of hybrids. The coefficient of correlation between the yield and the weight of 1,000 grains is +0.3 or so. These two kinds of correlation are: hybrids between synthetics>double crossing hybrids>varietal hybrids.

The above mentioned results explain that the number of grains per hill is the most influential component of the yield, the weight of 1,000 grains comes next, and the frequency of sterile plants also has a considerable effect on the yield of maize which is poor in compensating ability for missed plants.

The comparison of yield among the three kinds of hybrids (Table 1) shows that they are in the following order: hybrids between synthetics> double crossing hybrids> varietal hybrids. The hybrids between synthetics are much superior to the other two in number of grains per hill, while they are a little superior to the varietal hybrids and inferior to the double hybrids in the weight of 1,000 grains. The weight of 1,000 grains, however, is comparatively low in the correlation with the yield (Table 2), while the number of grains per hill is higher in the correlation with the yield. The hybrids between synthetics are also lower in the frequency of sterile plants (Table 1). Therefore the hybrids between synthetics in respect of yield components are much superior to other hybrids.

The double crossing hybrids are superior to the other two in the weight of 1,000 grains and as low as the hybrids between synthetics in the frequency of sterile plants. But they are the lowest in the number of grains per hill which is the most influential

component. The inferiority of them in the yield to the hybrids between synthetics is thought to be due to this fault.

At present we can not genetically explain the superiority of the hybrids between synthetics. This kind of hybrid, however, compares with the double crossing hybrids in the yield. So, taking into consideration the easiness of seed production and economic advantage, it is advisable that the breeding of maize is designed for utilization of the hybrids between synthetics in future.

Discussion

A. Anós, Spain: Have you checked the weight of each ear in the different hybrids? I think it is more important than the weight of 1,000 grains because we have realized that maximum yields are with the ear of 250–300 g.

Answer: I have checked the weight of ear and I also think that maximum yields are with the ear of 250–300 g, however, in general, the weight of an ear consists of the number of kernels per an ear and the weight of a kernel.

E. W. Sprague, Thailand: You indicate that the F_1 yield was satisfactory between synthetic crosses. How much decrease was observed in advanced generation? Assuming there was a depression do you think you could increase the performance of the advanced generation through population improvement and eliminate the need for hybrids types seed production.

Answer: 1. I have no accurate data, but I think the decrease in advanced generation would be about 15–20 percent. 2. I think I can increase the performance of a synthetic variety to some extent, but still it may be inferior to that of a hybrid between synthetic varieties.

A. Senanarong, Thailand: Do you have any information on the yield of the F_2 or F_3 of the hybrid between synthetics? How many percent decrease from F_1?

Answer: The answer to your question is same as the previous one.

T. Gonzales, Philippines: You concluded that it is advisable that breeding of maize is designed for utilization of the hybrids between synthetics in the future. How many generations will the farmer use these synthetic hybrids to be profitable?

Answer: Farmers will use only the first generation of the hybrid.

D. Sharma, India: What is meant by the family in context with the breeding of synthetic variety from each family.

Answer: The family means a group of inbred lines originated from a particular flint or dent variety.

D. Sharma, India: On page 146 you state that large number of plants were selected, even then you account inbreeding depression due to selection. How is this possible?

Answer: If we select strictly desirable plants from the hybrid population in which heterosis is remarkable because different types (dent and flint) are combined, the decrease of yield will be brought about in the following generation as a result of the inbreeding effect of selection even if large number of plants are selected.