Barley stripe mosaic virus as the cause of sterility interaction between barley varieties

Sandfær, Jens

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appeared: XXY patients had the inactive X with an equal labelling pattern along both arms of the chromosomes, while in the XX male the distal part of the inactive X on its short arm was at most faintly labelled. Judging from the intensity of the labelling pattern of other chromosomes in the karyotype, the labelling of the short arm of the inactive X by XX males and of the Y chromsome in XXY patients ceased at the same time. In the XX male most of the long arm of the Y chromosome obviously has been translocated to the short arm of the inactive X chromosome. Despite the late replication of the X chromosome the Y chromosome showed its own replication behaviour (Fig. 1). The observation was thus in agreement with the hypothesis put forward by FERGUSON-SMITH (1966), according to which the male sex of the XX patients may be a result of interchange between the X and Y chromosomes in meiosis. But findings by OHNO et al. (1962) showed that if an autosomal locus in mice is translocated to the inactivated X, this locus could also be inactivated. FERGUSON-SMITH suggested that this might also apply to the Y chromosome in man if this chromosome is translocated to the inactive X.

The autoradiographic studies reported here indicate, however, that the process of inactivation may not be generalized. In the translocation in human material containing the inactive X and Y chromosome appears to preserve its own original replication behaviour and sex determinating activity.

Institute of Clinical Bacteriology, University of Umeå, Sweden; 2. Medical Clinic, University of Hamburg, Germany; Institute of Genetics, University of Lund, Sweden

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S. Bergman
Institute of Clinical Bacteriology
S-901 85 Umeå, Sweden

JENS SANDFÆR: Barley stripe mosaic virus as the cause of sterility interaction between barley varieties

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A previous paper (SANDFÆR 1968) described a sterility interaction in a mixture of two spring barley varieties, Tystofte Prentice and Svalöf Freja. In the mixture the percentage of sterile flowers in Freja increased considerably over that found in pure stand, whereas in T. Prentice a small decrease in the percentage of sterile flowers was observed. The experiments excluded competition for light and carbon dioxide, root competition, and cross-sterility as possible causes of the interaction, but failed to pinpoint the mechanism involved.

It has now been found that the T. Prentice line used in our experiments carries barley stripe mosaic virus (BSMV). The virus has been identified by serodiagnosis, electron microscopy and sap inoculation of the barley varieties Atsel and Black Hulless, known to be very sensitive to the virus and to exhibit clear-cut symptoms. This virus can be transmitted through the seeds and by rubbing infected leaves against the leaves of healthy plants. The most common symptoms of BSMV are bleached, yellow, or light green stripes of various lengths, light green to yellow mottling, and sometimes almost complete yellowing of the leaves (MOSEMAN 1968). The virus has not previously been found in Denmark, and the leaf symptoms are absent in T. Prentice under many growing-conditions, which explains why the plants in our first experiments were not virus tested.

Infected plants are known to have more sterile flowers than uninfected plants (INOUYE 1962; MCKINNEY and GREELEY 1965; MOSEMAN 1968), and experiments were thus made to

Table 1. The percentage of sterile flowers in Freja

Treatment	Mean of three replications
Non-inoculated	10.1
Inoculated with sap from:	
Freja	8.0
Virus-free T. Prentice	10.4
Virus-infected T. Prentice	29.3*

* Difference between this and the other treatments highly significant. No other differences significant.

Table 2. The percentage of sterile flowers in Freja and T. Prentice grown in pure stand and in 1 : 1 mixtures

Variety--treatment	No. of replications	Mean
Freja—pure stand	4	6.2
Freja—mixture with virus-free T. Prentice	4	6.5
Freja—mixture with virus-infected T. Prentice	1	13.9
Virus-infected T. Prentice—pure stand	1	11.6
Virus-infected T. Prentice—mixture with Freja	1	11.0
Virus-free T. Prentice—pure stand	1	7.1
Virus-free T. Prentice—mixture with Freja	4	7.2

test whether BSMV might be the cause of the sterility interaction between T. Prentice and Freja.

A virus-free T. Prentice line was raised from sixty virus-free plants selected from a sample with 40 per cent healthy plants, and tested three times during the growth period by sap inoculation into Atsel or Black Hulless. The influence of the virus on sterility was then tested in the greenhouse by inoculating Freja plants with sap from virus-free and virus-infected T. Prentice plants. The percentages of sterile flowers in Table 1 are based on approximately 2000 flowers in each of three replications. Whilst there were no significant differences between non-inoculated Freja and Freja inoculated with sap from Freja or from virus-free T. Prentice, there was a three-fold increase in the percentage of sterile flowers in Freja inoculated with sap from virus-infected T. Prentice plants.

To see whether a sterility interaction also occurs in a mixture of Freja and virus-free T. Prentice, we grew Freja, virus-free T. Prentice and normal T. Prentice containing about 60 per cent virus-infected plants in pure stand and in mixtures. The plants were raised in a growth chamber with only one replication of some of the treatments. The percentage of sterile flowers in each replication is based on approximately 3500 flowers.

The sterility of Freja in pure stand and in mixture with the virus-free T. Prentice differed only insignificantly, but in agreement with previous experiments a considerable increase in sterility was observed in mixtures with virus-infected T. Prentice (Table 2). These results clearly indicate that BSMV is the cause of the sterility interaction between Freja and T. Prentice. The sterility of the virus-infected T. Prentice line was slightly and insignificantly lower in mixture with Freja than in pure stand, and since the same tendency was found in the previous experiments (SANDFÆR 1968), the difference may be real. In a virus-infected T. Prentice population a certain percentage of the plants will by virus-free, and the probability of infection of these plants decreases when the virus-infected plants are diluted with virus-free Freja plants.

The percentage of sterile flowers in the virus-infected T. Prentice was about 11 and that in virus-free T. Prentice about 7, which is close to the percentage found in Freja under the same growing conditions. This supports that the rather high sterility normally found in T. Prentice is mainly due to BSMV.

If the induced sterility found in Freja grown in mixture with T. Prentice is caused by BSMV, it is to be expected that progeny of Freja plants from the mixture with T. Prentice will maintain an increased sterility. From a Freja—T. Prentice mixture, Freja seeds originating from 17 heads were selected and sown in the field in 1968. The frequency of sterile flowers was determined in the heads on the two longest culms of 150 plants. Averaged over all plants the percentage of sterile flowers was 18.7 as compared with 3.7 per cent in a control material of Freja plants originating from a normal seed lot. The induced sterility in Freja is thus maintained in the next generation after removal of Freja from the mixture with T. Prentice.

The BSM-virus has never been found by us in normal seed samples of Freja, but evidence is available that the virus infection builds up gradually in Freja when it is grown in successive generations in mixture with T. Prentice. A mixture originally consisting of 95 per cent Freja and 5 per cent T. Prentice was grown from 1964 to 1968. Of the Freja seeds harvested in 1964, 8.2 per cent carried BSMV. In seeds harvested in 1966 and 1968 the percentages were 28.8 and 44.3 respectively, which shows that the virus spreads in the Freja component of the mixture. The percentage of sterile flowers in Freja in the mixture was not determined in the first year, but in 1965, 1966, 1967, and 1968 it was found to be 5.8, 9.7, 13.4, and 15.9, which indicates a correspondence between the frequency of virus-infected plants and the average percentage of sterile flowers in Freja.

In summary: About 60 per cent of the plants in the T. Prentice line used in our competition experiments carried BSMV. Virus-free T. Prentice plants isolated from this line showed less flower sterility than the infected line. Inoculation of Freja with sap from virus-infected T. Prentice plants resulted in a considerable increase in flower sterility in Freja whereas no effect was found after inoculation with sap from virus-free T. Prentice plants. While the sterility of Freja was increased in mixtures with the virus-infected T. Prentice line, no sterility interaction was observed in mixture with virus-free T. Prentice plants. Freja from a mixture with infected T. Prentice maintained a high sterility also in the next generation after removal from the mixture. The virus infection was found in Freja only when it was grown in mixture with virus-infected T. Prentice, and a correspondence was found between the frequency of virus-infected seeds and the degree of sterility in Freja. It is concluded that BSMV is the cause of the sterility interaction between Freja and T. Prentice.

In barley samples from the variety collection at the Royal Veterinary and Agricultural University, Copenhagen, several of the old varieties were found to be infected with BSMV, whereas no virus infection was detected in any of the newer varieties even when these had been maintained in the collection for a number of years. Therefore it seems probable that the virus was formerly more common in Denmark, but has been eliminated unconsciously through selection for fertility in the breeding and through seed cleaning, by which all small shrivelled kernels, among which most of the virus-infected seeds are found (INOUYE 1962), are discarded. The results of these experiments will be published in detail elsewhere.

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Agricultural Research Department, Danish Atomic Energy Commission, Research Establishment Risö, DK-4000 Roskilde, Denmark

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