SEMI-STERILITY IN SOME TWO-ROWED VARIETIES OF BARLEY FOR MALT AND THE BARLEY STRIPE MOSAIC VIRUS AS ITS POSSIBLE CAUSE

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INTRODUCTION

Some two-rowed varieties of barley, such as Chevalier and Hokudai No. 1, had long been grown in Hokkaido as the materials for malt with invariable success. However, in about 1930 some of the growers became aware of a fact that semi-sterility* occurred very commonly in these varieties, which resulted in an appreciable decrease in yield. And, this became before long so marked that some of the farmers gave up growing barley for malt. Consequently, a renewal of the variety and improvement of the culture method were tried, and at the same time efforts had been devoted to clarify the cause of the semi-sterility.

Yamamoto, Y. and Terada (1940) and Sutō (1942) demonstrated experimentally that rainfall at the time of anthesis caused sterility. Nevertheless, Sutō (1942) was of the opinion that the semi-sterility so prevalent in Hokkaido might not be wholly attributed to such a simple cause, but that the unfavorable conditions of the soil might be its principal cause. He pointed out in his paper that the semi-sterile plants were stunted in general ; their height was below normal, their appearance slender, their roots underdeveloped and most of the heads did not emerge completely from the sheaths.

Yamamoto, T. (1950, 1952, and 1955), using two strains with high and low fertility isolated from Moravia, investigated the physiological mechanism of the semi-sterility. As a result, it was confirmed that the semi-sterility was mostly due to the unsplitted anthers and also that the degree of sterility was affected by the sowing time and other physiological factors.

Yamamoto, Y. (1942) and Takano (1942) provided the evidence of the fact that the degree of sterility differed considerably among different varieties or strains even under the same growing condition. Takano, on this basis, emphasized the renewal of the variety in order to face the difficult situation in barley growing in Hokkaido. This led to a concept that the cause of the semi-sterility was genetical rather than physiological.

Taking these findings in account, it seems most reasonable to consider that the occurrence of semi-sterility might be due to the physiological

* This is popularly called in Hokkaido as the lantern head or simply as lantern because of the transparence of the unfertilized spikelets.

disorder of the plant, which was genetically controlled in the issue. Since the genetical behavior was quite obscure, Takahashi and Akaki made a genetical experiment using fertile and semi-sterile strains of Moravia. The results suggested maternal inheritance of the semi-sterility. However, there were some illegitimate behaviors of the hybrids and the parental lines. Moreover, in the course of another genetic experiment conducted in 1956, there was a prevalent occurrence of morbid symptoms similar to those of the so-called yellow mosaic and stripe diseases on some of the genetic materials. These suggested that the semi-sterility might be caused by the infection of a seed-borne virus disease. Therefore, Inouye made further inquiries from the phytopathological viewpoint and indicated that the barley stripe mosaic virus was probably the principal cause of the semi-sterility. In the following will be given the summarized results obtained thus far.

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STUDIES FROM THE GENETICAL VIEWPOINT

Comparison of the Fertility between Progenies of two Moravia Strains, M. 40 and M. 14

Pedigree culture of two strains, M. 40 and M. 14, both isolated in 1947 from a variety Moravia and given to us by T. Yamamoto in January 1953, was made for 4 years. Five to two lines of descent from both strains, each line consisting of about 30 plants, were raised from 1954 to 1956. The fertility of each line was determined by the average of 30 plants, each of which 4 to 5 well-developed heads were investigated. The summarized result was given in Table 1. It became evident from this pedigree culture that the progeny lines from M. 40 strain were always as fertile as in the original one, while M. 14 derived lines were considerably lower in fertility than M. 40 lines, although the fertility of M. 14 seemed to be somewhat improved at Kurashiki. Therefore, high and low fertility of both strains were deemed to be their inherent character.

It should also be noted that in contrast with M. 40 derived lines the fertility means differed markedly among M. 14 derived lines and there was also a large difference between the individuals within a progeny line. Thus, the difference in the average between progeny lines of M. 14 was statistically significant in all three years from 1954 to 1956, and moreover, the standard deviation of the average of each line was 3 to 7 times as high

TABLE 1

Comparison of fertility between two strains, M. 40 and M. 14, isolated from a variety Moravia (Mean and its standard deviation).

Strains	Original (Sapporo)	1953	1954	1955	1956
M. 40	95.1	95.4 ± 3.996	97.1 ± 2.100 97.7 ± 1.414 97.6 ± 2.261 97.2 ± 2.282 97.4 ± 1.881	93.8 ± 3.049 93.6 ± 3.739	
(Mean)	**95.1**	**95.4 ± 3.996**	**97.4 ± 2.013**	**93.7 ± 3.412**	
M. 14	58.2	67.6 ± 13.899	72.1 ± 11.376 94.0 ± 8.050 77.1 ± 7.990 87.5 ± 9.241 59.4 ± 9.226	74.7 ± 12.908 49.7 ± 16.198 50.0 ± 15.381 52.2 ± 12.058 66.2 ± 15.501	97.6 ± 13.948 62.7 ± 8.214 66.6 ± 6.637
(Mean)	**58.2**	**67.6 ± 13.899**	**78.0 ± 9.258**	**58.6 ± 14.500**	**69.6 ± 10.101**

as those of the M. 40 lines. The growth of the M. 40 derived lines was quite uniform and normal, whereas the M. 14 derived lines were less vigorous and unequal in plant height, and many heads of them did not emerge completely from the sheaths.

On the Reciprocal Crosses between M. 14 and M. 40

In 1953, reciprocal crosses were made between M. 40 and M. 14, and F_1 plants were grown together with their parental lines. In the following year, a total of 200 F_2 plants of each cross and 50 plants of each parental line were raised on 4 replicated plots. Table 2 shows mean fertilities and

TABLE 2

Average fertilities of F_1 and F_2 of the reciprocal crosses between M. 40 and M. 14 and their parents.

Crosses or Parents		F_1	F_2
M. 40 (♀) × M. 14 (♂)		95.0 ± 6.452	94.1 ± 5.764
M. 14 (♀) × M. 40 (♂)		90.2 ± 6.402	83.6 ± 9.260
Parents	M. 40	97.1 ± 2.100	93.8 ± 3.049
	M. 14	72.1 ± 11.376	74.7 ± 12.908

standard deviations of F_1, F_2 and their parental lines. Variations in the percentage of fertility of F_2's and parents are shown in Fig. 1.

According to Table 2, M. 40 line is highly fertile, while M. 14 line is about 25 % lower in fertility than M. 40 line. It is interesting to note that the fertility of the F_1 plants of the cross with M. 14 as its female parent is 4.8 % lower than that of the cross with M. 40 as the female parent, the difference being statistically significant on a 5 % level. A similar situa-

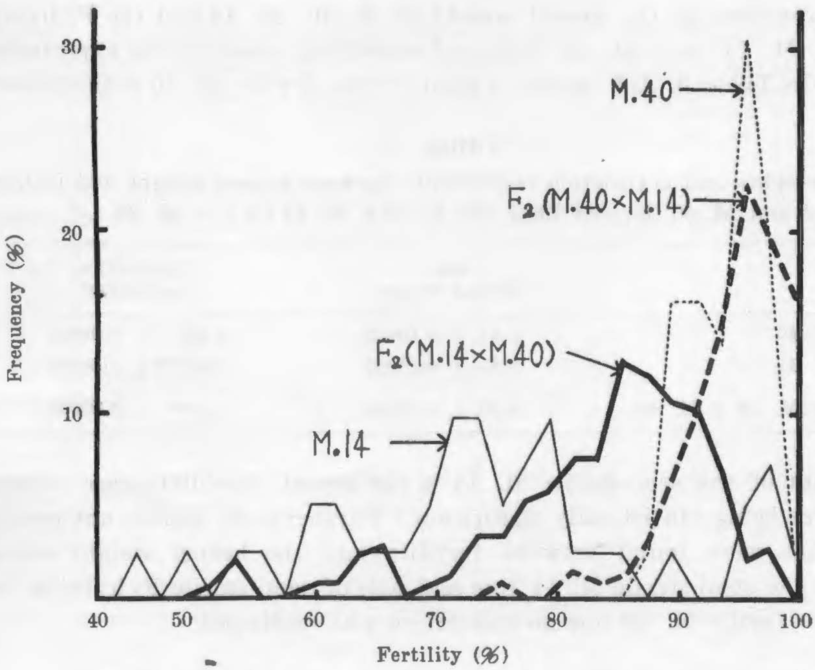

Fig. 1. Variations in fertility of plants from M. 14, M. 40 and the F_2's of their reciprocal crosses.

tion is found in their F_2 generation: F_2 of M. 40 (♀) × M. 14 (♂) is as high in fertility as the female parent, M. 40, though the standard deviation is somewhat larger, while the reciprocal F_2 population is 10.5 % less fertile than the F_2 derived from the cross with M. 40 as its female parent. Such differences existing between reciprocal F_1 and F_2 populations suggest that the semi-sterility under consideration may be inherited through maternal cytoplasm.

However, the degree of sterility differs considerably among the F_1 and F_2 of a M. 14 × M. 40 cross and their female parent, M. 14: M. 14 is the highest, which is followed by F_2 and finally by F_1. Furthermore, as shown in Tables 1 and 2 and also in Fig. 1, the variation in fertilities of F_1 and F_2 is larger than that of M. 40, but less than that of M. 14, and it appears that the magnitude of the variations in fertility varies with the percentage of fertility of the populations and the lines. These facts are difficult to explain adequately on the basis of the ordinary maternal inheritance.

Relation of Kernel Weight with Fertility

As a rule, partial sterility results in heavier kernel weight. For example, Meguro and Yamasaki (1956) showed that barley kernels of artificially partially fertilized heads were heavier than those of normally fertilized heads.

Comparison of the kernel weight of M. 40, M. 14 and the F_2 hybrids between M. 14 and M. 40 disclosed something contrary to expectation. As seen in Table 3, 100 kernel weight of the fertile M. 40 is the highest,

TABLE 3

Kernel weights and correlation ccefficients between kernel weight and fertility in M. 14 and M. 40 derived lines and F_2 of a M. 14 (♀) × M. 40 (♂) cross.

	100 Kernel weight	Correlation coefficient
M. 40	4.87 ± 0.04633	0.239 ± 0.09813
M. 14	3.87 ± 0.05996	0.613** ± 0.06742
F_2 (M. 14 × M. 40)	4.20 ± 0.03015	0.280* ± 0.05009

while that of the semi-sterile M. 14 is the lowest, the difference between these three being statistically significant. Furthermore, significant positive correlations were found between fertility and the kernel weight among plants of the semi-sterile M. 14 line and also of semi-sterile F_2 hybrids, but within the fertile M. 40 line no correlation was confirmed.

Occurrence of Disease-like Symptoms on Hybrids with M. 14

In 1955-1956, F_2 hybrids from the reciprocal crosses of M. 40 and M. 14 with Aohadaka, together with parents, were grown in order to investigate the interaction of the "semi-sterility factor" in M. 14 with u_4u_4, another semi-sterile gene in Aohadaka (Takahashi, Yamamoto and Yasuda 1953). It was reaffirmed in this experiment that the F_2 hybrids with M. 14 as the female parent, and M. 14 line as well, were less vigorous and many of their heads did not emerge completely from the sheaths. However, such "abnormal" plants, though small in number, were also found scattered on the plots of M. 40 and F_2 hybrids with M. 40 as the female parents. Moreover, a plant of Aohadaka close to F_2 hybrids with M. 14 had also a similar appearance.

It is noted here that almost all of these "abnormal" plants have developed the following yellow mosaic-like symptoms with brown stripes. Namely, pale green to yellow spots and irregular stripes were found on the leaves of the abnormal plants. In many cases, brown necrotic streaks were developed and whole leaves turned brownish. Such mosaic symptoms were found often also on the leaf-sheaths and stems (Plate I, Fig. 1). These leaves were sometimes shriveled or twisted and more or less small in size as compared with the normal ones.

Abundant occurrence of pronounced mosaic and necrotic symptoms as such naturally led us to a supposition that the semi-sterility of at least M. 14 might be due to the infection from a kind of mosaic virus, probably of seed-borne, and if so, abnormal growth, decrease in kernel weight, large variability in fertility, as well as maternal inheritance-like transmission of semi-sterility will all be explained adequately on this basis. A series of pathological surveys were, therefore, commenced by Inouye to ascertain this supposition.

EXPERIMENTS FROM THE PHYTOPATHOLOGICAL VIEWPOINT

The characteristic symptoms on the plants of the semi-sterile strain of Moravia, according to the field observation in 1956, seemed not to be those of the diseases caused by any kind of parasitic organisms, but of a virus disease. To confirm this, phytopathological experiments were carried out.

Transmission of the Mosaic Symptoms and Identification as a Virus Disease

In a preliminary test, many seedlings with mosaic symptom appeared from the seeds of M. 14 grown in 1955: yellowish green or whitish yellow or grayish white spots and streaks developed on the first leaves of the seedlings. Chlorotic symptoms were seen at the tip or the base of many primary leaves. These mosaic seedlings were generally stunted in some degree. The seeds from some plants taken at random from the F_2 of a M. 14 (♀) × Aohadaka (♂) cross cultivated in 1956 were sown, and the seedlings with mosaic symptoms were counted. As seen in Table 4, 454 out of 670

TABLE 4

Seed-borne infections of seedlings grown from the seeds of the F_2 plants of a M. 14 (♀) × Aohadaka (♂) cross.

	Seedlings examined	Seedlings healthy appearence	Mosaic seedlings	Symptoms of mosaic seedling		
				Severe	Moderate	Faint
No.	670	216	454	117	240	97
%	100.0	32.2	67.8			

Final counts were made at the 3rd leaf stage

seedlings (67.8 %) carried mosaic symptoms. Therefore, it was recognized that the mosaic symptoms of the seedling were apparently seed-borne.

As stated before, mosaic symptoms were observed on a single plant of Aohadaka which stood closely to F_2 hybrids between M. 14 and Aohadaka, which had expressed mosaic symptoms. This suggested that the transmission of the symptoms to the Aohadaka plant might be due to the inter-plant contact. Healthy seedlings were inoculated by juice expressed from mosaic seedlings of M. 14 and mosaic leaves of some F_2 hybrids of M. 14 grown in the field (July, 1956, under glasshouse condition). After 3～4 days, necrotic spots and streaks appeared on the inoculated leaves and the mosaic symptoms developed on the youngest leaves. In some varieties, heavily mottled leaves turned entirely yellowish. A pronounced chlorosis was followed occasionally by a necrosis in severe infections. In many cases brown necrotic spots, dushes and streaks occurred on the leaves which had already unfolded before the first symptoms appeared. Fig. 2 of Plate I shows the symptoms on the leaves of the varieties, Omugi No. 2 and Aidzu No. 4, both mechanically infected with the disease. Dwarfing of the inoculated plants was marked as seen in Figs. 2 and 3, where Shunsei and Moravia were inoculated at the first and the third leaf stage, respectively. The symptoms on a barley seedling infected artificially were more severe than the seed-borne symptoms. Seed- and sap-transmissible systemic mosaic symptoms might be caused by a seed-borne virus, which was a reasonable cause of mosaic symptoms characteristic to M. 14 strain.

Transmission by inter-plant contact and by infected juices was tested by a series of inoculations by various methods. As seen in Table 5, there

TABLE 5

Transmission by inter-plant contacts and by infected juices.

	Treatment	Occurrence of infection
1	Rubbed the healthy leaves of seedlings with the infected ones	3/17
2	After dusting carborundum, treated the same way as (1)	2/ 9
3	After dusting fine dry soil, treated the same way as (1)	0/15
4	Sprayed infected juice	0/ 8
5	After dusting carborundum, treated the same way as (4)	0/10
6	After dusting fine dry soil, treated the same as (4)	0/ 9
7	Handled leaves with fingers by which crushed infected leaves	5/19
8	Rubbing method, without carborundum	8/10
9	Rubbing method, with carborundum	10/10

were many chances of infection from diseased to healthy seedlings by plant contact or rough handlings with contaminated fingers. The disease was easily transmitted by the leaf-wiping method with the juices of infected leaves, and was more easily transmitted using carborundum as an abrasive. The symptoms caused by inter-plant contact were almost the same as those by the sap inoculation, but brown necrotic lines or streaks developed along the margin or midrib of the leaf where the infections occurred.

There has never been a sign of infection of this disease through the soil, according to the field observations and some experiments with the infested soil.

The insect transmission was also examined, using a kind of aphid and planthopper which migrated on barley grown in glasshouse (June, 1956). These insects, after cultured on diseased barley, transferred to some healthy plants and fed 1 and 3 days. The result proved to be negative.

The characteristic X-body is generally found in the epidermal cells of

Fig. 2 Plants uninoculated (right) and those inoculated at their first leaf stage (left). Variety : Shunsei.

Fig. 3 Plants uninoculated (right) and those inoculated at their third leaf stage (left). Variety : Moravia.

cereal crop plants infected with the known virus diseases in Japan. The epidermis of infected seedlings and mosaic leaves of F_2 hybrid with M. 14 were stripped and stained by orange GG, safranin, basic fuchsin, eosin or methylen-blue, and examined under the microscope. No X-body was found, however.

Host range of the causal virus has not been studied in detail as yet, but the following species proved to be susceptible to the virus ; *Hordeum vulgare, Triticum sativum, Secale cereale, Avena sativa, Panicum miliaceum and Lolium perenne. Dactylis glomerata, Agropyron semicostatum, Nicotiana tabacum* and *N. glutinosa* were not susceptible.

The possible cause of semi-sterility and characteristic mosaic symptoms of M. 14, from above results obtained, may be a virus disease. And, this is a seed-borne virus disease new to Japan, which may be the same as the barley stripe mosaic in North America, as described in another paragraph.

Semi-sterility of Two-rowed Barleys in Hokkaido and a Seed-borne Virus Disease

It has been ascertained by the foregoing experiments that a seed-borne virus disease may be the possible cause of semi-sterility of M. 14 barley. Therefore, further studies were made to ascertain whether the virus disease was also responsible for the semi-sterility of two-rowed varieties prevalent in Hokkaido.

In the first experiment, the following materials were used which were supplied from Sapporo Factory, Nippon Beer Co., in Hokkaido: (a) matured 10 semi-sterile plants of Shunsei variety obtained from Furano, Hokkaido, in 1956, (b) seed samples of Shunsei and Nissei varieties produced at the nurseries of Naebo and Shin-Kotoni, Hokkaido, in 1956. Fifty seeds taken at random from each of the 10 semi-sterile plants of Shunsei and from the samples from Naebo and Shin-Kotoni. Seeds were sown 7×7 cm apart in wooden boxes. Seedlings grown had been examined every day, until the third leaves were unfolded. Infected seedlings were discarded when first observed to avoid plant to plant contact. Recovery of the virus from 5 mosaic seedlings taken from each of 10 semi-sterile plants was tested on healthy susceptible barley seedlings. Table 6 shows that the percentages of sterility and the infected seedlings were 0 to 71 and 53 to 100, respectively, in the 10 semi-sterile Shunsei plants. Correlation between both characters was as high as + 0.92, which proved to be significant on 1 % level, but no correlation was found between the semi-sterility and the germination percentage. All the viruses from the seedlings sampled were recovered on healthy barley seedlings.

In the 2nd experiment, seeds from 60 lines of 6 semi-sterile strains, A, B, C, D, E and F, isolated from Harbin two-rowed were used, which were

TABLE 6

Detection of seed-borne infection in the seedlings grown from the seeds of semi-sterile plants of Shunsei barley collected at Furano, and seed samples of Shunsei and Nissei barley from Naebo and Shin-Kotoni nurseries, Hokkaido, in 1956.

No. of plant	Sterility %	Seeds sown	Seeds germinated	Seedlings diseased	Seed-borne infection %	Recovery of virus
1	71	32	30	27	90.0	+
2	64	46	43	40	93.0	+
3	52	53	53	50	94.3	+
4	56	50	49	43	87.8	+
5	68	29	25	25	100.0	+
6	28	50	47	37	78.8	+
7	55	50	48	41	85.4	+
8	0	50	49	26	53.0	+
9	69	31	31	29	93.5	+
10	44	37	35	31	88.5	+
Total	28.3	428	410	349	81.5	
Shunsei (Naebo)		50	49	0	0	—
Shunsei (Shin-Kotoni)		50	50	0	0	—
Nissei (Shin-Kotoni)		50	50	0	0	—

Seeds were sown on Sept. 5, final count on Sept. 28, 1956

supplied by the Kitami Branch of the Hokkaido Agricultural Experiment Station, Memanbetzu, Hokkaido, in 1956. The semi-sterility per cent of these 6 strains in the 3-year period, 1954–1956, are presented in Table. 7. Their seedling test was made in the same way as in the above experiment, the results of which are shown in Table 8. Seed-borne infections of the seed-

TABLE 7

Percentages of sterility of 6 strains isolated from Harbin two-rowed at Memanbetzu, Hokkaido, for a 3-year period, 1954—1956.

Year	Strain A	B	C	D	E	F
1954	4.1	23.0				8.0
1955	3.0	15.9				9.6
1956	0.7	14.5	32.6	32.2	29.3	10.0

Strains C, D, and E were isolated from strain B in the previous year

lings did not occur at all in A and E. But in C and D strains, they occurred in 8 and 9 out of 10 lines respectively, and in both B and F strains, in all lines. Both A and E strains were not immune, since they were susceptible to all of the viruses isolated from B, C, D and F strain of Harbin two-rowed,

TABLE 8

Detection of seed borne infection with the use of 6 strains of Harbin two-rowed. (c. f. Table 7.)

Strain	Sterility %	Seeds sown	Seeds germinated	Seedlings diseased	Seed-borne infection of strain %	Seed-borne infection in each line* %
A	0.7	489	478	0	0	
B	14.5	500	480	343	71.5	38.0 ~ 86.0
C	32.6	422	392	269	68.6	60.5 ~ 83.3
D	32.2	497	440	272	61.8	36.8 ~ 86.0
E	29.3	500	462	0	0	
F	10.0	500	487	354	72.7	64.0 ~ 85.7

* Those lines, in which the seedling infections were not detected, were omitted
Seeeds were sown on Sept. 19, final count on Oct. 14, 1956

semi-sterile Shunsei barley and M. 14 strain. Therefore, these two strains might be virus free or their percentages of seed infection were very low. There was no correlation between the sterility and seed-borne infection in 4 diseased strains. Relation of the sterility per cent of the lines with their seedling infection could not be surveyed, for the sterility of each line was not known.

Comparisons among the Virus Disease under Discussion, the Virus Diseases of Barley known to Japan and the Barley Stripe Mosaic in North America

Soil-borne resette, soil-borne barley mosaic, northern cereal mosaic and soil-borne necrotic yellow blight of barley are the virus diseases of barley known to Japan. Presence or absence of the X-body and the mode of transmission of the virus disease under consideration and the barley stripe mosaic found in North America together with the virus diseases known to Japan, are shown in Table 9. As apparent in Table 9, the disease resembles very

TABLE 9

Comparisons among the virus disease under discussion, the virus diseases of barley known to Japan and the barley stripe mosaic in North America.

Virus diseases	X-body	By means of Soil	Insects	Infected juices	Infected seeds
Soil-borne resette of wheat and barley	+	+	−	−, +**	−
Soil-borne barley mosaic	+	+	−	−, +**	−
Northern cereal mosaic	−, +*	−	+	−	−
Necrotic yellow blight of barley	+	+		+	?
Barley stripe mosaic		−	−	+	+
The virus disease under discussion	−	−	−***	+	+

* Observed only in the tissue of young tiller
** Positive reactions after McKinney or Yasu and Yoshino
*** Negative results with an aphid and a planthopper

closely the barley stripe mosaic in North America but not any other virus disease known to Japan. It may be safe to conclude from the above facts and from the similarities of symptoms and host range that the virus disease under discussion is a strain of the barley stripe mosaic virus, which has ever been found in North America, but not in Japan.

In these circumstances, it seems appropriate to present here a review of outline of the studies on the barley stripe mosaic in North America.

This disease was first found in about 1910 in U. S. A. (McKinney, 1951), and it was first reported in Canada in 1924 by I. L. Conner (Hagborg, 1951). This was thought to be a non-parasitic or physiologic disease, and named "barley false stripe" for its brownish foliage streaking symptoms (Christensen, 1934; Dickson, 1947). In 1951, however, McKinney identified barley false stripe as a seed-borne virus disease, and designated the disease as barley stripe mosaic. The false stripe in Canada was found to be similar to McKinney's by Hagborg in 1951.

Many works on this disease have been published since McKinney's work in 1951, especially in more recent few years. McKinney (1954) studied the culture method of detecting seed-borne infection in Glacier barley seedlings, stressing the importance of seedling test. There are many reports on seed-borne infections and yield reductions in barley or wheat (Eslick, 1953; McKinney, 1953; Hagborg, 1954; Eslick and Afanasiev, 1955; McNeal and Afanasiev, 1955, 1956). Eslick reported that the average yield reductions of diseased Glacier barley amounted to 31 % in a 5-year period, 1947 - 1951. McKinney, too, found the marked reductions in yield and seed size in 5 barleys by the virus infection. Hagborg's results was that 65.5 % of yield and 7.9 % of kernel weight were lost by this disease in Plush barley, and in Redman wheat 75.4 % of yield, 30.5 % of kernel weight and 13.1 % of plant height were reduced by the virus infection.

Timian and Sisler (1955) found out 4 spring barleys from Abyssinia to be resistant to the virus, and studied the mode of inheritance of the resistance to this disease. There are also several reports dealing with strains, host range, some characters of the virus or the occurrences and the distributions of the disease (McKinney, 1951; Slykhuis, 1952; Hagborg, 1954; Gold and others, 1954; Sill and Hansing, 1955). Gold and others (1954) studied the electron-microscopy of the virus particles of California "E" strain of the virus and suggested the pollen transmission of the disease.

SUMMARY

The present work was made in order to know the principal cause of the semi-sterility in the barley varieties for malt, which has prevalently occurred in Hokkaido. A crossing experiment made with the use of fertile and semi-sterile strains, M. 40 and M. 14, both isolated from Moravia suggested

that the semi-sterility under consideration might be inherited through maternal cytoplasm. However, some phenomena incompatible with this hypothesis were found also: considerable differences in fertility among the semi-fertile parent, M. 14 and the F_1 and F_2 of a M. 14 (♀) × M. 40 (♂) cross and also a tendency of increasing variability in fertility with the rise of sterility. It was also found that incomplete emergence of heads from the shealths, light weight of the kernels, loss of vigor, uneven plant height and heading were generally accompanied with semi-sterility. In the spring of 1956, pronounced mosaic and necrotic symptoms happened to be found in majority of the plants of the semi-sterile lines and a hybrid population. These suggested the semi-sterility not to be due to a genetic cause but to a kind of seed-borne virus. Therefore, this problem was approached by pathological measures.

Mosaic symptoms were observed in 60-80 % of the seedlings from the seeds of M. 14 strain and those of the semi-sterile plants of Shunsei and Harbin two-rowed varieties collected in Hokkaido in 1956. The seed-borne mosaic symptoms were thought to be due to a seed-borne virus disease, presumably by a strain of the barley stripe mosaic virus that have been found in North America, but new to Japan. It was because the disease under consideration was closely similar to the barley stripe mosaic virus in the mode of transmission, symptoms and host range.

A significant positive high correlation was found between percentage of sterility of plants and that of seedling infections in the samples from Furano, Hokkaido.

This disease was transmitted very easily by the carborundum leaf-wiping method. Infection occurred occasionally by inter-plant contacts. It was not soil-borne, and insect transmission could not be confirmed.

On account of scantiness in materials available, it was difficult to accumulate sufficient evidences showing that the semi-sterility of two-rowed barley in Hokkaido was wholly attributed to this disease. However, this virus disease is thought at least to play a great role on the semi-sterility as a causal agent, because the virus has been detected not only in such old varieties, Moravia and Harbin two-rowed, but also in newly delivered one, Shunsei.

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PLATE I.

Fig. 1 Yellow mosaic-like symptoms with brown stripe on the flag leaves and sheaths.

Fig. 2 Various foliage symptoms of a single seedling after mechanical inoculation. At the left end of a set of four is shown the leaf of healthy appearance. The other three are those with various symptoms.
Left 4 leaves : Omugi No. 2. Right 4 leaves : Aidzu No. 4.