Barley Stripe Mosaic Virus in North Dakota

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Barley stripe mosaic (BSMV), a seed-borne virus disease of barley, has cost North Dakota growers millions of dollars. This virus spreads from plant to plant in the field by leaf rubbing, and several plants can become infected from a single source plant in a growing season. In barley the virus causes a mosaic, striping, stunting, chlorosis and necrosis. The symptoms vary considerably depending on the host variety and virus strain involved (4).

There is no known insect vector of the virus and no evidence to support the hypothesis that such exists.

Yield of virus-infected plants is reduced as a result of fewer tillers per plant, fewer seeds per head, and a higher per cent of thin kernels. Losses in barley yield resulting from BSMV infection have been reported as high as 90 (3) and 64 per cent (2) when the plants were inoculated; and losses of 31 (1) and 24 per cent (5) were reported in naturally infected plots.

Studies were made to determine the distribution and severity of the disease in North Dakota, and a program was developed for its control.[1]

This paper gives the results of these studies and shows how losses from the disease have been eliminated.

Materials and Methods

The distribution and severity of the disease caused by BSMV was determined by surveying growers' fields throughout North Dakota and in areas of adjoining states. Counts were made to

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[1]Cooperative investigations of the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the North Dakota Agricultural Experiment Station, Fargo.

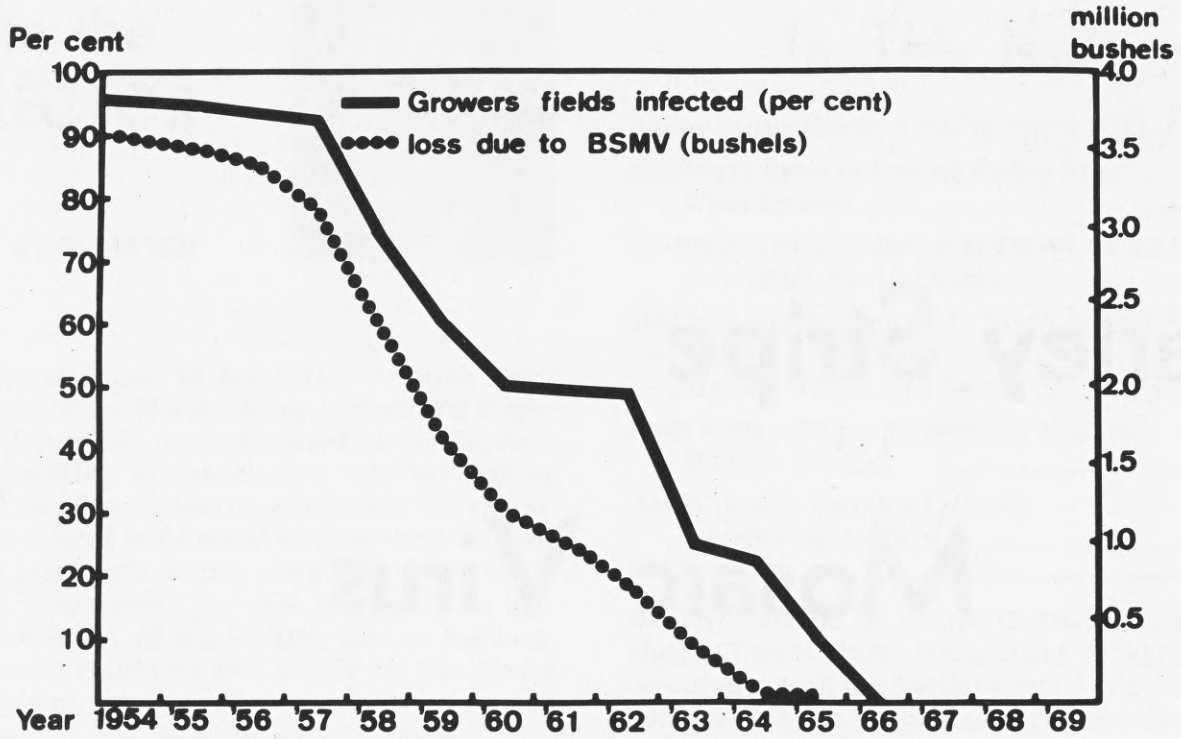

Fig. 1. The per cent of barley grower's fields infected with barley stripe mosaic virus in North Dakota and the estimated loss in bushels of barley from 1954 to 1969.

determine the percentage of infected plants in the fields. Verification of field diagnosis was made by inoculating test plants under controlled environmental conditions. These surveys were made each year from 1954 to 1970, with the most extensive ones at the beginning and end of the survey period.

Losses as a result of the disease were determined by comparing yields of virus-free and virus-infected plots in controlled experiments. Virus-infected seed lots with known levels of infection were planted in paired plots with virus-free seed lots of the same variety. Yields were determined from these replicated trials, and quality information was obtained through the cooperation of the USDA Barley and Malt Laboratory at Madison, Wisconsin. Yield trials were made at a number of locations in the upper Mississippi Valley area by cooperating barley breeders.

The effect on yield of barley caused by different levels of infection in planted seed was also determined. Seed lots with known levels of infection were planted in plots 12 feet square with six-inch row spacing to simulate normal cultural conditions. Areas 10 feet square from the center of the plots were harvested for yield determinations.

The level of seed transmission was determined by assaying harvested seed. Plants grown from the seed were maintained under a minimum light intensity of 1,200 foot-candles at 27±2°C and examined for symptoms 7 to 10 days after planting.

The effect on yield as influenced by time of infection was determined by inoculating plants at various times in their growth stages. Four-row plots with row spacing of 12 inches were replicated four times for each inoculation date. Yields were measured on 12 feet of the two center rows of each plot. Inoculum was applied as a spray, at 40-60 pounds per square-inch nozzle pressure, from a distance of 5 to 15 centimeters. Plants were sprayed to run-off, and inoculum consisted of freshly expressed plant juice from infected barley plants mixed with 10 parts water. Silicon carbide (400 grain) was added to the inoculum at the rate of 10g/100 milliliters to enhance the infection process.

Virus-free seed of barley was obtained by growing, in isolated pots or plots, plants found to be free of virus. Seed from these plants was ascertained free of virus, as determined by lack of symptoms and testing on indicator plants. It was bulked and increased under isolation. Utilizing the above procedures, barley stripe mosaic virus was eliminated from all breeding material at the North Dakota Agricultural Experiment Station. This work was done in cooperation with barley breeders and others associated with the program.

Results

In 1954, when an extensive survey of growers' fields was made, BSMV-infected plants were pres-

ent in 97 per cent of the fields examined in North Dakota (Fig. 1). The estimated level of infection varied from trace amounts to 50 per cent, with an average of 10 per cent.

Reduced barley yield resulting from BSMV infection depends on several factors, including variety, per cent of the infected seed planted, time of infection, and the environmental conditions during the growing season.

Table 1. Yield of virus-free barley and barley infected with barley stripe mosaic virus.

Year	Variety	Yield in bu/acre[1]		Reduction in yield per cent
		Virus free	Virus infected	
1954	Manchuria	41.3	33.9	17.9
	Mars	49.8	37.8	24.0
1955	Manchuria	50.5	39.0	22.8
	Mars	56.5	48.3	14.5
	Kindred	49.8	43.4	12.9

[1]Average of either three or four replications at 12 locations in 1954 and at 10 locations in 1955, upper Mississippi Valley area.

In yield trials made for two years at several locations in the upper Mississippi Valley area, Manchuria barley was reduced in yield 17.9 per cent in 1954 and 22.8 per cent in 1955 (Table 1). The loss in yield in Mars was 24.0 and 14.5 per cent, respectively, in the two years. Kindred, which was included in the trials only one year at 10 locations, was reduced in yield an average of 12.9 per cent. The quality of all three varieties was reduced when they were infected with virus. Barley nitrogen was increased, the kernel plumpness and weight were reduced, and malt extract was lowered.

The per cent of seeds infected with virus at planting time influenced the yield of barley. The greatest reduction in yield occurred in those plots planted with seed having 25 per cent or more infected seeds (Fig. 2). There was a 5 per cent loss in plots planted with seed having 5 per cent infection; and the loss increased as the per cent seed infection increased up to 25 per cent.

The time at which plants became infected with virus influenced the seed yield (Table 2). Plants inoculated in the late tiller and boot stage of development were reduced most and yielded only 55 per cent compared to non-inoculated plants. When plants were inoculated at heading stage they produced 92 per cent as much as the virus-free checks.

Table 2. Reduction in yield of barley inoculated at various stages of growth with barley stripe mosaic virus.

Treatment	Yield[1] bu/acre	Yield (per cent of check)
Virus free check	32.2	
Seed-borne infection[2]	28.3	88
Inoculation Stage:		
Seedling	24.5	76
Tiller	17.7	55
Boot	22.8	71
Heading	29.5	92

[1]Average of four replications.
[2]Excess of infected seed planted and virus-free plants rogued. Final stand equal to stand of other plots.

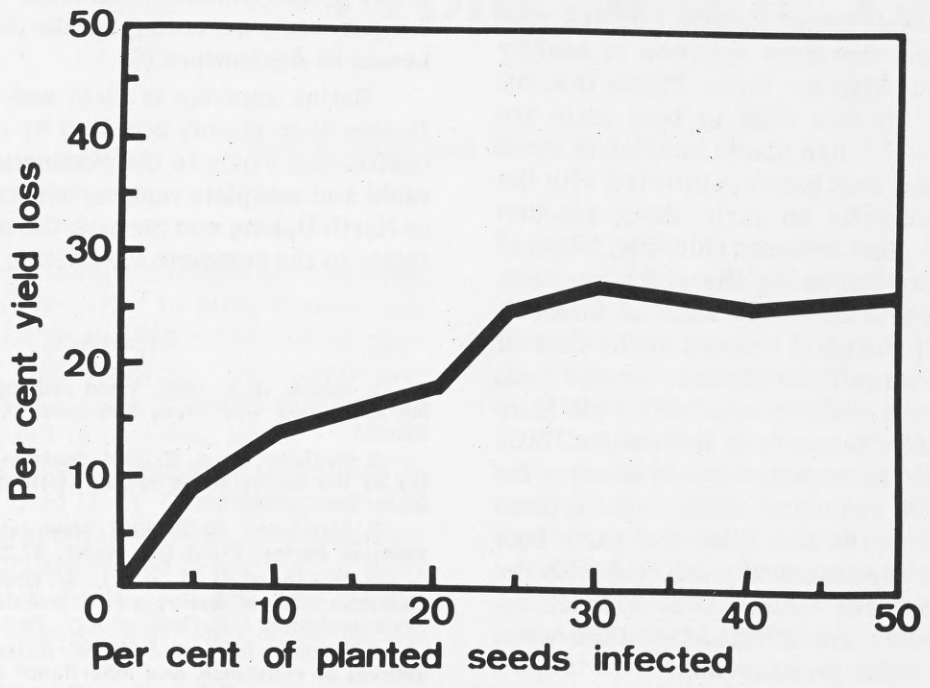

Fig. 2. The per cent loss in yield of Kindred barley resulting from barley stripe mosaic virus infection in planted seed.

Plants grown from infected seeds yielded 88 per cent that of the check.

The number of growers' fields infected with BSMV did not decline until 1958 (Fig. 1). At that time virus-free seed of Kindred and Traill barley became available to growers. As this seed displaced virus-infected supplies, the number of infected fields decreased. As new agronomically improved free BSMV varieties were released (Trophy and Larker in 1961 and Dickson in 1964), growers switched rapidly to these varieties. The number of fields with BSMV infection declined to 0 in 1966 and no infection has been observed in growers' fields since then (Fig. 1). North Dakota growers produce on the average 100 million bushels of barley per year. Losses to growers have declined from a high of at least 3.5 per cent or 3.5 million bushels per year to zero (Fig. 1) in 1966. This represents a saving to the state of at least $3 million annually.

Discussion

The amount of loss due to BSMV infection varied among varieties and locations. There is an inherent difference in the susceptibility and tolerance to infection among varieties (5). In these trials Manchuria was reduced in yield more than Mars and Kindred, and the per cent of infected seed produced was greater in the former variety. The amount of infection in seed produced from infected plants may also vary and thus influence the yield from year to year.

Some varieties of barley became infected easier than others, and therefore infection to healthy plants occurred at different times. Plants that become infected in the late tiller or boot stage are reduced in yield more than plants infected at other times. When a plant first becomes infected with the virus there is generally an early shock reaction when much of the plant becomes chlorotic, followed by severe necrosis. Following the shock reaction, barley plants recover and symptoms of infection are less severe. If the plant is small at the time of infection it will have sufficient time to recover from the initial shock and will produce fairly well. If infection occurs later, recovery is limited and little seed is produced. This reaction would account for the greatest yield reduction occurring in those plants inoculated in the late tiller and early boot stage. Plants that are chronically infected with the virus through the seed never suffer a shock reaction, and therefore are affected less than when infection occurs in the growing plant.

In plots planted with different percentages of BSMV-infected seed, the greatest yield reduction should theoretically occur in those plots where the greatest number of plants become infected during the current growing season. All the seeds in an infected seed lot are not infected with virus. In order to get a plot with all plants infected through the seed, it was necessary to plant extra seeds and rogue out all virus-free plants. In such plots the yield was 88 per cent of the check. Plants inoculated in the tiller stage yielded 55 per cent of the check.

In the experiment reported here, in plots that were planted with different percentages of infected seed, little loss in yield resulted at very low levels of infection. Maximum losses in yield occurred in plots planted with seed having 25 to 30 per cent infection. No further yield decrease occurred in plots planted with higher percentages of infected seeds. These results support the hypothesis that the greatest reduction in yield occurs in plants infected during the growing season.

Results from quality testing showed that part of the yield reduction was caused by the thinner kernels produced on virus-infected plants.

The elimination of barley stripe mosaic virus in North Dakota was made possible through the cooperative efforts of all the workers involved with barley production.

Based in part on the above results, barley yield losses due to BSMV infection were estimated at least 3.5 per cent in North Dakota in 1954 and perhaps considerably higher. The estimated loss from BSMV in the United States from 1950 to 1960 was 3.5 per cent, according to the USDA Handbook, **Losses in Agriculture** (6).

Barley superior in yield and other agronomic factors were readily accepted by growers, and this contributed vastly to the elimination of BSMV. The rapid and complete replacement of barley varieties in North Dakota was perhaps the main contributing factor to the complete elimination of the virus.

References

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