

# SOYBEAN MOSAIC: SEED TRANSMISSION AND EFFECT ON YIELD<sup>1</sup>

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## INTRODUCTION

Rather extensive inoculation tests in field and greenhouse have failed to reveal any host for soybean mosaic other than the soybean itself. Cross inoculations from mosaic red clover and garden bean to soybean were unsuccessful, and cross inoculations from soybean to sixty varieties of garden beans and seven other species of *Phaseolus*, to two species of *Dolichos*, to field peas, and to cowpeas gave only negative results.

Mosaic has been noted on the following varieties of soybeans at La Fayette, Ind.: Midwest or Medium Yellow, Haberlandt, Manchu, Ito San, Mongol, Hurrelbrinks, Mammoth Black, Habara, A. K., Arlington, Hoosier, Elton, Wea, Lexington, Black Eyebrow, Pinpu, 36847, Feldun, Dunfield, Soysota, Wilson Black, Mammoth Yellow, Brown, Virginia, and Tar Heel Black. The disease seems to be most prevalent in the Midwest, Haberlandt, and Black Eyebrow varieties and the symptoms seem to be most conspicuous in the Midwest variety. The Midwest or Medium Yellow variety has been erroneously known locally as Hollybrook, according to Wiancko and Mulvey (9),<sup>3</sup> and it was in this variety that we (5) first noted the disease.

As yet the mosaic disease does not seem to have become seriously prevalent in Indiana. F. E. Robbins found the disease in only 4 out of 27 soybean fields inspected in 1923. With the exception of one field of the Midwest variety, only a very low percentage of infection has been found in commercial fields.

In addition to the typical mosaic symptoms described in a previous account by the authors (5), other symptoms have been found associated with the disease, but these have not been relied upon as criteria of mosaic in the following work. Among these symptoms are a bronzing of the young leaves produced by a brown discoloration of short segments of the veins and large splotches on the older leaves produced by a lacelike yellowing or browning of the veins. In the Lexington variety severe symptoms were evinced in 1923. The mosaic plants were extremely stunted, the growing tips were killed outright, and brown necrotic streaks developed on the stems and petioles.

## SEED TRANSMISSION

In the previous account (5) it was recorded that about 13 per cent of the seed from mosaic plants transmitted the disease. Subsequent tests have given similar results with a number of varieties and with older seed.

The presence of the disease in ordinary commercial seed one year old was shown in 1921. Fifteen varieties and selections were planted in

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parallel plots of three rows each on May 26, 1921, and the occurrence of a very small percentage of seed-borne mosaic in 9 of the 15 varieties was determined by a careful examination of the seedlings on June 26 as shown in Table I. The secondary spread of infection as shown by the records of August 16 will be referred to later.

TABLE I.—*Mosaic in variety plot, 1921*

Variety.	Number of plants.	Mosaic seedlings June 26.	Mosaic plants, Aug. 16.	
			Number.	Per cent.
Midwest.....	272	0	79	29
Elton.....	253	2	24	9
36847.....	236	0	1	0.4
Haberlandt.....	255	5	57	22
Wea.....	294	0	28	9
Lexington.....	352	1	8	2
Soysota.....	221	0	0	0
A. K.....	205	1	17	8
Black Eyebrow.....	160	1	21	13
Pinpu.....	209	0	7	3
Feldun.....	270	1	7	2
Dunfield.....	259	2	14	5
Ito San.....	250	0	4	2
Arlington.....	301	2	18	6
Manchu.....	166	1	12	7

In a small plot of Midwest soybeans planted in 1921 with seed from a field in which the disease occurred in 1920, 17 out of 423 seedlings, or 4 per cent, developed mosaic. A number of volunteer seedlings came up in 1921 in the field used in 1920 and one of these showed mosaic, indicating that the disease persisted over winter in the seed lying in the field.

Two rows were planted in 1921 with seed saved from mosaic Midwest plants in 1920 and out of the 156 seedlings, 14, or 9 per cent, showed mosaic. Among the progenies of six mosaic plants, 12 out of 65 seedlings, or 18 per cent, were mosaic.

In a plot planted in 1922 with seed saved from mosaic Midwest plants in 1921, 172 out of 993 seedlings, or 17 per cent, showed mosaic, while in another plot planted with seed from healthy plants, 590 seedlings came up and none were mosaic.

These results with seed from mosaic plants corroborate the writers' previous conclusion that a varying and usually rather low percentage of such seed carries the disease. Dickson (3, p. 83-86) obtained similar results in connection with the seed transmission of mosaic in *Trifolium pratense* L. and *Melilotus alba* Desr. Reddick and Stewart (8) found a varying but much higher percentage of transmission of bean mosaic through the seed, and Archibald (1, p. 62) found that 43 per cent of the seed from mosaic bean plants transmitted the disease. Doolittle and Gilbert (4) found that a low percentage of the seed from mosaic wild cucumber transmitted cucurbit mosaic, and Newhall (6) likewise found in the case of lettuce mosaic that a very low percentage of the seed transmitted the disease.

Seed saved from mosaic soybean plants of a number of varieties in the fall of 1921 were planted in the greenhouse the following winter with results as shown in Table II. The results of a similar test made with seed selected from mosaic plants in 1922 are shown in Table III.

TABLE II.—Seed transmission by different varieties, 1921

Variety.	Number of plants.	Number of seeds.	Number of seedlings.	Per cent germination.	Number of mosaic.	Per cent mosaic.
Midwest.....	10	676	535	79	121	23
Haberlandt.....	8	435	350	80	23	7
Black Eyebrow.....	1	31	23	74	8	35
Arlington.....	1	46	17	37	1	6
Feldun.....	1	151	122	88	4	3
Lexington.....	1	62	58	93	0	0
Dunfield.....	1	45	17	38	0	0
Manchu.....	1	64	27	42	0	0

TABLE III.—Seed transmission by different varieties, 1922-23

Tested.	Variety.	Number of plants.	Number of seedlings.	Number of mosaic.	Per cent mosaic.
In winter in greenhouse.	Midwest.....	19	114	11	10
	Haberlandt.....	8	97	7	7
	A. K.....	3	17	2	12
	Feldun.....	2	21	0	0
	Lexington.....	3	23	0	0
In summer of 1923 in field.....	Midwest.....	17	54	5	9
	Haberlandt.....	6	88	3	3
	A. K.....	2	18	0	0
	Lexington.....	2	20	0	0
	Manchu.....	2	18	0	0

The results shown in Tables II and III indicate that varieties differ somewhat in their ability to transmit mosaic. The Midwest, Haberlandt, Black Eyebrow, A. K., and Arlington varieties apparently transmit the disease more readily than Feldun, Manchu, Lexington and Dunfield.

Individual plants of the same variety also differ greatly in the extent to which the disease is transmitted to their progeny. In the progenies of six single selections (Midwest) planted in the field in 1921, the percentage of mosaic varied from 0 to 33 per cent.

In the progenies of the ten single plant selections from mosaic Midwest plants in Table II, the percentage of mosaic seedlings varied from 6 to 38 per cent, and among the eight Haberlandt progenies the percentage of mosaic varied from 0 to 16. In the progenies of the 19 Midwest plants recorded in Table III, mosaic was absent in eight and varied from 7 to 50 per cent in the others. Four of the eight Haberlandt progenies also showed no mosaic.

To determine whether this peculiar incidence of mosaic had any relation to the node at which the pods were borne, the seeds from nine mosaic Midwest and seven mosaic Haberlandt plants were harvested separately by nodes in 1921 and tested in the greenhouse. No particular relation was found between the percentage of mosaic seedlings and the location of the node at which the seed was borne. Numbering the bearing nodes from the top down, the second, third, fourth, and seventh yielded the most mosaic seedlings in the Midwest plants and the fourth node in the Haberlandt plants. Numbering the bearing nodes from the base upward, the fourth, seventh, and eighth yielded the most mosaic in the Midwest plants.

That the variation in percentage of seed transmission of mosaic was not dependent upon the date of infection of the parent plant is indicated by the fact that in the 19 Midwest parent plants recorded in Table III the mosaic was of seed origin, and yet an average of only 10 per cent of mosaic occurred in the progenies of these plants; in fact, in eight progenies no mosaic occurred. In 4 of the 8 Haberlandt parent plants the mosaic was also of seed origin and the progenies of these plants showed a lower average percentage of mosaic than the progenies of the other four plants.

The effect of age of seed upon the transmission of mosaic is of practical interest. The field tests noted above proved that the disease persisted in the seed from one season to the next. Among 1,105 Haberlandt seedlings grown in the greenhouse in December, 1922, from commercial seed 15 months old, 3.2 per cent were mosaic. To test the effect of an extra year's storage, commercial seed from two of the same lots tested in 1921 (Haberlandt and Arlington, Table I) was planted in the field in 1922. Of the 560 Haberlandt seedlings, 7 were mosaic and of the 629 Arlington seedlings 2 were mosaic. It thus appears that the disease was present in 2-year-old seed.

That 2-year-old seed may carry the mosaic disease was further demonstrated by greenhouse tests in the spring of 1923 with seed harvested from single mosaic plants in 1921. The results, as shown in Table IV, indicate that there was a considerable percentage of mosaic transmission in the old seed from mosaic plants in the Black Eyebrow and Midwest varieties and a low percentage in the Haberlandt variety.

TABLE IV.—Presence of mosaic in seed stored 16 months

Plant.	Variety.	Per cent germination.	Number of seedlings.	Number of mosaic.	Per cent mosaic.
1	Haberlandt.....	77	88	3	3.4
2	Black Eyebrow.....	35	21	3	14.3
3	Wea.....	75	40	0	0
4	Lexington.....	77	31	0	0
5	Arlington.....	28	19	0	0
6	.....do.....	14	14	0	0
7	Midwest.....	64	38	26	68.4
8	.....do.....	98	46	3	6.5
9	.....do.....	69	22	6	27.2

In the summer of 1923, seed from six mosaic Midwest plants collected in 1921 was planted in the field and 36 of the 208 seedlings, or 12 per cent, came up showing mosaic. These results indicate that the use of 2-year-old seed can not be recommended as a mosaic control measure.

In 1921 and 1922 a conspicuous brown mottling of the seed coat occurred rather generally and occasioned considerable concern among the growers of soybeans for seed. As yet no relationship has been established between this seed mottling and the mosaic disease. Mottled seeds have been produced by both healthy and mosaic plants and in germination tests a few mosaic seedlings were obtained from clean as well as from mottled seeds.

Ordinarily the seed from plants apparently free from mosaic has yielded only healthy seedlings. In a field plot in 1922 planted with such seed, no mosaic occurred among the 590 seedlings, while in another

plot planted with seed from mosaic plants, 172 out of 993, or 17 per cent, of the seedlings were mosaic. Owing to the drought of 1922, the field symptoms were not easily recognizable at the time the seed was collected, and among 42 single plant selections from supposedly healthy plants, 3 showed mosaic when tested.

It would seem, therefore, that seed selection from mosaic-free plants may be fairly effective, but not absolutely infallible, as a control measure.

#### SECONDARY SPREAD OF MOSAIC

The degree of spread of mosaic during the season of 1921 is shown in Table I in which the number of mosaic plants on August 16 is very greatly in excess of those noted on June 26. In the Midwest variety this secondary infection involved 29 per cent of the stand. In another plot of the same variety, 37 per cent of the stand became infected during the month between July 19 and August 19.

The spread of infection in 1922 was not so extensive as in 1921. In field plots, 14 per cent of the 2,174 Midwest plants, 16 per cent of the 487 Haberlandt plants, and 1 per cent of the 640 Arlington plants became infected during the season.

During 1923 the spread of infection was much more extensive than in the two preceding seasons. Among variety plots equally exposed to infection and showing no mosaic among the seedlings, the extent of secondary spread of mosaic is evidenced by the percentages of mosaic recorded August 7 to 14, as shown in Table V. The varieties Soysota and Virginia seemed to escape infection.

TABLE V.—*Secondary spread of mosaic, 1923*

Variety.	Number of plants.	Per cent mosaic.	Variety.	Number of plants.	Per cent mosaic.
Midwest.....	181	90	Brown.....	220	41
Manchu.....	24	79	Lexington.....	92	40
Haberlandt.....	76	73	Pinpu.....	50	38
Elton.....	28	64	Black Eyebrow.....	30	33
Feldun.....	43	63	36847.....	30	33
Dunfield.....	38	55	Mammoth Yellow.....	79	23
Wea.....	60	45	Tar Heel Black.....	253	22
Arlington.....	61	44	Wilson Black.....	329	14
Ito San.....	211	41	Soysota.....	163	2
A. K.....	39	41	Virginia.....	308	0.6

The agent of dissemination has not been determined. Aphids have not been noted to any extent on the soybeans. Leafhoppers and tarnished plant bugs have been found in abundance, but numerous tests with caged plants have failed to incriminate either of these insects.

#### EFFECT OF MOSAIC ON SEED GERMINATION

Dickson (3, p. 18-19) has shown that there is a reduction in the germinating power of seed due to the mosaic disease in the case of red clover and Canada field pea, and Cunningham (2, p. 27) states that seed from mosaic bean plants has a low germinating quality. In the greenhouse tests with seed from mosaic soybean plants presented in Table II there was 79 per cent germination of the 676 Midwest seeds planted,

80 per cent germination of the 435 Haberlandt seeds, and 88 per cent germination of the 151 Feldun seeds. Although lower percentages of germination occurred in some of the other varieties, there was no marked reduction of germinating power in the larger lots of seed nor was the germinability in any way correlated with the percentage of mosaic in the seedlings. The latter also holds true for older seed as shown in Table IV.

In field plots planted in 1921 with 370 seeds from mosaic plants only 61 per cent germinated. The relative germinability of the seed from mosaic and healthy plants grown in 1922 was tested in the greenhouse and the results, as shown in Table VI, indicate that mosaic had little if any influence on the germinating power of seed.

TABLE VI.—Effect of mosaic on the germinating power of seed

Variety.	Seed from healthy plants.			Seed from mosaic plants.			
	Number of plants.	Number of seeds.	Per cent germination.	Number of plants.	Number of seeds.	Per cent germination.	Per cent mosaic.
Haberlandt.....	8	176	74	8	137	71	7
A. K.....	2	45	78	3	21	81	12
Lexington.....	3	80	66	3	39	59	0
Feldun.....	2	51	63	2	39	54	0

#### EFFECT OF MOSAIC ON YIELD OF SEED

Reddick and Stewart (7) found that bean mosaic suppressed seed production, and Dickson (3, *p.* 18-19) has recorded a marked reduction in yield of seed due to mosaic in pea beans, broad beans, and red clover. As the writers (5) have previously reported, reduction in yield of seed is likewise one of the outstanding features of soybean mosaic. In the fall of 1921 a comparison was made of the yield of seed from mosaic and normal plants and the results, as presented in Table VII, show that mosaic caused a very serious reduction in yield, especially in the Haberlandt variety.

The comparative yield of healthy and diseased plants in the variety plots in 1922 is shown in Table VIII. The mosaic seedlings had been tagged so that it was possible to record whether the disease was of seed origin or the result of secondary infection during the season, and except in the Midwest variety, the mosaic was all of the latter type.

TABLE VII.—Effect of mosaic on yield of seed, 1921

Variety.	Healthy.		Mosaic.		
	Number of plants.	Average yield per plant in grams.	Number of plants.	Average yield per plant in grams.	Per cent reduction in yield.
Midwest.....	24	14.59	27	9.58	34
Haberlandt.....	5	41.57	9	10.96	76
Arlington.....	3	7.65	3	4.60	40
Lexington.....	2	12.01	2	4.82	60

TABLE VIII.—Effect of mosaic on yield of seed, 1922

Variety.	Condition of plants.	Number of plants.	Average number seeds per plant.	Average yield per plant.	Reduction in yield.	Average weight of a seed.
				Gms.	Per cent.	Gms.
Midwest .....	{ Healthy .....	28	18.0	1.85	.....	0.103
	{ Mosaic (seed origin)...	95	4.4	.46	75	.105
Haberlandt .....	{ Healthy .....	22	22.0	3.01	.....	.137
	{ Mosaic .....	13	14.7	2.04	32	.138
Feldun .....	{ Healthy .....	6	21.6	3.25	.....	.141
	{ Mosaic .....	5	14.0	1.77	45	.126
Lexington .....	{ Healthy .....	7	22.8	2.00	.....	.151
	{ Mosaic .....	6	12.5	.93	53	.075
Dunfield .....	{ Healthy .....	4	35.7	4.65	.....	.130
	{ Mosaic .....	4	13.2	1.47	68	.111
Arlington .....	{ Healthy .....	6	40.8	2.56	.....	.062
	{ Mosaic .....	4	6.7	.23	93	.033
Manchu .....	{ Healthy .....	3	19.3	2.40	.....	.124
	{ Mosaic .....	3	10.3	1.10	54	.106
A. K. ....	{ Healthy .....	9	27.2	3.75	.....	.137
	{ Mosaic .....	8	9.6	1.14	69	.118

Owing to the drought, all of the yields were very low in 1922 as compared with 1921. However, the results in Table VIII show that mosaic caused heavy losses in all of the varieties. The loss in the Midwest variety, of which the greatest number of mosaic plants were available, amounted to 75 per cent. All of these Midwest plants represented mosaic of seed origin and 37 of the 95 bore no seeds whatever. In the Haberlandt variety, however, the average yield of seven plants with mosaic of seed origin, not recorded in Table VIII, was only 14 per cent less than that of the healthy plants.

It will be noted that in general the loss was due to the fewer number of seeds per plant rather than to the smaller size of the seeds, although in the last six varieties the seeds from mosaic plants were considerably smaller, especially in the Lexington and Arlington varieties.

#### SUMMARY

No host for soybean mosaic has been found other than the soybean itself.

Varieties of soybean seem to differ somewhat in susceptibility. Midwest has proved very susceptible; Soysota and Virginia have shown a tendency to escape infection.

Generally about 10 to 25 per cent of the seed from mosaic plants produced mosaic seedlings.

Varieties seem to differ in their ability to transmit mosaic through the seed. Midwest, Haberlandt, Black Eyebrow, A. K., and Arlington readily transmitted the disease.

Marked differences occurred in the percentages of mosaic in the progenies of individual mosaic plants of the same variety.

The transmission of mosaic seems to bear little or no relation to the location of the node at which the seed was produced nor to the date of infection of the parent plant.

The disease has been found in 2-year-old seed saved from mosaic plants.

A conspicuous brown mottling of the seed coat has not been correlated with mosaic.

Seed selected from mosaic-free plants gave rise to mosaic-free seedlings.

A considerable spread of mosaic occurred during the growing season. This secondary spread was more extensive in some seasons than in others.

Apparently the disease did not materially lower the percentage of seed germination.

Mosaic reduced the yield of seed 30 to 75 per cent. The number of seeds per plant was greatly reduced; in fact, plants with mosaic of seed origin frequently bore no seeds whatever.

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