Section C. Sugar Beet Diseases - Chairman: G. H. Coons

EFFECT OF MOSAIC UPON YIELD OF SEED BY SUGAR BEET ROOTS 1/

by
John O. Gaskill 2/

The mosaic disease of sugar beets has been considered by various investigators to be detrimental to the sugar-beet seed crop. Robbins (7), in 1921, discussing observations in Colorado and Nebraska, reported the occurrence of an occasional plant in sugar-beet fields which produced an unusually small quantity of seed, apparently as a result of severe reaction to mosaic. In Europe, Schaffnit (8) stated that seed beets attacked during the first year, frequently produced one third less seed than normal beets; and Muraviov (5) summarized experiments conducted by himself and I. S. Shevtshenko in which it was shown that the disease reduced the yield of sugar-beet seed by 12.9%. Jones (4), considered mosaic to be an important factor in limiting the yield of garden-beet seed in the state of Washington.

Several hundred acres of sugar-beet seed are produced annually in northern Colorado at the present time, largely by the ordinary steckling method. Mosaic is usually quite prevalent in these fields, and has been suspected of causing serious damage.

The work reported in this paper was undertaken in order to obtain more definite information regarding the effect of mosaic upon the sugar-beet seed crop under northern Colorado conditions.

EXPERIMENTS IN 1938 AND 1939

Fall selection of mosaic plants and of comparable, apparently healthy plants for determination of the respective seed yields was employed in order to be certain of the presence of virus in all roots of the mosaic class, and, following selection, to give both classes similar storage. Preliminary trials had indicated the danger of latent infection in plants which appeared free from mosaic, which were to serve as checks, and consequently commercial sugar-beet fields in which the degree of apparent mosaic infection was relatively low were chosen as a source of roots. As a further precaution, after selection of a group of mosaic-infected roots from a field, the comparable check plants were taken at a distance of at least several feet from any plants showing mosaic. As a rule, check roots were taken within a radius of not more than 50 feet from the place of selection of the corresponding diseased beets, but in several instances the two groups were taken from opposite ends of a field. Root selection was strictly random, in all cases, subject to the above restrictions. The varieties of sugar beets in the 10 fields used for the selections in the two years of experiments included two foreign brands and one American variety.

Sugar-beet mosaic has been described by numerous investigators, including Robbins (7), and Smith (9), and a detailed discussion of the symptoms of the disease need not be repeated. In the selection of plants for use in these

---

1/ Contribution from the Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture. Read by G. H. Coons.

2/ Assistant Pathologist.

experiments, it was observed that mottling and the frequent tendency toward puckering in the leaves of mosaic-infected plants agreed with the description given by Robbins. The severe type of malformation, often culminating in death of the leaf tip, which was considered by Robbins to be a manifestation of advanced stages of the disease, was not observed to an appreciable extent in any of the fields in which selections were made, and did not appear to be associated with mosaic at any time during the course of the subsequent experiments.

The roots selected were trimmed in the usual manner for mother beets and stored over winter in crates in the Station root cellar at Fort Collins, Colo. under conditions of relatively low temperature and high humidity, as described by Gaskill and Brewbaker (2). In the spring immediately following the year of selection, these roots were transplanted for seed production as described below.

TESTS IN 1938

Experiment 1

Five groups of mosaic-infected roots and the five corresponding groups of control roots were planted together as paired plots on May 13, 1938 at one location, the roots in each pairing having come from the same source field. Check plots were larger and contained correspondingly more beets, in order to allow for anticipated early occurrence of an occasional infected plant. Beets were spaced 3 X 3 feet, with check-row arrangement, and the entire experiment was surrounded by a row of roots of a commercial variety for buffer purposes. The crop was given ordinary care, with the addition of an occasional dusting or spraying for aphis control.

Each beet was examined for mosaic symptoms one month after planting. All plants in the plots planted with roots recorded as infected in the fall showed definite symptoms on that date. A few check plants also showed distinct evidences of the disease, and it was assumed that this was due largely, if not entirely, to fall infection which was too late to produce recognizable symptoms before the roots were selected. All such plants were disregarded entirely at harvest, but were left in place until that time. As was to be expected, a few beets died during the season because of root rot but these losses did not appear to be associated with mosaic. The resulting gaps in stand were ignored, and all plants which died before maturing any seed were disregarded entirely in the summarization of yield data.

All seed was harvested on August 16, at what was considered the normal degree of maturity, no appreciable difference in maturity being evident between mosaic-diseased and check plots. After being dried the seed was threshed and cleaned in a manner approximately comparable with that employed commercially, except that a 6/64-inch round-hole type of screen was used for elimination of small seed instead of the customary slotted type. Average germination percentage was determined for the seed from each plot, in accordance with accepted practice, with germinator temperatures alternately 20° C. for 18 hours, 30° C. for 6 hours. Final counts were made on the eleventh day.

The summarized yield and germination data, presented in Table 1, show a significantly lower production of seed per plant for the plots in which mosaic-infected roots were planted, but indicate an apparently negligible difference in germination percentage. In connection with the yield figures, it should be pointed out that mosaic had spread in the check plots to a considerable extent in midseason, although actual counts were not made.

TABLE 1.--Effect of mosaic upon yield and viability of seed produced by sugar-beet roots, in a compact experiment, Fort Collins, Colorado, 1938 a/

Replication	No. of plants per plot		Aver. wt. of seed per plant b/		Aver. germination c/	
	Check	Mosaic d/ infected	Check (grams)	Mosaic infected (grams)	Check (%)	Mosaic infected (%)
1	30	15	138.3	93.4	90.0	91.3
2	30	13	122.0	78.9	85.5	86.8
3	27	16	122.5	129.7	89.5	88.0
4	23	15	125.6	93.0	87.0	78.5
5	14	8	156.0	115.7	92.8	92.3
Average	24.8	13.4	132.88	102.14	88.96	87.38
Difference:						
Actual			30.74		1.58	
Percent (based on check)			23.13%		1.78%	
t			3.161		0.872	
Odds e/			>19:1		<1.5:1	

a/ Plants spaced 3' x 3' throughout; no additional space between plots.
b/ Seed retained on 6/64-inch round-hole type screen.
c/ Each germination value based on 400 seed balls; final count on 11th day.
d/ Plants naturally infected during first year of growth.
e/ Odds against the occurrence of the indicated difference, due to chance.

Experiment 2

In preliminary experiments, attempts to prevent serious spread of mosaic from infected plots to adjacent check plots by means of dusting or spraying had been unsuccessful. In order to obtain data regarding the current problem, under conditions less conducive to spread of mosaic among the check plants than in Experiment 1, a parallel experiment was conducted in 1938 in a corn field, with a minimum distance of approximately 150 feet between plots. Five pairs of plots similar to those just described were planted, with a minimum spacing of approximately four feet between beets. Corn was not permitted to grow within any plot. One replication was lost as a result of an alkali spot in the field.

The crop was planted on May 13, soon after corn planting, and was handled in a manner similar to that of Experiment 1, except that the single check plant which showed mosaic symptoms on June 13 was removed at that time. All but one of the plants in the plots of mosaic-infected roots showed definite mosaic symptoms when examined on June 13. That plant was too small to permit an accurate conclusion at that time. It was noted in mid-season that the development of mosaic in check plots was relatively slight as compared with that in the experiment discussed above, though counts of infected plants were not made.

The crop was harvested on August 22, and the seed yield and germination percentages were determined in the manner described above. These data are shown in summary form in Table 2. It is of interest to note that, in this experiment, with less mosaic in the check plots, the indicated loss in seed yield, attributable to mosaic, was highly significant and amounted to 38.94% as compared with 23.13% in Experiment 1. The difference in average germination between checks and disease plots in Experiment 2, as in the other test, did not approach significance.

TABLE 2.--Effect of mosaic upon yield and viability of seed produced by sugar-beet roots, in space-isolated plots, Fort Collins, Colorado, 1938

Replication	No. of plants per plot		Aver. wt. of seed per plant [a]		Aver. Germination [b]	
	Check	Mosaic-infected [c]	Check (grams)	Mosaic-infected (grams)	Check (%)	Mosaic-infected (%)
1	20	9	147.4	82.6	78.8	76.0
2	19	9	104.8	59.0	80.5	82.8
3	19	10	159.2	120.7	81.0	74.8
4	18	8	176.4	96.6	87.8	83.5
Average	19.0	9.0	146.95	89.73	82.03	79.28
Difference:						
Actual			57.22		2.75	
Percent (based on check)			38.94%		3.35%	
t			6.127		1.510	
Odds [d]			>99:1		<4:1	

[a] Seed retained on 6/64-inch round-hole type screen.
[b] Each germination value based on 400 seed balls; final count on 11th day.
[c] Plants naturally infected during first year of growth.
[d] Odds against the occurrence of the indicated difference, due to chance.

1939 TEST

Experiment 3

In view of results obtained in the preceding year, a plan in which the plots with mosaic-infected plants were separated some distance from the check plots and screened by corn plants was used in 1939. Experiment 3 was set up which, in general, was similar to the second 1938 test, except that an additional series of plots was included for the purpose of obtaining more definite evidence regarding the effect of mosaic when infection occurs in the seed-bearing year. Three series of plots were set up in this experiment as follows: (1) the check series, planted with apparently healthy roots; (2) a mosaic-diseased series, planted with roots infected in the preceding season; and (3) a mosaic-diseased series, in which apparently healthy roots comparable with the first series were artificially inoculated with mosaic in the seed-bearing year. The inoculations of Series 3 were made one month after planting, using a mechanical-injury method which was a modification of the techniques described by Hoggan (3) and by Rawlins and Tompkins (6). The experiment was laid out in a corn field, and the roots were planted on May 11, immediately after the corn was drilled. There were six widely-separated replications, and in each replication Series 2 and 3, which involved mosaic-infected plants, were located as adjacent plots. More than 100 feet intervened between these plots and the corresponding check plot of a replication. The arrangement of plots within each replication was randomized, subject to the restriction indicated.

The crop was handled in a manner similar to that employed during the preceding year, though more detailed notes were taken. All plants in check plots were examined twice during the first month after planting, and five with mosaic symptoms were found and destroyed immediately. Examination of all other plants in the experiment on June 10 revealed one obviously infected individual in the six plots to be inoculated (Series 3) and four plants without mosaic symptoms in the six plots of mosaic-infected beets (Series 2). Three of the

latter four plants were extremely small at the time of the examination.

Seed yield and germination data were obtained in approximately the same manner as in 1938, except that the seed was passed over a slotted type screen with slots 7/64-inch wide--a method more nearly comparable with commercial practice. The results are presented in Table 3. As before, average germination percentages for the three contrasted series did not differ significantly. The average seed yield obtained from control roots was higher for each replication than that obtained from roots known to be infected with mosaic in the previous fall; the averages for the six replications showing a highly significant difference in favor of the controls. The average seed yield from Series 3 --plants inoculated in the seed-bearing year--was significantly below that of the check.

TABLE 3.--Effect of mosaic upon yield and viability of seed produced by sugar-beet roots, Fort Collins, Colorado, 1939[a/]

Replication	Treatment and number of plants per plot			Treatment and Average wt. of seed per plant [b/]			Treatment and average germination [c/]		
	(1) Check	(2) Mosaic[d/] -early	(3) Mosaic[e/] -late	(1) Check (grams)	(2) Mosaic -early (grams)	(3) Mosaic -late (grams)	(1) Check (%)	(2) Mosaic -early (%)	(3) Mosaic -late (%)
1	22	15	15[f/]	109.1	70.1	94.7	76.0	62.0	67.5
2	16	17	18	132.8	63.0	55.2	57.5	72.5	58.5
3	22	18	18	97.0	61.2	88.9	62.0	67.0	72.5
4	19	14	14	63.0	60.1	89.3	55.0	61.0	74.0
5	17	13	14	151.1	106.0	103.9	78.5	70.0	77.0
6	19	11	11	133.5	109.4	77.2	71.0	81.0	69.0
Average	19.2	14.7	15.0	114.42	78.30	84.87	66.67	68.92	69.75
z					0.8295 [g/]			0.6653 [h/]	
S.E. of mean of 6 replications					8.3963				
Difference for significance between means of 6 replications:									
Based on 5% point					26.46				
Based on 2% point					32.82				

a/ Within each replication treatments 2 and 3 occurred in adjacent plots, but otherwise all plots were space-isolated.
b/ Seed retained on 7/64-inch slotted screen.
c/ Each germination value based on 200 seed balls; final count on 10th day.
d/ Plants naturally infected during first year of growth.
e/ Plants artificially inoculated, June 12, 1939.
f/ Includes one plant showing mosaic symptoms at time of inoculation.
g/ z-value exceeds the 5% point.
h/ Negative z-value indicates absence of significant differences.

It was recognized that the symptoms of mosaic in mother beets, known to be infected, frequently become indistinct or may disappear entirely during the latter part of the seed-bearing year. However, it seemed desirable to follow, in so far as possible, the progress of mosaic in the inoculated plots in this experiment by means of individual plant records taken at appropriate intervals. Counts of positive mosaic cases were made in all other plots for comparative purposes. At the same time, the occurrence of bolting 3/ and blooming was recorded.

Although the percentages of the population which became infected in Series 3 cannot be stated, because of suspected masking of symptoms, it is known that at least 49.6% of these plants had the disease on July 12. It is of interest to note the low percentage of obviously infected plants in the checks, throughout the season, as compared with that in the other two series.

Bolting appeared to be retarded somewhat by mosaic, particularly in Series 3. The average percentage of bolting plants in that series was significantly below that for Series 1 (check) on July 2 and 12, and was also significantly below that for Series 2 on July 12 4/. It should be pointed out that the percentage of bolters in Series 3 did not increase at all during the 10-day period, beginning 20 days after inoculation, suggesting a rather strong reaction to the virus at that point. Average bolting percentages for the three contrasted conditions did not differ significantly on June 10 or August 3. Likewise, in percentage of plants which failed entirely to produce seed, as a result of delayed bolting or vegetative tendencies, none of the differences among the various experimental treatments were significant. Statistical analysis further indicated that there were no significant differences among the series in percentage of blooming plants.

DISCUSSION AND CONCLUSIONS

In no case in the 1938 and 1939 experiments, were root rot losses abnormally severe, and there appeared to be no association of rotting with mosaic. A statistical study of field counts for the two experimental treatments which occurred in each of the three experiments in the two seasons indicated that the difference between the rot losses for control roots and that for beets carrying first-year mosaic infection was not significant.

Gaps in stand resulting from early removal in Experiments 2 and 3 of the few mosaic-infected beets found in check plots, within one month after planting, were considered of negligible importance because of the wide spacing of the plants as used in these experiments, the minimum distance between beets being approximately four feet. Effects from these gaps were disregarded.

In planning the experiments reported here, it was necessarily assumed that, in commercial sugar-beet fields showing a moderate or low percentage of mosaic infection in the fall, plants with symptoms of the disease would not be appreciably inferior to the remainder of the population in seed-producing ability for any reason other than the effects of mosaic. It seemed improbable that plants with low seed-producing capacities, as a class, would be more palatable to the insect vectors. Some information regarding infected beets was

---

3/ The term "bolting" as used here denotes the presence, on a given plant, of at least one seed stalk--approximately one-half inch or more in length.

4/ Variance analyses of all percentage data obtained from field counts were made in accordance with the procedure suggested by Clark and Leonard (1), using the transformation, $p = \mathrm{Sin}^{2}\theta$.

obtained in the fall of 1938. For the purpose of making comparisons in root weight and sucrose percentage between apparently uninfected plants and beets showing obvious symptoms of the disease, twenty-four pairs of samples, averaging 18 roots per sample, were taken by a random method, just before harvest, from commercial sugar-beet fields in which apparent mosiac infection averaged approximately 30%. The two classes of roots did not differ significantly in sucrose percentage, but in average weight per root the mosaic-infected class was 6.8% above the checks--a difference which was statistically significant. These results suggest a slight tendency in the vectors to feed upon the more vigorous plants. Any effects upon seed production which might arise from variation in root size are eliminated in the comparisons between Series 3, spring-inoculated plants, and the check series in Table 3.

The results from two years of experiments, in which the performance of check roots was compared, by means of space-isolated plots, with that of beets which were infected with mosaic in the year preceding seed bearing, are summarized in Table 4. The indicated reduction in yield of seed attributed to mosaic, amounting to 34.97%, was highly significant, being far above odds of 99:1. The difference in germination percentage did not approach the point of significance.

The evidence presented in this paper seems to justify the conclusion that, under the conditions of the experiments, mosaic was responsible for serious reduction in sugar-beet seed yield, first, when infection occurred during the vegetative year, and second, when it occurred in the seed-bearing year. Lowering of seed viability because of mosaic in the seed bearer was not shown.

TABLE 4.--Effect of mosaic upon yield and viability of seed produced by sugar-beet roots in space-isolated plots, Fort Collins, Colorado; summary of two years' data -- 1938 and 1939 a/

	Aver. wt. of seed per plant		Aver. germination	
Year	Check (grams)	Mosaic-infected b/ (grams)	Check (%)	Mosaic-infected (%)
1938	146.95	89.73	82.03	79.28
1939	114.42	78.30	66.67	68.92
Weighted average	127.43	82.87	72.81	73.06
Difference:				
Actual		44.56		0.25
Percent (based on check)		34.97%		0.34%
t		6.240		0.088
Odds c/		>99:1		<11:1

a/ Summary, taken from tables 2 and 3.
b/ Plants were naturally infected during first year of growth.
c/ Odds against the occurrence of the indicated difference, due to chance.

SUMMARY

Sugar-beet roots showing mosaic in their first year of growth were brought to seed production the following year in replicated plots in comparison with plots of apparently healthy roots taken from the same commercial fields. The average seed yield per root from the mosaic-infected class was approximately 23% below the average yield for apparently healthy roots, a significant difference. The seed obtained from the two classes of roots did not differ significantly in viability. In this experiment, the plots planted with mosaic-infected roots were contiguous with the plots planted with apparently healthy roots. Spread of mosaic occurred, which may have caused lowering of yields from the plants which were apparently healthy when set out for seed production. In a second experiment, the mosaic-infected roots were planted in plots in a corn field with some distance intervening between those plots and the respective control plots. With this space-isolation of plots, the spread of mosaic into the controls was probably rather limited. The average seed yield per root from the mosaic-infected class was approximately 39% below the average yield obtained from the class composed of apparently healthy roots, this difference being highly significant.

In a test the following year, in which the control plots were at some distance from those with mosaic-infected plants, seed production, on the basis of yield per plant, from mosaic-infected roots, averaged approximately 32% less than the corresponding seed yield from the checks—a highly significant difference. In this experiment, apparently healthy roots were inoculated one month after planting in an additional series of plots. Yields from the inoculated plants averaged 26% less than from the controls, a difference which was well above the point of statistical significance.

No significant differences in viability between the seed lots obtained from the mosaic-infected roots (either early or late infections) and from the apparently healthy roots were found. Mosaic may have delayed bolting to some extent in the case of plants inoculated in the seed-bearing year; apparently the disease did not significantly influence percentage of plants blooming, or significantly increase the percentage of plants which failed entirely to produce seed as a result of delayed bolting or vegetative tendencies. So far as found in these tests, the most conspicuous effect of mosaic on sugar beets grown for seed production is the reduction of seed yields.

LITERATURE CITED

(1) CLARK, ANDREW, and WARREN H. LEONARD. The analysis of variance with special reference to data expressed as percentages. Jour. Amer. Soc. Agron. 31: 55-66. 1939.

(2) GASKILL, JOHN O., and H. E. BREWBAKER. Storage of sugar beets under conditions of high humidity and low temperature. Jour. Amer. Soc. Agron. 31: 109-115. 1939.

(3) HOGGAN, ISMÉ A. Some viruses affecting spinach, and certain aspects of insect transmission. Phytopath. 23: 446-474. 1933

(4) JONES, LEON K. The mosaic disease of beets. Washington Agr. Expt. Sta. Bull. 250. 1931.

(5) MURAVIOV, V. P., ed. Mosaic diseases of the sugar beet. Kiev: Union Sugar Concern, Plant Breeding Dept., 286+(1) pp. 1930. (In Russian Abstract in Expt. Sta. Record 68: 57-60)

(6) RAWLINS, T. E., and C. M. TOMPKINS. Studies on the effect of carborundum as an abrasive in plant virus inoculations. Phytopath. 26: 578-587.

(7) ROBBINS, W. W. Mosaic disease of sugar beets. Phytopath. 11: 349-365. 1921.

(8) SCHAFFNIT, E. Der gegenwaertige Stand der Forschung ueber Viruskrankheiten. Beitraege zur Pflanzenzucht. Neuntes Heft. pp. 25-41. 1927. a/

(9) SMITH, KENNETH M. The mosaic disease of sugar-beet and related plants. Jour. Min. Agr. (Gt. Brit.) 41: 269-274. 1934.

RELATION OF 8-INCH AND 16-INCH SPACING TO CURLY-TOP INFECTION AND PERFORMANCES OF CERTAIN CURLY-TOP-RESISTANT SUGAR BEET VARIETIES
(Abstract)

By A. M. Murphy, Junior Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture.

Studies were made on the relation of 8-inch and 16-inch spacing to curly-top infection and performance of six economically acceptable curly-top resistant sugar beet varieties. The varieties varied in resistance to curly top from intermediate to highly resistant. Two dates of planting were made, the first on April 21 and the second on May 8. The varieties were planted in a 6x6 Latin square, each plot 80 feet long and four rows wide. One-half of each plot was thinned to 8 inches and the other half to 16 inches.

Under the conditions of the test it was found that by midseason there was approximately 50 percent more obvious curly top in the 16-inch spaced beets than in the 8-inch spaced beets. It was also found that the less resistant varieties gave better yield in the closer spacing.

VERTICILLIUM WILT OF SUGAR BEET
(Abstract)

John O. Gaskill and W. A. Kreutzer
Division of Sugar Plant Investigations, Bureau of Plant Industry
and Colorado Agricultural Experiment Station.

In the latter part of August 1939 an unusual wilt of the sugar beet (Beta vulgaris L.) was observed in fields in the vicinity of Ault, Colorado. The malady was characterized by a wilting and dying of the outer leaves which was soon followed by distortion and occasional loss of turgidity of the inner leaves. An examination of the interior of the tap root of any given plant showing such aerial symptoms generally revealed a discoloration of a few of the vascular bundles. The lateral roots usually showed a greater amount of this vascular necrosis than did the tap root. Rotting of the infected tap roots was seldom observed; the parenchymatous tissues being apparently un-

---

a/ English translation by H. A. Kuyper, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture.