OVERWINTERING OF TOMATO MOSAIC[1]

MAX W. GARDNER AND JAMES B. KENDRICK

(WITH PLATE XVII)

The annual recurrence of the mosaic disease in epiphytotic form in the canning tomato crop of Indiana has made it highly important to ascertain the mode of overwintering of the causal virus. It seemed within the realm of possibility that the virus might be perpetuated over winter in hothouse tomato crops, in tomato seed, in related perennial weed hosts, and by insects. The agency of insects in this connection has not been studied. The work of MCCLINTOCK and SMITH (9) on aphids as carriers of spinach blight would indicate that such insects might perpetuate other mosaic viruses, but MCCLINTOCK (10) has been unable to find this true for tomato mosaic. DOOLITTLE'S (7) work on cucumber mosaic has failed to incriminate any of the insects studied in connection with that disease. The present work has to do mainly with the second and third possibilities just mentioned.

Hothouse tomatoes as carriers

The mosaic disease has been found very commonly in hothouse tomato crops, and in the immediate neighborhood of hothouses it is possible that the disease may be carried from the late hothouse crop to the field crop plant-beds. This danger is very great in cases in which the plants for the field crop are started in hothouses or coldframes adjacent thereto. In one case noted in June 1920 at Kokomo, a severe early infestation of mosaic was present in a field, the plants for which had been grown in part of a hothouse occupied by a tomato crop. In fact, mosaic was found on many of the tomato plants left in the plant-bed. Hothouse tomatoes, however, are grown only in a relatively few localities in the state, and are usually near the towns and cities. The canning tomato crop, on the other hand, is contracted primarily among general farmers

[1] Contribution from the Botanical Department of Purdue University Agricultural Experiment Station, Lafayette, Indiana.

rather than truck gardeners, so that the fields are widely scattered through the country, and as a rule are not in the neighborhood of hothouses. Hothouses, therefore, can play only a very minor rôle as reservoirs of mosaic infection for the canning tomato crop.

Transmission with tomato seed

Miss WESTERDIJK (12), in her work with tomato mosaic, concluded that the disease was transmitted through the seed, but her evidence appears to be based on a field test with only ninety-six plants, and these unprotected from insects. ALLARD (3), in extensive tests involving about a thousand plants grown from seed from mosaic tomato plants, obtained no evidence whatever that the disease was transmitted through the seed. The same investigator (2) found that the related tobacco mosaic is not seed-borne.

The general occurrence of mosaic in fields used as a source of seed for the canning tomato crop of Indiana made it necessary to test thoroughly the possibility of seed carriage of the virus. A quantity of tomato seed was saved from mosaic tomato plants in the fall of 1920, in cooperation with I. C. HOFFMAN and H. D. BROWN of the department of horticulture, and was planted in a greenhouse December 2, 1920. Because of the season the plants grew rather slowly. In a careful examination made on January 20, 1921, no mosaic was found in a total of 13,573 of these plants. The crop was thinned at this date, and on February 26 no mosaic was found among the 2823 plants which remained. On February 3, 1921 seed saved from two mosaic tomato plants in 1920 was planted in soil flats in the greenhouse, and in the 135 plants present on May 9 no mosaic had appeared. In the summer of 1921 another test of tomato seed collected from mosaic plants in 1920 was made in the greenhouse and under a cloth cage in the field. The seed was planted on June 23, and on August 10 no mosaic was found in a total of 5091 plants in the greenhouse and 218 under the field cage. Thus, in a total of 19,017 plants grown from seed from mosaic tomato plants, no mosaic appeared. Similar tests in the greenhouse in 1921 with two-year-old tomato seed from mosaic plants also yielded negative results. In a total of 3927 plants grown from such seed no mosaic occurred.

The possibility of the presence of the mosaic virus dried on the exterior of the seed coat was also taken into consideration. About four ounces of tomato seed collected from mosaic plants four months previously was washed in sterile water, and eight tomato plants were inoculated by wounding the stem near the growing tip with a needle, and rubbing the wounded area with cotton soaked in this wash water. No mosaic developed in these plants. In the light of this evidence there appears to be no indication that tomato mosaic is transmitted through the seed.

Mosaic in perennial Solanaceous weeds

Historical

The susceptibility of certain perennial weeds to tobacco and tomato mosaic is highly significant in connection with the overwintering of the virus. Allard (1) transmitted mosaic from tobacco to the perennial *Solanum carolinense*, and points out the possibility of the mosaic virus persisting over winter in the rootstocks of this weed. He states, however, that he had noted only one case of mosaic occurring naturally in *S. carolinense*, but recognizes the difficulty of detecting the disease in this weed because the symptoms may be very inconspicuous. He also found the mosaic which occurs commonly on the perennial *Phytolacca decandra* to be distinct from and unrelated to the tobacco mosaic.

Nishimura (11) transmitted mosaic from tobacco to *Physalis alkekengi*. In his tests the *Physalis* plants developed no mosaic symptoms, but the juice expressed from the inoculated plants proved infectious to tobacco. This exotic species of *Physalis* is recorded as a perennial which is not hardy in the northern states. Nishimura also proved that a mosaic disease found on the perennial *Solanum aculeatissimum* in Florida by R. A. Harper was transmissible to tobacco.

Recently Crawford (6) in Iowa has reported successful cross inoculations from mosaic tomatoes to *Physalis longifolia*, a common weed of that region. He also found mosaic occurring in the field on that weed, and with the virus from the rootstocks made successful inoculations of tomato plants. He points out the probability of the mosaic virus overwintering in the rootstocks of *Physalis longifolia*. This species has not been found in Indiana.

An example of the persistence of a mosaic virus in a perennial herbaceous host is afforded by the pokeweed mosaic studied by ALLARD (4). The work of CARSNER (5) on the weed hosts of the virus of the curly-top disease of sugar beets in California has been very suggestive in connection with the problem of overwintering of mosaic viruses. He has pointed out the probability that the curly-top virus may persist over winter in *Erodium cicutarium*, a winter annual. Recent work by DOOLITTLE on the relation of *Micrampelis lobata* (7) and *Asclepias syriaca* (8) to cucurbit mosaic also has been suggestive.

PERENNIAL SOLANACEOUS WEEDS IN INDIANA[2]

The following Solanaceous perennials occur in Indiana: *Lycium halimifolium* Mill., *Solanum dulcamara* L., *S. carolinense*, *Physalis lanceolata* Michx., *P. heterophylla* Nees., *P. subglabrata* Mack. and Bush, and *P. virginiana* Mill. *S. carolinense* and the three species of *Physalis*, *P. heterophylla*, *P. subglabrata*, and *P. virginiana*, are weeds of common occurrence in and about cultivated fields. Of these, *P. subglabrata* and *P. virginiana* have been found to be by far the most abundant in the tomato regions, and most of the observations have been made upon these species. These two species are not easily differentiated, and no consistent attempt has been made in this work to separate them. The larger leaved *P. subglabrata* has appeared to be the more abundant of the two in central Indiana. Unless otherwise qualified, the term *Physalis* as used herein should be understood to refer to these two very similar species.

CROSS INOCULATION TESTS

Mosaic has been found occurring naturally in the field on *Solanum carolinense*, *Physalis heterophylla*, *P. subglabrata* (pl. XVII), and *P. virginiana*. On July 5, 1921, ten potted tomato plants in the greenhouse were inoculated by wounding the stem and rubbing the wounded area with cotton soaked in the juice from mosaic *S. carolinense* plants collected at Vincennes. By July 29 all had developed mosaic. None of the ten control plants, similarly treated except that distilled water was substituted for the juice

[2] CHARLES C. DEAM, state forester, very kindly furnished authoritative records concerning the Solanaceous flora of Indiana.

from the mosaic plants, developed the disease. On July 28, 1921, sixteen potted tomato plants in the greenhouse were similarly inoculated with the juice from mosaic *P. heterophylla* plants, and by August 18 nine had developed mosaic. Four uninoculated plants held as controls remained healthy. In a tomato field, on August 21, 1919, thirteen plants of *P. subglabrata* were inoculated with the juice from crushed leaves of mosaic tomato plants. Twelve days later eight had developed mosaic. Nearby uninoculated plants observed as controls did not develop the disease. Late in August 1919, seventeen potted tomato plants in the greenhouse were inoculated with the juice from mosaic *P. subglabrata* plants, and fourteen developed the disease; the seventeen uninoculated control plants remaining free from mosaic. On May 25, 1921, four potted tomato plants in the greenhouse were inoculated by wounding the stem with a needle and rubbing the wounded region with cotton soaked in the juice of crushed leaves of mosaic *P. subglabrata* collected at Frankfort, and fifteen days later all had developed mosaic. The two control plants, similarly treated except that distilled water was substituted for the mosaic virus, remained healthy. On July 15, 1921, forty-seven tomato seedlings grown under a cloth cage in the field were inoculated with the virus from mosaic *P. virginiana*. Ten days later twenty had developed mosaic. None of the numerous uninoculated seedlings in the cage developed the disease. The identity of this *Physalis* species was verified by PAUL C. STANDLEY of the United States National Museum. The results of these cross inoculations show that the mosaic disease found on these weeds in the field is transmissible to tomatoes.

OBSERVATIONS ON PHYSALIS MOSAIC IN 1919 AND 1920

The attention of the writers was directed to the importance of *Physalis* as a carrier of tomato mosaic in the summer of 1919. Large numbers of *P. subglabrata* occurred in an experimental field of tomatoes near Frankfort, Indiana. Mosaic became epiphytotic on the tomatoes during the latter part of the season, and also appeared on many of the *Physalis* plants, especially in a low-lying section of the field where the weeds were most abundant. In this

part of the field about 5 per cent of the *Physalis* plants showed mosaic. The reciprocal cross inoculations proved that the causal viruses were identical. *Physalis* was generally distributed in this vicinity, and a survey showed that mosaic did not occur to any extent on the plants at a distance from the tomato field. In a corn field about 40 rods distant, several hundred *Physalis* plants were examined and only two showed mosaic. Horse nettle was present in the tomato field, but showed no mosaic symptoms.

The location of a number of the mosaic *Physalis* plants in the tomato field was carefully noted. The following year this field was planted in corn and no tomatoes were grown in the neighborhood. On July 15, 1920, an inspection of the field showed the *Physalis* plants again abundant, and in the same part of the field where mosaic was noted in 1919 the disease was now conspicuous on a much higher percentage of the plants than had been observed the preceding fall. In a corn field adjacent to the west side of the experimental field, mosaic was found among the *Physalis* plants along the edge, but not over 100 feet distant from the fence. In another corn field near the east side of the experimental field, mosaic was also found on many of the *Physalis* plants. Since no tomatoes were being grown in the vicinity this season, the prevalence of mosaic on *Physalis* at this early date indicated that the disease must have persisted in the weeds over winter. The greater prevalence of the disease as compared with the preceding September may possibly be explained by the fact that many of the weeds had not shown definite mosaic symptoms in the fall, whereas the young shoots of the following spring showed conspicuous symptoms. It has been noted that mosaic symptoms on old plants in the fall may become very inconspicuous.

Overwintering of virus in rootstocks

Physalis subglabrata is perennial by means of a thick rootstock 12–18 inches below the surface of the soil, deep enough to escape harm from ordinary cultivation practices. In the fall of 1919 some of these rootstocks of mosaic plants were dug, and an unsuccessful attempt was made to carry them over winter in pots of soil. The test was repeated the next year. Late in August

1920 a number of rootstocks of mosaic *P. subglabrata* plants were dug in the Frankfort field and planted in a small plot surrounded by a wooden frame sunk in the soil in a garden at Lafayette. These rootstocks established themselves and produced shoots in the fall of 1920. The rootstocks remained alive over winter, and in the spring of 1921 sent up shoots showing mosaic. Six shoots had appeared by May 13, thirteen by May 23, and on June 3 fifteen plants were present. These mosaic *Physalis* shoots appeared well before the date that tomatoes are transplanted to the field, and all showed definite mosaic symptoms as soon as the leaves unfolded.

A number of aphids were found on these *Physalis* plants early in the season. On May 23 about twenty-five of these aphids were collected and caged on three small healthy tomato plants in the greenhouse. Fourteen days later one of these tomato plants showed mosaic. None of the six control plants developed the disease. The aphids soon disappeared from the *Physalis* plants in the field, but this test indicates that mosaic might be transmitted from *Physalis* to tomatoes by these insects.

Artificial inoculation of tomatoes with the virus obtained by crushing some of the leaves from three of these mosaic *Physalis* shoots also was successful. Ten small tomato plants were inoculated on June 24 by wounding the stem with a needle and rubbing the wounded area with cotton soaked in the *Physalis* virus. Eleven days later all had developed mosaic. Ten control tomato plants were similarly treated except that sterile water was substituted for the mosaic virus, and nine of these remained free from mosaic. These tests show that the mosaic virus persists over winter in the rootstocks of *P. subglabrata*, that the young shoots come up diseased at an earlier date than tomatoes are set out in the field, and that the disease is readily transmissible from these shoots to tomatoes.

Mosaic Physalis in fields previously in tomatoes

To determine how generally the mosaic disease was carrying over winter in the *Physalis* plants (including both *P. subglabrata* and *P. virginiana*), an examination was made in and near fields

where tomato mosaic had occurred in previous years. On May 24, 1921, an examination was made in and near the experimental field at Frankfort which had been in tomatoes in 1919, and in which mosaic was found on the *Physalis* plants in 1920. In the old tomato field, 147 out of 203 *Physalis* plants examined (or 74 per cent) showed mosaic. The disease occurred more generally distributed throughout the field, and on a much higher percentage of the plants than in 1919 and 1920. In the manner characteristic of the perennial species of *Physalis*, many of the plants occurred in clumps, and as a rule the plants in each clump were all healthy or all mosaic.

In the field west of the old tomato field, 11 out of 179, or 6 per cent of the *Physalis* plants examined in a strip about 50 feet wide along the fence showed mosaic. In the fields east of the old tomato field, 11 out of 39, or 29 per cent of the *Physalis* plants examined showed mosaic. In the field to the north, no mosaic was found on the 66 plants examined, but most of these were at a considerable distance from the tomato field. From these mosaic *Physalis* plants the disease was transmitted to tomato plants in the greenhouse, as noted in a previous paragraph. In this area, therefore, the mosaic disease persisted in *Physalis* plants two years after the tomatoes, and even became more prevalent on the weeds.

On May 23, 1921, mosaic *Physalis* plants were found in a small plot and in a field near Lafayette, in both of which tomato mosaic had occurred in 1920. On May 25, 1921, a study was made of the *Physalis* plants in a three-acre field near Indianapolis in which tomato mosaic had been especially severe in 1920. On one side of the field, 6 out of 209 *Physalis* plants examined showed mosaic, and on the other side, 67 out of 159 showed mosaic. Thus a total of 73 out of 368, or 20 per cent of the *Physalis* plants were affected with mosaic. No mosaic had been noted on the *Physalis* plants among the tomatoes in this field on September 14 of the preceding fall. In an adjacent portion of this field which had been in corn in 1920, 104 *Physalis* plants were examined and none showed mosaic.

These observations showed that the mosaic *Physalis* shoots were appearing rather generally in fields which had been in tomatoes in

previous years, well before the date when the tomato plants for the current season would be transplanted to the field. It is evident that the *Physalis* plants once infected constitute a perennial reservoir of mosaic infection, which remains a constant danger to any future crops of tomatoes (or tobacco) in the vicinity.

Further observations were made later in the season upon the prevalence of mosaic on the *Physalis* plants in fields previously planted to tomatoes. In the field near Lafayette in which tomato mosaic had occurred in 1920, 43 out of 77, or 55 per cent of the *Physalis* plants examined the third week in July showed mosaic. Many volunteer tomato plants had come up in this field, but among the 186 examined, no mosaic was found at this time, although later in the season a few developed the disease.

TABLE I

Physalis MOSAIC IN OLD TOMATO FIELDS

Field	Crop			*Physalis* plants, July 13, 1921		
	1919	1920	1921	No. examined	No. mosaic	Percentage mosaic
1	Tomatoes	Corn	Corn	79	43	54
2	Tomatoes	Oats	Clover	34	7	20
3	Tomatoes	Corn	Oats	61	16	26
4	.....	Tomatoes	Oats	27	17	63
5	.....	Tomatoes	Weeds	40	27	67
6	.....	Tomatoes	Wheat	107	55	51
7	Not tomatoes		Tomatoes	138	34	25
8	Not tomatoes		Wheat	543	4	0.7

A study of the mosaic prevalence among the *Physalis* plants was made July 13 on a large farm near Indianapolis, of which a considerable acreage was devoted to tomatoes in 1918, 1919, 1920, and 1921. The 1919 tomato crop, comprising about 100 acres, was practically 100 per cent mosaic in September. No observations were made on the 1920 crop on this farm, but it is safe to assume that mosaic was prevalent that year. Mosaic was already prevalent in the 1921 crop. The results of the survey of eight fields on this farm and the relation between previous tomato crops and *Physalis* mosaic are presented in table I. From these data it is evident how prevalent mosaic may be on *Physalis* one and two

years after tomatoes have been grown. The mosaic in field no. 7 probably was due to the tomatoes in the field at the time, since many of these also showed the disease. The scarcity of the disease in field no. 8, which had never been in tomatoes, indicates that the high incidence of mosaic in field nos. 1 to 6 was due to the previous tomato crops.

Distance mosaic may spread

Field no. 8 had never been in tomatoes before, and the nearest tomato crop, that of 1919 in field no. 1, was 400 feet distant. The few cases of *Physalis* mosaic in field no. 8 were found along the edge nearest to field no. 1, and are probably attributable to long distance transmission of mosaic from that crop. In a wheat stubble field which had never been in tomatoes, mosaic was found on *Physalis* along the edge adjacent to one of the 1919 tomato fields (field no. 3) in a strip 150–200 feet wide. No mosaic *Physalis* plants were noted at a distance of 250 feet from the edge of the field. The occurrence of mosaic *Physalis* plants along the edges of fields adjacent to the Frankfort experimental field has previously been noted. The occurrence of two mosaic *Physalis* plants 40 rods distant from this field, if attributable to spread from the tomatoes, would represent an exceptionally long distance of mosaic transport.

Surveys of numerous wheat stubble and corn fields have revealed that mosaic very rarely occurs on *Physalis* plants except in the vicinity of tomato crops, past or present. In only two instances have apparently spontaneous cases of mosaic on *Physalis* been found. One mosaic plant was found in a wheat stubble near Knightstown, and another in a corn field near Monticello. In the light of such observations it is unsafe to assume that mosaic is indigenous in these wild hosts. It seems evident, however, that once the disease is introduced by means of tomatoes, it may become enphytotic in the *Physalis* flora of the immediate vicinity.

Prevalence and correlation of Physalis and mosaic in tomato fields

To ascertain the general prevalence of *Physalis* and *Physalis* mosaic in Indiana tomato fields, and the correlation between these factors and mosaic in the tomato crop, a number of tomato fields

in six localities were examined in the summer of 1921. Of necessity much of this survey work was rather hastily performed. Included in this survey are 2 fields in Washington County visited June 29; 13 fields in Johnson County, June 30; 21 fields in Howard and Tipton Counties, July 2; 4 fields on a large farm near Indianapolis, July 13; 11 fields in Hancock County, July 20; 25 fields in Marion County, July 21; and 5 fields in Grant County, September 17. The results may be summarized as follows:

Tomato fields examined	81
Fields in which *Physalis* was found	65
Fields in which mosaic on *Physalis* was found	35
Fields in which mosaic on tomatoes was found	60
Fields in which *Physalis* and mosaic on tomatoes were found	48
Fields in which mosaic on both *Physalis* and tomatoes was found	29

The wide occurrence of *Physalis* is evidenced by its presence in 65 out of 81, or 80 per cent of the tomato fields examined. The prevalence of mosaic on *Physalis* is shown by its presence in 35 out of 65, or 54 per cent of the fields in which the weeds were noted. The prevalence of tomato mosaic is shown by its occurrence in 60 out of 81, or 74 per cent of the fields examined. Some correlation between tomato mosaic and the presence of *Physalis* is indicated by the fact that 48 out of 65, or 74 per cent of the fields containing *Physalis* showed tomato mosaic, and the fact that 48 out of 60, or 80 per cent of the fields showing tomato mosaic contained *Physalis* plants. Some degree of correlation between the occurrence of mosaic on both *Physalis* and tomatoes is indicated by the presence of mosaic on tomatoes in 29 out of 35, or 83 per cent of the fields in which *Physalis* mosaic was found, and by the presence of mosaic *Physalis* plants in 29 out of 60, or 48 per cent of the fields in which tomato mosaic was found.

Plant-bed origin of mosaic

There were convincing indications in many of the fields examined that mosaic was transported to the field with the tomato transplants. In many of the fields in Johnson and Hancock counties, originally set out with tomato transplants imported from southern states, the heavy losses in stand due to the presence of *Fusarium*

wilt in these imported transplants necessitated the use of large numbers of locally grown replants to fill the blank spaces. Mosaic was distinctly more prevalent on these locally grown replants.

An examination was made of the plant-beds in three localities which served as sources of these replants, and *Physalis* plants were found in or near these beds in all cases. No mosaic, however, was noted on these *Physalis* plants. The replants from one of these localities had been very generally diseased in every field in which they were used, and on July 20 mosaic was found very general on the tomato plants remaining in the outdoor plant-beds from which these replants had been taken. These plant-beds were grown up to weeds at this time, and thirty *Physalis* plants were found, but none showed mosaic. In fact, *Physalis* was a particularly abundant weed in this neighborhood, and was also noted in the coldframes of another grower.

The occurrence of *Physalis* plants in and about coldframes and plant-beds is considered of especial significance, because here tomato plants are grown year after year, and once mosaic gains a foothold in these weeds, all succeeding crops of tomato plants will be exposed to infection before they are transplanted to the fields. This source of infection is considered especially dangerous, because from the plant-beds the disease may be introduced into numerous fields, and because mosaic reduces the yield much more severely on plants infected when very young. It has been shown that the mosaic disease, once introduced into a locality, may persist year after year in the perennial weed relatives of the tomato. Since, under Indiana conditions, canning tomatoes are grown in rotation with other crops, and many new fields are being used each year for tomato production, the mosaic disease will undoubtedly be thus introduced into the perennial weed flora of new fields and localities each season. This will inevitably result, it would seem, in the disease becoming more and more widespread in the weed flora each year, and consequently in an alarming annual increase in the reservoir of mosaic infection for future tomato crops unless the vicious cycle is broken.

Mosaic transmission

The means by which the mosaic disease may be transmitted from *Physalis* to tomato have not been thoroughly studied, although from analogy with other mosaic diseases it has seemed safe to assume that insects are the responsible agents. Certain it is that insects are responsible for much of the spread of mosaic among tomatoes, because, by the use of cages to exclude insects, the occurrence of mosaic has been uniformly prevented. Plants thus caged remain free from mosaic in badly diseased fields.

The occurrence of aphids on mosaic *Physalis* plants early in the season, and the successful transmission of the disease to a tomato plant by these insects has been mentioned. Flea-beetles (*Epitrix cucumeris*) are abundant on *Physalis* plants throughout the season, and these insects also attack young tomato plants. A preliminary test indicates that they may carry the disease. On July 16, 1921, a number of flea-beetles collected on mosaic *Physalis* plants were placed in a large cloth cage containing young tomato plants. On August 17 six of the 338 plants in this cage showed mosaic, while no mosaic was found in the 218 control plants in a similar cage in which no flea-beetles had been placed.

Mosaic on Physalis heterophylla and Solanum carolinense

Although not as abundant as the two *Physalis* species previously discussed, *Physalis heterophylla* and *Solanum carolinense* are of common occurrence in cultivated fields in Indiana, the former usually in sandy soils. Mosaic in a conspicuous form was found in abundance on both of these species in a peach orchard near Vincennes, June 28, 1921. A clump of five mosaic *P. heterophylla* plants was found on July 27 along the edge of a field near Lafayette in which tomato mosaic occurred the previous year. Mosaic was noted on *S. carolinense* near a canning factory at Indianapolis, September 7. Successful cross inoculations of mosaic from both of these species to tomatoes have previously been described. Both species are commonly attacked by flea-beetles.

Among the eighty-one tomato fields visited in the survey, *P. heterophylla* was noted in seven fields and *S. carolinense* in thirteen

fields. In three fields, all in Marion County, mosaic was noted on *P. heterophylla* and also occurred on the tomatoes. In one of these (field no. 7) ten *P. heterophylla* plants were noted and one showed mosaic. Mosaic was noted on *S. carolinense* in only one field, a garden near Kokomo in which mosaic also occurred on *P. subglabrata* and on the tomatoes. It is evident that *P. heterophylla* and *S. carolinense* may function as reservoirs of mosaic infection. Both species are perennial by deep rootstocks and difficult to eradicate or control by cultivation.

Mosaic in annual Solanaceous weeds

ALLARD (1) transmitted mosaic from tobacco to two garden species of *Physalis* (probably annuals) and to the annual *Solanum nigrum* and *Datura stramonium*. In Indiana mosaic has frequently been noted on these weeds. Attempts to cross inoculate from *D. stramonium* to tomato and vice versa have yielded negative results. In preliminary tests mosaic has been transmitted successfully from tomato to *S. nigrum* and to *S. integrifolium* and *Lycopersicum pimpinnellifolium*. Mosaic has been noted on cultivated *Physalis pubescens*. The disease, of course, is common on tobacco, and has been transmitted to tomatoes by artificial inoculation. Mosaic has been noted on tobacco plants occurring as weeds in hothouses. While annual hosts cannot carry the mosaic disease over winter, they may serve as sources of infection during the growing season, and aid in the annual spread of the disease. Annual Solanaceous weeds are undesirable in tomato fields and plant-beds and in hothouses.

Mosaic control suggestions

The danger involved in growing plants for the field tomato crop in hothouses used for tomatoes should clearly be understood.

Tomato growers should recognize in the perennial ground cherries and horse nettle a distinct danger to their crop. Drastic measures should be taken to eradicate these weeds in the vicinity of tomato seed-beds and plant-beds. Furthermore, during the early part of the season these weeds should be destroyed or at least kept down in and around the tomato field by frequent cultivation and hand

pulling. This is especially important during the first part of the season, since early mosaic infection results in the greatest loss.

These perennial species present extreme difficulties in the way of control because of the deep rootstocks and the prompt reappearance of new shoots after the old ones are destroyed.

The annual Solanaceous weeds, such as nightshade and certain ground cherries, should be destroyed in and near tomato fields and plant-beds.

Hothouses to be used for tomatoes should be kept free from Solanaceous weeds.

Tomato plant-beds should be cleared of all weeds and remaining tomato plants as soon as no more transplants are needed.

Transplants from plant-beds in which mosaic is present should not be used.

Theoretically these weed relationships are equally important in connection with the control of mosaic in tobacco.

Summary

1. Tomato mosaic may be carried over winter in hothouse tomato crops, but this does not account for the great bulk of mosaic infection in the canning crop.

2. In a total of 22,944 tomato plants grown from seed from mosaic plants, no evidence of seed transmission of the disease was obtained.

3. The mosaic disease has been found occurring in the field on the following perennial weed relatives of the tomato in Indiana: *Physalis subglabrata*, *P. virginiana*, *P. heterophylla*, and *Solanum carolinense*. Mosaic has been transmitted to tomatoes from each of these species.

4. It has been proved that the mosaic virus persists over winter in the rootstocks of *P. subglabrata*. The young mosaic shoots appear in the spring before tomatoes are transplanted to the field. From these shoots the disease has been transmitted to tomatoes.

5. *Physalis subglabrata*, with some admixture of the very similar *P. virginiana*, is a very prevalent weed in Indiana tomato fields.

6. Examination of these weeds in fields previously in tomatoes shows that a considerable percentage of the *Physalis* plants come

up showing mosaic the next year, and likewise the second year after the tomatoes. The disease persists among these weeds year after year, and such weeds serve as a perennial reservoir of mosaic infection for future tomato crops.

7. Mosaic has not been found to any extent occurring spontaneously in *Physalis*, and is present in the weeds only in and near fields once used for tomatoes. As more and more new fields are used for tomatoes, however, the reservoir of mosaic infection in the perennial weed flora will increase each year.

8. Evidence of spread of the disease to *Physalis* plants 200 to 400 feet from tomato fields has been adduced.

9. In a field survey *Physalis* was observed in 65 out of 81 tomato fields, and mosaic was noted on *Physalis* in 35 of these fields, and on both *Physalis* and tomatoes in 29 fields. Tomato mosaic was noted in 60 fields, and in 48 of these *Physalis* was found.

10. In many fields the tomato mosaic was undoubtedly of plant-bed origin. Mosaic was found on tomatoes in plant-beds. *Physalis* is often present in and near plant-beds.

11. Aphids and flea-beetles may play a part in the transmission of mosaic between *Physalis* and tomatoes.

12. *Physalis heterophylla* was found in 7 of the 81 tomato fields examined, and in 3 fields showed mosaic.

13. *Solanum carolinense* was found in 13 of the 81 tomato fields examined, and in one field showed mosaic.

14. The eradication of perennial Solanaceous weeds in and near tomato fields, and particularly the plant-beds early in the season, is recommended as a mosaic control measure.

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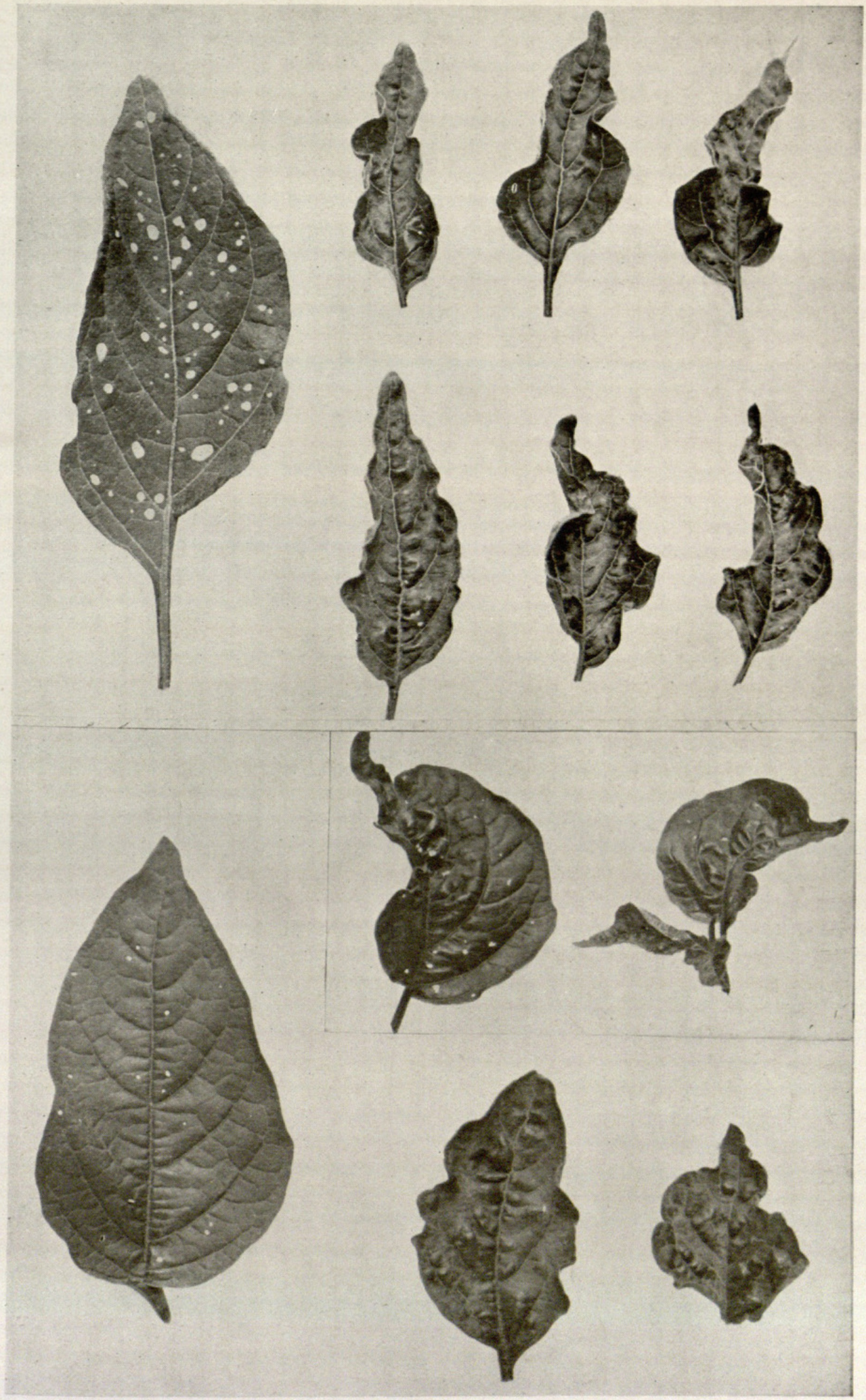

GARDNER and KENDRICK on MOSAIC