OCCURRENCE AND IMPORTANCE OF TOMATO VIRUSES IN LEBANON

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TOMATO VIRUSES IN LEBANON

CHAND

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AN ABSTRACT OF THE THESIS OF

Ali Akbar Chand for M.S. in Plant Pathology

Title: Occurrence and importance of tomato viruses in Lebanon.

In the survey program of 1965-66, virus disease specimens were collected to identify and record the species and strains of viruses occurring on tomatoes. Tobacco mosaic virus (TMV), potato virus X (PVX), potato virus Y (PVY), cucumber mosaic virus (CMV), and tomato big bud virus (BBV) were found in Lebanon. Of these CMV was wide spread and was predominant in the North, TMV and PVX were abundantly present in the South and the Beqa'a Plain, and BBV was restricted to Agricultural Research and Education Centre.

TMV collected from Tabarja had subnormal thermal inactivation point (80°C to 90°C) which suggested a special strain of TMV different from the normal one (90°C to 95°C).

A field experiment was set up to evaluate the deleterious effect of TMV, PVX, TMV + PVX, and CMV on the yield of five tomato varieties. The results indicated that TMV, PVX, and the combination of TMV + PVX were more destructive to tomato yield than were CMV and control. Among the varieties, the worst affected one by virus infections was Local Malty. Although none of the tested varieties was immune from all the virus infections, Red Jacket was found superior in yielding ability to others. As a result of CMV infection Red Jacket yielded even higher than unaffected control.

None of these viruses was seed transmissible. Therefore, it is safe to use seed from local sources for planting.

The present findings will substantially contribute to other established facts about the virus species in suggesting judicious control measures. For CMV, introduction of Red Jacket variety and use of insecticides against the virus vector *Myzus persicae* will constitute a dependable measure of control. Selection of resistant varieties for replacement of Local Malty, the cultural

practices such as wide spacing and avoiding of staking of tomato plants and disinfection of the hands and tools of workers with 20 percent trisodium phosphate will effectively minimize TMV and PVX infections.

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I. INTRODUCTION

The tomato (*Lycopersicum esculentum*) is grown widely in Lebanon. It is planted in the mild climate of the littoral zone throughout the year and in the Beqa'a Plain (900 - 1050 m in elevation) in the spring when the danger of the frost is over. The area and production of the tomato crop in Lebanon are increasing rapidly and were nearly doubled during the last five years. The rise in tomato fruit tonnage was recorded from 25,000 tons in 1960 to 45,000 tons in 1965 (Anonymous 1966).

The tomato crop is subject to numerous diseases which cause substantial reductions in yield. Among the virus diseases not less than twenty virus species have been reported on tomatoes from other parts of the world (Smith 1937, pp. 289-335 Wiltshire 1957, pp. 55-58). In this country Weltzien and Jabur (1963) have mentioned only the big bud disease. Evidently the virus species occurring in Lebanon have not been ascertained.

Some degree of reduction in total yield has been found in nearly all crops attacked by viral diseases (Holmes 1964, p. 36). In tomatoes large reductions in yield have been observed as a result of virus infections (Mc Ritchie and Alexander, 1957). The extent of losses sustained by tomato growers in Lebanon on account of virus diseases has not been evaluated.

Before measures to control a virus disease can be formulated and applied it is necessary to identify the causal virus (Broadbent 1964, p. 330). Furthermore the magnitude of loss resulting from the disease will determine the practicability of any control measures. Control based on these two considerations must be feasible and low in cost so that the investment in terms of labour and money will result in a net profit to the growers.

In view of these facts the present study was undertaken to ascertain the status of tomato virus diseases based on data collected during the survey program of the year 1965-66. The work was intended to differentiate between virus infections and the other diseases and to determine the virus species involved. Investigations were also concerned with the distribution of tomato virus diseases. Such information can be of practical value for determining the type of control measures which should be employed in certain areas.

Another aspect of the study was aimed at assessing the yield reductions induced by widely prevalent tomato viruses found in Lebanon. Finally it was hoped to determine to what extent such losses can be minimized by selection of resistant or tolerant varieties and by planting seed from healthy tomato crops.

II. REVIEW OF LITERATURE

Susceptibility of tomatoes (*Lycopersicum esculentum* L.) to more than twenty virus diseases has been reported by Smith (1937, pp. 290-331). The similarities in symptoms produced by some viruses are so nearly alike that there has been marked inconsistency between different authors regarding the naming of the causal agents. Wiltshire (1957, pp. 55-58) in an attempt to bring uniformity to the nomenclature of plant viruses, summarized the previous work, assigned final names to the known viruses, and included their synonyms.

Tomato Virus Symptomatology

According to Ross (1964, pp. 68-91) symptomatology has been the most widely used criterion for identification of plant viruses. This is a natural consequence of the fact that the known plant viruses, with few exceptions, have been discovered and recognized on the basis of the disease they cause. As such the symptoms produced by any virus on tomatoes are expected to be characteristic. However the complications created by those viruses which induce identical symptoms are illustrated amply in the following discussion of the several viruses and the symptoms exhibited when they attack the tomato plant.

Alfalfa mosaic virus was described as causing black necrotic lesions on tomatoes which ultimately kill the plants (Holmes 1964, pp. 17-38).

Aster yellows virus induced chlorosis and dwarfing of the plants which assumed bushy habit as a result of stimulated growth in the axils of the leaves and leaflets (Smith 1937, pp. 214-222).

Cucumber mosaic virus was described by Doolittle (1916), as exhibiting mottling and distortion of the leaves, which in extreme cases, show fern leaf and show-stringing. Holmes (1964, pp. 17-38) observed that the plants as a whole may be dwarfed. Simple dead spots may be formed on the leaves, the size and shape of the fruit is adversely affected, and the yield is reduced.

Delphinium stunt virus showed dwarfing of the plant and vein clearing accompanied by rolling of the leaf margins and of the tips (Smith 1937, pp. 1-5). The leaves often become lobed (Holmes 1964, pp. 17-38).

Potato virus X induced necrotic lesions followed by mosaic and mottling (Smith 1937, pp. 341-350). It was also observed to cause over all reduction in fruit yield (Holmes 1964, pp. 17-38).

Potato virus Y induced vein clearing and mottling, followed by characteristic green banding of the veins. The symptoms were never strongly marked, disappeared entirely as the plant grew and the mature tomato plant carried the virus without symptoms (Smith 1937, pp. 348-353).

Tobacco etch virus is characterized by twisted leaves hooked together with rolled margins (Holmes 1964, pp. 17-38).

Tobacco mosaic virus produced mosaic and mottling of the leaves, which may also show a distortion leading to fern leaf and shoe-stringing. The total yields of the fruit may be reduced. (Anonymous 1948, pp. 36-50).

Tomato apical virus manifests the curving of apices (Holmes 1964, pp. 17-38).

Tomato aspermy virus inhibited the growing point of the main stem resulting in axillary growth giving the plant a bushy stunt appearance. Distortion and mottling in the leaves appeared. The production of fruit by diseased plants was severely curtailed. The number of the fruit set was decreased, the size was reduced and the formation of seed was completely suppressed (Blencowe and Caldwell 1949).

Tomato big bud virus induced abnormalities in the floral parts and in normal geotropic response. Virescence of flowers and proliferation were the most characteristic symptoms. The stem became thicker and the plant as a whole was dwarfed (Samuel et al. 1933). The leaves of the diseased plants may become purplish and thickened. The sepals were not separated and the fruits became woody (Holmes 1964, pp. 17-38).

Tomato black ring virus showed both systemic lesions as small black necrotic rings, and at the same time, dark reddish streaks on the stem and petiole, the former sometimes also bore rings. An oak leaf pattern occasionally was noticed in ring type diseases. The disease was fatal to young tomato plants (Smith 1945).

Tomato bunchy top virus produced a tuft of leaves at the top and caused reduction in internode length (Holmes 1964, pp. 17-38).

Tomato bushy stunt disease appeared as yellow spots on the top-most-leaves, and the rest of leaves became yellow and purplish in color. The growing points were sometimes killed, followed by growth of the secondary shoots giving a characteristic bushy appearance to the plant (Smith 1937, p. 317).

Tomato ring spot virus manifested a circular water-soaked intricate pattern of necrotic rings on young leaves, streaks on the stems and faint to conspicuous concentric necrotic rings of varying size on the fruits (Samson and Imle 1942).

Tomato shatter virus was observed by Fraser (1949) to produce small, dark brown, irregular, necrotic areas between the main veins. Necrotic streaks up to 2 mm or more in length may border the main or the lateral veins.

Affected leaves continued growth and the necrotic spots split giving the mature leaf a shattered appearance.

Tomato spotted wilt virus exhibited the characteristic bronze colored, circular markings which tended to coalesce. The young leaves may curl downwards. Tomato Fruit bronzing occurred in the green fruits and produced variable symptoms in the ripe fruits (Smith 1937, pp. 296-315, Jenkins et al. 1964).

Tomato symptomless virus described by Vasudeva and Samraj (1947) developed a faint transient mottle after 6 to 12 days. Following the disappearance of this symptom the plant looked normal while continuing to harbour the virus.

Tomato top leaf curl affected the top of the plant and is characterized by chlorosis, growth restriction, downward curling and twisting of the leaves (Newton and Peiris 1953). This virus caused curling with or without thickening of the leaves. The shoot growth was also arrested (Yasin and Nour 1965).

Tomato twisted leaf commonly appeared with marked stunting and downward twisting of the leaves. The leaflets were reduced in size. After several days infected plants may tend to recover and normal height may be attained but the leaves will remain smaller than the healthy ones and show an interveinal chlorosis (Ferguson 1951).

A virus designated as V-52-1 is characterized by vein clearing with an occasional necrosis of leaf areas, and an interveinal chlorosis with veinal areas remaining green (Miller 1953).

Tomato yellow net virus expressed pronounced yellow chlorosis of the veins and the veinlets of the infected plants. The initial phase of the disease symptoms was bright coloration on new growth which became less noticeable as the infection aged, and after six months the chlorosis vanished. The setting of fruit was normal (Sylvester 1954).

Rochow _et al_. (1955) observed an intermediate type of symptoms when plants were affected by two strains of a virus. In striking contrast the simultaneous infection by two unrelated viruses gave a more severe disease and perhaps a disease of a different type than that of either virus alone. The symptoms of single viruses were reviewed above. The typical examples of effect of simultaneous infection of 2 viruses are as follows:

In double streak caused by infection of potato virus X and tobacco mosaic virus the symptoms are light green mottling accompanied by a number of grayish brown dead spots and stunted growth. The narrow dark brown streaks that appear on the stem give it the name. Streaked plants set few fruits and these few are mis-shapen (Anonymous 1948).

Fern leaf caused by tobacco mosaic virus and cucumber mosaic virus shows short plants with peculiar bushy and upright habit of growth near the growing point. The young leaflets are curled and distorted and a few may show shoe-stringing and malformation. The blossoms are malformed and abortive. The fruits are deeply ridged showing protrusions at the blossom ends (Anonymous 1948).

According to Ross (1964, pp. 68-91), the inadequacy of symptomatology alone, as a basis for identification has been recognized because although a given virus usually causes similar symptoms in a species, different strains or isolates of the same virus can cause entirely different diseases and the symptoms induced by a given strain in a given host can vary greatly under different environments.

Symptomatology may become a more effective tool for identification if indicator or differential host plants are found and employed for the purpose. The reaction of a single indicator species is sometimes sufficient for a practical diagnosis. Potato virus-X is recognized on the basis of strictly local lesions of *Gomphrena globosa*. This single test might not detect the presence of a second virus if present, hence it is best to use two or more indicator species. Tobacco mosaic virus can be identified by the comparative response of two tobacco varieties, one with, and one without the "N" gene from *Nicotiana glutinosa*. Potato virus Y is identified by local lesions on USDA seedling 41956 and the immunity of *Datura stramonium* (Ross 1964, pp. 68-91). Cucumber mosaic virus and delphinium stunt virus are infective to *Cucumis sativus*, but the delphinium stunt virus produces no symptoms on *Datura stramonium* (Smith 1937, pp. 1-89).

The indicator plants need to be grown under optimal conditions of light (Bawden and Roberts 1947), temperature (Daft 1964), and nutrition (Bawden and Kassanis 1950), and are to be inoculated at a particular age for a particular test.

Tomato Virus Transmission

The property of transmissibility is a characteristic of viruses which can facilitate in identification of viruses and also can help in control measures of virus diseases. Several viruses can be transmitted only by specific vectors. The tomato spotted wilt virus is known to be transmitted by thrips only. Thus if an unknown tomato virus can be transmitted by thrips, very little further information is needed to identify the virus as tomato-spotted wilt virus. Consequently the control measures against thrips will minimize the transmission of the virus. Sap transmission is possible in cucumber mosaic virus, potato virus X, potato virus Y, delphinum stunt virus, tomato bunchy top virus and tomato V-52-1. Of these cucumber mosaic virus and potato virus Y can also be transmitted by insects (Smith 1937, pp. 1-397).

Some tomato infecting viruses that are not mechanically transmissible but can easily be transmitted by insects: Examples are spotted wilt transmitted by *Thrips tabaci* L. (Smith 1937, pp. 285-331), tomato yellow net virus by *Myzus persicae* (Sylvester 1954), and tomato symptomless virus by *Bemesia tabaci* (Vasudeva and Samraj 1947). All viruses can be transmitted by budding or grafting.

The possibilities of transmission of certain viruses found on tomatoes through seed has been considered by many workers. Cucumber mosaic virus was reported to be transmitted through seed of *Cucumis sativus* (Doolittle and Gilbert 1919), tomato black ring virus through *Glycine max* (Lister 1960), whereas cucumber mosaic virus and tomato black ring virus are not transmitted through the seed of *Lycopersicum esculentum* (Fulton 1964, pp. 39-63).

Tobacco mosaic virus (Bewley and Corbett 1930) was reported to be transmitted through the seed of *Lycopersicum esculentum*. Doolittle and Beecher (1937) found that tobacco mosaic virus can not be transmitted through tomato seed. Taylor *et al.* (1961) stated that germinating seed remained healthy even though accompanied by trash containing tobacco mosaic virus. Broadbent (1965) found that tomato seeds usually carried tobacco mosaic virus externally, occasionally high infections occurred internally. He, however, admitted that the plants never became infected when allowed to grow undisturbed after such infected seeds were sown. Seed infection occurred only when the seedlings were pricked or transplanted.

Influence of Viruses on Tomato Yield

An infection of tobacco mosaic virus influences the yield adversely.

Different varieties of tomato respond differently to tobacco mosaic virus infection (McRitchie and Alexander 1957, Sinclair and Brown 1958). The latter authors found that yields of marketable and cull fruits as well as total yields were significantly higher in non-inoculated plants when compared with inoculated plants in two of the three tested varieties.

Early infections cause the greatest reductions in yield (Heuberger and Moyer 1931, Alexander 1950, Walter 1950, Weber 1960, Broadbent 1964). According to Weber (1960), the younger the plants were at the time of infection, the greater was the reduction in yield. Infections of TMV made 4 to 5 days after planting reduced the yield of Marglobe about 54% whereas inoculations made 2 months later reduced the yield only 14%. Broadbent (1964) observed that the yield losses were a result of poor setting of fruits when plants were systemically infected in early stages and due to necrotic pitting and severe bronzing in late infected plants.

Weber (1960) noted yield reduction at the first picking about 11½ weeks after inoculation in early infections. Late infection reduced yield in the second picking. On the other hand, the variety W.R. Brookston A gave higher yield in the first picking in early inoculated plants than in late inoculated ones.

Walter (1950) tested yield reduction in tomatoes infected by three viruses namely tobacco mosaic virus, cucumber mosaic virus and tobacco etch virus. All the three viruses were equally harmful on W185-6, but although tobacco etch virus and cucumber mosaic were equally damaging on Wst-W210-5, this variety was not affected by tobacco mosaic virus. Alexander (1950) observed that the plants in unstaked plots remained free of TMV but that 13.2% of the plants in the staked plots were infected, because of virus transmission through wounds as a result of staking. Holmes (1964) stated that fruits may become woody when infected by tomato big bud virus, fail to reach maturity with tomato spotted wilt disease, and are decreased in number in the case of tomato aspermy. No reduction in yield of fruit occurs when plants are affected by tomato yellow net virus (Sylvester 1954).

III. MATERIALS AND METHODS

Survey of Tomato Diseases

In 1965/66 tomato growing areas of the littoral zone of Lebanon and Beqa'a Plain were surveyed for occurrence of tomato virus diseases. The samples were collected from plants which manifested necrosis (Figure 1), malformation and shoe-stringing (Figure 2), curling, fern leaf symptoms. At Agricultural Research and Education Centre (AREC), tomato big bud disease was observed. A healthy plant (Figure 3) and that with big bud symptoms (Figure 4) were collected for comparison of symptomatology.

Symptomatology on Indicator Plants

The identification of viruses causing these diseases was carried out through bio-assay on indicator plants which included *Nicotiana tabacum* var. *Samsun*, *N. tabacum* var. *Xanthi*, *N. glutinosa*, *Datura stramonium*, *Gomphrena globosa*, *Chenopodium amaranticolor*, *Cucumis sativus*, *Vigna sinensis* and *Phaseolus vulgaris* var. *Pinto*.

Efforts were made to raise the test plants, as far as possible, under optimal conditions required for good growth. The soil was steam sterilized at 15 lbs/sq. inch for an hour and plants were grown in pots which were occasionally supplied with Molar's nutrient solution to supplement the essential elements. The light and temperature conditions were maintained near to the optimum by providing artificial light and keeping the plants in the laboratory where the temperature was below 27°C. The age at which indicator plants were inoculated with viruses varied with different host species. In most of the cases it was the 2 to 4 leaf stage but in the case of *Cucumis sativus* the cotyledon leaflets were prefered.

For inoculations the juice extract was obtained by crushing the diseased leaves of tomatoes in a mortar and a pestle. The leaves of indicator plants were dusted with carborundum and the infectious juice extract was applied on these either by finger, cotton swab, or pestle. The excess of carborundum and plant extracts was washed off by a jet of water. The inoculated plants were then kept in the laboratory for development of disease symptoms. The temperature requirement for CMV was below 27°C. In order to provide a lower temperature to CMV infected the plants were kept in an air-conditioned laboratory during the hot season.

The symptoms produced by the indicator plants used, also observed by other workers (Smith 1937, Holmes 1964, Ross 1964) are as follows;

A. Tobacco mosaic virus (TMV)

(a) *Nicotiana tabacum* var. *Samsun* developed vein clearing and afterwards systemic mosaic (Figure 5) with malformation in young leaves.

(b) N. tabacum var. Xanthi produced local necrotic lesions (Figure 7) which are characteristic for TMV.

(c) N. glutinosa showed necrotic lesions as dark sunken areas which tended to be of light tan color in the centre with dark brown margins.

(d) Datura stramonium was observed to develop local necrotic lesions with a pale to lighter tan centre and darker periphery.

(e) Gomphrena globosa was found with systemic mosaic.

(f) Chenopodium amaranticolor exhibited faint mosaic (Figure 11).

(g) Cucumis sativus could not be infected.

(h) Phaseolus vulgaris var. Pinto produced tiny local lesions.

Of these indicator plants only Nicotiana tabacum var. Xanthi, N. glutinosa, and Phaseolus vulgaris var. Pinto are considered to be differential hosts for TMV and symptoms manifested by these hosts lead to identification of this virus.

B. Potato virus X (PVX)

(a) Nicotiana tabacum var. Samsun showed mottling of young leaves.

(b) N. tabacum var. Xanthi produced mottling symptoms.

(c) _N. glutinosa_ showed a pronounced mosaic symptom (Figure 8) becoming necrotic.

(d) _Datura stramonium_ produced mottling and mosaic (Figure 10) sometimes coupled with a scorch type of necrosis.

(e) _Gomphrena globosa_ developed dark brown local lesions with a lighter centre (Figure 9).

(f) _Chenopodium amaranticolor_ gave faint grayish local lesions (Figure 11).

(g) _Cucumis sativus_ developed no symptoms.

(h) _Vigna sinensis_ produced no symptoms.

(i) _Phaseolus vulgaris_ var. _Pinto_ showed no symptoms. _Gomphrena globosa_ produced local lesions characteristic for PVX

C. Potato virus Y (PVY)

(a) _Nicotiana tabacum_ var. _Samsun_ developed vein clearing followed by mottling of the leaves.

(b) _N. tabacum_ var. _Xanthi_ exhibited vein clearing and mottling.

(c) _N. glutinosa_ produced vein clearing and faint mosaic symptoms.

(d) _Datura stramonium_ showed no symptoms. It is immune from PVY (Ross 1964, pp. 68-91).

(e) _Gomphrena globosa_ produced no symptoms.

(f) _Chenopodium amaranticolor_ remained symptomless.

(g) *Cucumis sativus* developed no symptoms.

(h) *Phaseolus vulgaris* var. *Pinto* did not produce any symptoms.

(i) *Vigna sinensis* remained without any symptoms.

Nicotiana tabacum var. *Samsun* and *Datura stramonium* served as differential hosts for identification of PVY.

D. Cucumber mosaic virus (CMV)

(a) *Nicotiana tabacum* var. *Samsun* produced mosaic and malformation symptoms (Figure 6).

(b) *Nicotiana tabacum* var. *Xanthi* developed mosaic with occasional malformation.

(c) *Nicotiana glutinosa* showed heavy mosaic symptoms (Figure 8) and distortion leading to shoe-stringing.

(d) *Datura stramonium* manifested pale spots turning to mosaic and mottling, forming chlorotic rings and line patterns. These rings were not necrotic and were darker than the rest of the leaf.

(e) *Gomphrena globosa* developed systemic mosaic (Figure 9).

(f) *Chenopodium amaranticolor* produced local lesions with bright red borders and light red centres (Figure 11).

(g) *Cucumis sativus* showed a typical mosaic (Figure 12) with dark green to greenish yellow areas and leaf distortion.

(h) Vigna sinensis developed very small brownish local lesions.

(i) Phaseolus vulgaris var. Pinto produced no symptoms.

Chenopodium amaranticolor and Cucumis sativus are differential host plants for cucumber mosaic virus.

Mixed infections could be separated on the basis of susceptibility of indicator plants. CMV was infective to Cucumis sativus whereas PVX and TMV were not. TMV could be separated from the mixture of PVX and CMV by inoculating indicator plants, after heating the virus extract up to 60 to 70^{o}C for 10 minutes, PVX and CMV lost infectivity and only TMV was still infective.

Big bud symptoms observed at AREC, when mechanically transmitted on indicator plants produced the symptoms characteristic of TMV. It seems that there was a mixed infection of big bud virus (BBV) and tobacco mosaic virus. According to Samuel et al. (1933) big bud disease can not be transmitted mechanically but can be done so by budding and grafting.

Thermal Inactivation Point (TIP)

The heat inactivation point of TMV, PVX, and CMV was determined by using tomatoes as host plants. One ml portions of virus juice extract were heated in a water bath with temperature thermostatically controlled. Portions of each virus extract were heated to the following temperatures: 50°C, 60°C, 70°C, 80°C, 90°C, and 95°C for ten minutes and cooled immediately. Tomato plants were inoculated with heated virus extract and time was given for disease symptoms to develop. The heat inactivation point was determined by the portion in the temperature series of virus extract which produced no symptoms on the tomato host plant.

Design and Description of Field Experiment

A field experiment was set up at the Agricultural Research and Education Centre (AREC) in the Beqa'a Plain to estimate the losses by viruses on tomatoes when infections were caused by a single virus or by a mixture of viruses.

A split plot design with 4 replications was adopted with viruses in the main plots and tomato varieties in the sub-plots. The treatments consisted of tobacco mosaic virus (TMV), tobacco mosaic virus plus potato virus X (TMV + PVX), cucumber mosaic virus (CMV) and no inoculation (control). The tomato varieties were: Marglobe, Red Jacket, Red Long, Pearson, and Local Malty.

The rows were 5 meters long. These were spaced 1.5 meters in order to avoid contamination of the plants from the adjacent rows through contact of foliage or roots. Each plant was 1 meter apart within the rows, and each row had 6 plants, from which the central 4 plants were chosen for observations.

The seedlings were started in a hot bed at a temperature ranging from 29 to 31^{o}C and transplanted to the field in late April when the danger of the last frost was over. The plants were inoculated in early July with viruses obtained from the diseased leaves of *Nicotiana tabacum* var. *Samsun* for TMV culture, *N. tabacum* var. *Xanthi* for PVX, and *Cucumis sativus* for CMV. In all cases the reaction of these source plants was systemic mosaic which is preferable to local lesions as a source of inoculum. The diseased leaves were crushed in a mortar and the inoculum was applied with a brush to two leaves per plant, which had been dusted previously with carborundum.

The operation of inoculation was performed by a single person for a particular virus, in order to avoid undesired contaminations. To keep off the interference of insects and fungi in the experiment Dipterex; 1:1000 and Dithane; one kg/400 litres were sprayed on alternate weeks. The yield data were analysed statistically according to split plot design, assigning virus treatments in main plots and varieties in sub-plots. The least significant differences for viruses, varieties and interaction between viruses and varieties were calculated to compare the means with control.

A visual estimate of rating symptoms was adopted, in which the type of symptom was recorded as Mosaic (M), Necrosis (N), malformation (Mf), and curling (C) and the intensity of symptoms were shown as light (+), medium (++), and severe (+++).

The observations on the development of symptoms were taken on 15.7.65, 24.8.65, and 18.9.65. The fruit yields were harvested on 25.8.65, 17.9.65, and 29.9.65.

Transmission of Viruses Through Tomato Seed

To study transmission of viruses through seed, the seeds from heavily affected tomato fruits were sown and the seedlings were observed for the development of disease symptoms.

IV. RESULTS AND DISCUSSION

Collection and Identification of Tomato Viruses

A survey of tomato virus diseases conducted during the year 1965-66, included localities selected at random from the tomato growing areas along the coastal strip of the Mediterranean Sea and in the Beqa'a Plain of Lebanon. The samples were collected in all seasons of the year. The following symptoms were observed on tomatoes growing in selected localities.

1. Light or heavy mosaic accompanied with curling and malformation of the leaflets with manifestation of fern leaf and shoe-stringing.

2. Light mosaic with extreme distortion in which the leaf lamina was completely suppressed into "shoe-stringing".

3. Young leaves with necrotic lesions and mosaic symptoms.

4. Vein clearing and characteristic green banding of the veins.

5. Plants short with upright habit of growth, the young leaflets curled, and distorted showing shoe-stringing and malformation.

6. Numerous small grayish brown necrotic spots having a thin papery appearance, mosaic and narrow dark brown streaks on the stems.

7. Leaves dwarfed, youngest fruit truss attachment in upright position, calyx enlarged to form bladder with toothed opening and fruit turning woody.

The symptoms obtained on the indicator plants are summarized in Table 1.

Symptoms observed on tomatoes were typical for big bud virus infection. The symptomatology, in this case, was considered reliable criterion for correct identification of the virus.

Summarizing the results of the identification of viruses corresponding to the symptoms of disease specimens collected during the survey program, the following viruses, in the given combinations, were detected:

1. Tobacco mosaic virus (TMV)
2. Cucumber mosaic virus (CMV)
3. Potato virus X (PVX)
4. Potato virus Y (PVY)
5. TMV + CMV or CMV + PVX
   (it was not possible to differentiate between the mixtures because symptoms on tomatoes were identical)
6. TMV + PVX
7. TMV + BBV

Table 1. The identification through bioassay, on indicator plants, of the viruses causing tomato diseases in different localities of Lebanon during 1965-66.

Locality	Tomato Sympt.[x]	Reactions of indicator plants									Identity[xxxx]
		1[xxx]	2	3	4	5	6	7	8	9	
Abdeh	WM	S[xx]	S	S	S	S	LL	S	LL	-	CMV
Tripoli	WM	S	S	S	S	S	LL	S	LL	-	CMV
Tripoli	HM	S	S	S	S	S	LL	S	LL	-	CMV
Chekka	M	S	S	S	S	S	LL	S	LL	-	CMV
Amchit	M	S	LL	LL	LL	S	LL	-	-	LL	TMV
Byblos	M+N	S	LL+S	LL+S	LL+S	S+LL	LL	-	-	LL	TMV+PVX
Byblos	M	S	LL	LL	LL	S	LL	-	-	LL	TMV
Tabarja	M+N	S	LL	LL	LL	S	LL	-	-	LL	TMV
Tabarja	HM	S	LL	LL	LL	S	LL	-	-	LL	TMV_1
Tabarja	HM+N	S	LL	LL	LL	S	LL	-	-	LL	TMV1
Tabarja	MF	S	LL	LL	LL	S	LL	-	-	LL	TMV
Nahrl-kalb	M+Sh	S	LL+S	LL+S	LL+S	S	LL	S	LL	LL	TMV+CMV

Table 1 (continued).

Locality	Tomato sympt.[x]	Reactions of indicator plants									Identity[xxxx]
		1[xxx]	2	3	4	5	6	7	8	9	
Nahrl-kalb	M	S	LL	LL	LL	S	LL	-	-	LL	TMV
Beirut	M+C	S	LL	LL	LL	S	LL	-	-	LL	TMV
Beirut	M+N	S	LL	LL	LL	S	LL	-	-	LL	TMV
Beirut	M	S	S	S	-	-	-	-	-	-	PVY
Damour	M+MF	S	LL+S	LL+S	LL+S	S	LL	S	LL	LL	TMV+CMV
Saida	M+N	S	S	S	S	LL	LL	-	-	-	PVX
Saida	M+Sh	S	S	S	S	S+LL	LL	-	LL	-	CMV+PVX
Saida	M+FL	S	LL	LL	LL	S	LL	-	-	LL	TMV
Saida	M+N	S	S	S	S	LL	LL	-	-	-	PVX
Sarafand	FL	S	LL	LL	LL	S	LL	-	-	LL	TMV
Sarafand	M+Sh	S	LL	LL	LL	S	LL	-	-	LL	TMV
AREC	BB	S	LL	LL	LL	S	LL	-	-	LL	TMV+BBV
AREC	MF	S	LL+S	LL+S	LL+S	S+LL	LL	-	-	LL	TMV+PVX

Table 1 (continued).

x

M	=	Mosaic
WM	=	Weak mosaic
HM	=	Heavy mosaic
N	=	Necrosis
C	=	Curling
MF	=	Malformation
Sh	=	Shoe-stringing
FL	=	Fern leaf
BB	=	Big bud

xx

S	=	Systemic mosaic
LL	=	Local lesions

xxx

1	=	_Nicotiana tabacum_ var. _Samsun_
2	=	_N. tabacum_ var. _Xanthi_
3	=	_N. glutinosa_
4	=	_Datura stramonium_
5	=	_Gomphrena globosa_
6	=	_Chenopodium amaranticolor_
7	=	_Cucumis sativus_
8	=	_Vigna sinensis_
9	=	_Phaseolus vulgaris_ var. _Pinto_

xxxx

CMV	=	Cucumber mosaic virus
PVX	=	Potato virus X
PVY	=	Potato virus Y
TMV	=	Tobacco mosaic virus
TMV_1	=	Special strain of TMV
BBV	=	Big bud virus

The locations in Lebanon surveyed for tomato virus diseases and the viruses found in these areas are shown in Figure 13.

According to Figure 13 CMV was most prevalent in the North which includes Abdeh, Tripoli and Chekka. Whereas TMV and PVX were mainly found in the central and southern parts of Lebanon. The reason for such a distribution may be the careful handling of comparatively smaller culture of tomatoes in the northern areas. The viruses TMV and PVX, readily transmitted mechanically, are most harmful in densely cultivated areas where trailing and careless handling of the tomato crop are practiced.

CMV was not only found in the North but also in other parts of the littoral zone because this virus is readily transmissible by insects as well as by mechanical means. The main sources of inoculum are the many different crops which are susceptible hosts for this virus. The practice of planting a variety of cucurbits and solanaceous crops in the same garden all the year round in the littoral zone is an unavoidable source for contracting the virus infection in these areas.

TMV was found very widely spread in the areas between Byblos and Beirut where tomatoes are commonly grown, supported on stakes. The careless handling of the crop during staking and the use of contaminated stakes from previous crops can constitute one of the main sources of infestation in the tomato crop. This explanation is in agreement with the findings of previous workers. Alexander (1950) found 13.2% of plants were infected in staked as compared to healthy unstaked control plants. It was not surprising to find that many fields checked, were one hundred percent infected by the virus. In several fields, 6 to 8 week old tomato plants exhibited mosaic symptoms due to TMV infection. Most probably the roots that were injured during transplanting contracted the disease from the viruses mechanically lying on the seed coat, or from the soil in the plots which were heavily contaminated due to intensive and continuous production of tomato and other TMV-susceptible crops. Another possibility for infection at such a young age might be from the contaminated hands of the workers and unsterilized tools which were used in various agronomic practices. These observations are in agreement with the results of many workers who found that TMV can be transmitted through the contaminated seed during transplanting (Broadbent 1964), or through the soil and through tools or hands of workers (Broadbent 1966).

Symptoms due to big bud virus infection were only found in plots at the Agricultural Research and Education Centre. This virus, which is not mechanically transmitted but can be transmitted by certain leaf hoppers, has already been reported by Weltzien and Jabur (1963) and seems to occur every year.

Thermal Inactivation Point of Virus

To confirm the results of the identification through bioassay, the thermal inactivation point (TIP) of sap transmitted viruses namely TMV, TMV_1, PVX, and CMV were determined.

Table 2. Thermal inactivation point (TIP) of viruses TMV, TMV_1, PVX, and CMV.

Temperatures	Viruses			
	TMV	TMV_1	PVX	CMV
Control	+	+	+	+
50^oC	+	+	+	+
60^oC	+	+	+	+
70^oC	+	+	-	-
80^oC	+	+	-	-
90^oC	+	-	-	-
95^oC	-	-	-	-

+ = Infection
\- = No infection
TMV = Normal tobacco mosaic virus
TMV_1 = Special strain of tobacco mosaic virus.
PVX = Potato virus X
CMV = Cucumber mosaic virus
Control: Juice extract unheated.

From table 2 it can be seen that tobacco mosaic virus (TMV), potato virus X (PVX) and cucumber mosaic virus (CMV) when heated for ten minutes were inactivated at the temperatures indicated as in the literature (Smith 1937, pp. 50-348), characteristic for these viruses. In case of TMV from two fields at Tabarja the TIP was lower than the normal (between 80 and 90^oC). It is suggested that these isolations belong to a special strain which could be called TMV_1. The symptoms on indicator plants were not different from the normal.

Effect of Virus Infection on Tomato Yield

The effects of the viruses TMV, PVX, TMV + PVX, and CMV on the yields of tomato varieties Marglobe, Red Jacket, Red Long, Pearson, and Local Malty are shown in Table 3.

The data were analysed statistically (Table 4). The least significant differences for testing significance between viruses, varieties and the interactions are presented in Table 3. The statistical analysis of the experiment showed significant differences between viruses, between varieties and the interaction of virus X varieties was also significant.

Among the virus treatments, PVX, TMV, TMV + PVX, were significantly detrimental to tomato yield as compared to CMV and control. CMV was least damaging and the yields in this treatment did not differ significantly from the control. From the harmful virus treatments, double infection caused by TMV + PVX was comparatively more destructive than were single infections of PVX or TMV. Infections of TMV alone or PVX alone resulted in similar losses.

Table 3. The influence of viruses on the yield (kg/du.) of five tomato varieties grown at AREC, 1965.

Viruses	Tomato varieties					Average of virus effect kg/du.
	Marglobe kg/du.	Red Jacket kg/du.	Red Long kg/du.	Pearson kg/du.	Local Malty kg/du.	
TMV	873.1	1435.1	965.2	672.2	730.4	935.2
TMV + PVX	424.7	1051.9	772.9	732.8	289.8	644.3
PVX	786.2	927.0	1328.2	818.2	698.1	911.5
CMV	925.2	1985.3	1057.5	974.6	573.5	1108.6
Control	952.3	1585.1	1498.0	1030.0	1321.9	1277.5
Average of varieties	797.7	1396.9	1124.4	845.6	722.7	

TMV = Tobacco mosaic virus; PVX = Potato virus-X; CMV = Cucumber mosaic virus.

	At 5% level	At 1% level
LSD for comparison between viruses and control	231.4	323.7
LSD for comparison between varieties	179.4	238.5
LSD for comparison of interactions	401.1	533.4

Table 4. Analysis of variance of viruses, tomato varieties, and the interaction of viruses X varieties.

Treatments	SS	d.f.	MSS	F
Blocks	377602.9	3	125867.61	1.11
Viruses	4353790.1	4	1088447.5	9.6
Error (a)	1352122.6	12	112676.8	
Varieties	6242319.0	4	1560579.7	19.4
Viruses X varieties	3300889.4	16	206305.5	2.6
Error (b)	4825282.3	60	80421.3	
Total	20452006.3	99		

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Total	20452006.3	99		

The productivity of the four foreign tomato varieties Red Jacket, Red Long, Pearson, and Marglobe was compared with Local Malty. It was found that Red Jacket was highly superior to Local Malty. On the other hand Marglobe and Pearson were inferior to Local Malty in yielding ability, and Red Long was comparable to the Local Malty.

A response of individual tomato varieties to the different virus infections as compared to control was noted. Marglobe was not much affected by any infection except that caused by the double infection of TMV + PVX. This double infection resulted in significant reduction in yield.

In the Red Jacket the most damaging effect on yield was caused by PVX followed by the double infection of TMV + PVX. Both these treatments, PVX and TMV + PVX reduced the yield of Red Jacket significantly. An important contrast was observed when Red Jacket was infected with CMV. This variety when infected with CMV gave a significantly greater yield than when not infected. This reaction of Red Jacket can be explained on the basis of stimulation of metabolism of tomato plant. The effect of the virus was not severe enough to bring about adverse effects after stimulation due to virus infection.

The yielding ability of the Red Long was damaged by CMV, TMV, and TMV + PVX. It seems that PVX was not very injurious to Red Long and in this treatment its yield was comparable to that of the uninfected control.

The yield of the variety Pearson was seriously reduced by TMV, TMV + PVX, and PVX.

Local Malty was more sensitive to virus infections than were the foreign varieties tested. Maximum reduction was observed in Local Malty when infected by the TMV + PVX mixture.

From the above discussion it can be observed that TMV was more harmful to Local Malty, Pearson, and Red Long than to Marglobe and Red Jacket. PVX was significantly reducing the yield in varieties Local Malty, Red Jacket and Pearson but it was not so harmful to the other two varieties.

From the yield figures in Table 3 it can be observed that the mixture of TMV + PVX reduced the yields of all the tomato varieties but its effect was most detrimental in case of Local Malty. The double infection of TMV + PVX had two contrasting effects. In varieties Red Jacket and Pearson yield reductions occurred which were intermediate to those caused by either TMV or PVX alone. On the other hand, the effects of single infections of TMV or of PVX were additive when the viruses were present together in varieties Marglobe, Red Long, and Local Malty. A double infection by TMV + PVX caused more serious losses in some of the varieties, as compared to that effected by single infections. Such results have also been obtained by Rochow and Ross (1955). Alternately the mixed infection caused reductions intermediate to those induced by either virus alone in other varieties. This type of phenomenon, although reported in viruses, is rarely met with in the case of TMV + PVX.

CMV caused significant reduction in Local Malty and Red Long.

Although none of the varieties tested was found to be immune or even tolerant to all the viruses in the experiment, Red Jacket has certain merits for consideration. This variety is relatively high yielding, is less affected by the mixed infection tested and was stimulated by CMV infection to produce higher yields.

The reaction of Red Jacket to CMV indicates that the search for the selection of tomato varieties which might show tolerance to other viruses too, may be continued. Walter (1950) had already found WStw 210-5 resistant to TMV.

Effect of Symptom Development on Tomato Yield

The type of symptoms expressed and the degree of severity as induced by virus infections on Tomato varieties were recorded at intervals. The data were collected on the basis described under Chapter III. The observations are summarized in Table 5.

Table 5. The type and intensity of symptoms on tomato varieties infected by viruses observed on different dates at the AREC in 1965.

Viruses	Dates of obs.	Marglobe I[xx]	Marglobe II[xxx]	Red Jacket I	Red Jacket II	Red Long I	Red Long II	Pearson I	Pearson II	Local Malty I	Local Malty II	Average I	Average II
TMV[x]	15/7	M+	65.5%	M(+)	192.6%	M+	40.1%	M++	70.7%	M+	67.7%	M+	87.3%
		N-		N-		N+		N-		N+		N(+)	
		MF-		MF-		MF-		MF-		MF-		MF-	
		C-		C-		C-		C-		C-		C-	
	24/8	M+	76.6%	M+	105.4%	M+	103.6%	M+++	55.8%	M+++	40.7%	M++	76.4%
		N+	N	N-		N+		N+		N+		N(+)	
		MF-		MF-		MF-		MF-		MF+		MF(+)	
		C-		C-		C-		C-		C-		C-	
	18/9	M++	112.1%	M+	67.5%	M++	32.0%	M+++	72.8%	M+++	71.3%	M++	65.4%
		N++		N++		N++		N++		N++		N++	
		MF-		MF-		MF-		MF-		MF+++		MF(+)	
		C-		C-		C-		C-		C-		C-	

Table 5 (continued).

Viruses	Dates of obs.	Varieties											
		Marglobe		Red Jacket		Red Long		Pearson		Local Malty		Average	
		I[xx]	II[xxx]	I	II	I	II	I	II	I	II	I	II
TMV+ PVX	15/7	M+	88.2%	M+	141.1%	M+	57.6%	M+	229.7%	M+	20.8%	M+	108.3%
		N+		N+		N+		N+		N+		N+	
		MF-		MF-		MF-		MF-		MF-		MF-	
		C-		C-		C-		C-		C-		C-	
	24/8	M++	50.4%	M+	95.5%	M+	53.9%	M++	83.2%	M+++	16.4%	M++	59.9%
		N++		N++		N++		N+		N++		N++	
		MF-		MF-		MF-		MF-		MF-		MF-	
		C-		C-		C-		C-		C-		C-	
	18/9	M++	26.5%	M++	33.3%	M++	49.5%	M++	58.5%	M+++	28.7%	M++	39.3%
		N+++		N+++		N+++		N++		N+++		N+++	
		MF+++		MF-		MF+++		MF+++		MF+++		MF+++	
		C-		C-		C-		C-		C++		C(+)	

Table 5 (continued).

Viruses	Dates of obs.	Varieties											
		Marglobe		Red Jacket		Red Long		Pearson		Local Malty		Average	
		I[xx]	II[xxx]	I	II	I	II	I	II	I	II	I	II
PVX	15/7	M+	117.4%	M+	69.7%	M-	100.3%	M+	199.6%	M+	64.4%	M+	110.3%
		N+		N+		N+		N+		N-		N+	
		MF-		Mf-		Mf-		Mf-		Mf-		Mf-	
		C-		C-		C-		C-		C-		C-	
	24/8	M+	77.1%	M++	74.5%	M-	100.4%	M+	85.8%	M+	56.3%	M+	78.8%
		N++		N++		N+		N+		N-		N+	
		MF-		MF-		MF-		MF-		MF-		MF-	
		C(+)		C-		C-		C-		C-		C-	
	18/9	M++	106.3%	M++	41.4%	M++	77.0%	M++	64.7%	M++	47.2%	M++	67.3%
		N+++		N+++		N++		N++		N+++		N+++	
		MF-		MF-		MF++		MF++		MF+++		MF++	
		C+		C-		C-		C+++		C-		C+	

Table 5 (continued).

Viruses	Dates of obs.	Varieties											
		Marglobe		Red Jacket		Red Long		Pearson		Local Malty		Average	
		I[xx]	II[xxx]	I	II	I	II	I	II	I	II	I	II
CMV	15/4	M+	31.4%	M+	83.6%	M+	16.5%	M+	128.1%	M++	66.5%	M+	65.2%
		N-		N-		N+		N-		N+		N(+)	
		MF-		MF-		MF-		MF-		MF-		MF-	
		C-		C-		C-		C-		C-		C-	
	24/8	M++	113.1%	M++	130.4%	M+	81.5%	M+++	72.3%	M+++	36.8%	M++	86.8%
		N-		N-		N+		N+		N+		N(+)	
		MF-		MF-		MF-		MF-		MF-		MF-	
		C-		C-		C-		C-		C-		C-	
	18/9	M++	92.3%	M++	123.4%	M++	66.5%	M+++	112.0%	M+++	48.6%	M++	88.7%
		N+		N-		N+		N+		N+++		N+	
		MF++		MF++		MF+++		MF+++		MF+++		MF+++	
		C-		C-		C-		C-		C-		C-	

x TMV = Tobacco mosaic virus; PVX = Potato virus-X; CMV = Cucumber mosaic virus.
xx I = Type and intensity of symptoms.
M = Mosaic; N = Necrosis; MF = Malformation; C = Curling.
\+ = Light; ++ = Medium; +++ = Severe; - = No symptoms.
xxx II = Yield expressed in percentage of control of three harvests picked.

It can be noticed that after inoculation the first manifestation of the symptoms induced by all the virus infections on tomatoes was a mosaic. This was followed or accompanied by necrosis. The combination of mosaic and necrosis was most destructive to the plant growth and the production of fruit. Malformation and curling were only advanced stages in the development of symptoms.

Comparing the "averages" of degrees of symptom expressions caused by different viruses on the five varieties of tomatoes, it was evident that after TMV-infection, mosaic symptoms (M), later combined with necrosis (N) were most pronounced.

The plants infected by PVX were mainly damaged by the necrosis. The mixture of both TMV and PVX caused heavy necrosis and malformation. Malformation was the most pronounced symptom of CMV infections. The curling effect was more or less specific to PVX being severe on the variety Pearson, where as other varieties did not react in the same manner.

The effect of symptom expressions on the yield was examined. It was noticed that the type and severity of the symptoms appearing in early stages influenced the yield of subsequent and final harvests. The appearance of light mosaic (M+) accompanied by light necrosis (N+), in early stages, induced by TMV + PVX, in the variety Marglobe (Table 5) reduced the yield more than light mosaic (M+) alone produced by TMV on the same variety.

The final manifestations of symptoms and their effect on yield can be concluded as follows. The necrotic reactions were seriously affecting the yield, mosaic symptoms have an intermediate influence and the malformation a very slight effect. This may be explained by the role of assimilation area on the production of fruit. Necrotic reactions are killing the tissue, reducing the assimilation area considerably. Mosaic symptoms are due to the destruction of chlorophyll in certain parts of the tissue so that the assimilation area is reduced to a certain degree. Malformation does not affect the assimilation as long as the leaf margin is not reduced to the shoe-stringing stage.

The effect of early infections on the yield has been recognized by many workers (Weber 1960, Broadbent 1960), but the comparative influence of mosaic, necrosis, malformation, and curling on tomato yield has not been worked out. The present study has given a useful information regarding the different types of symptoms produced by certain viruses, and the extent losses, each type of symptom can do, in terms of yield reductions.

Transmission of Viruses Through Tomato Seed

The seed from tomatoes heavily infected by CMV, PVX, and TMV were selected. The seeds were sown in pots and the seedlings were checked for symptom development. It was found that none out of 100 seedlings in each case developed any disease.

The transmission of PVX through any seed has never been recorded. CMV has been reported seed-transmissible through *Cucumis sativus* (Doolittle and Gilbert 1919) but there is no evidence as to its transmission through the seed of *Lycopersicum esculentum*.

Transmission of TMV through tomato seed has remained a controversial issue for a long time. Most of the workers agreed that tobacco and tomato seedlings produced from seed of plants infected by tobacco mosaic virus are virus free. A few have described infections, which they attribute to TMV as seed borne virus (Bawden 1964, p. 9). Taylor *et al*. (1961) observed that infection of tomato seedlings by TMV occurs during and after germination of seed by contamination. They substantiated that it may occur partly at least, because virus from the seed coat is transferred mechanically to the seedlings when they are handled. They found that germinating seed remained healthy when accompanied by trash containing TMV. Broadbent (1964) claimed that TMV is carried through tomato seed externally as well as internally. However, he admitted that seedlings never became infected if allowed to grow undisturbed. Seedlings were infected only when transplanted or pricked.

From the above, it can be concluded that infection, which has been described as seed borne, is not an embryo infection but a contamination of the seed coat which becomes the source of inoculum for the seedlings injured during transplanting.

V. SUMMARY AND CONCLUSIONS

A survey of tomato virus diseases occurring along the littoral zone and in the Beqa'a Plain was conducted during 1965-66. Mosaic, necrosis, malformation, fern leaf, shoe-stringing, curling, big bud, and woody fruit symptoms typical of virus infection were observed and specimens were collected for identification of the causal virus species on the basis of symptomatology and the reaction of indicator plants. It was found that out of twenty viruses reported on tomatoes from other parts of the world, only BBV, CMV, PVX, PVY, and TMV were prevalent in Lebanon, CMV being predominant in the North.

Thermal inactivation point between 60 and 70^{o}C confirmed the presence of CMV and PVX. Thermal inactivation temperatures in case of TMV was inconsistant. Besides a normal TMV which was inactivated between 90^{o}C and 95^{o}C, presumably, a special strain of TMV inactivated between 80 and 90^{o}C was also present.

The yield reductions induced by virus infections caused by TMV, TMV + PVX, PVX, and CMV in tomato varieties Marglobe, Red Jacket, Red Long, Pearson, and Local Malty were assessed. It was obvious that reductions in the yields of virus affected crop were highly significant as compared to unaffected healthy crop. Maximum damage was caused by double infections by TMV + PVX and, to a lesser extent, by PVX and TMV. CMV was least injurious. Reductions in yield depended upon the species of virus and also on the variety of tomatoes. The yield was increased in Red Jacket, unaffected in Marglobe and decreased in Local Malty when infected by CMV.

Local Malty was most susceptible to virus infections. On the other hand variety Red Jacket was found to be less affected by TMV + PVX and was stimulated as a result of CMV infection.

The type and intensity of the symptoms appearing in early stages determined the yield reductions in subsequent and final harvests of the crop. Necrosis in early stages was highly detrimental to the yield, the mosaic had intermediate effect and the malformation was least damaging.

Seed transmission studies indicated that TMV, PVX, and CMV were not transmissible through tomato seed.

The present studies have shown that five species, namely, BBV, CMV, PVX, PVY, and TMV were occurring in Lebanon. None of these viruses was found transmissible through tomato seed. Therefore, it is safe to obtain tomato seed from any source for planting, if treated with trisodium phosphate.

Among these viruses, CMV was most widely spread and TMV and PVX were most harmful as they induced significant yield reductions. The most susceptible variety in these investigations was Local Malty which sustained losses up to 78% when infected by TMV + PVX.

CMV, on account of its wide host range and its transmissibility by sap and insects, is very tedious to control. It can be minimized by forbidding the planting of cucurbits, pepper, eggplant, tobacco, celery, and swiss-chard in the same field or close to it, by using certified seed of cucurbits to avoid seed transmission, in the vicinity of tomatoes and by applying chemical control measures against *Myzus persicae*. The best control measures are the production of virus resistant varieties but it is difficult to find and develop such varieties. Red Jacket a superior yielder variety, was found to be tolerant to virus infections and yielded even better, when infected by CMV, than the healthy. This can well replace Local Malty.

TMV and PVX are most readily transmitted by sap. The viruses are found in abundance where trailing and careless handling are practiced. These viruses can be minimized by planting at wider distances, by discouraging trailing and staking of tomatoes and by disinfecting hands and tools of the workers as well as sticks used with previous crops with 20 percent solution of trisodium-phosphate. The search for selecting resistant varieties to all the viruses has to be started.

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APPENDICES

Figure 1. Lycopersicum esculentum. Left: Necrotic symptoms. Right: Healthy leaf.

Figure 2. Lycopersicum esculentum. Left: A healthy leaf. Centre: Malformation symptoms. Right: Shoe-stringing symptoms.

Figure 3. Lycopersicum esculentum. A healthy tomato plant.

Figure 4. Lycopersicum esculentum. A tomato plant with big bud symptoms: Upright habit, enlarged calyx and unseperated sepals as a result of BBV.

Figure 5. Nicotiana tabacum var. Samsun. Systemic mosaic induced by TMV.

Figure 6. Nicotiana tabacum var. Samsun. Mosaic and malformation induced by CMV.

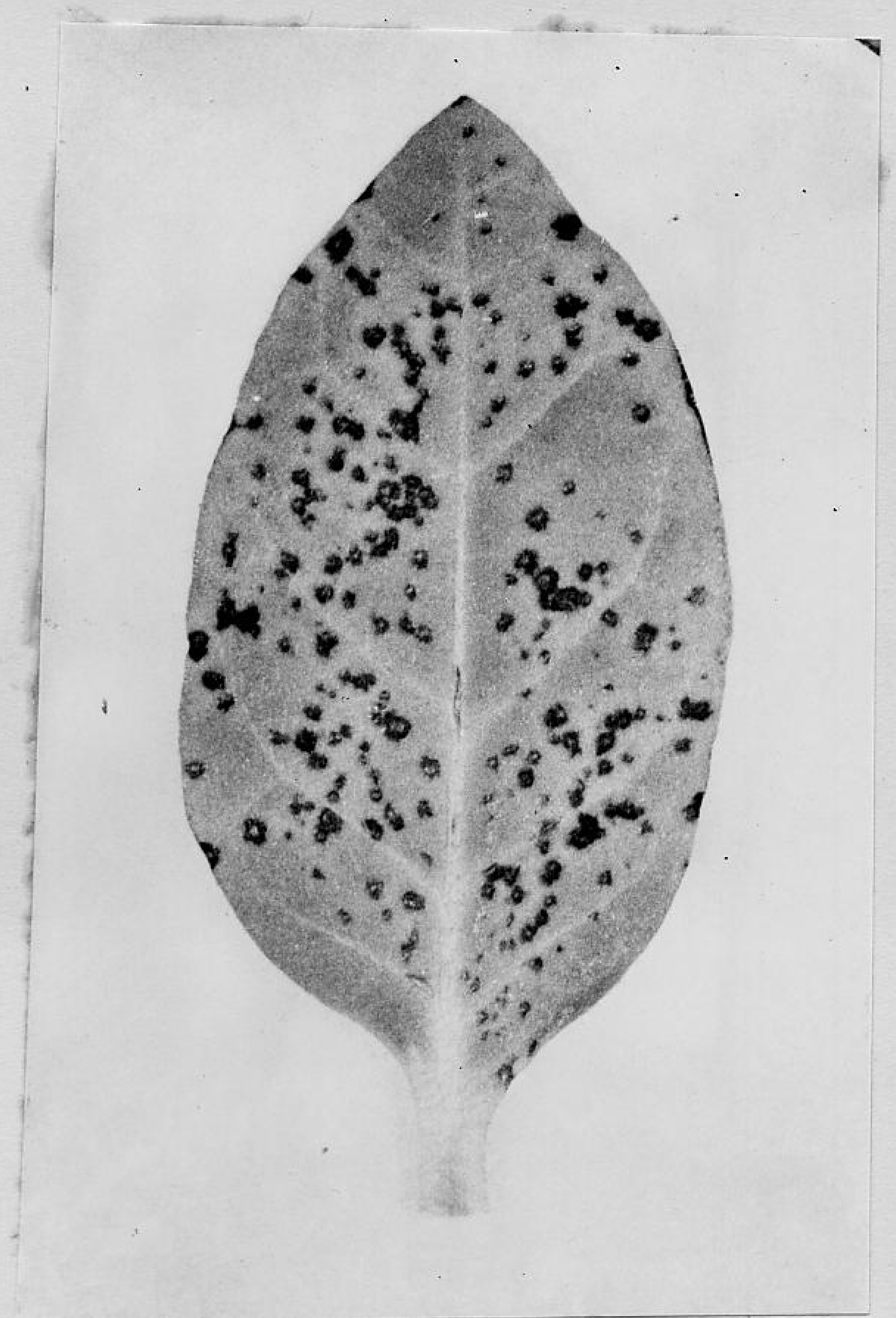

Figure 7. *Nicotiana tabacum* var. *Xanthi*. Local lesions (differential host for TMV).

Figure 8. Nicotiana glutinosa. Left: Systemic mosaic induced by CMV. Right: Mosaic induced by PVX.

Figure 9. Gomphrena globosa. Left: Mosaic induced by CMV. Centre and right: Local lesions (differential host for PVX).

Figure 10. Datura stramonium. Left: a healthy leaf. Right: Mosaic symptom induced by PVX .

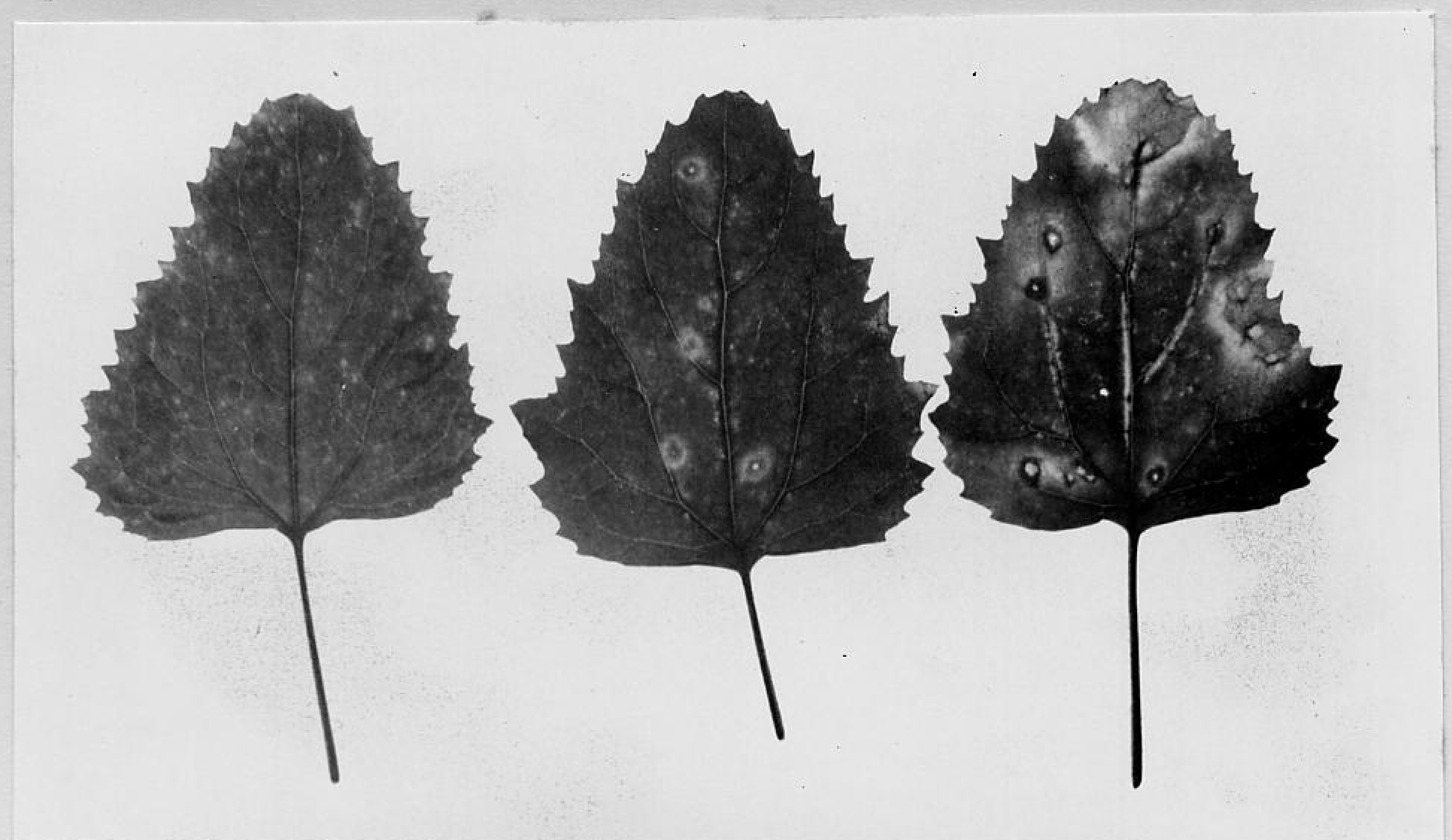

Figure 11. Chenopodium amaranticolor. Left: A faint mosaic induced by TMV. Centre: Faint grayish local lesions induced by PVX. Right: Pronounced local lesions with bright borders and light centres (differential host for CMV).

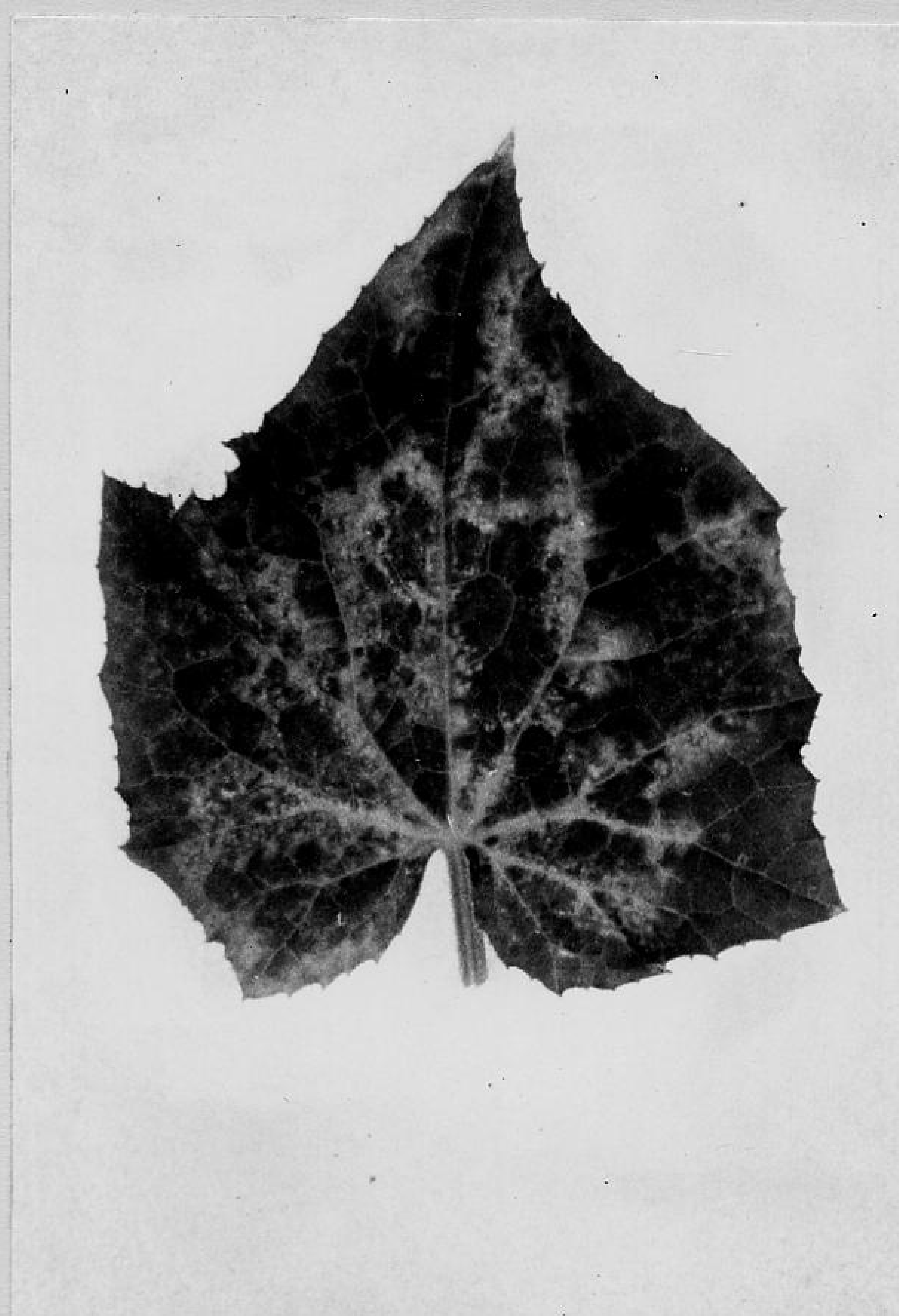

Figure 12. *Cucumis sativus*. Mosaic (differential host for CMV).

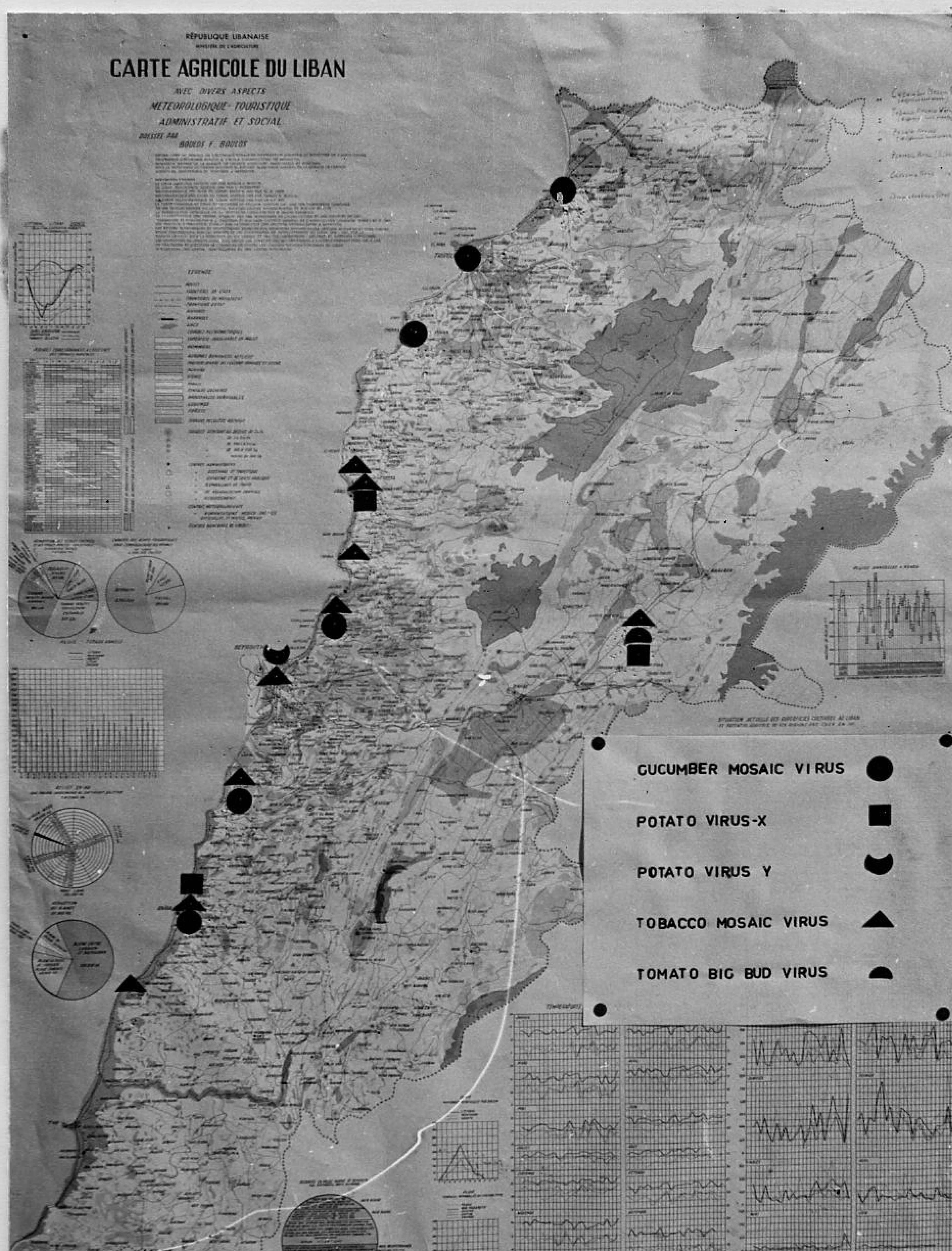

Figure 13. A map of Lebanon showing the different viruses occurring at various locations, during survey program 1965-66.