

Virus Diseases of Peas and Sweet Peas.

By

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According to the Revised List of Plant Diseases occurring in South Africa (3), the only virus disease of peas and sweet peas that has been positively identified, is the one caused by the tomato spotted wilt virus.

Other disorders due to virus infections have long been recognised but the causal organisms were not determined.

This report concerns eight viruses which occur naturally on *Pisum sativum* and *Lathyrus odoratus* in South Africa.

Apart from tomato spotted wilt there are three other diseases which are commonly found on both peas and sweet peas, viz. pea mosaic, pea stunt and a strain of lucerne mosaic.

Further, peas are naturally infected by pea virus 2, pea mosaic virus 4, and a strain of pea wilt virus. Sweet peas are also susceptible in the field to bean local chlorosis virus B and a strain of bean yellow mosaic.

Although pea mosaic, pea virus 2 and pea stunt are well-known elsewhere, they are reported for the first time in South Africa. (Pea mosaic virus 4 was discussed in detail in the paper on lupin virus diseases, as it occurs frequently on *Lupinus* species.)

Details of what appear to be new strains of the pea wilt, lucerne mosaic and bean yellow mosaic viruses are given, and a virus causing vivid local chlorotic spots on bean is described.

Pea mosaic has long been recognised as the primary virus disease of peas, but in this country more damage is caused by the tomato spotted wilt virus. This occurs frequently, and results in a systemic necrosis and possible collapse of the plants.

The other viruses are found spasmodically but the effect on individual plants can be severe. The necrotic ring strain of the lucerne mosaic virus also induces a systemic necrosis and collapse of the plant, while the pea stunt and pea wilt viruses cause necrotic stem streaks with a mosaic.

With the pea mosaic virus and pea virus 2 there is only a mosaic or mottle.

On the sweet pea, chlorotic spots, veinbands or a mosaic, may develop on the leaves of plants infected with the pea mosaic virus, or strains of the bean yellow mosaic and bean local chlorosis viruses.

Systemic necrosis occurs when the spotted wilt virus, pea stunt virus or a strain of lucerne mosaic virus are present.

Most of these viruses can cause a colour break on the flowers.

METHODS AND MATERIALS.

The standard test plants used were: *Phaseolus vulgaris* var. Canadian Wonder, *Vicia faba* var. Aquadulce and *Pisum sativum* var. Greenfeast. In addition about 30 other legumes and some plants belonging to the *Solanaceae* were used in susceptibility tests.

Aphis craccivora or *Macrosiphum pisi* were used for the insect transmission tests, although they are not necessarily the natural vectors. Carborundum powder was used for the sap inoculations.

In this report eight virus diseases are described—their physical properties, methods of transmission, host ranges and symptoms on susceptible hosts.

Their identification is based on information from the literature, but when no complete correlation can be found, new names are provisionally proposed.

1. Pea Mosaic Virus Doolittle & Jones.

Physical properties: Thermal inactivation point, 56–58°C. Longevity *in vitro*, 2–3 days. Dilution end point, 1: 1,000–1: 2,000.

Transmission: Mechanical sap inoculation. *Aphis craccivora*.

Host range: *Crotalaria juncea* L., *Glycine javanica* L., *Lathyrus odoratus* L., *Lens esculentum* L., *Lupinus albus* L., *L. luteus* L., *Medicago lupulina* L., *Melilotus officinalis* Willd., *Phaseolus mungo* L., *P. vulgaris* L., (?) *Pisum sativum* L., *Trifolium hybridum* L., *T. incarnatum* L., *T. pratense* L., *T. repens* L., *Vicia faba* L.

REACTION OF SUSCEPTIBLE SPECIES.

Crotalaria juncea.

Local. Necrotic rings can be seen after 6 days. These fuse and the leaf drops.

Systemic. The young leaves develop chlorotic spots with necrotic centres. This necrosis spreads until the leaf is “scorched” and eventually drops. Due to streak necrosis, the stem curves at the top, and the plant soon dies.

Glycine javanica.

A symptomless carrier.

Lathyrus odoratus.

Local. No reaction.

Systemic. The leaves develop chlorotic spots and later a mosaic. They are rolled and reduced in size. The flowers have a marked colour break (Fig. 1c).

Lens esculentum.

Local. No reaction.

Systemic. In about 11 days the young leaves show chlorotic spots or streaks. Later necrosis may set in, in these areas and the plant collapses. If necrosis is not present the leaves are tightly curled and the stems are rosetted, with a general stunt of the plant.

Lupinus albus.

Local. In 6 days there are small chlorotic spots with necrotic centres.

Systemic. In 14 days the veins of the young leaves become necrotic and the leaflets drop. Later formed leaves are firstly chlorotic but soon become necrotic. The growing point is stunted and almost completely defoliated. The stem becomes necrotic and the plant collapses. The stem necrosis occurs in streaks on one side only, resulting in a curved stem (Fig. 1d).

L. luteus.

Local. No reaction.

Systemic. The young leaves remain folded and have wavy margins. They are mottled. The plant is stunted and no flowers are formed.

Medicago lupulina.

A symptomless carrier.

Melilotus officinalis.

Local. No reaction.

Systemic. Chlorotic vein slashes develop in one month.

Phaseolus mungo.

Local. The veins become necrotic and the leaves collapse.

Systemic. The young leaves curl down and their veins become necrotic, with the interveinal areas quite chlorotic. A stem necrosis may develop and the plant then collapses.

P. vulgaris var. Canadian Wonder.

Local. No reaction.

Systemic. Occasionally the first trifoliates develop large chlorotic blotches. The young leaves may have a chlorotic network.

var. Haricot.

Local. No reaction.

Systemic. The leaves may be mottled with a slight malformation.

Pisum sativum.

Local. No reaction.

Systemic. In 7 days there is a clearing of the veins of the young leaves with small chlorotic flecks. A week later this is followed by a mosaic mottle of the youngest leaves, (Fig. 1a) but there may also be dark green veinbands or irregular chlorotic slashes. The leaves remain slightly folded, and are puckered and reduced in size. The growing point is rosetted and the tendrils abnormally curled.

Trifolium hybridum.

Local. No reaction.

Systemic. After a vein clearing the leaves show a chlorotic streaking.

T. incarnatum.

Local. No reaction.

Systemic. The young leaves develop a clearing of the veins in 7 days. Later formed leaves may show a chlorotic spot mottling, veinbanding or a characteristic chlorotic triangle at the apex. These leaves are crinkled and rolled and the plant is stunted (Fig. 1b).

T. pratense.

A symptomless carrier.

T. repens.

A symptomless carrier.

Vicia faba.

Local. No reaction.

Systemic. After 7 days a diffuse mottle develops on the young leaves. A week later the young leaves show a mosaic, and they are rolled and reduced in size.

Natural source of virus: *Pisum sativum* (Pretoria and district). The older leaves were flecked and mottled and the younger ones had a mosaic mottle. The plants were rosetted and the tendrils were abnormally curled.

Lathyrus odoratus (Pretoria). The leaves had a chlorotic streak mottle and there was a marked colour break on the flowers.

IDENTIFICATION.

From the symptom expression, host range and physical properties, there can be little doubt that this is the pea mosaic virus.

2. Pea Virus 2 Osborn.

Physical properties: Thermal inactivation point, 60–62°C. Longevity *in vitro*, 3–4 days. Dilution end point, 1: 2,000.

Transmission: Mechanical sap inoculation. *Macrosiphum pisi*.

Host range: *Lathyrus odoratus* L., *Lupinus albus* L., *Medicago lupulina* L., *Phaseolus vulgaris* L., *Pisum sativum* L., *Trifolium hybridum* L., *T. pratense* L., *Vicia faba* L.

REACTION OF SUSCEPTIBLE SPECIES.

Lathyrus odoratus.

Local. No reaction.

Systemic. In 14 days the leaves show a mosaic mottle with chlorotic streaks. These leaves are slightly curled downwards.

Lupinus albus.

Local. In 9 days there are large necrotic lesions which fuse, and the leaflets drop.

Systemic. 3 to 4 days later the necrosis extends up the stem and into the growing point, and the plant collapses (Fig. 2d).

Medicago lupulina.

Local. No reaction.

Systemic. Only a fine chlorotic network of the younger leaves develops.

Phaseolus vulgaris var. Canadian Wonder.

Local. No reaction.

Systemic. In a week chlorotic spots appear on the young leaves. The second and third trifoliates develop chlorotic flecks, and later formed leaves show only irregular chlorotic areas. These leaves have slightly uneven surfaces (Fig. 2b). The plant is stunted and rosetted, with pods blistered in dark green.

Pisum sativum.

Local. The inoculated leaves wither and drop.

Systemic. In a week the young leaves develop a vein clearing and chlorotic spotting. Later leaves show a mosaic with dark green veinbands and they are curled upwards. The plant is rosetted and stunted, and the tendrils are abnormally curled (Fig. 2a).

Trifolium hybridum.

Local. No reaction.

Systemic. There are alternate chlorotic and green streaks following the veins of the leaves.

T. pratense.

Local. No reaction.

Systemic. Diffuse chlorotic vein slashes develop in one month.

Vicia faba.

Local. No reaction.

Systemic. In 7 days there is a clearing of the veins of the young leaves followed by a chlorotic spotting. Later leaves have a mosaic in which the dark green areas are raised (Fig. 2c.) There may also be concentric chlorotic patterns on these leaves.

Natural source of virus: *Pisum sativum* (Pretoria and district). The plants were rosetted and the leaves showed a chlorotic flecking and mosaic mottle.

IDENTIFICATION.

This virus is similar to the pea mosaic virus of Doolittle & Jones (4) in many respects, but it regularly causes a systemic reaction on the bean.

The pea virus 2 Osborn (10), shows this ability to infect certain varieties of bean; and therefore this virus appears to be identical with or closely related to it.

3. Pea Stunt Virus Zaumeyer.

Physical properties: Thermal inactivation point, 60–62°C. Longevity *in vitro*, 2–3 days. Dilution end point, 1: 5,000–1: 10,000.

Transmission: Mechanical sap inoculation.

Host range: *Crotalaria juncea* L., *C. spectabilis* Roth., *Glycine max* (L.) Merr., *Lathyrus odoratus* L., *Lupinus albus* L., *L. luteus* L., *Medicago sativa* L., *Phaseolus vulgaris* L., *Pisum sativum* L., *Trifolium hybridum* L., *T. incarnatum* L., *Vicia faba* L., *Vigna sesquipedalis* (L.) Wight., *V. unguiculata* (L.) Walp., *Voandzeia subterranea* Thouars.

REACTION OF SUSCEPTIBLE SPECIES.

Crotalaria juncea.

Local. Some necrosis may occur.

Systemic. After 17 days there are dark green veinbands and a speck mottle. The leaves are small, rolled and rosetted, and the plant is stunted.

C. spectabilis.

Local. No reaction.

Systemic. The young leaves show chlorotic veins and spots in 7 days. Later leaves are malformed and crinkled, with irregular chlorosis. The plant is stunted.

Glycine max.

Local. The leaves become chlorotic and drop.

Systemic. After a chlorotic spotting the leaves develop a mottle with some yellow specks. The old leaves have a chlorotic network.

Lathyrus odoratus.

Local. No reaction.

Systemic. After 2 weeks many leaves show dark green veinbands or a mottle. They are rolled and slightly puckered.

Lupinus albus.

Local. There are necrotic specks with chlorotic halos.

Systemic. The young leaves have necrotic specks and veins, and soon drop. The next leaves are chlorotic with dark green blisters, and they are rolled and crinkled. There are necrotic stem streaks and the plant is stunted.

L. luteus.

Local. No reaction.

Systemic. The young leaves remain folded and in 9 days there is a vein clearing. Later ones are mottled, elongated and crinkled with wavy margins. The plant is stunted and rosetted.

Medicago sativa.

Local. No reaction.

Systemic. There is a chlorotic network followed by a chlorotic flecking on some leaves.

Phaseolus vulgaris var. Canadian Wonder.

Local. No reaction.

Systemic. In 6 to 8 days the young leaves show a vein clearing while the first and second trifoliates develop chlorotic blotches, spots, or vein flecks. Later leaves are mottled and rolled with a slight puckering (Fig. 3b). The pods are blistered (Fig. 3c) and the plant is stunted.

var. Haricot.

Local. No reaction.

Systemic. The young leaves may drop after a veinal necrosis. The next formed leaves are small and malformed with a chlorotic mottle.

Pisum sativum.

Local. No reaction.

Systemic. The young leaves develop chlorotic veins in 6 days, and then spots. Later leaves have a mosaic, and they are malformed and reduced in size. The tendrils are abnormally curled (Fig. 3a). Later leaves have necrosis in the chlorosis and there are necrotic stem streaks. The pods have purple lesions.

Trifolium hybridum.

Local. No reaction.

Systemic. After 16 days the leaves show chlorotic veins, spots and streaks, and they may be slightly crinkled.

T. incarnatum.

Local. No reaction.

Systemic. There is a chlorotic network on the young leaves. Later ones have dark green veinbands or a mosaic, and they are crinkled. The old leaves may have necrotic specks.

Vicia faba.

Local. No reaction.

Systemic. After 7 days there are chlorotic spots on the young leaves. Later leaves have dark green veinbands or a mosaic; they are long and narrow and rolled (Fig. 3d).

Vigna sesquipedalis.

A symptomless carrier.

V. unguiculata.

A symptomless carrier.

Voandzeia subterranea.

A symptomless carrier.

Natural source of virus: *Lathyrus odoratus* (Pretoria and district). Most leaves had a chlorotic mottle, and there were necrotic stem streaks. The flowers showed a marked colour break. *Pisum sativum* (Pretoria and district). The leaves had irregular chlorotic areas with varying amounts of necrosis. There were also necrotic stem streaks and the plants were stunted.

IDENTIFICATION.

This virus shows most similarity with the stunt virus of Zaumeyer (17), both in respect of symptomology and physical properties. Although not identical, it is considered closely related to the pea stunt virus.

4. Pea Wilt Virus—New Strain.

Physical properties: Thermal inactivation point, 58–60°C. Longevity *in vitro*, 2–3 days. Dilution end point, 1: 10,000.

Transmission: Mechanical sap inoculation. *Aphis craccivora*.

Host range: *Arachis hypogaea* L., *Crotalaria juncea* L., *C. spectabilis* Roth., *Dolichos lablab* L., *Glycine javanica* L., *G. max* (L.) Merr., *Lathyrus odoratus* L., *Lupinus albus* L., *L. luteus* L., *Medicago lupulina* L., *Melilotus officinalis* Willd., *Phaseolus acutifolius* Gray var. *latifolius* Freem., *P. lunatus* L., *P. mungo* L., *P. vulgaris* L., *Pisum sativum* L., *Trifolium hybridum* L., *T. incarnatum* L., *T. pratense* L., *Vicia faba* L., *Vigna sesquipedalis* (L.) Wight., *V. unguiculata* (L.) Walp., *Voandzeia subterranea* Thouars.

REACTION OF SUSCEPTIBLE SPECIES.

Arachis hypogaea.

Local. No reaction.

Systemic. Some leaves have a chlorotic mottle with patterns and the older ones have chlorotic blotches.

Crotalaria juncea.

Local. No reaction.

Systemic. In 15 days the growing point becomes stunted and may bend over. The leaves are uniformly chlorotic with only isolated dark green areas. Later formed leaves are chlorotic with dark green blisters and veinbands. They have crinkled surfaces and are slightly malformed. The plant is stunted.

C. spectabilis.

Local. There are necrotic lesions in 7 days.

Systemic. After a chlorotic vein flecking of the young leaves, later ones are chlorotic with dark green specks. These leaves are crinkled and the plant is stunted.

Dolichos lablab.

A symptomless carrier.

Glycine javanica.

A symptomless carrier.

G. max.

Local. There are chlorotic spots which later have a necrotic ring. There is also some veinal necrosis.

Systemic. In 9 days the young leaves show a clearing of the veins. This becomes a dark green mottle on the next formed leaves, which are also puckered. The older leaves may have small necrotic spots.

Lathyrus odoratus.

Local. No reaction.

Systemic. The leaves remain folded and they are chlorotic with dark green islands, and slightly malformed. Some plants collapsed from necrosis.

Vicia albus.

Local. Small chlorotic spots appear in 9 days and the leaflets drop later.

Systemic. The young leaves have a chlorotic network and the leaflets remain folded and have wavy margins. There may be stem necrosis. There is little upward growth so that the growing point becomes stunted and rosetted with many small string-like leaves. These are chlorotic with dark green marginal blisters. No flowers are formed.

L. luteus.

Local. No reaction.

Systemic. In 13 days the young leaves show chlorotic spots and they remain folded. Later leaves are mottled or have dark green blisters on malformed, stringlike leaves. The plant is stunted and rosetted.

Medicago lupulina.

Local. No reaction.

Systemic. A diffuse chlorotic mottle develops.

Melilotus officinalis.

Local. No reaction.

Systemic. After a vein clearing of the young leaves, there are chlorotic spots or streaks on later formed leaves.

Phaseolus acutifolius.

Local. In 4 days the veins are necrotic and later chlorotic spots develop.

Systemic. After 10 to 11 days, the young leaves show a vein clearing and later a mottle. There may be some malformation. New leaves have almost yellow specks.

P. lunatus.

Local. Chlorotic veins and irregular areas develop in 7 to 9 days.

Systemic. In 9 days there is a vein clearing of the young leaves. Later ones have a diffuse mottle, veinbanding or flecking.

P. mungo.

Local. No reaction.

Systemic. There is a diffuse chlorotic speckling after 2 weeks. On the old leaves there is also necrosis.

P. vulgaris var. Canadian Wonder.

Local. No reaction.

Systemic. After 9 days the first trifoliate shows large chlorotic star flecks. The young leaves have a vein clearing and later ones a spot mottle with the dark green along the veins (Fig. 4d).

var. Haricot.

Local. The veins are slightly necrotic and later small chlorotic spots with necrotic halos appear.

Systemic. There is a chlorosis with dark green blisters, and malformation and twisting of the leaves. There is only a slight necrosis.

Pisum sativum.

Local. The inoculated leaves collapse.

Systemic. There is a vein clearing in 2 weeks, followed by a chlorotic mottling of the leaves which remain slightly folded. The plant is rosetted and stunted (Fig. 4a). The stem may have necrotic streaks and the tendrils are abnormally curled.

Trifolium hybridum.

Local. No reaction.

Systemic. In 24 days there is a clearing of the veins of the young leaves, and thereafter, alternate streaks of yellow and green develop on later formed leaves.

T. incarnatum.

Local. There are necrotic specks in 7 to 8 days.

Systemic. The young leaves develop a vein clearing. Later ones have dark green veinbands and they are puckered and crinkled.

T. pratense.

Local. No reaction.

Systemic. There are occasional chlorotic vein streaks which become necrotic and result in a malformation of the leaf surface (Fig. 4c).

Vicia faba.

Local. The leaves develop dark green or necrotic rings. They become flaccid and drop (Fig. 4b).

Systemic. No reaction, but the virus is present.

Vigna sesquipedalis.

Local. Within a week chlorotic spots appear.

Systemic. In 21 days the young leaves show chlorotic spots, and later ones a mottle and malformation.

V. unguiculata.

Local. There are necrotic specks with chlorotic halos.

Systemic. In 2 weeks there is a vein clearing followed by a diffuse chlorotic mottle.

Voandzeia subterranea.

Local. No reaction.

Systemic. There are chlorotic specks and dark green veinbands.

Natural source of virus: *Pisum sativum* (Pretoria). The plants were stunted and unthrifty and the leaves had a very diffuse mottle. *Phaseolus vulgaris* (Pretoria and district). On the variety Black Wonder the younger leaves had vivid chlorotic spots and the older ones a dark green veinbanding and mottle. The plants were stunted.

IDENTIFICATION.

On the major host plants e.g. pea, cowpea, bean and broad bean, the symptoms produced by this virus are very similar to those caused by the pea wilt virus Johnson (8). But on other plants there are small differences and the physical properties differ in the longevity and dilution end points.

Nevertheless, this virus is grouped with it as a possible strain, and is named pea wilt virus, strain A.

5. Lucerne Mosaic Virus—Necrotic Ring Strain.

Physical properties: Thermal inactivation point, 62–65°C. Longevity *in vitro*, 7–8 days. Dilution end point, 1: 3,000–1: 5,000.

Transmission: Mechanical sap inoculation. *Aphis craccivora*.

Host range: *Crotalaria juncea* L., *C. spectabilis* Roth., *Glycine max* (L.) Merr., *Lathyrus odoratus* L., *Lupinus albus* L., *L. luteus* L., *Melilotus officinalis* Willd., *Phaseolus acutifolius* Gray var. *latifolius* Freem., *P. vulgaris* L., *Pisum sativum* L., *Trifolium hybridum* L., *T. incarnatum* L., *Vicia faba* L., *Vigna unguiculata* (L.) Walp., *Voandzeia subterranea* Thouars.

REACTION OF SUSCEPTIBLE SPECIES.

Crotalaria juncea.

Local. In 6 days there are necrotic lesions.

Systemic. The young leaves show chlorotic spots which soon become necrotic and cause a malformation of the leaves. The plant is stunted.

C. spectabilis.

Local. There are dark green rings with necrosis.

Systemic. The young leaves show chlorotic spots and later leaves have chlorotic ring and line patterns and are crinkled. There may be a slight malformation and dark green blisters.

Glycine max.

Local. No reaction.

Systemic. After a chlorotic spotting of the young leaves, later ones develop a mottle. They are slightly crinkled.

Lathyrus odoratus.

Local. Small chlorotic spots develop which later become necrotic.

Systemic. In 3 weeks the stem has become necrotic and the plant collapses.

Lupinus albus.

Local. No reaction.

Systemic. The young leaves develop chlorotic spots. Later ones are crinkled and rolled with chlorotic veinbands.

L. luteus.

Local. No reaction.

Systemic. The young leaves remain folded and have chlorotic spots. Later ones are crinkled or malformed, with an irregular chlorotic mottle. The plant is rosetted and stunted.

Melilotus officinalis.

Local. No reaction.

Systemic. There are chlorotic areas and a slight distortion.

Phaseolus acutifolius.

Local. No reaction.

Systemic. In 15 days there is a vein clearing, followed by a mottle with slight necrosis.

P. vulgaris var. Canadian Wonder.

Local. Within 5 days there are small chlorotic spots which later have a halo. Severe necrosis sets in, in the chlorosis (Fig. 5c).

Systemic. No reaction.

var. Haricot.

Local. In a week there are necrotic ringspots and veins.

Systemic. On some plants the young leaves show severe rolling and curling down. There are small chlorotic spots with necrotic veins and specks which spread until the plant collapses (Fig. 5d).

vars. Black Wonder, Idaho Refugee and Long Tom develop only local chlorotic rings or irregular areas in 3 to 6 days.

vars. S.A. Black and White and Tendergreen have no local reaction and only a transient vein clearing or spotting.

Pisum sativum.

Local. There may be necrotic rings and spots which cause the leaves to collapse.

Systemic. In 11 to 12 days the young leaves show a vein clearing or chlorotic flecks which soon become necrotic. This necrosis progresses down the stem and the growing point collapses. Secondary shoots may develop and these have malformed twisted and rosetted leaves with irregular chlorotic areas. The tendrils are abnormally curled (Fig. 5a).

Trifolium hybridum.

Local. No reaction.

Systemic. After 12 days there are chlorotic spots on the young leaves and later formed ones develop a streak mottle.

T. incarnatum.

Local. The leaves may collapse.

Systemic. In 12 days a vein clearing develops on the young leaves. Later leaves show a mosaic mottle and are crinkled and malformed. The plant is stunted.

Vicia faba.

Local. In 4 to 5 days large chocolate-coloured necrotic lesions develop. The leaves become flaccid (Fig. 5b).

Systemic. A week later small chlorotic spots or a vein clearing may occur on the young leaves. Usually the necrosis spreads quickly up the stem and into the growing point and the plant collapses.

Vigna unguiculata.

Local. In 5 days the leaves develop chlorotic spots with necrotic rings and veins. These soon drop.

Systemic. Only occasionally are there similar symptoms on the trifoliate, which collapse. If symptomless the virus can be recovered.

Voandzeia subterranea.

Local. No reaction.

Systemic. The young leaves develop a chlorotic spotting.

Natural source of virus: *Pisum sativum* (Northern Transvaal). The young leaves were mottled, the stems were necrotic and the growing points flaccid. The plants were stunted and rosetted and the tendrils abnormally curled.

Lathyrus odoratus (Pretoria and district). The leaves had a vein-clearing, chlorotic spotting or veinbanding, with necrosis setting in. Some plants collapsed after this necrosis, while others produced secondary shoots with malformed, blistered leaves. Flowers on these stems showed a marked colour break.

IDENTIFICATION.

Several viruses show similar reactions on the pea, but cannot be considered the same as the above for the following reasons: Both pea American streak virus Zaumeyer (16) and Wisconsin pea stunt virus Hagedorn & Walker (5) are unable to infect the *Phaseolus* spp. which are hosts of this virus.

Pea Wisconsin streak virus Hagedorn & Walker (6) does not infect *Vicia faba*, whereas this virus causes severe necrosis.

The pea stunt virus Zaumeyer (17) and the pea stunt virus strain Klessner (9) induce only a systemic reaction on the bean, while in addition the latter causes only a systemic chlorosis on the broad bean.

Pea New Zealand streak virus Chamberlain (2) infects several non-legumes, induces different symptoms on many hosts and has different physical properties.

On the bean the symptoms are very like those caused by the lucerne mosaic virus, Weimer (15). Physical properties and legume host range are also similar, although lucerne mosaic virus is able to infect the non-legumes.

On pea and broad bean the symptoms resemble those of Zaumeyer's alfalfa mosaic viruses 1A and 1B (16), but neither of these induces a lethal necrosis of the sweet pea. Further, there is a considerable discrepancy in physical property values.

Apart from the necrotic reaction on the sweet pea this virus is almost identical with, and can be considered the same as the lucerne mosaic virus necrotic ring strain Klessner.

6. Bean Local Chlorosis Virus—Strain B.

Physical properties: Thermal inactivation point, 58–60°C. Longevity *in vitro*, 2–3 days. Dilution end point, 1: 1,000–1: 2,000.

Transmission: Mechanical sap inoculation. *Aphis craccivora*.

Host range: *Crotalaria spectabilis* Roth., *Glycine max* (L.) Merr., *Lathyrus odoratus* L., *Lupinus albus* L., *L. luteus* L., *Phaseolus vulgaris* L., *Pisum sativum* L., *Trifolium hybridum* L., *T. incarnatum* L., *Vicia faba* L., *Vigna unguiculata* (L.) Walp.

REACTION OF SUSCEPTIBLE SPECIES.

Crotalaria spectabilis.

Local. No reaction.

Systemic. After 7 days the young leaves show a vein clearing and spotting. Later leaves have irregular, almost white, streaks which lead to malformation of the leaf surface (Fig. 6c).

Glycine max.

Local. No reaction.

Systemic. A diffuse chlorotic mottle develops on most leaves.

Lathyrus odoratus.

Local. No reaction.

Systemic. After 11 days the young leaves show chlorotic streaks. This continues on later leaves or there is a mosaic. Necrotic streaks may occur on the stem and petioles. (Fig. 6f). There is a colour break on the flowers (Fig. 6e).

Lupinus albus.

Local. No reaction.

Systemic. After a vein clearing and spotting of the young leaves the next formed are crinkled with dark green blisters. There may be small necrotic speckles.

L. luteus.

Local. No reaction.

Systemic. Most leaves remain folded and have small chlorotic spots.

Phaseolus vulgaris var. Canadian Wonder.

Local. In 5 days vivid chlorotic spots appear (Fig. 6a).

Systemic. Shortly afterwards the young leaves also develop chlorotic spots and vein flecks (Fig. 6d). Later leaves are malformed and mottled (Fig. 6b). The old leaves show large chlorotic blotches.

Pisum sativum.

Local. No reaction.

Systemic. In 6 days there is a vein clearing and spotting of the young leaves. Later leaves are small and malformed with irregular dark green areas. The plant is rosetted and stunted and the tendrils are abnormally curled. There are necrotic stem streaks.

Trifolium hybridum.

Local. Small chlorotic spots develop.

Systemic. Most leaves have a chlorotic streak mosaic.

T. incarnatum.

Local. No reaction.

Systemic. In 16 days there is a vein clearing. Later leaves have a mosaic and are slightly malformed.

Vicia faba.

Local. No reaction.

Systemic. Chlorotic spots develop on the young leaves in a week. The next leaves all have a mosaic.

Vigna unguiculata.

Local. Small red necrotic lesions appear in 5 days.

Systemic. No reaction.

Natural source of virus: *Lathyrus odoratus* (Pretoria district). The leaves had chlorotic veinbands or streaks, and they were small and puckered.

IDENTIFICATION.

The vivid chlorotic spotting on the inoculated leaves of the bean is a characteristic feature of a group of viruses recorded in England by the writer.

The only published reports of similar viruses are those by Ainsworth and Zaumeyer.

Ainsworth (1) isolated a virus which caused a "sweet pea streak" and which induced a local chlorotic spotting on the bean. However, necrotic rings developed later on these leaves and the plant collapsed from a systemic necrosis, whereas this virus causes no necrosis on the bean.

On other plants there are also differences—on broad bean and sweet pea Ainsworth's virus resulted in a systemic necrosis whereas this virus induces a mottle or mosaic.

Zaumeyer's alfalfa yellow mosaic virus (18) causes symptoms on some varieties of bean which are very similar to those described for this virus, but on other varieties there is both a local and systemic necrosis.

However, on other host plants the symptoms differ. On broad bean and pea Zaumeyer's virus induces a local and systemic necrosis whereas this virus causes a mosaic on broad bean, and malformation and stunt on pea. On cowpea, there is a local necrosis as well as a yellow mottle and malformation with the alfalfa yellow mosaic, but only local lesions develop with this virus.

Further, Zaumeyer's virus has a larger host range which includes solanaceous spp., and the physical properties differ.

Although this virus was isolated from *Lathyrus odoratus* the disease it causes on that host is very similar to many others, but on *Phaseolus vulgaris* the symptoms are unusual.

Therefore the name chosen for this virus is bean local chlorosis virus. Of the three strains described in England (9) there is most similarity with the B strain—the A strain induces a local chlorosis on broad bean and a local and systemic necrosis on pea, whereas the C strain causes a veinbanding on broad bean and a mottle only on pea. Physical property values also differ.

This virus is therefore considered the same as bean local chlorosis virus—strain B.

7. Bean Yellow Mosaic Virus, Necrotic Strain.

Physical properties: Thermal inactivation point, 58–60°C. Longevity *in vitro*, 2–3 days. Dilution end point, 1: 1,000.

Transmission: Mechanical sap inoculation. *Aphis craccivora*.

Host range: *Crotalaria juncea* L., *C. spectabilis* Roth., *Glycine max* (L.) Merr., *Lathyrus odoratus* L., *Lupinus albus* L., *L. mutabilis* Sweet., *L. luteus* L., *Melilotus officinalis* Willd., *Phaseolus acutifolius* Gray var. *latifolius* Freem., *P. lunatus* L., *P. vulgaris* L., *Pisum sativum* L., *Trifolium hybridum* L., *T. incarnatum* L., *Vicia faba* L., *Voandzeia subterranea* Thouars.

REACTION OF SUSCEPTIBLE SPECIES.

Crotalaria juncea.

Local. No reaction.

Systemic. After 2 weeks the young leaves are chlorotic with dark green specks. Necrosis may set in, in the chlorosis and the plant may collapse. Usually the necrosis causes an uneven surface on the leaves which are small and malformed. The plant is stunted.

C. spectabilis.

Local. In 7 days there are chlorotic spots with a slight necrosis.

Systemic. At the same time the young leaves develop chlorotic spots or vein flecks. Later leaves are mottled and malformed with dark green blisters and necrotic specks. The plant is stunted.

Glycine max.

Local. No reaction.

Systemic. A diffuse chlorotic spotting develops.

Lathyrus odoratus.

Local. Some leaves become chlorotic (Fig. 7e).

Systemic. In 2 weeks the young leaves develop a vein clearing and chlorotic spotting. Later leaves are mottled and rolled (Fig. 7d).

Lupinus albus.

Local. No reaction.

Systemic. In 2 weeks the young leaves show a veinal necrosis. This may extend to the stem and the plant may collapse. Secondary shoots have small malformed and rolled leaves which are mottled. The plant is stunted.

L. mutabilis.

Local. No reaction.

Systemic. The young leaves curl back severely; there is a stem necrosis and the plant collapses.

L. luteus.

Local. No reaction.

Systemic. The young leaves remain folded and in 10 days there is a vein clearing and chlorotic spotting. The next ones are small and crinkled with dark green veinbands. Later leaves are almost stringlike. The plant is rosetted and stunted.

Melilotus officinalis.

A symptomless carrier.

Phaseolus acutifolius.

Local. No reaction.

Systemic. A diffuse chlorotic mottle develops on some leaves.

P. lunatus.

Local. No reaction.

Systemic. Only chlorotic vein flecks develop.

P. vulgaris var. Canadian Wonder.

Local. The leaves bend at right angles to the petiole and in 5-6 days there are chlorotic blotches and slightly necrotic veins (Fig. 7a). These leaves become leathery and remain attached.

Systemic. The first and second trifoliates also show a marked reflexing and they have chlorotic flecks or blotches. Later leaves develop a vein clearing, spotting or flecking and then a mottle. The next leaves are small and malformed and the plant is rosetted and stunted. The pods have sunken dark green areas (Fig. 7b).

var. Haricot.

Local. In 7 days there are chlorotic spots on the reflexed leaves.

Systemic. A week later, the first trifoliates bend down and show a vein clearing. Later leaves are mottled with dark green blisters. The plant is stunted, and the stem may have short necrotic streaks. The pods develop sunken necrotic rings.

vars. Black Wonder, Idaho Refugee, Long Tom and Tendergreen develop symptoms similar to those on Canadian Wonder.

var. S.A. Black and White shows no local reaction but the systemic is similar to Canadian Wonder.

Pisum sativum.

Local. In 6 days there may be necrotic rings or the leaves just wilt and collapse.

Systemic. Soon afterwards the young leaves develop a vein clearing and chlorotic spotting. Necrosis sets in on the leaves, stipules and stem, and the growing point collapses (Fig. 7f). Secondary shoots are stunted and rosetted, and the leaves are small, malformed and mottled. The tendrils are abnormally curled.

Trifolium hybridum.

Local. No reaction.

Systemic. After 3 weeks the young leaves show a vein clearing and chlorotic spotting. Later ones develop vivid yellow streaks and a slight puckering (Fig. 7c).

T. incarnatum.

Local. No reaction.

Systemic. After 2 weeks there is a vein clearing of the young leaves followed by a chlorotic veinbanding. The leaves are slightly puckered and the plant is stunted.

Vicia faba.

Local. No reaction.

Systemic. In 7 days the young leaves show a vein clearing, or chlorotic spots or flecks. Later leaves develop a mosaic.

Voandzeia subterranea.

Local. No reaction.

Systemic. Diffuse chlorotic spots develop on some leaves.

Natural source of virus: *Lathyrus odoratus* (Pretoria district). The leaves had chlorotic spots, veinbands or a mottle, and there was a colour break of the flowers.

IDENTIFICATION.

There are several viruses which cause a reflexing of the bean leaves, but only with alsike clover mosaic virus 2 Zaumeyer (17) is this characteristic associated with a systemic necrosis on the pea. However, as the necrosis caused by the alsike virus results in the complete defoliation of the pea plant, and the physical properties differ, the casual virus is not the same as the one described here.

Although the type bean yellow mosaic virus Pierce (11) does not induce a necrosis on the pea, symptoms on many other hosts and the physical properties are very similar to this virus.

The bean yellow mosaic virus necrotic lesion strain of Zaumeyer and Fisher (19) is not infectious to pea, white lupin or crimson clover, all of which are hosts to this virus. Further, it induces a local and systemic necrosis on broad bean (whereas this virus causes a mosaic) and local lesions on tobacco, which is not susceptible to this virus.

The severe yellow strain of Thomas and Zaumeyer (13) is excluded as there are differences in the symptoms on several host plants and in the physical property values. It is also able to infect tobacco.

The bean yellow mosaic virus "Isolate I" of Hagedorn and Walker (7) does not cause any necrosis on the pea and other symptoms and properties also differ.

Although the virus described here does not infect the cowpea and remains latent in sweet clover, so many details are similar to a virus found in England by the writer (9), that it is considered to be the same, and is named bean yellow mosaic virus, necrotic strain.

8. Tomato spotted Wilt Virus. Samuel *et al.*

Physical properties: Thermal inactivation point, 40–42°C. Longevity *in vitro*, –1 day. Dilution end point, 1: 5,000–1: 10,000.

Transmission: Mechanical sap inoculation. *Thrips* spp.

Host range in *Leguminosae*: *Arachis hypogaea* L., *Crotalaria juncea* L., *C. spectabilis* Roth., *Glycine max* (L.) Merr., *Lathyrus odoratus* L., *Lupinus albus* L., *L. luteus* L., *Medicago denticulata* L., *M. sativa* L., *Melilotus officinalis* Willd., *Phaseolus mungo* L., *Pisum sativum* L., *Trifolium fragiferum* L., *T. incarnatum* L., *T. pratense* L., *Vicia faba* L., *Vigna unguiculata* (L.) Walp., *Voandzeia subterranea* Thouars.

REACTION OF SUSCEPTIBLE SPECIES.

Arachis hypogaea.

Local. Usually no reaction.

Systemic. There is a veinal necrosis of the young leaves and the growing point collapses. Secondary shoots are rosetted, with small, malformed leaves. These have concentric chlorotic patterns or dark green veinbands. Necrotic speckling may be severe.

Crotalaria juncea.

Local. There are necrotic spots in 5 days which enlarge by concentric bands (Fig. 8h).

Systemic. There are concentric chlorotic patterns and possibly a lethal necrosis.

C. spectabilis.

Local. Necrotic ringspots develop in 5 days. Later there is also a veinal necrosis (Fig. 8b).

Systemic. Some leaves are severely curled and have a chlorotic network.

Glycine max.

Local. There are necrotic specks with chlorotic haloes. The leaves later become almost orange (Fig. 8e).

Systemic. No reaction.

Lathyrus odoratus.

Local. Large necrotic lesions develop and the leaves soon absciss.

Systemic. The necrosis spreads into the main stem causing external streaks, and the plant eventually collapses.

Lupinus albus.

Local. Necrotic specks develop and the rest of the leaflet becomes chlorotic. The necrosis spreads and the leaflets drop (Fig. 8 j).

Systemic. No reaction.

L. luteus.

Local. There are chlorotic rings which soon become necrotic and the leaflets absciss.

Systemic. No reaction.

Medicago denticulata.

Local. A scorch necrosis causes a defoliation.

Systemic. There is a vein clearing of the young leaves followed by a veinal necrosis. Later leaves have necrotic ringspots (Fig. 8f).

M. sativa.

Local. There are necrotic ringspots on a vivid yellow background (Fig. 8i).

Systemic. No reaction.

Melilotus officinalis.

Local. Chlorotic ringspots develop in 10–11 days.

Systemic. No reaction.

Phaseolus mungo.

Local. Isolated necrotic lesions develop.

Systemic. No reaction.

Pisum sativum.

Local. After a general necrosis the leaves wilt.

Systemic. A veinal necrosis of the leaves follows, and young plants may collapse. On older plants there are necrotic spots on the leaves and necrotic streaks on the stems. (Fig. 8c). The pods may have necrotic lesions and the tendrils are abnormally curled.

Trifolium fragiferum.

Local. There are necrotic specks with chlorotic haloes in 5 days (Fig. 8g).

Systemic. No reaction.

T. incarnatum.

Local. Chlorotic spots with necrotic rings develop and there is a slight veinal necrosis.

Systemic. No reaction.

T. pratense.

Local. There are necrotic specks which enlarge and fuse to give a "scorch" effect.

Systemic. No reaction.

Vicia faba.

Local. A severe veinal necrosis may develop.

Systemic. Usually this necrotic effect is first seen on the young leaves. It is soon followed by sunken necrotic stem streaks and a collapse of the plant (Fig. 8a).

Vigna unguiculata.

Local. There are red necrotic spots with chlorotic rings.

Systemic. No reaction.

Voandzeia subterranea.

Local. Necrotic spots develop which later enlarge by concentric bands.

Systemic. A diffuse chlorotic mottle may occur.

Natural source of virus: The natural incidence of spotted wilt is high on peas, sweet peas and broad beans. On groundnuts and the *Crotalaria* spp. it occurs less frequently.

IDENTIFICATION.

Sub-inoculations to several Solanaceous hosts proved that this is the tomato spotted wilt virus (12).

HOST RANGES.

Host Plant.	1. Pea Mosaic Virus.	2. Pea Virus 2.	3. Pea Stunt Virus.	4. Pea Wilt Virus Strain.	5. Lucerne Mosaic Virus Strain.	6. Bean Local Chlorosis Virus B.	7. Bean Yellow Mosaic Virus Strain.	8. Tomato Spotted Wilt Virus.
<i>Arachis hypogaea</i>	—	—	—	+	—	—	—	+
<i>Crotalaria juncea</i>	+	—	+	+	+	—	+	+
<i>C. spectabilis</i>	—	—	+	+	+	+	+	+
<i>Dolichos lablab</i>	—	—	—	+	—	—	—	—
<i>Glycine javanica</i>	+	—	—	+	—	—	—	—
<i>G. max</i>	—	—	+	+	+	+	+	+
<i>Lathyrus odoratus</i>	+	+	+	+	+	+	+	+
<i>Lupinus albus</i>	+	+	+	+	+	+	+	+
<i>L. luteus</i>	+	—	+	+	+	+	+	+
<i>Medicago lupulina</i>	+	+	—	+	—	—	—	—
<i>M. sativa</i>	—	—	+	—	—	—	—	+
<i>Melilotus officinalis</i>	+	—	—	+	+	—	+	+
<i>Phaseolus acutifolius</i> ...	—	—	—	+	+	—	+	—
<i>P. lunatus</i>	—	—	—	+	—	—	+	—
<i>P. mungo</i>	+	—	—	+	—	—	—	+
<i>P. vulgaris</i>	+	+	+	+	+	+	+	—
<i>Pisum sativum</i>	+	+	+	+	+	+	+	+
<i>Trifolium fragiferum</i> ...	—	—	—	—	—	—	—	+
<i>T. hybridum</i>	+	+	+	+	+	+	+	—
<i>T. incarnatum</i>	—	—	+	+	+	+	+	+
<i>T. pratense</i>	+	+	—	+	—	—	—	+
<i>T. repens</i>	+	—	—	—	—	—	—	—
<i>Vicia faba</i>	+	+	+	+	+	+	+	+
<i>Vigna sesquipedalis</i>	—	—	+	+	—	—	—	—
<i>V. unguiculata</i>	—	—	+	+	+	+	—	+
<i>Voandzeia subterranea</i> ..	—	—	+	+	+	—	+	+

PHYSICAL PROPERTIES AND METHODS OF TRANSMISSION.

Virus.	Thermal Inactivation Point °C.	Longevity in vitro Days.	Dilution End Point.	Transmission.		
				Sap.	Seed.	Aphid.
1. Pea mosaic virus.....	56-58	2-3	1: 1,000-1: 2,000	+	—	+
2. Pea virus 2.....	60-62	3-4	1: 1,000-1: 2,000	+	—	+
3. Pea stunt virus.....	60-62	2-3	1: 5,000-1: 10,000	+	—	—
4. Pea wilt virus strain.....	58-60	2-3	1: 10,000	+	—	+
5. Lucerne mosaic virus necrotic ring strain.....	62-65	7-8	1: 3,000-1: 5,000	+	—	+
6. Bean local chlorosis virus B.	58-60	2-3	1: 1,000-1: 2,000	+	—	+
7. Bean yellow mosaic virus necrotic strain.....	58-60	2-3	1: 1,000	+	—	+
8. Tomato spotted wilt virus...	40-42	-1	1: 5,000-1: 10,000	+	—	—

SYMPTOMS ON THE MAIN TEST PLANTS.

Virus.	<i>Phaseolus vulgaris.</i>	<i>Vicia faba.</i>	<i>Pisum sativum.</i>
1. Pea mosaic virus.....	Loc. no reaction Syst. chl. blo. (?)	Loc. no Syst. mosaic	Loc. no Syst. mosaic, ros.
2. Pea virus 2.....	Loc. no Syst. csp., stunt	Loc. no Syst. csp. mosaic	Loc. necrosis. Syst. mosaic, ros.
3. Pea stunt virus.....	Loc. no Syst. mot., stunt	Loc. no Syst. mos., 1 & n.	Loc. no Syst. mos., necr. s.s.
4. Pea wilt virus strain.....	Loc. no Syst. mot.	Loc. necr. rings Syst. no	Loc. coll. Syst. mot., necr. s.s.
5. Lucerne mosaic virus necrotic ring strain	Loc. csp., necr. O Syst. no	Local. necr. sp. Syst. c.sp., necr. coll.	Loc. necr. O Syst. c.fl., necr. coll.
6. Bean local chlorosis virus B	Loc. vivid c.sp. Syst. mos., malf.	Loc. no Syst. c.sp., mos.	Loc. no Syst. c.sp., malf., necr. s.s.
7. Bean yellow mosaic virus necrotic strain	Loc. reflexing Syst. 7, mot., malf.	Loc. no Syst. c.sp., mos.	Loc. necrosis Syst. necr. coll.
8. Tomato spotted wilt virus	Loc. no Syst. no	Loc. necrosis Syst. necr. coll.	Loc. necrosis Syst. necr. coll.

ABBREVIATIONS USED:

blo.—blotches.
c. } chlorotic.
chl. }
coll.—collapse.
fl.—flecks.
loc.—local.

1 & n—long and narrow leaves.
malf.—malformation.
mos.—mosaic.
mot.—mottle.
necr.—necrotic/necrosis.
no—no reaction.

ros.—rosette.
sp.—spots.
s.s.—stem streaks.
syst.—systemic.
O.—rings.
7—reflexing.

SUMMARY.

The virus diseases which occur naturally on peas and sweet peas in South Africa are described in detail.

In the field, peas develop mosaic and/or necrotic symptoms. The mosaic is caused by the pea mosaic virus or pea virus 2; the necrosis (and ultimate collapse) by the lucerne mosaic virus necrotic ring strain or by the tomato spotted wilt virus; and a mosaic with necrotic stem streaks by pea stunt virus or a strain of the pea wilt virus.

Symptoms on naturally infected sweet peas are similar viz. a mosaic develops with the pea mosaic virus, the necrotic strain of bean yellow mosaic or the bean local chlorosis virus B. A necrosis develops with the lucerne mosaic virus necrotic ring strain or with the tomato spotted wilt virus; and mosaic plus necrotic stem streaks develops with the pea stunt virus.

Of these, tomato spotted wilt has already been reported as a virosis of legumes in South Africa, but the others are new records.

Pea mosaic virus, pea virus 2 and pea stunt virus were identified by comparing with published descriptions.

Three others were found to be very similar to, but not identical with previously described viruses, and are considered to be strains of the type viruses, viz. a strain of the pea wilt virus, bean yellow mosaic virus necrotic strain, and lucerne mosaic virus necrotic ring strain.

One is apparently a new entity, and is named bean local chlorosis virus B, after the characteristic reaction on the bean.

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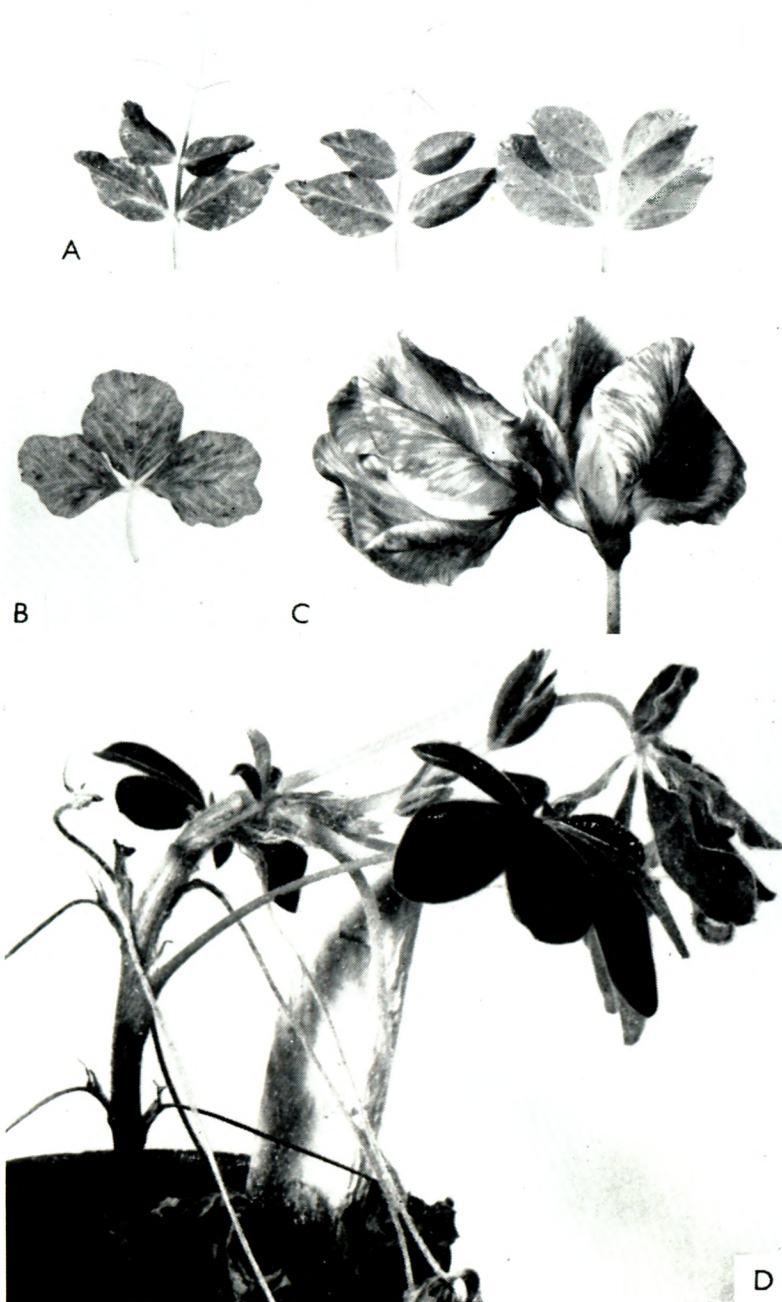


FIG. 1.—PEA MOSAIC VIRUS.

A. *Pisum sativum*. B. *Trifolium incarnatum*. C. *Lathyrus odoratus*. D. *Lupinus albus*.

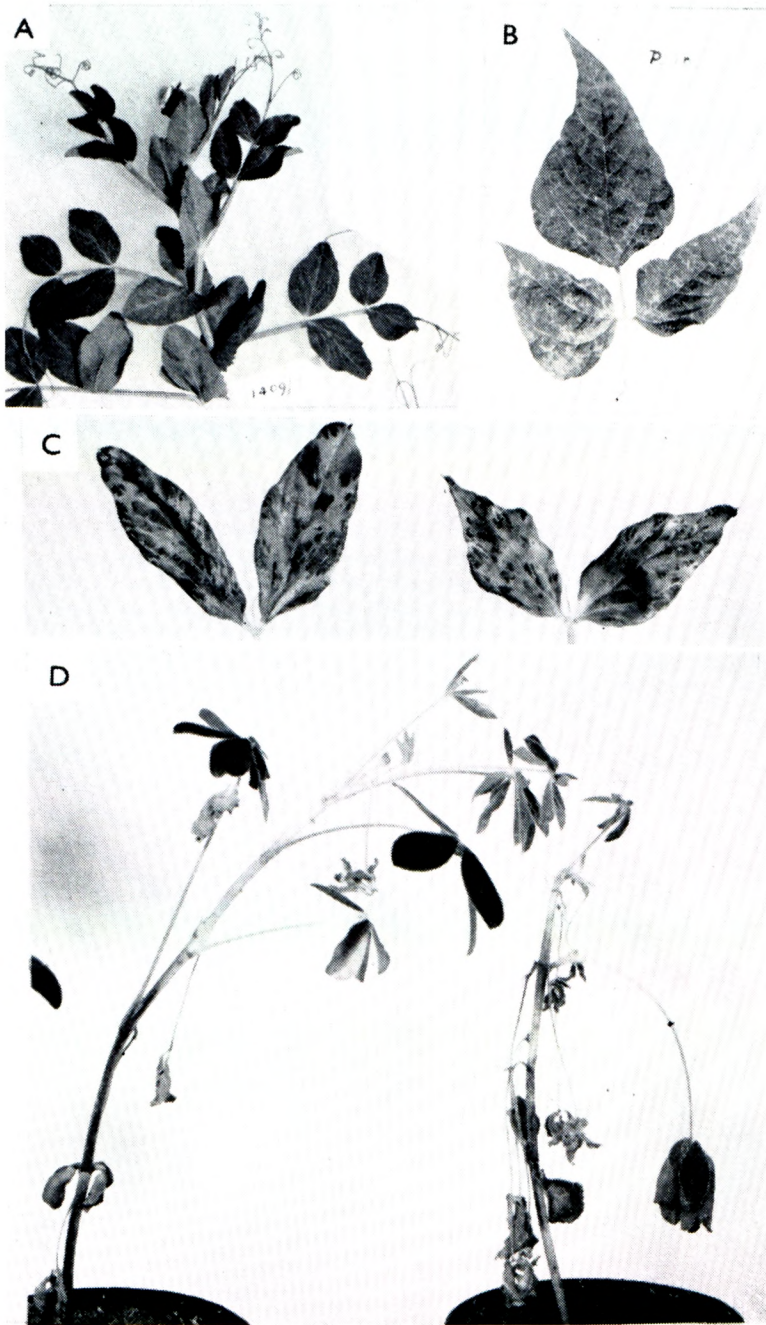


FIG. 2.—PEA VIRUS 2.

A. *Pisum sativum*. B. *Phaseolus vulgaris*. C. *Vicia faba*. D. *Lupinus albus*.

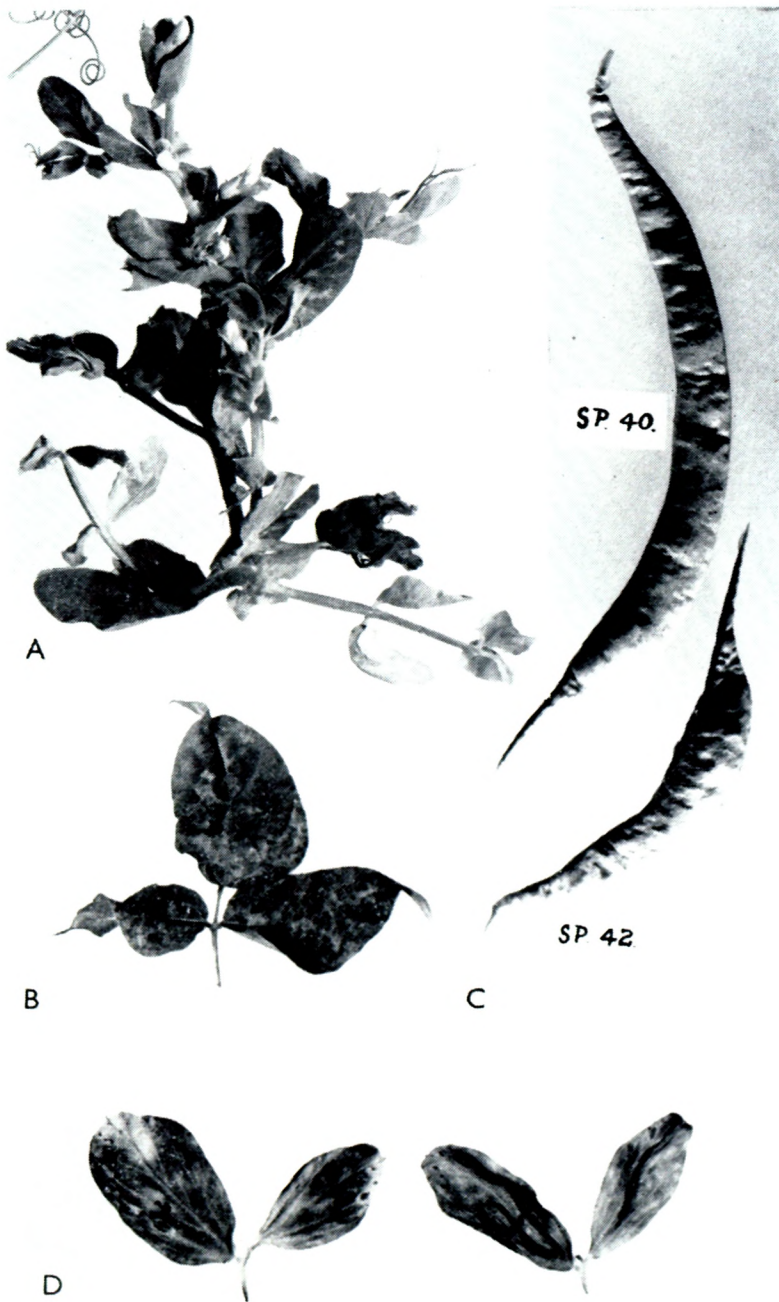


FIG. 3.—PEA STUNT VIRUS.

A. *Pisum sativum*. B. and C. *Phaseolus vulgaris*. D. *Vicia faba*.

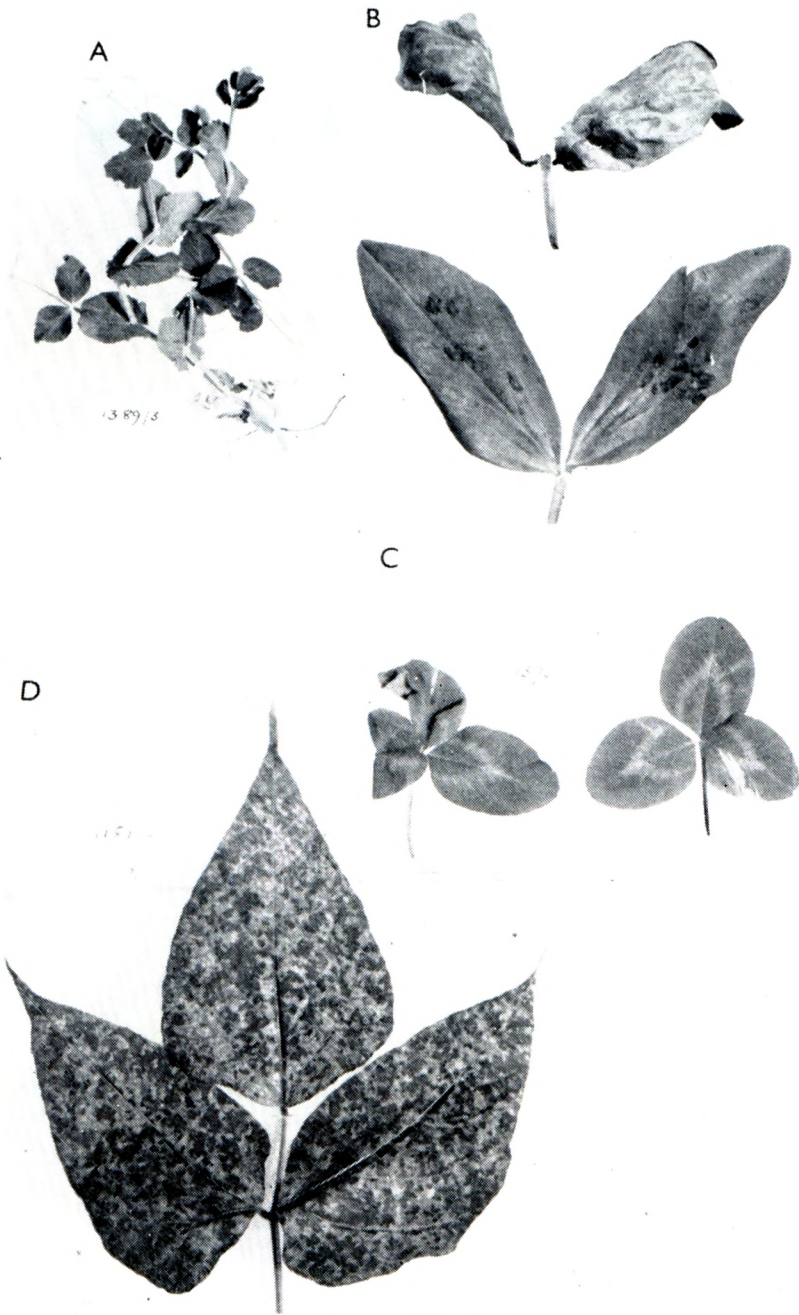


FIG. 4.—PEA WILT VIRUS, STRAIN.

A. *Pisum sativum*. B. *Vicia faba* (local lesions). C. *Trifolium pratense*. D. *Phaseolus vulgaris*.

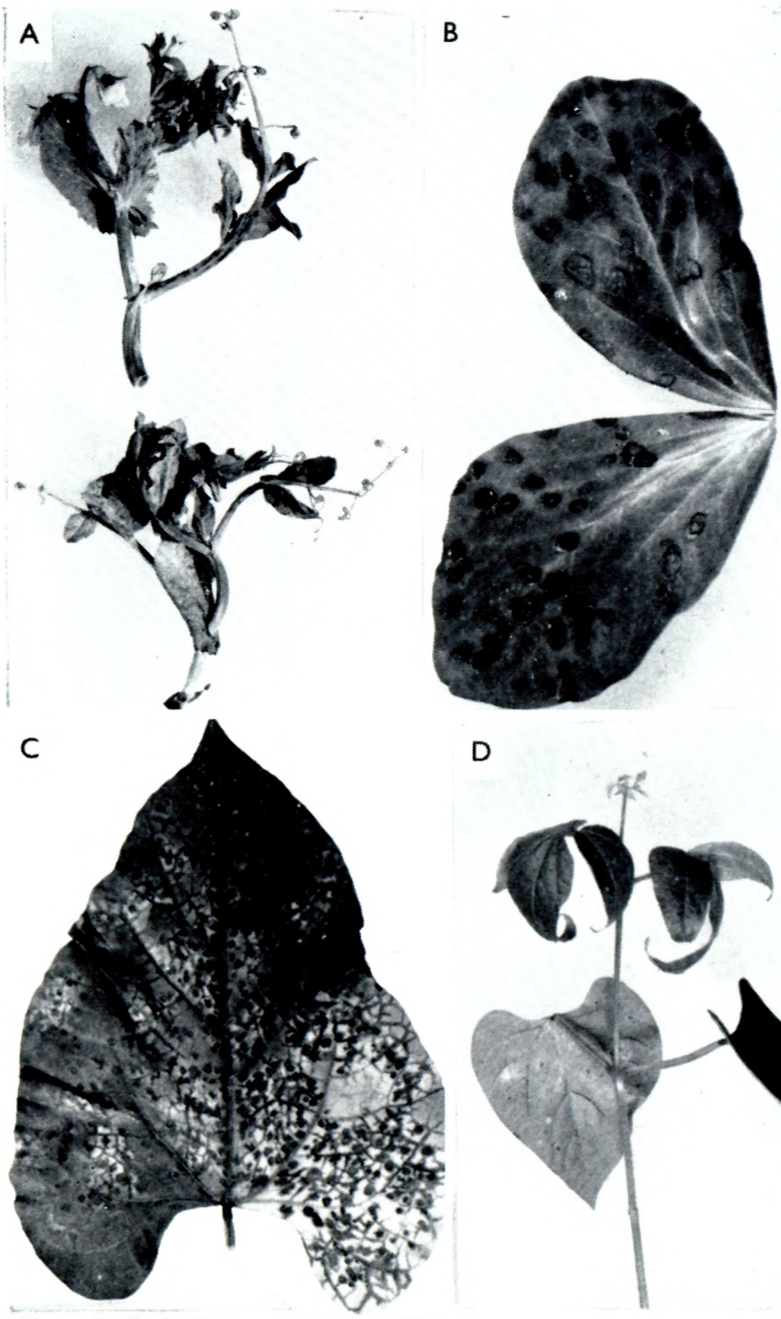


FIG. 5 —LUCERNE MOSAIC VIRUS, NECROTIC RING STRAIN.

A. *Pisum sativum*. B. *Vicia faba* (local lesions). C. *Phaseolus vulgaris* var. Canadian Wonder (local lesions). D. *Phaseolus vulgaris* var. Haricot.

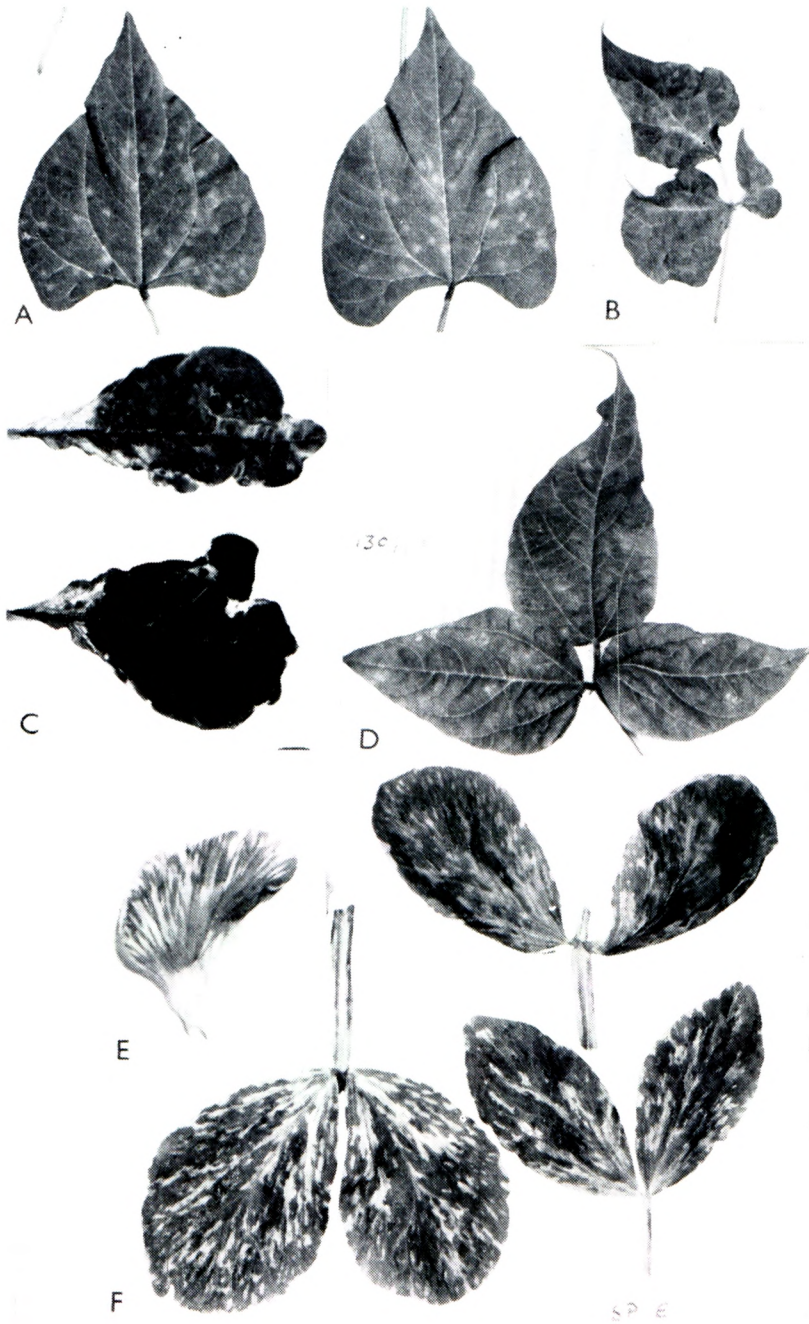


FIG. 6.—BEAN LOCAL CHLOROSIS VIRUS B.

A., B. and D. *Phaseolus vulgaris* A. local lesions. B. and D. systemic reaction. C. *Crotalaria spectabilis*. E. and F. *Lathyrus odoratus*.

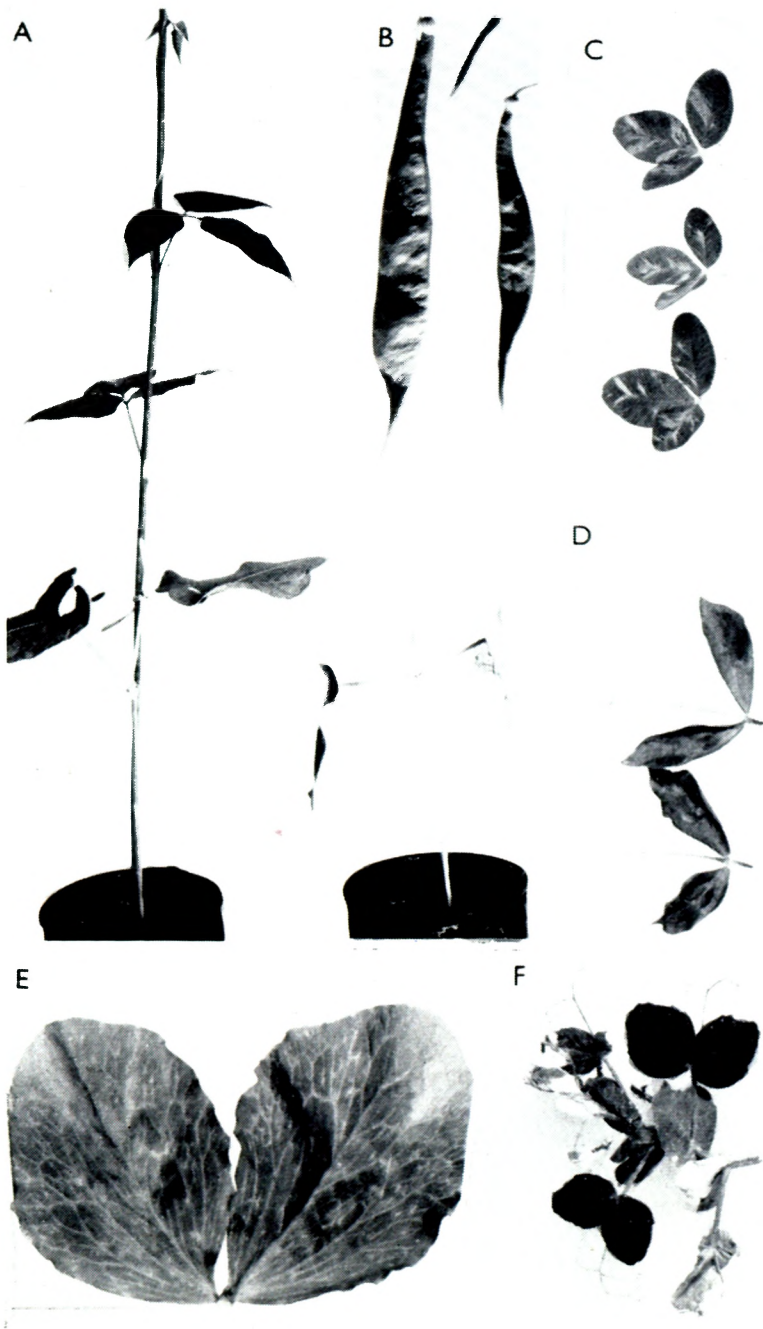


FIG. 7.—BEAN YELLOW MOSAIC VIRUS, NECROTIC STRAIN.

A. and B. *Phaseolus vulgaris*. C. *Trifolium hybridum*. D. and E. *Lathyrus odoratus*. F. *Pisum sativum*.

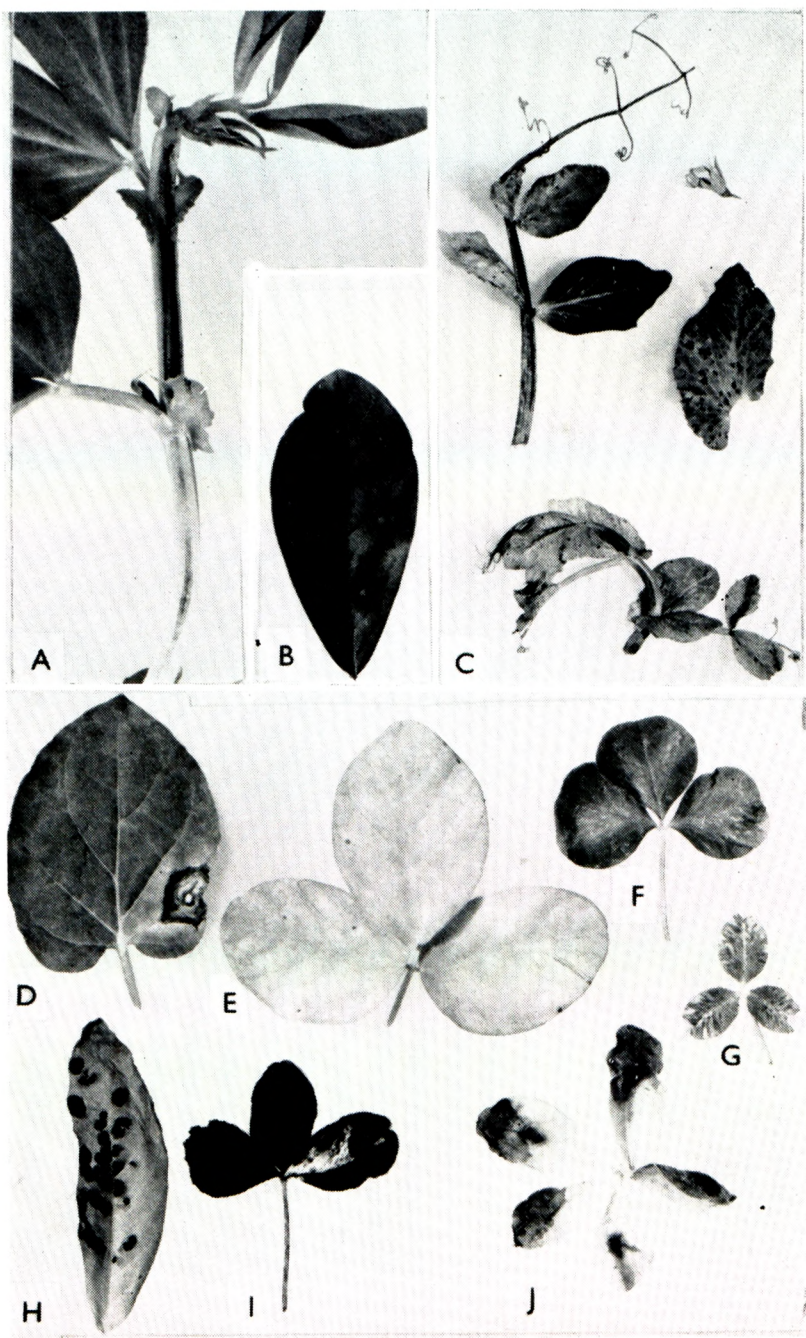


FIG. 8.—TOMATO SPOTTED WILT VIRUS.

A. *Vicia faba*. B. *Crotalaria spectabilis*. C. *Pisum sativum*. D. *Nicotiana glutinosa*. E. *Glycine max*. F. *Medicago denticulata*. G. *Trifolium fragiferum*. H. *Crotalaria juncea*. I. *Medicago sativa*. J. *Lupinus albus*.