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CONTENTS

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INSECT TRANSMISSION, HOST RANGE, AND FIELD SPREAD OF POTATO CALICO[1]

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INTRODUCTION

DURING INVESTIGATIONS of the infectious nature of potato calico[6] because of the increased prevalence of this disease in the field in 1929 and 1930, studies were made of the insect vectors, host range, and rate of spread in potato fields. Though still present in all the important potato districts of California, the disease has recently caused very slight loss. Maximum infection during 1932, 1933, and 1934 was less than 3 per cent, with less than 1 per cent average for the state.

In the search for other host plants, attention has been directed chiefly to cultivated species closely related to *Solanum tuberosum* L., and several varieties of this species have also been tested for relative susceptibility. Insect transmission trials have been limited to the aphid *Macrosiphum solanifolii* Ashm.[3] The rate of natural field spread was measured at Davis, Stockton, and Santa Clara.

The infectious nature of this disease has recently been questioned,[5] although McKay and Dykstra[4] state that their transmission trials in 1927 and again in 1929 were successful, antedating by three years the successful inoculations[6] made by the present author.

The studies herein reported add further proof of the infectious nature of potato calico; they show that the virus is transmitted by a common insect, that both cultivated and wild plants are susceptible, and that the disease is readily spread in the field. Unless otherwise stated, these studies were conducted with the White Rose (Wisconsin Pride) variety, although previous investigations[7] have demonstrated the susceptibility of certain other varieties.

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[3] Identified by F. H. Wymore, Associate in Entomology, University of California.

INSECT TRANSMISSION

In January, 1931, a colony of aphids (*Macrosiphum solanifolii* Ashm.) was collected on potato plants at Colma, near San Francisco. These insects were brought to Davis and transferred to young barley plants growing in an aphid-proof cage. After two weeks' confinement on barley, half of the young aphids were transferred to healthy[4] potato plants and half to calico-infected plants, both growing in aphid-proof cages. After two days, some of the aphids from both the healthy and the calico plants were transferred to other healthy plants. After allowing them to feed for two days, all the aphids were killed by fumigation. Of 15 check plants, none contracted calico from the aphids that had fed first on barley and then on healthy potato plants. Of 25 plants on which the calico-exposed aphids fed, 19 contracted calico. From these plants, calico was then successfully transmitted, mechanically, to both healthy White Rose and seedling potato plants. The technique of mechanical transmission has been described elsewhere.[6]

In March, 1931, a somewhat different procedure was followed. Again a colony of aphids, collected near San Francisco, was confined for two weeks on young barley plants in aphid-proof cage. Each healthy tuber had been cut into two seed pieces, the plant produced by one seed piece had been mechanically inoculated with calico while that from the other was uninoculated, and both were confined in aphid-proof cages. Young, virus-free aphids were allowed to feed for two days on both the calico-infected and the healthy plants of each of 19 tuber units. They were then transferred to healthy plants, allowed to feed for two days, and killed by fumigation. After 22 days, the controls were free of calico, whereas 16 of 19 plants on which calico-exposed aphids had fed manifested calico symptoms. Mechanical transmission from these calico-infected to healthy plants was successful.

A still different procedure was followed in February, 1932, when aphids collected from calico-infected plants in the field near San Francisco were allowed to feed for two days on healthy plants, with half of each tuber unit used as a control. Of 14 aphid-exposed plants, 9 became infected with calico, whereas all the controls remained healthy.

This experimental evidence of insect transmission may explain the apparent field spread of calico observed in the field in 1930[6] and 1931, as well as the measured field spread discussed later herein.

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[4] Any reference to healthy plants means that such plants were produced by tubers that had previously been indexed and found free of calico or other known virus diseases.

HOST RANGE

As mentioned in a previous publication,[6] alfalfa and certain weeds were suspected of being hosts because these plants, growing near calico-infected potato plants in the field, manifested symptoms very suggestive of calico infection. Numerous attempts to induce the disease in healthy potato plants as well as seedlings, using juice from diseased alfalfa,

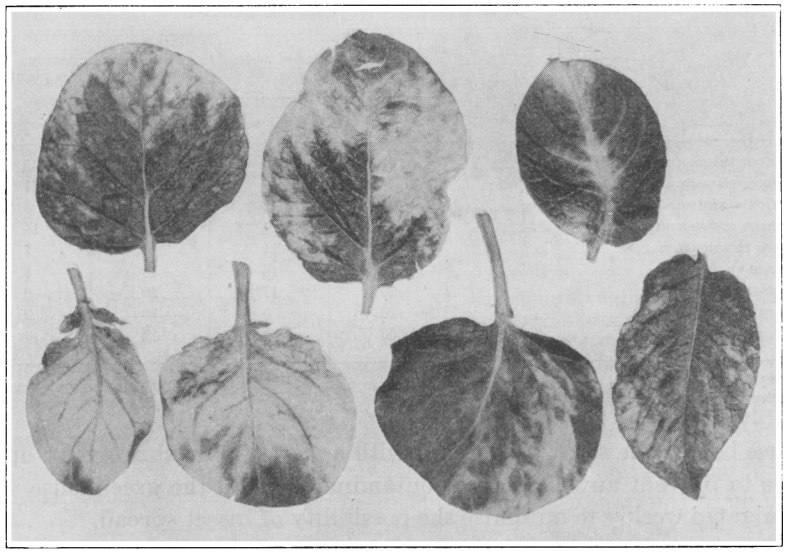


Fig. 1—Symptoms of potato calico on leaflets of White Rose plants naturally infected in the Delta region in 1930. For color plate of symptoms see terminal citation 6.

Ambrosia, and *Amaranthus,* have failed. Likewise, alfalfa plants inoculated with infectious juice from potato plants have not become infected, nor have they served as symptomless carriers. Nonviruliferous aphids (*Macrosiphum solanifolii*) have not transmitted the disease from infected potatoes to healthy alfalfa nor from diseased alfalfa to healthy potatoes. To date there is no experimental evidence that alfalfa is a host of the potato-calico virus.

In addition to alfalfa, *Ambrosia psilostachya* DC., and *Amaranthus graecizans* L., the following plants were grown from seed and inoculated with the calico virus: Jimsonweed (*Datura stramonium* L.), Marglobe tomato (*Lycopersicum esculentum* Mill.), New York eggplant (*Solanum melongena* L.), Ruby King pepper (*Capsicum annuum* L.), *Petunia* sp., and *Nicotiana tabacum* L.

Infectious juice was obtained by crushing calico-infected potato leaflets (fig. 1), straining the juice through two layers of cheesecloth, and mixing with five parts of sterile distilled water. Only the youngest foliage of suspected host plants was inoculated, using the blunt end of a pot label wrapped with sterilized cheesecloth, saturated with infectious juice. These inoculated plants were kept in 4-inch pots on a green-

TABLE 1

RESULTS OF INOCULATIONS WITH CALICO FROM POTATO BY LEAF MUTILATION, 1930 TO 1932 INCLUSIVE

Species tested	Plants inoculated with the calico virus		Return inoculations to healthy potato plants	
	Total	Infected	Total	Infected
Solanum tuberosum, var. White Rose	88	63	40	31
Lycopersicum esculentum, var. Marglobe	25	11	14	11
Capsicum annuum, var. Ruby King	25	16	10	8
Solanum melongena, var. New York	25	21	15	14
Datura stramonium	25	11	10	7
Petunia sp.	30	16	10	8
Nicotiana tabacum	20	17*	20	0
Amaranthus graecizans	20	0	10	0
Medicago sativa	50	0	10	0

* Note that although apparent infection was secured, it was not calico, for return inoculations to healthy potato plants did not produce calico.

house bench, the soil was watered with a slow stream through an open hose to prevent any chance of contamination, and the greenhouse was fumigated weekly to minimize the possibility of insect spread.

Several series of inoculations, made during three winters, are summarized in table 1. With each series, a few healthy potato plants were inoculated in order to check the potency of the juice used. The symptoms of potato calico are shown in figure 1.

The data in table 1 show that of the species tested, all except tobacco, alfalfa, and *Amaranthus* were susceptible. Calico-like symptoms appeared on tomato, pepper, eggplant, *Datura,* and *Petunia;* and from representative infected plants of these species the disease was successfully transmitted to healthy potato plants, a fact proving that the symptoms were those of calico infection, plus symptoms which might have been caused by the latent virus described by Johnson.[2] The symptoms produced in tomato, eggplant, pepper, and *Datura* are shown in figures 2 to 5 inclusive. In general, the chlorotic areas were not extremely yellowed as in potato (fig. 1). On pepper (fig. 6), death of the entire plant often resulted, probably because of the latent virus, as shown by Blodgett.[1] The symptom complex, evident on these host plants, cannot alone be considered evidence of calico infection, for the

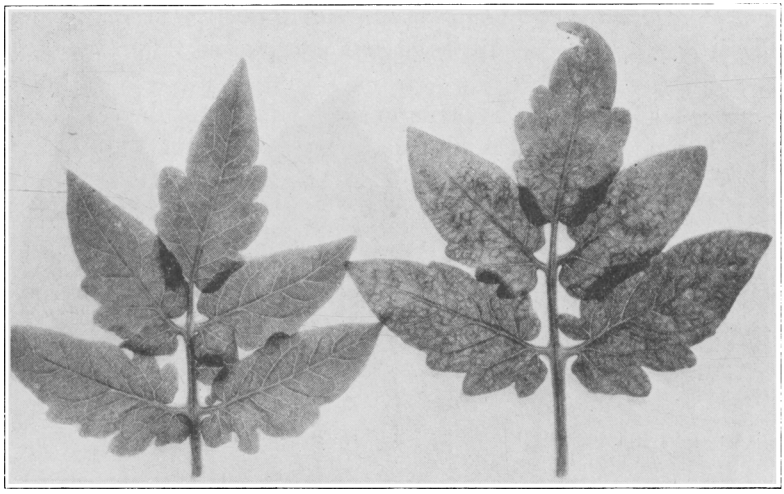


Fig. 2.—Symptoms produced on leaflets of Marglobe tomato (right) from inoculation with the potato-calico virus. Healthy Marglobe at left. The juice used in making the inoculations also contained the latent virus; hence these symptoms may be caused by a combination of both the calico and the latent virus. See text for discussion.

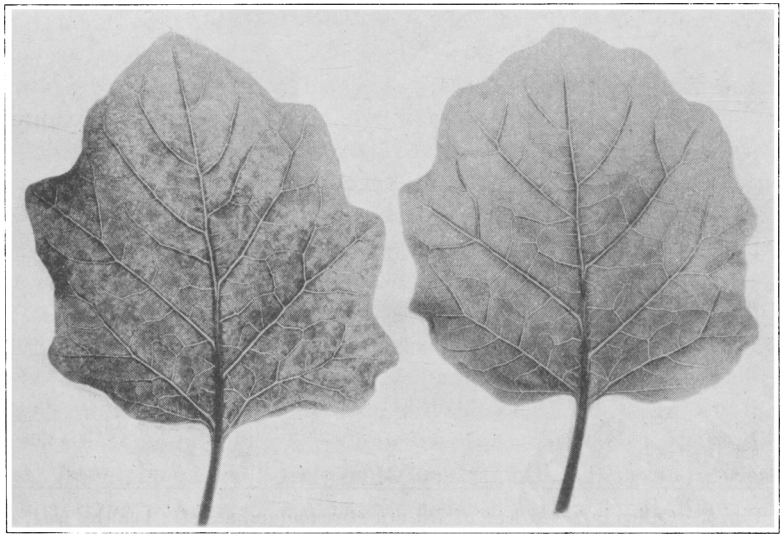


Fig. 3.—Calico-infected leaf of eggplant, variety New York, at left; healthy leaf at right.

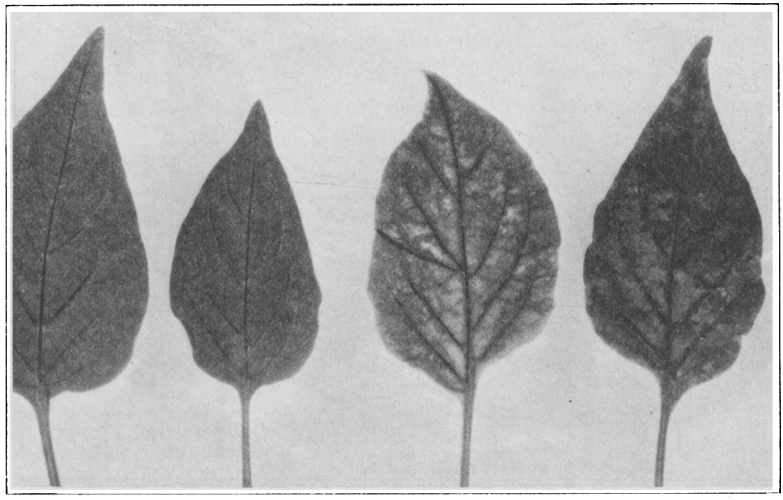


Fig. 4.—Two pepper leaves, at right showing reaction to calico inoculation; two healthy leaves at left. The latent virus produces necrosis in the pepper.

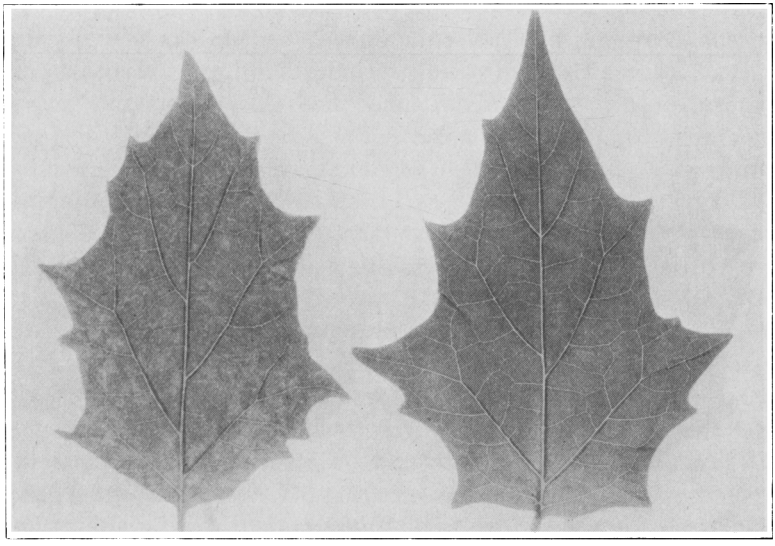


Fig. 5.—Calico-infected leaf of *Datura stramonium*, at left; healthy leaf, at right. Similar symptoms are produced on *Datura* by the latent virus, but from the diseased leaf (left) calico was successfully transmitted to healthy potato seedlings.

latent virus, as shown by Johnson,[2] may produce mottling, general necrosis, or even "spot-necrosis" on some of these hosts. Proof that the calico virus was in these plants was obtained by return inoculations to healthy White Rose potatoes and to seedlings, where the disease developed.

No abnormalities in the foliage or stems of alfalfa or of *Amaranthus* were observed, and all return inoculations from these to healthy potato

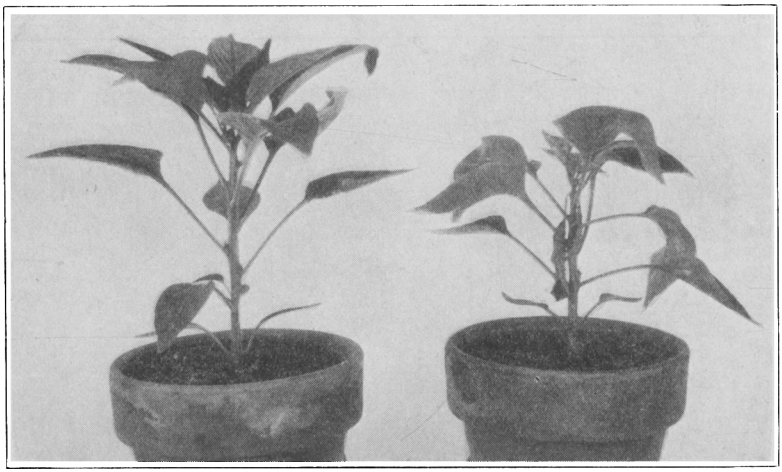


Fig. 6.—Leaf-dropping symptom produced on Ruby King pepper (right) after inoculation with potato calico; healthy plant, at left. The latent virus will also produce this symptom.

plants were negative. In the field, these two species often manifest symptoms suggestive of calico infection.

Of 20 inoculated tobacco plants, 17 manifested symptoms of infection. This was not calico, for return inoculations to healthy potato plants were consistently negative. The symptoms on tobacco were doubtless produced by the latent virus alone.

VARIETAL SUSCEPTIBILITY

On potatoes in California, calico has chiefly been seen in the field on the variety White Rose, locally known as Wisconsin Pride. This is the most important variety grown here; but the disease has also been found on Bliss Triumph, Idaho Rural, and Garnet Chili. The varieties White Ohio, Katahdin, Chas. Downing, Rural New Yorker No. 2, Early Rose, Jersey Red Skin, Green Mountain, Irish Cobbler, Earliest of All, Russet Burbank, and White Rose have been experimentally infected.

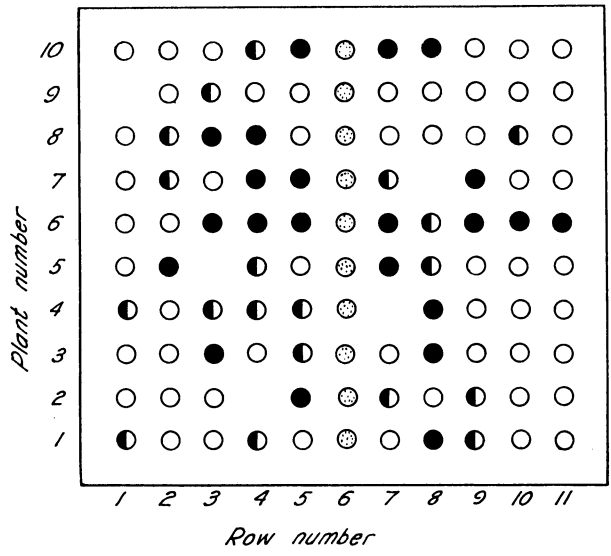
FIELD SPREAD

A previous publication[6] showed that natural spread might occur in the field; and there was some indication (page 280, table 2) that the extent of infection rapidly decreased with an increase in distance from infected plants. It seemed worth while to measure rate and distance of field spread more accurately in different localities in interior California where the disease was most prevalent. The results are given below.

Fig. 7.—A typical calico-transmission plot, with five rows of healthy stock planted on either side of a diseased row.

The method was as follows: During the winter, greenhouse indexing provided healthy as well as calico-infected stock. In the field, 11 rows of 10 hills each constituted a plot (fig. 7); the middle row was planted with calico-infected tubers, and 5 rows on either side with healthy tubers. Each plot was isolated from other potatoes. Two weeks after emergence, all hills were thinned to one stalk. Frequent readings indicated the extent of visible current-season spread. At maturity the originally healthy hills were dug separately, and the tubers numbered with India ink to preserve their original location in the field. When the normal dormant season had passed, two tubers from each hill were indexed in the greenhouse; and resulting plants furnished complete information on the actual field spread during the growing season.

Three of these transmission plots were established during 1930 and 1931. In 1930, one plot was located at Santa Clara; and in 1931 one was



Key to symbols:

- ⊙ Diseased when planted; previously determined by indexing.
- ● Disease evident on plants in the field and also on progeny plants in the greenhouse.
- ◐ Disease not evident in the field but manifest on progeny plants in the greenhouse.
- ○ Plants healthy both in field and greenhouse; blank spaces indicate missing hills.

Fig. 8.—Field spread of calico at Santa Clara in 1930, indicating visible current-season spread and actual spread as determined by indexing the progeny of each hill in the greenhouse.

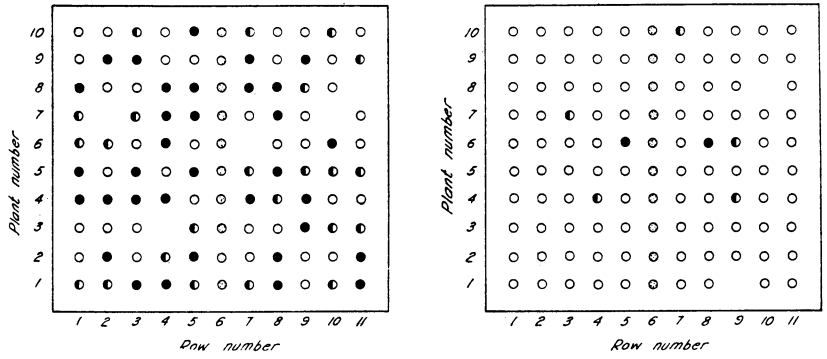


Fig. 9.—Field spread of calico in 1931 at Stockton (left, planted April 12) and at Davis (right, planted June 16). See figure 8 for legend.

located in the Delta region near Stockton, and one at Davis. The rate of spread at Santa Clara in 1930 is shown in figure 8. Visible field spread was evident on 22 out of 100 plants; but when the tubers from each hill were indexed in the greenhouse, 41 hills were found infected with calico.

The Stockton plot, in 1931, was intentionally planted early (April 12) because virus spread was known to be much more rapid then than if planting was delayed.[8] To check this supposition, the Davis plot was planted late (June 16) with stock identical with that used at Stockton; that is, tubers were halved, and one half used in each plot. The rate of spread in these two plots is shown in figure 9.

At Stockton, visible field spread was noted on 33 out of 100 originally calico-free plants, while indexing detected 55 infected plants. Tubers from *all* visibly infected plants in the field produced diseased plants in the greenhouse. According to some writers,[5] tuber perpetuation of potato calico is not inevitable. Possibly tubers of plants that become infected when nearly mature might be calico-free, for the rate of movement of the virus from the leaflets into the tubers is unknown. In the writer's experiments, the disease has remained tuber-perpetuated during six successive generations, both of seedlings and of White Rose plants.

At Davis in 1931, where stock identical with that used at Stockton was planted, visible field spread was noted on only 2 plants out of 100, and indexing detected the disease on only 7 (fig. 9). It has been shown[8] that with certain other virus diseases of potatoes, the rate of spread at Davis and Stockton is practically identical, provided the planting dates are the same at both places. The difference in rate of spread of calico at Davis and Stockton in 1931 was probably due entirely to the respective planting dates (April 12 at Stockton and June 16 at Davis). The explanation is thought to be that aphids are seldom active on plants growing during the high summer temperatures prevalent in July, August, and September at Davis and Stockton. Since these insects are the chief vectors of virus diseases of potatoes, their scarcity naturally contributes to the absence of severe calico infection in late-planted stock. It has been shown,[8] in fact, that the practice of late planting in the Sacramento and San Joaquin valleys of California often produces seed stocks relatively free of virus infection and capable of producing high yields in the next generation.

SUMMARY

Potato calico may be spread from infected to healthy White Rose and seedling potato plants by originally nonviruliferous aphids, *Macrosiphum solanifolii.*

Besides *Solanum tuberosum,* the following species are susceptible to calico: *Lycopersicum esculentum, Capsicum annuum, Solanum melongena, Datura stramonium,* and *Petunia* sp.

Calico has been mechanically transmitted to the following potato varieties: White Rose, Garnet Chili, Idaho Rural, White Ohio, Katahdin, Chas. Downing, Rural New Yorker No. 2, Early Rose, Jersey Red Skin, Green Mountain, Irish Cobbler, Earliest of All, and Russet Burbank (Netted Gem).

Natural field spread occurred at Santa Clara, Stockton, and Davis. Late planting in the Sacramento Valley decreased actual spread from 55 per cent to 7 per cent when compared with early-planted stock in the San Joaquin Valley.

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