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5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.

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HILGARDIA

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CALIFORNIA AGRICULTURAL EXPERIMENT STATION

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THE INFECTIOUS NATURE OF POTATO CALICO

D. R. PORTER[1]

The nature of potato calico, a degeneration disease of the Irish potato, has been under investigation at the California Agricultural Experiment Station during three seasons. The disease has been observed in every important potato-producing district in the state, from San Diego County, in the extreme southern part, to Humboldt County, in the extreme north. It was prevalent in certain fields in the Delta region in 1929–1930; and growers in San Bernardino, Riverside, Tulare, and Kern counties have stated that calico is steadily increasing in prevalence in their fields, even though they continue to plant only their own seed stock. The evidence presented herewith establishes the infectious nature of potato calico, adding one more virus disease to the present list. All experiments and observations reported herein were carried out with the potato variety White Rose, or, where indicated, with seedlings.

HISTORICAL

In 1920, Hungerford[7] described potato calico as a non-infectious disease and in later reports[8] [18] [19] brought out that the disease was tuber-perpetuated; that the yield reduction by calico was slight, if measurable at all; and that chlorophyll deficiency was less pronounced at blossoming time than in the early life of the diseased plant. He further observed that about three per cent of the plants were infected and that the disease was commonly found in irrigated fields. Although he did not consider the disease a serious one, he recommended that diseased plants should be removed from the field.

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In Washington, Dana[3] [4] [5] observed apparent spread in the field, redemonstrated tuber perpetuation, and reported negative results with transmission by means of tuber grafts, or aphids. In 1926[12] it was reported from Oregon that calico was among the virus diseases which had been identified in that state. Young and Morris[20] reported calico from Montana in 1929, and in 1931[21] reported unsuccessful attempts to transmit the disease by tuber grafting; they found that the disease was tuber-perpetuated and that infected plants produced low yields. They suggested that infected plants should be rogued. McKay and Dykstra[10] temporarily classified calico as a virus disease, although they obtained only one positive case of transmission. They reported that diseased plants were stunted, that tuber perpetuation did not always occur, and that the increase in regional prevalence suggested the infectious nature of the disease.

NATURAL FIELD SYMPTOMS

Some of the leaflets of infected plants growing in the field become irregularly spotted or blotched. These areas do not become necrotic; rather they appear devoid of chlorophyll and generally assume a bright brilliant-yellow, yellowish-white, or gray color. The spots are not always inter-veinal and may occupy as much as 95 per cent of the leaflet area, being, as a rule, irregularly scattered. As a probable result of chlorophyll deficiency, plants infected when young seldom attain normal size. If infected when nearly mature, they show no significant stunting. If more than 50 per cent of the plants in the field are infected, the crop appears from a distance to be diseased. Under conditions of close planting, such as is commonly practiced in the Delta region, non-infected plants often grow over and obscure plants which were infected when small. The symptoms of calico as they appear on infected leaflets in the field are shown in plate 1 (lower).

INOCULATIVE SYMPTOMS

The young leaflets of healthy[2] plants which have been artificially inoculated with unfiltered juice extracted from infected plants assume symptoms practically identical with those observed in the field; but, in

[2] In this paper any reference to healthy plants indicates plants produced by tubers which had been indexed and found free of calico. Such stock was likewise free from visible symptoms of other virus diseases. Indexing was accomplished by planting the stem-end bud of each tuber in steamed peat in the greenhouse. If the resulting plant was visibly free of calico or other known virus diseases, it was assumed that the remainder of the indexed tuber was likewise virus-free.

addition to yellowing, the lower leaflets may become necrotic at the tip, crinkled or ruffled, and in some instances slightly stiffened. Plants inoculated when 15 inches tall rarely exhibit yellowing of the lower leaflets or of those which were inoculated. Artificially infected plants are stunted; the leaflets are smaller and the leaves shorter than normal. Under certain undefined environmental conditions, diseased leaflets may regain their normal color as they age. The stems are usually smaller on diseased than on non-infected plants produced by the same tuber. Inoculative symptoms produced on a seedling plant are shown in plate 1 (upper).

SPREAD IN THE FIELD

Much circumstantial evidence suggests the infectious nature of potato calico. In September, 1929, tubers were harvested from infected plants and from adjoining plants apparently calico-free. These tubers were cut with a flamed knife, and planted in the field at Davis on March 25, 1930. The progeny of the infected plants harvested in 1929 showed a higher per cent of calico in the field in 1930 than the progeny of the apparently calico-free plants which adjoined the infected plants in 1929. The progeny of the apparently calico-free plants, however, manifested enough calico in the field in 1930 to suggest that transmission had occurred in the field in 1929. Data from this trial appear in table 1. Tubers from the 1930 crop were planted the following winter in the greenhouse. The results of the greenhouse planting are also given in table 1.

TABLE 1

RELATIVE PER CENT CALICO PRODUCED BY TUBERS FROM INFECTED AND HEALTHY-APPEARING PLANTS GROWN NEAR INFECTED PLANTS IN THE FIELD

Seed stock, grown in 1929	Number of progeny plants in the field, 1930	Per cent infected plants in the field 1930			Per cent infected plants in second generation in the greenhouse 1930-31
		May 6	May 28	July 6	
A, tubers from calico-infected plants	12	83	83	83	85
B, tubers from non-infected plants adjacent to A in the same row	40	15	20	25	56
C, tubers from non-infected plants in the rows adjoining those of infected plants, A	48	0	11	11	49

Further circumstantial evidence of calico transmission was obtained in the field at Davis in 1930. Calico-infected stock was planted in one row (row 57) across the field; and four rows on either side (rows 53 to 56, inclusive, and 58 to 61, inclusive) were planted with healthy stock. The healthy stock planted in rows 58 to 61 was also planted in isolated fields at San Jose, Shafter, and Temecula; and, as no calico developed in these distant plots, the evidence indicates that this stock was free of calico when planted at Davis. The fact that calico appeared in this healthy stock in the field at Davis indicates current-season transmission of the disease in the field in 1930. Data from this trial are presented in table 2. It appears that a higher per cent of calico was present in the rows of healthy stock nearest row 57, and that slightly less transmission occurred in rows 53 and 61, each situated 14 feet from row 57.

TABLE 2

INDICATIONS OF CURRENT-SEASON TRANSMISSION OF POTATO CALICO IN THE FIELD AT DAVIS, 1930, WHERE FOUR ROWS OF HEALTHY STOCK WERE PLANTED ON EITHER SIDE OF A ROW PLANTED WITH CALICO-INFECTED STOCK

Row No.	Stock planted	Distance in feet from calico-infected stock (row 57)	Per cent infected plants		
			May 6	May 28	June 11
53	Healthy	14.0	0.0	1.25	3.75
54	Healthy	10.5	0.0	6.25	6.25
55	Healthy	7.0	0.0	7.50	7.50
56	Healthy	3.5	2.5	12.50	13.75
57	Calico-infected	.....	27.1	38.50	40.30
58	Healthy	3.5	?	15.00	15.00
59	Healthy	7.0	?	12.50	13.75
60	Healthy	10.5	?	5.00	6.25
61	Healthy	14.0	?	7.50	10.00

White Rose stock, here designated as lot D, grown in Minnesota in 1929 in a place where no calico was seen,[3] was planted in 1930 in the greenhouse at Davis, and by a grower in the Delta region near Stockton. In the greenhouse no calico was evident on any of 240 plants, each produced by a different tuber—a fact indicating that lot D was free of calico.

The plantings of lot D in the Delta were made in two places. Field No. 1 was situated near the levee, the north slope of which was cropped with alfalfa. In this field lot D was planted in two 40-foot

[3] J. J. Thompson, seed expert with Zuckerman Brothers, who inspected lot D growing in Minnesota, saw no calico there either in 1929 or in 1930.

strips, each running parallel with the levee and separated from one another by a seven-foot space, as shown in figure 1. Four feet of this space was occupied by an irrigation ditch. The plot between the levee and the first ditch was designated as D and that beyond the first

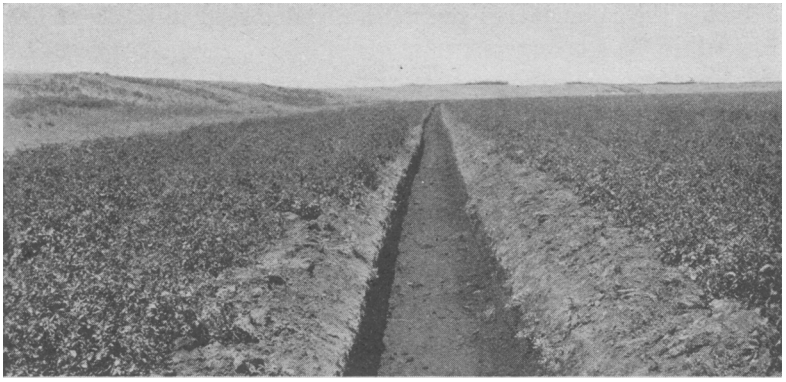

Fig. 1. The irrigating ditch in the center separates seed lot D on the left from lot D*a* on the right. Note alfalfa plants on the high levee on the extreme left. A condition suggestive of calico was observed on some of these and on certain weeds in this field in 1930.

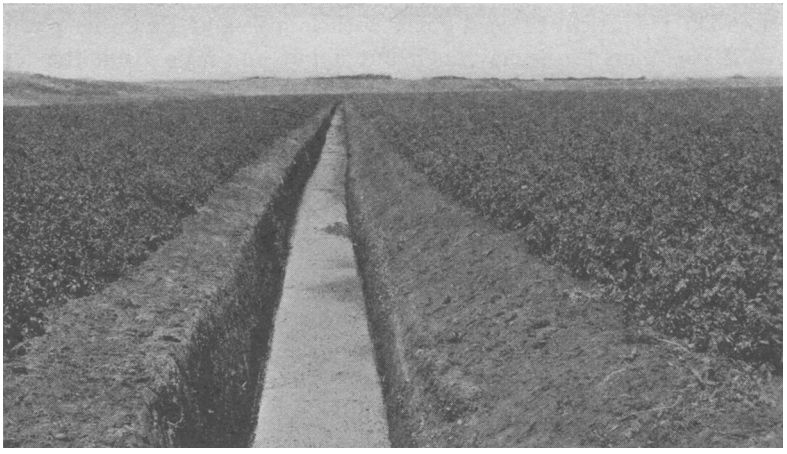

Fig. 2. The ditch separates seed lot D*a* on the left from lot E on the right.

ditch as D*a*. Another irrigation ditch separated lot D*a* from a third lot, E, as shown in figure 2. The seed stock for lot E also came from an apparently calico-free field in Minnesota, though not from the same source as D. Calico was first observed in lot D; and, as shown in table 3, the disease seemed to spread from lot D across the first ditch

into lot D*a* and thence into lot E. Although there was 16 per cent calico in lot E, close to D*a*, on July 2, it was observed that calico infection in lot E decreased with increasing distance from lot D*a*, there being only a trace at a distance of 200 feet from D*a*. The data in table 3 indicate the increase in prevalence of calico in these three lots during the summer and suggest natural spread in the field.

TABLE 3

INDICATION OF CURRENT-SEASON SPREAD OF POTATO CALICO IN TWO FIELDS AT STOCKTON, 1930

Stock	History of stock	Location in field, 1930	Per cent infected plants			
			May 13	May 23	June 13	July 2
D	Grown at Thief River Falls, Minn., in 1929. No calico seen.	Adjacent to levee and alfalfa	18	63	91	....
D*a*	Same as D.	Separated by a seven-foot space from D.	trace	11	46	....
E	Grown in Minnesota in 1929. No calico seen	Separated by a seven-foot space from D*a*	none	trace	13	16
D*b*	Same as D and D*a*	About one mile from D	?	trace	trace	1

Lot D*b* (identical in seed stock with lots D and D*a*) was planted in field No. 2 on the same ranch but about one mile from the levee and from field No. 1. Only a trace of calico was observed in the field on June 13, when 91 per cent infection was present in lot D. The results in this field are included also in table 3. Thus, lot D when grown at Davis or at some distance from the levee at Stockton, was comparatively free from calico—a fact indicating that probably no infection had been carried in the seed grown in Minnesota. The apparent spread to lot D near the levee indicated that primary infection probably had come from some source other than the seed. An abnormality suggestive of calico was observed on volunteer potato plants and on certain weeds in the field, as well as on alfalfa growing on the levee. Juice from such diseased alfalfa plants was used in inoculating potato plants, but no calico developed. Insect vectors may have served as agents of transmission, for insects of the genera *Cicadula, Eutettix, Empoasca,* and *Agallia,* as well as plant lice, were found on calico-infected potato plants. Alfalfa plants have been inoculated with the infectious principle, but calico-like symptoms have not developed. There is no experimental evidence to indicate that alfalfa is susceptible to calico infection, even though the symptoms on alfalfa resemble those on potato.

On June 4, 1930, tubers were dug from 50 plants of lot D, which manifested moderate infection (table 4) and from 50 plants which appeared free of calico infection. On November 19, a number of tubers of each of these two lots were indexed, and the sets were planted in steamed peat in five-inch pots in the greenhouse. The per cent of calico-infected tubers thus tested appears in table 4 and indicates that the progeny of the "apparently calico-free" plants were not so thoroughly infected as the progeny of the "moderately infected" plants. The "apparently calico-free" plants may have been infected; but at the time of digging the tubers were immature, the plants were still green and vigorous, and the infectious principle may not have been diffused into the tubers by that time.

TABLE 4

PER CENT CALICO-INFECTED PLANTS PRODUCED BY TUBERS FROM MODERATELY INFECTED AND APPARENTLY CALICO-FREE PLANTS OF LOT D, GROWN IN THE GREENHOUSE

Stock	Number of tubers indexed	Per cent infected plants in the greenhouse		
		January 5	January 15	January 24
Moderately infected with calico in the field	48	27.0	43.2	58.5
Apparently calico-free in the field	24	18.2	21.4	31.2

TABLE 5

APPARENT TRANSMISSION OF POTATO CALICO AT STOCKTON, 1930, AS INDICATED BY TUBER INDEXING IN THE GREENHOUSE

Description of stock indexed	Number of tubers indexed	Per cent infected plants in the greenhouse				
		January 5	January 9	January 15	January 24	February 9
One tuber from each plant infected with calico in the field	16	27	36	46	60	86
One tuber from each plant adjacent to the infected plants, grown in the same row	34	15	22	26	50	64
One tuber from each plant nearest to the infected plant but in adjoining rows	32	0	4	16	41	56

For further tests of field spread, tubers were harvested from 17 calico-infected plants growing in the Delta region. The plants came from seed stock grown in Minnesota in 1929. Tubers were also harvested from the four nearest apparently calico-free plants. The progeny of these 85 plants were planted in the greenhouse at Davis in January, 1931. Calico infection is recorded in table 5, and shows

that the per cent of infection was higher in the progeny of the 17 infected plants than in the others. There is also slight evidence that spread was more complete to plants in the same row than to those in adjoining rows. The normal distance between plants in the row was 10 inches, while that between rows was 32. Possible mechanical transmission might be more complete from plant to plant in the row than between rows. Such relative spread is evident from the data in both tables 1 and 5.

ARTIFICIAL TRANSMISSION

Tuber Grafting.—Many attempts to transmit calico through the medium of tuber grafts have been made, but a very low per cent of infection has been obtained by this method. In 1930, Dr. E. S. Schultz tuber grafted 25 Green Mountain half-tubers with tissue from tubers produced by calico-infected plants (secured in California), and planted them at Presque Isle, Maine. In a letter dated September 25, 1930, Dr. Schultz stated that 2 of the 25 tuber grafts produced plants which manifested symptoms of calico, while the ungrafted sister half-tubers produced calico-free plants. Although the results of this experiment suggested the infectious nature of the disease, Dr. Schultz considered the per cent of infection too low for adequate proof. Tuber grafting experiments conducted by the writer have, in general, resulted in failure to transmit the disease. Failure to obtain a high per cent of infection might result from incomplete diffusion of the infectious principle into tubers produced by infected plants, for, as indicated by McKay and Dykstra,[10] and in this paper, neither all the tubers from an infected plant nor all the buds of an infected tuber produce visibly infected plants. Thus, unless the infectious principle is definitely known to be completely diffused in a tuber used for grafting into calico-free tubers, such incomplete diffusion might account for the nature of the results obtained by Dr. Schultz, and those reported herein.

In another trial, two indexed tubers produced plants definitely infected with calico, in the greenhouse in January, 1931, and tissue from the mother seed-pieces was used for core grafting 12 healthy White Rose tubers. The grafted tubers were planted in steamed soil in five-inch pots in the greenhouse. Controls consisted of sister sets of ungrafted healthy tubers. None of the plants produced by grafted tubers developed calico—a fact indicating that either tuber grafting often fails to transmit the disease or that the infectious principle

possibly does not persist in an old seed-piece after it has produced a diseased plant.

Two other tubers which, when indexed produced calico-infected plants, were used for grafting into five healthy White Rose tubers on January 11, 1931. The grafted half-tubers and the sister-pieces used as controls were planted in steamed peat in five-inch pots. Only one of the plants produced by the grafted tubers became infected, suggesting that calico may be transmitted by core grafting. The per cent of transmission in this trial was approximately equal to that obtained in the experiment of Dr. Schultz. The results secured in this trial are not considered as adequate proof of transmission by tuber grafting.

TABLE 6

TRANSMISSION OF POTATO CALICO BY LEAFLET MUTILATION OF SEEDLING POTATO PLANTS; INOCULATED JANUARY 9, 1931, IN THE GREENHOUSE

Method of inoculation	Number of plants inoculated	Per cent infected plants					Ave. plant height, inches		
		Jan. 30	Feb. 2	Feb. 6	Feb. 15	Feb. 21	Jan. 9	Feb. 6	Feb. 21
Sterile distilled water applied with cheesecloth to leaflets (see text)	10	0	0	0	0	0	6.3	13.4	17.6
Needle pricks through infectious juice into leaflets	19	11	21	37	37	37	6.6	12.2	13.1
Leaflets rubbed with fingers moistened with infectious juice	8	12	37	75	75	87	6.8	11.3	12.6
Leaflets rubbed with cheesecloth saturated with infectious juice	4	25	50	50	75	75	6.1	12.1	13.0

Leaflet Inoculation.—While the disease has not been transmitted by means of filtered juice, successful inoculations have been made with *unfiltered* juice from infected leaves. On January 9, 1931, plants produced by true potato seed were inoculated with juice from calico-infected leaves by the use of three methods, as follows: (1) a drop of infectious juice was placed on the upper surface of the leaflet, and 50 small needle pricks were made through this juice into the tissue; (2) the fingers were moistened with infectious juice, and the leaflet was rubbed so as to cause surface injury; (3) sterilized cheesecloth was saturated with infectious juice, and the upper surface of the younger leaflets was rubbed so as to injure the epidermal cells and leaf hairs. Controls were inoculated as above with sterile distilled water. The results of this trial, appearing in table 6, indicate that the

disease is of an infectious nature and can spread through the medium of *unfiltered* juice from infected leaves. On February 11, juice was extracted from the infected plants, indicated in table 6, and three potato seedlings were inoculated. These manifested calico symptoms on February 28. Thus the disease has been transmitted from naturally-infected plants to seedlings and then transferred from these to other seedlings. Comparison of controls and inoculated foliage is shown in figure 3 and on seedlings in figures 4 and 5.

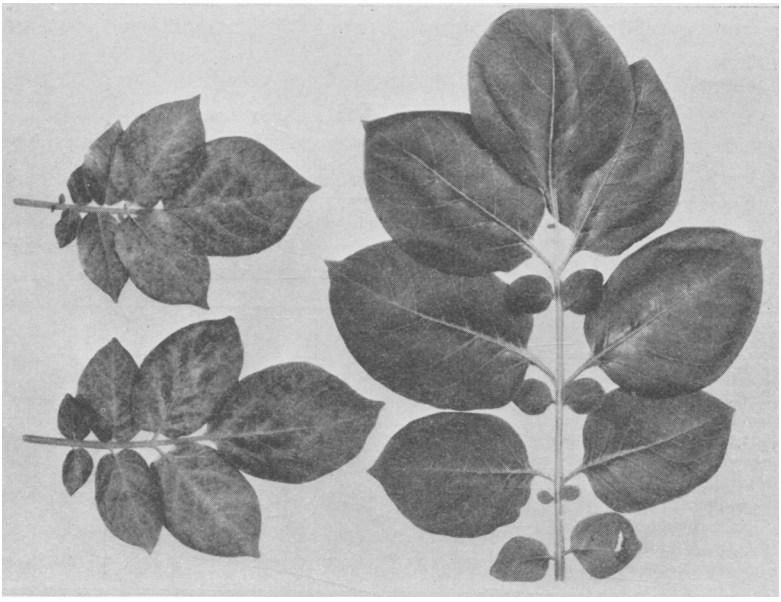

Fig. 3. Calico symptoms on White Rose leaflets (on the left) resulting from mechanical transmission by the use of cheesecloth saturated with *unfiltered* infectious juice. Healthy leaflets (on the right) from a plant inoculated in like manner with sterile distilled water.

Similar results were obtained when healthy plants (from tubers) were inoculated. In this trial healthy White Rose plants were inoculated by leaflet mutilation when approximately eight inches in height, small needle pricks or saturated cheesecloth being used. One hundred per cent infection was obtained 34 days after inoculation by the use of cheesecloth, while needle pricks induced 60 per cent infection after 36 days. In addition to the relatively high per cent of infection, those plants which manifested calico symptoms were stunted when compared with the controls on February 7, as shown in table 7.

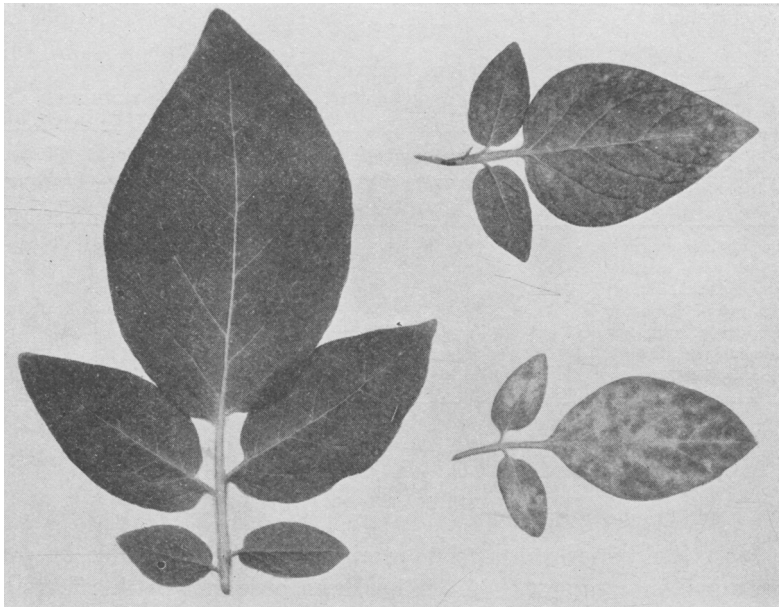

Fig. 4. Right, potato calico on foliage of seedling plants artificially inoculated with *unfiltered* juice. Left, from a seedling plant inoculated with sterile distilled water.

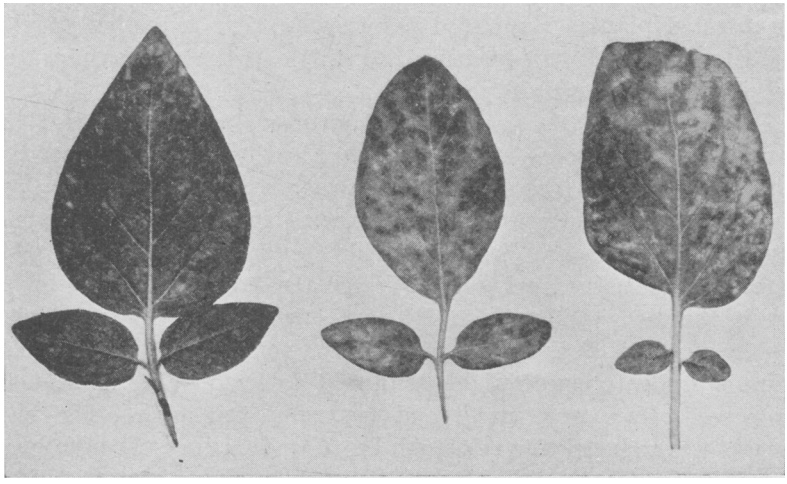

Fig. 5. Various degrees of calico infection on leaflets of potato seedlings artificially inoculated with *unfiltered* juice. Reading from left to right: mild, moderate, and severe types.

TABLE 7

TRANSMISSION OF POTATO CALICO BY LEAFLET MUTILATION OF HEALTHY WHITE ROSE PLANTS; INOCULATED JANUARY 10, 1931, IN THE GREENHOUSE

Method of inoculation	Number of plants inoculated	Per cent infected plants					Average plant height, inches			
		Jan. 30	Feb. 13	Feb. 15	Feb. 17	Feb. 24	Jan. 10	Jan. 30	Feb. 7	Feb. 24
Sterile distilled water applied with sterile cheesecloth	5	0	0	0	0	0	8.0	15.1	30.4	32.6
Needle pricks through infectious juice	5	0	40	60	60	60	8.5	14.5	25.0	26.1
Cheesecloth saturated with infectious juice	5	80	100	100	100	100	8.1	14.2	23.0	23.8

EFFECT OF CALICO ON YIELD

Controlled experiments to determine the effect of calico on yield have not been conducted; but it has been observed in the field that infected plants usually produce lower yields than adjacent, non-infected plants. In September, 1929, infected plants were selected at random in a field of about 200 acres, and the tubers of each plant were weighed, and the relative yields compared. It was found that there was a consistent tendency for infected plants to yield less than non-infected plants. Expressed numerically, this reduction in yield was 31 per cent. In September, 1930, this experiment was repeated; the yield decrease was 16 per cent.

In January, 1931, several healthy tubers were quartered and planted in a greenhouse bed in peat that had been steamed for three hours at 30 pounds pressure. When two weeks old, two plants produced by each tuber were inoculated with calico, two sister plants being left as controls. The inoculated plants became infected while the controls remained calico-free. When the tubers were dug in late March, the total yield produced by infected plants was found to be 19 per cent less than that produced by non-infected plants. This figure is probably more reliable than that determined in the field, for sister seed-pieces were used, and contamination with other virus diseases was reduced to a minimum by tuber indexing, through insect control by frequent fumigation of the greenhouse, and by the utilization of steamed soil for the experiment.

COMPARISON OF CALICO WITH SOME SIMILAR POTATO DISEASES

In addition to potato calico, similar diseases manifested by some type of foliage yellowing have been described. Some of these, e.g., aucuba mosaic, yellow top, yellow dwarf, and psyllid yellows, are herewith described, and some of their differential characteristics are listed in table 8. Aucuba mosaic, yellow top, and calico have been artificially transmitted.

Calico.—Hungerford[8] described calico as follows: "This disease is characterized by a pronounced variegation of the leaves of the plant. In extreme cases as much as half of the surface of the leaf may be almost entirely lacking in chlorophyll. The plants appear normal in every other way. Calico is much more pronounced early in the season, many of the leaves appearing to develop chlorophyll in these chlorotic areas at about blossoming time. All evidence to date seems to show that this condition is heritable but not infectious. . . . . When tubers from plants showing this variegation were planted in the greenhouse, the symptoms which developed were similar to those noted in the field except that in some cases the chlorotic areas turned brown. . . . ."

Aucuba Mosaic.—Quanjer[13] in 1922, described an infectious potato disease which he named aucuba mosaic because the leaf symptoms resembled the variegation of the foliage of *Aucuba japonica.* Later work by Quanjer[14] and Atanasoff[1] established the following facts: (a) the symptoms on the leaflets are manifested by conspicuous yellow spots, usually more or less round and regular in outline; in extreme cases, when these spots coalesce, half of the surface of the leaflet is lacking in chlorophyll; (b) symptoms may be induced in the leaves of plants produced by tubers into which has been grafted other tuber tissue which manifested a certain type of necrosis; (c) transmission may be induced after leaflet mutilation. While the primary symptoms of aucuba mosaic are manifested by small, round spots, the primary symptoms of calico are manifested by irregular, often large areas of yellow, chlorophyll-deficient tissue. Net necrosis of the tuber is reported as a symptom of aucuba mosaic but does not appear to be associated with calico. Comparison of inoculative symptoms of aucuba mosaic and calico is shown in figure 6.

TABLE 8

SOME DIFFERENTIAL CHARACTERISTICS OF CERTAIN POTATO DISEASES* MANIFESTED BY FOLIAGE YELLOWING†

Characteristics	Aucuba mosaic	Psyllid yellows	Yellow top	Yellow dwarf	Calico
Infectiousness	Positive	Probably negative	Positive	Probably positive	Positive
Tuber perpetuation	Positive	Negative	Positive	Positive	Positive
Transmission by: Insects	?	Induced by insect	?	?	?
Transmission by: Leaflet mutilation	Positive	?	?	?	Positive
Transmission by: Tuber grafts	Positive	?	Positive	?	Probable
Dwarfing	None	Extreme	Distinct	Distinct	Moderate
Spindliness	Absent	Mild	Distinct in sprouts	More stocky than normal	Mild
Rolling of leaflets	Absent	Distinct	Distinct at times	Distinct	Absent
Type of leaflet yellowing	Small, lemon - yellow round spots which may coalesce to form irregular blotches	Basal portion of young leaflet has yellowish tinge. Older leaves become yellow and die	Extreme chlorosis at times	Yellowish tinge	Large irregular yellow to cream-colored or gray spots or splotches
Tuber symptoms	Net necrosis at times	None	Net necrosis. Often many small tubers	Often sessile, small, few, and cracked. Flesh discolored as rusty specks. Prominent lenticels	None
Effect on yield	Slight, if any	Reduced	?	Reduced	Reduced
Premature death	No effect	Longer lived	Distinct	?	Very slight

* Exclusive of those known to be caused by microorganisms.

† This comparison would be more accurate if all five diseases could be studied on one clon and under identical environmental conditions. Such has not been possible, and the table was prepared from data and descriptions in the literature, except for calico.

Yellow Top.—According to Folsom,[6] yellow top is manifested by distinct dwarfing, by spindliness, sometimes by extreme chlorosis, sometimes by distinct rolling, by stiff leaf texture, and sometimes by tuber net necrosis, and is tuber-perpetuated. He found that the disease was transmissible by means of grafts.

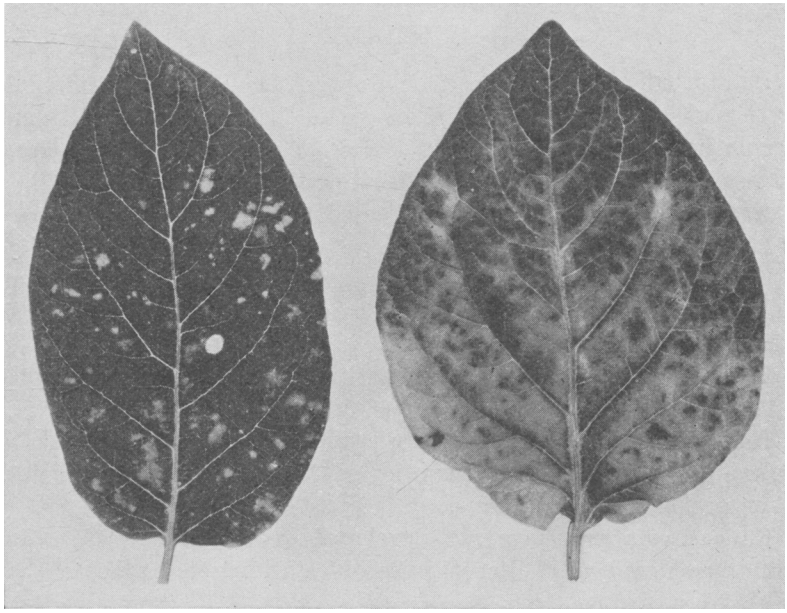

Fig. 6. Inoculative symptoms of aeuba mosaic on seedling, left, and of calico on White Rose, right. White Rose manifests calico symptoms identical with those of calico on seedlings.

Yellow Dwarf.—Barrus and Chupp[2] described in 1922 a non-infectious disease which was named yellow dwarf by Dr. F. M. Blodgett. Infected plants manifested a dwarfed condition and yellow color, and tubers produced by infected plants were usually small, deformed, deeply cracked, and were often sessile.

Psyllid Yellows.—Recently Richards[15] [16] has reported a serious non-infectious potato disease in the northwest. Because of its association with nymphs of the psyllid, *Paratrioza cockerelli,* and because of the yellowing of the foliage of infected plants, the disease is known as psyllid yellows. Infected plants are severely stunted. There is an upward rolling of the basal portion of young leaves, this rolled portion becoming light pink, yellow, or purple in color. Axillary buds are stimulated into one or a combination of three types of growth: thick

shoots which may exceed the leaf in length, aerial tubers, and rosettes of small and frequently highly colored leaves. In Utah[16] tubers from diseased plants produced normal plants, but in California[17] results which indicated tuber-perpetuation were secured.

SUMMARY

Potato calico is an infectious disease, manifested by irregular blotches of various shades of yellow on the leaflets of infected plants. Inoculative and perpetuation symptoms appear identical. The disease is tuber-perpetuated. Plants artificially infected are stunted.

Natural spread in the field, indicated by inoculative symptoms on healthy plants, has been observed.

The distance, direction, and rapidity of spread in the field and the natural increase in prevalence in certain regions suggest that insects may serve as vectors.

There is questionable evidence that the disease may be transmitted by tuber grafting.

Infection results when healthy leaflets are inoculated with *unfiltered* juice taken from calico-infected plants. The minimum incubation period is about 15 days.

Calico symptoms have not developed in the foliage of healthy plants inoculated with filtered juice of calico-infected plants.

LITERATURE CITED

[1] ATANASOFF, D.
1926. Net necrosis of potato. Phytopathology **16**:929–940.

[2] BARRUS, M. F., and CHARLES C. CHUPP.
1922. Yellow dwarf of potatoes. Phytopathology **12**:123–132.

[3] DANA, B. F.
1924. Rhizoctonia and related diseases. Washington Agr. Exp. Sta. Bul. **187**:68–70. (34th Ann. Rpt. Wash. Agr. Exp. Sta.).

[4] DANA, B. F.
1925. Mosaic and related diseases of the potato and other crops. Washington Agr. Exp. Sta. Bul. **196**:33 (35th Ann. Rpt. Wash. Agr. Exp. Sta.).

[5] DANA, B. F.
1926. Mosaic and related diseases of potato and other crops. Washington Agr. Exp. Sta. Bul. **208**:33 (36th Ann. Rpt. Wash. Agr. Exp. Sta.).

[6] FOLSOM, D.
1926. Virus diseases of the potato. Quebec Soc. Protect. Plants 17th Ann. Rpt. **1925–1926**:14–29.

[7] HUNGERFORD, C. W.
1920. Some newer aspects of the potato disease situation. Washington Hort. Soc. Proc. 16th Ann. Meeting p. 266–270.

[8] HUNGERFORD, C. W.
1922. Leafroll, mosaic and certain related diseases in Idaho. Phytopathology **12**:133.

[9] MCINTOSH, T. P.
1927. The potato: history, culture and diseases. p. 190. Oliver and Boyd, Edinburgh, Scotland.

[10] MCKAY, M. B., and T. P. DYKSTRA.
1930. Potato diseases in Oregon and their control. Oregon Agr. Exp. Sta. Cir. **96**:1–83.

[11] MORRIS, H. E., and P. A. YOUNG.
1930. Potato diseases in Montana. Montana Agr. Exp. Sta. Bul. **227**:45.

[12] OREGON STATE COLLEGE, DEPARTMENT OF PLANT PATHOLOGY.
1926. Oregon Agr. Exp. Sta. Bien. Rpt. **1924–26**:90.

[13] QUANJER, H. M.
1922. New work on leaf-curl and allied diseases in Holland. Internat. Potato Conf. Rpt., **1921**:127–145. (Royal Hort. Soc. 1922).

[14] QUANJER, H. M.
1923. General remarks on potato diseases of the curl type. Internat. Conf. Phytopath. and Econ. Entom. Rpt. **1923**:23–28. H. Veenman and Sons, Wageningen, Holland.

[15] RICHARDS, B. L.
1928. A new and destructive disease of the potato in Utah and its relation to the potato psylla. Phytopathology **18**:140 (abstract).

[16] RICHARDS, B. L.
1931. Further studies with psyllid yellows of potatoes. Phytopathology **21**:103 (abstract).

[17] SHAPOVALOV, M.
1929. Tuber transmission of psyllid yellows in California. Phytopathology **19**:1140 (abstract).

[18] UNIVERSITY OF IDAHO, DEPARTMENT OF PLANT PATHOLOGY.
1921. Idaho Agr. Exp. Sta. Bul. **122**:42. (Agr. Exp. Sta. Ann. Rpt. 1920. Investigation by C. W. Hungerford.)

[19] UNIVERSITY OF IDAHO, DEPARTMENT OF PLANT PATHOLOGY.
1922. Idaho Agr. Exp. Sta. Bul. **129**:11–12. (Agr. Exp. Sta. Ann. Rpt. 1921. Investigation by C. W. Hungerford.)

[20] YOUNG, P. A., and H. E. MORRIS.
1929. Plant diseases in Montana in 1928. U. S. Dept. Agr., Bur. Plant. Indus., Plant Disease Reporter, Sup. **69**:145.

[21] YOUNG, P. A., and H. E. MORRIS.
1930. Researches on potato-virus diseases in Montana. Montana Agr. Exp. Sta. Bul. **231**:25–27.

[22] YOUNG, P. A.
1930. Research on potato viruses in Montana. Phytopathology **20**:135 (abstract).

Upper: Potato seedling to which calico was mechanically transmitted by use of sterile cheesecloth saturated with *unfiltered* infectious juice.

Lower: Natural calico-infection of leaflets of White Rose potato. Note the irregular yellowed areas, their uneven distribution, and the faded areas in some of the leaflets.