THESIS

on

STUDIES OF THE CRINKLE DISEASE OF STRAWBERRY, WITH SPECIAL REFERENCE TO ITS TRANSMISSION

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INTRODUCTION[1]

The crinkle disease of strawberry is a disorder which has been observed in plantings of the Marshall variety since 1925. In that year it was noticed by S. M. Zeller and C. E. Schuster[2] and the term "crinkle" was applied to it by Zeller as a designating term in the field. This term crinkle became more and more in general use in Oregon and since that time has been applied to the disorder in California.

GEOGRAPHIC DISTRIBUTION AND ECONOMIC IMPORTANCE

In Oregon the disease is widespread in the Marshall type of strawberry. It is extremely difficult to find here any stock of this variety entirely free from crinkle. Other varieties as a rule are quite free from it, but where other varieties are planted in close proximity to diseased Marshall plants they may in time show symptoms. Other varieties in which symptoms similar to those of the Marshall have been noted are Corvallis (O.S.C. #12), Gene, Sear's La Grange, Dunlap, Magoon, Missionary, Nick Ohmer, Norwood, O.S.C. #7, Howard 17 (Premier), Redheart (U.S.D.A. #623), U.S.D.A. Numbers 227A, 400, 520, and 682. Occasional plantings of the Capitola, Ettersburg #121, and Clark's Seedling affected with similar symptoms have been observed.

For the most part the effects of the disease have not been severe enough to arouse the concern of the growers. Affected plants are not killed, but continue to yield, although the quantity and quality of the crop is doubtless not up to the standard. The disease

does not rank in destruction with root weevil, crown borer, or Rhizoctonia. Its general appearance and behavior are distinct from those produced by the other pasts and diseases under like conditions.

Crinkle is perhaps more similar in symptoms to the yellows (Xanthosis)[3] than to any other described strawberry disease. It seems probable that in his reported occurrence of yellows in Oregon (loc. cit. p. 1061) Plakidas was mistaken. It now seems more probable that the disease observed and reported by him was, in fact, crinkle. Yellows is evidently quite restricted to California and to some scattered stocks originating from that state. It does not occur generally in Oregon so far as is known but has been seen in a few cases where introduced on planting stock from California. These cases have been eradicated. Crinkle, on the other hand, is widely distributed in the Pacific Northwest and probably has spread into California through planting stock. Its origin, of course, is unknown. Recently seventeen plants were sent from The U. S. Department of Agriculture Field Station at Glenn Dale, Maryland, for observation. Of these, fourteen showed the characteristic symptoms. These plants were runner plants from stock originating in Oregon and doubtless the disorder was carried in the original plants.

Although no one person has studied the crinkle disease throughout all of its known North and South range, it would seem from the observations of several workers that the symptoms are more evident in the growing season toward the southern limits of this range than farther north.

SYMPTOMS OF CRINKLE

UNDER NATURAL CONDITIONS

Crinkle has the general appearance and behavior of a virus disease. The two most characteristic symptoms in the Marshall variety are the crinkled condition and chlorotic character of the leaves (plate 1.) The crinkled condition is undoubtedly due to the uneven distribution of the chlorotic areas in the early stages of leaf development. The rugose condition of the leaf seems to follow no distinct pattern but follows the chlorotic areas. The chlorotic character of leaf tissues mentioned here should not be confused with the physiologically abnormal condition known as "chlorosis" in which the tissues usually present a clear evenly distributed yellowing.

The chlorotic areas at first are extremely localized, starting in very small developing leaves as mere pin-point areas and expanding somewhat with leaf expansion. By transmitted light these areas show up plainly. Often the extremely chlorotic centers of these yellowed areas become necrotic, at first reddened and then brownish dead tissue resulting. It is not uncommon to find smaller leaves with several to many necrotic centers during the less favorable growing conditions from September until March. Besides the stippling of leaf areas by these pin-point lutescent spots, some leaflets exhibit a most uneven chlorosis. As a rule leaflets are yellower toward the margins. This yellowing may extend in streaks along a certain few veins toward the mid-vein. On the other hand, the veins for the most part may become cleared of chlorophyll and show considerable lack of growth. This

shortening of vein growth may extend into the islet venation. Together with the shortening of the veins there may be more or less normal growth expansion in the neighboring mesophyllous, green tissues, resulting in various degrees of crinkled leaf surface.

With the uneven distribution of growth there results an uneven margin of the leaflets. Instead of the more or less regular dentation of the normal leaf there is a tendency to deeper crenation and an unnatural wavy lobing of the margins.

The whole of an affected plant is a lighter shade of green than that of a normal plant during any season of the year. In the greenhouse or during late fall and winter the plants lose most of their erect growth. The leaves produced under these conditions have short petioles, the whole plant presenting a flattened appearance. During favorable growing periods in the field the affected plants may grow out of most of the symptoms and yet have some characters to distinguish them from healthy plants. The leaves of affected plants under these most favorable conditions do not have quite the uniform greenness and smooth surface exhibited by normal leaves and there is a tendency for the leaves to arch downward or cup upwards at the margins.

Under late fall and winter conditions the runner plants may show symptoms as characteristically as the parent plant. This is not always true in very fertile soils as pointed out in more detail below. All affected varieties which have been observed with runner plants have shown the symptoms in the runners as well as in the parent. The symptoms have shown exceptionally well in runner plants of the

Corvallis, Marshall, Nick Ohmer, and Norwood.

EFFECT OF LENGTHENED PERIOD OF LIGHT ON THE SYMPTOMS OF CRINKLE

It was mentioned above that in the spring and early summer, when the daylight period is long, plants affected with crinkle tend to grow out of the symptoms, making it very difficult to diagnose the disease positively. To determine what effect the lengthened period of light might have upon the symptoms of crinkle four diseased Marshall plants of the same age and showing approximately equal growth and equal crinkling were selected. Two of these were left on the greenhouse bench where they received only natural illumination of approximately ten hours per day; the other two were placed under a 500 Watt lamp and given six hours of artificial illumination daily, in addition to the natural illumination, making a total of sixteen hours per day. All other factors were the same. This treatment was continued for twenty-six days, interrupted from the ninth to the sixteenth day, inclusive, when no light was available, leaving a total of eighteen days during which the artificial illumination was carried out.

The plants which received only the natural illumination (Plate 2, left) showed striking symptoms of the disease, including the characteristic chlorotic areas and malformation of the leaves, the shortening of the petioles, lack of erect growth, and small leaves. Those which received the daylight augmented by artificial illumination produced an erect, nearly normal growth (Plate 2, right). The leaves were larger and presented more the appearance of normal

healthy leaves. The mottling and streaking, however, were brought out even more clearly than in the plants grown under natural illumination only. The increased period of light might then explain in part the recovery of the erect growth and normal size of leaves in the spring and early summer on plants in the field. It would seem, however, from the experiment, that the malformation and chlorosis should also be most evident during this season, which is exactly opposite to what actually occurs in nature.

EFFECTS OF DIFFERENT TEMPERATURES ON THE SYMPTOMS OF CRINKLE

It is reported that the symptoms of crinkle are much more pronounced in California plantings than in Oregon and Washington. In order to arrive at a possible reason why this should be true the effect of three different temperatures was tried. Nine Marshall plants grown in the cold frames were selected as showing about equal growth and equal crinkling. These were divided into three lots of three plants each and were placed in boxes in which constant temperatures of 60°, 70° and 80° F. were maintained. After four weeks the plants held at 60° showed practically no characteristic symptoms of crinkle. Those held at 70° and at 80° showed distinct and characteristic stippling, crinkling, and malformation of the leaves. The plants kept at 60° could easily be distinguished from those kept at 70° and 80° ; the difference between those kept at 70° and those

those kept at 80° was not apparent and the two could scarcely be distinguished. Apparently the temperature at which the symptoms are most apparent lies between 60° and 70°, nearer the upper end of the range. A check of the temperatures between 60° and 70° should now be made.

NATURE OF THE DISEASE

What is the cause of the crinkle disease? In August, 1931 plants affected with the disease were sent to the U. S. Department of Agriculture, Office of Nematology, for examination, but no parasitic nematodes were consistently found in the leaves or roots. It was mentioned above that crinkle has the general appearance and behavior of a virus disease. To determine whether or not crinkle is the result of a virus, transmission experiments were carried on in the greenhouse during the winter of 1931-'32.

PERPETUATION OF THE DISEASE THROUGH RUNNER PLANTS

Selections have made through two generations of greenhouse plants. Both healthy plants and those affected with crinkle were selected and planted in pots. These were segregated into healthy and diseased plants and the runner plants for two generations were potted into separate pots of sterile soil (Plate 3.) In all cases where parent plants were healthy the runner plants have remained healthy,

while in all cases where the parents were "crinkled" every runner plant from them showed symptoms of crinkle sooner or later. This behavior has become the basis for selecting runner plants or roguing fields for the elimination of this disease in planting stock of the Marshall variety.

TRANSMISSION BY GRAFTAGE

To determine whether or not crinkle could be transmitted by graftage ten healthy Marshall plants were grafted to ten diseased Marshall plants (Plate 4.) A thin piece was cut from the side of the crown of each, cutting just through the vascular ring, and making the cut surfaces match as closely as possible. The two plants were then fastened together securely with raffia and the crowns were covered with a thick coating of "Tree seal." The grafts were made December 23, 1931, and examinations were made April 30, 1932. In five of the plants no union whatever resulted; in the remaining five a doubtful union was formed between the two plants. There was no evidence of transmission of crinkle in any case, indicating that the disease was not transmitted under the conditions of this experiment.

TRANSMISSION BY CONTACT

In order to learn whether crinkle is transmitted from one plant to another four healthy and four diseased Marshall plants were planted in large pots, a diseased and a healthy plant in each pot. The plants were placed about three inches apart so that the roots would come in contact in the soil and the foliage would come in contact above ground. They were grown in this way for four months. In no

case was there any evidence of transmission of the disease. All four healthy plants appeared to be perfectly healthy.

TRANSMISSION BY MECHANICAL MEANS

Mr. B. F. Dana, Plant Pathologist, U. S. D. A., cooperating with the Oregon Experiment Station, and working on curly-top of sugar beets, has found it possible to transmit that disease by placing a diseased leaf over a healthy leaf and pricking down through the diseased leaf into the healthy one by means of a small device having many pin points. By this method the juices are introduced almost directly from the diseased leaf to the healthy, so that there is little chance of oxidation of any active principle which might be present in the plant juices. Ten healthy Marshall plants were treated in this manner, in each case a nearly mature but still succulent leaf of the healthy plant being treated. Examination at frequent intervals over a period of thirteen weeks failed to reveal any symptoms of crinkle in any of the healthy plants thus treated.

TRANSMISSION BY LEAF MUTILATION

Some of the more infectious virus diseases are quite readily transmitted by mutilation of leaf tissues. Leaves from diseased Marshall plants were crushed in a mortar and then rubbed well on the under surface of the leaves of ten healthy Marshall plants, rubbing sufficiently hard to bruise the healthy leaves severely. The inoculations were made February 7, 1932. No symptoms of crinkle had

appeared May 1, 1932, twelve weeks later.

TRANSMISSION BY USING VIRUS EXTRACT

Many virus diseases, notably tobacco mosaic, are transmissable by means of extracts from diseased tissues which are injected into healthy plants. Leaves from diseased Marshall plants were crushed in a mortar and a few cubic centimeters of the juice thus extracted. Two methods of infection using this extract were tried. (1) A few drops of the extract were placed on the leaves of ten healthy Marshall plants and pricked into the leaves, using a sterile needle. (2) A few drops were placed on the lower surface of the young leaves of ten healthy Marshall plants and the leaves were rubbed with a round-ended glass rod, rubbing so as to break the trichomes which were in contact with the drops of extract. No symptoms of crinkle had appeared on any of the plants after twelve weeks.

TRANSMISSION BY THE STRAWBERRY LEAF APHID (MYZUS FRAGAEFOLII COCKERELL)

The majority of virus diseases are transmissable by insect vectors. From the standpoint of the number of diseases they are known to transmit the aphids are the most important of these vectors. The strawberry leaf aphid has previously been shown to transmit yellows[3] and witches broom[7], and it was thought that it might also serve in the transmission of the crinkle disease.

On October 4, 1931, eighteen of the aphids were placed on a healthy strawberry plant of the Ettersburg #121 variety and a small cage placed over the plant. Probably due to the lateness of the

season, the short days, and the poor illumination in the cage, these aphids did not multiply and had decreased to six on October 9th, on which day fifteen more were added. These also failed to multiply. October 31st a 500 watt lamp was installed and left burning each evening until eleven o'clock. After this all insect transmission work was carried on under this artificial illumination. It is not known how much importance should be attached to the artificial illumination but it seems significant that whereas the aphids refused to multiply before the installation of the lamp, they multiplied very rapidly after its installation. By December 3rd sufficient aphids were available to transfer ten aphids to each of three diseased Marshall plants. Plant No. 1 was a crinkled plant obtained from one of Dr. Zeller's experiments on the Rhizoctonia disease of Strawberry[4]. Plant No. 2, a runner plant from one of this same set of plants, showed marked symptoms of crinkle. Plant No. 3 was a very badly crinkled plant obtained from Dr. G. M. Darrow in September, 1931. Aphids from these three plants were transferred to fifty healthy Marshall plants, the results being as shown in Table 1.

TABLE I.

EXPERIMENTS ON THE TRANSMISSION OF THE CRINKLE DISEASE BY THE STRAWBERRY LEAF APHID, (MYZUS FRAGAEFOLII CKLL.)

Plant No.	Date aphids were placed on plants	Number of aphids placed on plants	Date aphids were removed	Number of aphids removed	Date first symptoms of crinkle appeared	Date plant showed typical crinkle
1	Nov 17 '31	12	Nov 27 '31	20	Dec 21 '31	Feb 5 '32
2	Nov 17 '31	12	Nov 27 '31	8	Dec 21 '31	Feb 5 '32

Table I, Continued

Plant No.	Date aphids were placed on plants	Number of aphids placed on plant	Date aphids removed	Number aphids removed	Date first symptoms of crinkle appeared	Date plant showed typical crinkle
3	Nov 21 '31	10	Nov 27 '31	18	Dec 22 '31	Feb 5 '32
4	Nov 21 '31	10	Nov 27 '31	10	Dec 22 '31	Feb 5 '32
5	Nov 21 '31	10	None alive Nov 27th.		Dec 24 '31	Feb 5 '32
6	Dec 3 '31	15	Dec 10 '31	40	Dec 29 '32	x
7	Dec 3 '31	15	Dec 10 '31	25	Jan 2 '32	x
8	Dec 3 '31	15	Dec 10 '31	41	Jan 5 '32	x
9	Dec 3 '31	15	Dec 10 '31	20	Jan 2 '32	Feb 14 '32
10	Dec 3 '31	15	Dec 10 '31	32	Feb 27 '32	x
11	Dec 10 '31	20	Dec 17 '31	20	Jan 8 '32	x
12	Dec 10 '32	20	Dec 17 '32	41	Feb 21 '32	x
13	Dec 10 '31	20	Dec 17 '31	29	Jan 2 '32	Feb 27 '32
14	Dec 17 '31	20	Dec 24 '31	50	Jan 8 '32	Feb 5 '32
15	Dec 17 '31	20	Dec 24 '31	35	Feb 8 '32	Feb 27 '32
16	Dec 17 '32	20	Dec 24 '31	50	++	x
17	Dec 17 '31	20	Dec 24 '31	31	Feb 5 '32	Died
18	Dec 17 '31	20	Dec 24 '31	68	Jan 16 '32	Feb 27 '32
19	Dec 17 '31	20	Dec 24 '31	74	Jan 26 '32	x
20	Dec 17 '31	20	Dec 24 '31	33	Jan 8 '32	x
21	Dec 24 '31	20	Dec 31 '31	53	Feb 1 '32	Mar 2 '32
22	Dec 24 '31	20	Dec 31 '31	52	Feb 24 '32	Mar 26 '32
23	Dec 24 '31	20	Dec 31 '31	28	Jan 18 '32	x
24	Dec 24 '31	20	Dec 31 '31	46	Feb 24 '32	Mar 26 '32

Table I, Continued

Plant No.	Date aphids were placed on plants	Number of aphids placed on plants	Date aphids were removed	Number of aphids removed	Date first symptoms of crinkle appeared	Date plant showed typical crinkle
25	Dec 24 '31	20	Dec 31 '31	46	Feb 1 '32	Feb 27 '32
26	Dec 24 '31	20	Dec 31 '31	70	++	
27	Dec 24 '31	20	Dec 31 '31	36	++	
28	Dec 24 '31	20	Dec 31 '31	39	Jan 18 '32	x
29	Dec 24 '31	20	Dec 31 '31	42	Feb 24 '32	Mar 26 '32
30	Dec 24 '31	20	Dec 31 '31	38	Jan 18 '32	x
31	Dec 31 '31	20	Jan 8 '32	46	Jan 18 '32	Feb 27 '32
32	Dec 31 '31	20	Jan 8 '32	53	Jan 18 '32	Feb 27 '32
33	Dec 31 '31	20	Jan 8 '32	78	Jan 18 '32	Feb 27 '32
34	Dec 31 '31	20	Jan 8 '32	61	Jan 18 '32	Mar 26 '32
35	Dec 31 '31	20	Jan 8 '32	89	Jan 18 '32	Mar 26 '32
36	Dec 31 '31	20	Jan 8 '32	60	Jan 18 '32	Died
37	Dec 31 '31	20	Jan 8 '32	77	Damped off*	
38	Dec 31 '31	20	Jan 8 '32	52	Jan 18 '32	x
39	Dec 31 '31	20	Jan 8 '32	143	Jan 18 '32	Mar 6 '32
40	Dec 31 '31	20	Jan 8 '32	103	++	
41	Dec 31 '31	20	Jan 8 '32	85	Jan 29 '32	Feb 27 '32
42	Dec 31 '31	20	Jan 8 '32	39	++	
43	Dec 31 '31	20	Jan 8 '32	118	++	
44	Dec 31 '31	20	Jan 8 '32	78	++	
45	Dec 31 '31	20	Jan 8 '32	80	Jan 29 '32	x
46	Dec 31 '31	20	Jan 8 '32	60	Feb 19 '32	x

Table I, Continued

Plant No.	Date aphids were placed on plants	Number of aphids placed on plants	Date aphids were removed	Number of aphids removed	Date first symptoms of crinkle appeared	Date plant showed typical crinkle
47	Dec 31 '31	20	Jan 8 '32	76	Jan 29 '32	Feb 27 '32
48	Jan 8 '32	20	Jan 16 '32	66	Feb 14 '32	x
49	Jan 8 '32	20	Jan 16 '32	51	Feb 5 '32	Mar 7 '32
50	Jan 8 '32	20	Jan 16 '32	32	Feb 5 '32	Mar 11 '32

++ No symptoms of crinkle
x Crinkle appeared and later disappeared
* Examination of tissues showed Rhizoctonia

TABLE II

ANALYSIS OF TRANSMISSION REPORTED IN TABLE I

Number of plant from which aphids were transferred	1	2	3	Total
Number of plants to which aphids were transferred	19	23	8	50
Number of plants which developed symptoms of crinkle	15	20	7	42
Per cent which developed symptoms of crinkle	78.94	86.95	87.50	84.00
Number of plants on which symptoms of crinkle later disappeared	6	8	1	15
Per cent on which symptoms of crinkle later disappeared	40.00	40.00	14.28	30.00
Number of plants on which symptoms of crinkle persisted	8	12	6	26
Per cent on which symptoms of crinkle persisted	53.33	60.00	85.71	52.00

It would appear that the active principle from plant Number 3, which showed the most marked symptoms of the disease, was most virulent. Due to the generally poor health of the plant and to a severe infestation of spider mites in the cage, fewer aphids were available for transfer from this plant than from the other two, and it is possible that if an equal number of aphids had been available the results obtained would have been more nearly the same as those obtained with the other two plants.

An interesting feature in connection with the experiment was the fact that in fifteen of the plants symptoms of the disease appeared and in some cases were quite marked, and later disappeared to such an extent as to make diagnosis of the disease practically impossible. In certain virus diseases, such as Sugar cane mosaic, infected plants frequently overcome the disease entirely, as pointed out by Earle[8] and other workers; in other diseases, such as rugose mosaic and spindle tuber in potatoes, the symptoms are often "masked" by certain environmental factors, but upon the return of conditions favorable for the production of the characteristic symptoms it becomes evident that the disease is still present[9]. No investigations have been carried on to determine the correct explanation of the disappearance of the symptoms. It is possible that one of the above conditions occurs in the case of crinkle.

As proof that the aphids themselves were not responsible for the symptoms produced in these experiments non-viruliferous aphids were placed on a healthy Marshall plant. These virus-free aphids were

obtained by placing adult, agamic female aphids in petri plates, one aphid to the plate, with no food material whatever. Here they were observed at intervals of a few hours until a few young of the first instar were obtained, which, having had no opportunity for feeding, were supposedly free of virus contamination. After being allowed to colonize and multiply for thirty-nine days on healthy plants twenty of these aphids were transferred to each of ten other healthy Marshall plants. None of these plants showed any symptoms of crinkle eight weeks after having the aphids transferred to them.

These experiments have a two-fold significance; they show, first, that the aphids do not produce crinkle in themselves directly, but that viruliferous Myzus fragaefolii may act as vectors for the transmission of the infective principle; and, second, that the infective principle of the crinkle disease of strawberry does not pass from the adult aphids to the young, the first instars.

Since it is not always possible to detect the symptoms of crinkle in young plants, one could not state definitely that all of the plants used were entirely free of crinkle before having the aphids transferred to them. However, all of them were carefully selected and, as far as could be detected, were entirely free of the disease. Of 104 Washington Certified Marshall plants obtained in December, 1931 not one has developed crinkle unless it was inoculated, while of fourteen of these same plants used in the above transmission experiment with viruliferous aphids nine developed the disease. These experiments thus indicate that crinkle is transmitted by the straw-

berry leaf-aphid (Myzus fragaefolii Cockerell), but they should be repeated for verification.

OTHER INSECT VECTORS

Attempts to colonize the strawberry root louse (Aphis forbesi Weed), the peach aphid (Myzus persicae Sulzer), and an aphid from tobacco, on strawberry, were unsuccessful and so no efforst were made to transmit crinkle through these insects as vectors.

CONTROL OF CRINKLE

In western Oregon and Washington the field run of Marshall strawberries shows considerable variability in growth vigor. It is not difficult to select outstanding plants for vigor in some plantings, while in others the percentages of abnormal plants run so high that roguing or selecting is impracticable. Besides certain insect pests, the most apparent causes of this variability of growth are the two diseases, (1) Crinkle, and (2) the Rhizoctonia disease of strawberry[4].

The practicability of selection and roguing to eliminate crinkle from planting stock of the Marshall variety has been demonstrated by a system of selection which led up to the certification of strawberry plants in the state of Washington[5]. In the selection of plants and roguing for this certified stock the endeavor is made to eliminate all diseased and otherwise suspicious-looking plants. Some of this stock which has been planted in several places in Oregon shows almost complete elimination of crinkle.

It was hinted above that in fertile soils runner plants do not always show symptoms soon after rooting. This condition was first observed in the greenhouse. When runner plants were potted into fertile soil they sometimes grew almost, if not entirely, out of the symptoms, but in a few weeks the symptoms returned. Whether this temporary recovery is due entirely to fertility or to some other factors such as staling or self-induced toxicity is a question.

This temporary recovery is noticeable in some soils in the field and has a very practical bearing on selection or roguing of planting stock in the late fall. In several plantings less than a year old one could not be sure to recognize symptoms of the crinkle disease in the parent or runner plants, but under very similar conditions in plantings at least one-year-old or several years old the parents and most of the runner plants exhibit disease symptoms. This indicates that when the grower desires to distinguish healthy from diseased plants with reasonable certainty in selecting planting stock in the fall it is desirable to plant the field the previous fall rather than in the spring since spring-planted stock may not disclose crinkle by the end of the season while fall-planted stock will generally exhibit the symptoms plainly by that time.

A limited field experience in the production of stocks relatively free from this disease would indicate that where very high percentages of disease exist the fields should be abandoned as sources of planting stock. Selection of normal plants could be advised in fields containing perhaps 10 to 20 per cent of crinkle, but

roguing is practicable only in cases where very low percentages are found, perhaps 3 to 5 per cent.

There is no evidence that crinkle is spread by mechanical means. The only means of spread in the field is probably by insect transmission. Control of the disease in the field thus involves to some extent the control of aphids where practicable. Three methods may be suggested for controlling the aphids: (1) since the aphids winter over on the leaves of the plants, cutting away and destroying the tops during the winter to rid the field of practically all aphids, (2) eradication of all Potentilla (Potentilla spp.) which the aphids also attack, and (3) dusting the under sides of the leaves with some nicotine preparation like Nicodust during the summer. Whether the effects upon yield are sufficient to justify the expense of dusting except in fields used for the production of planting stock, is not certain.

SUMMARY

1. The distribution and description of symptoms of the crinkle disease of strawberry are given.

2. In this paper results of experiments are given to indicate that the crinkle disease of strawberry is a virus disease transmitted by the strawberry leaf-aphid (Myzus fragaefolii Ckl.)

3. 100 per cent perpetuation of the disease was obtained by planting runners from diseased parents, while in all cases the runner plants from healthy parents were free of the disease.

4. No infection was obtained by mechanical inoculation, by graftage, by leaf mutilation, or by the use of extracts from diseased leaves.

5. Control of aphids is suggested to control the spread of the disease in the fields.

6. Practical methods of eliminating the disease from planting stock by means of roguing or selection are deemed successful.

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PLATE 1

Leaves of the Marshall variety of strawberry showing symptoms of crinkle under late fall or winter conditions. Natural size. From plants grown at the East Farm, Linn County, Oregon.

Upper left.- Healthy, normal leaf, for comparison.

Upper center.- Leaf showing extreme malformation of the leaflets and pin-point chlorotic areas.

Upper right.- Leaf showing pin-point chlorotic areas quite distinctly and the lighter green of the margins of the leaflets.

Lower left.- Leaf showing "streaking" in from the margins.

Lower center.- Leaf showing extremely irregular margin of the crinkled leaves. Notice the two necrotic centers in pin-point areas on the right-hand leaflet.

Lower right.- Leaf showing the irregular surface and margin, and the lighter green color of affected leaves.

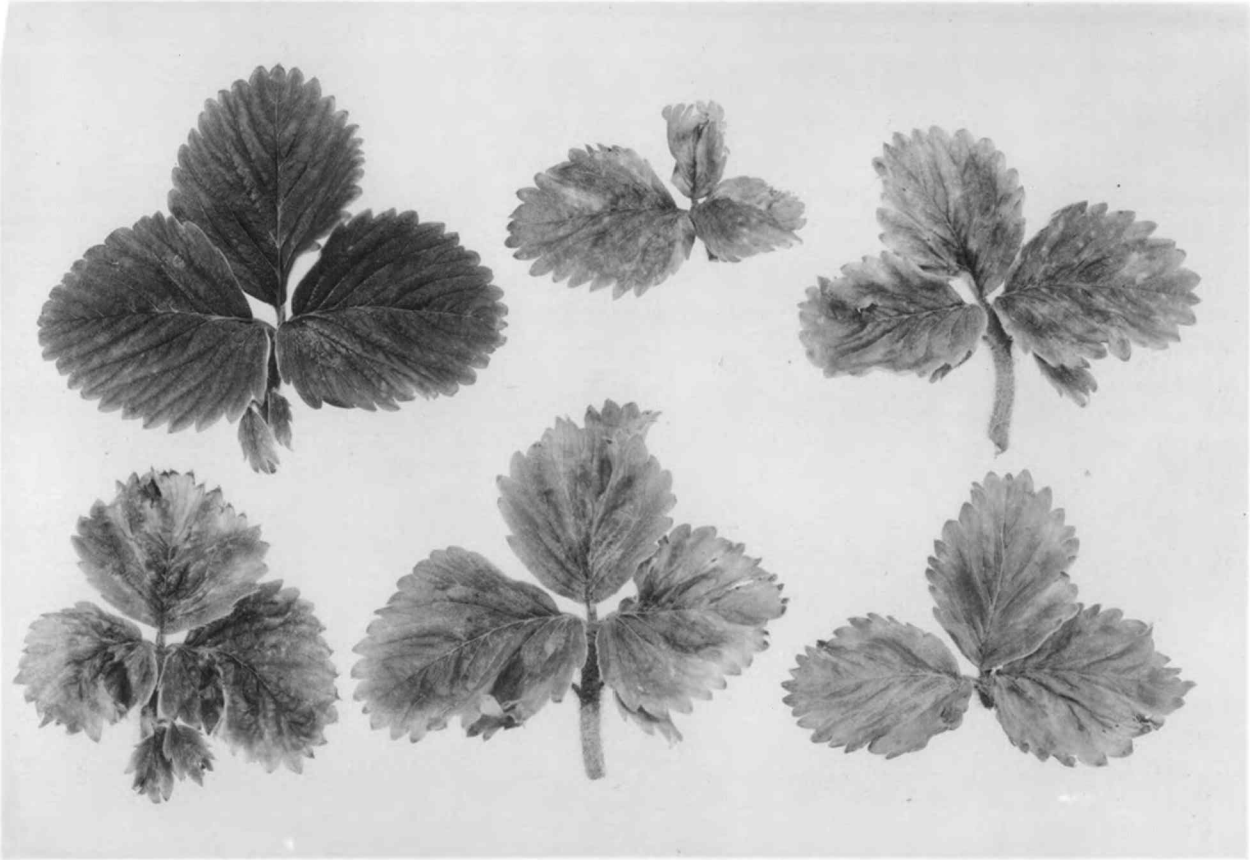


PLATE 2

Strawberry plants of the Marshall variety showing the effects of lengthened period of light. These plants were selected at the start as showing approximately equal growth and equal symptoms of crinkle. The plant on the left received only natural illumination of about ten hours, while that on the right received six hours of artificial illumination per day, in addition to the natural illumination, making a total of about sixteen hours per day. This treatment was carried on for eighteen days. The picture shows the recovery of nearly normal growth, but does not bring out the uneven chlorosis which was much more evident in the plant which received the artificial illumination (plant to right) than on the other.

PLATE 3

Selected runner plants of the Marshall variety of strawberry grown in the greenhouse in sterile soil. One (right) from a healthy parent, and one (left) from a parent with crinkle.

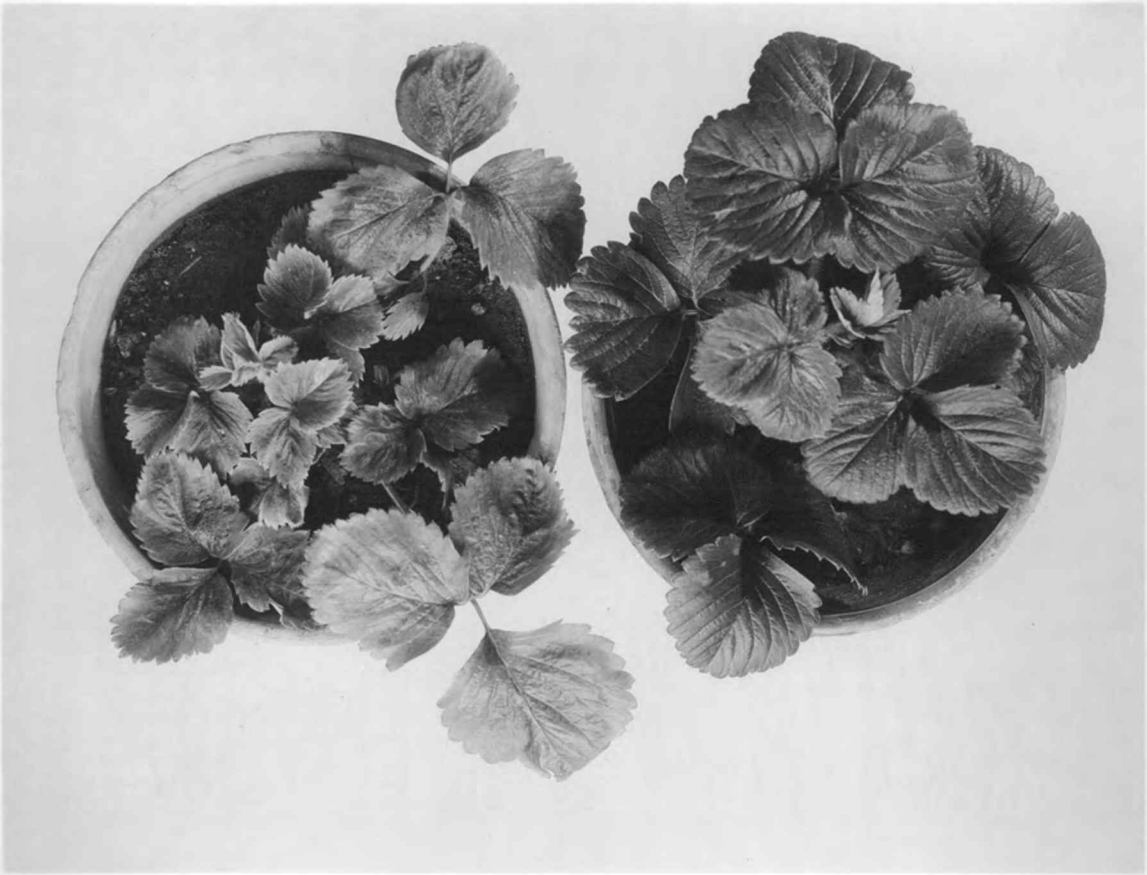
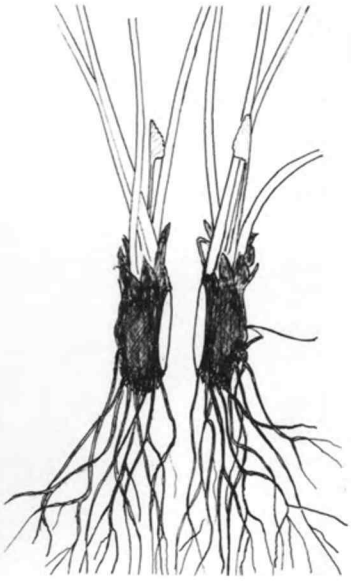


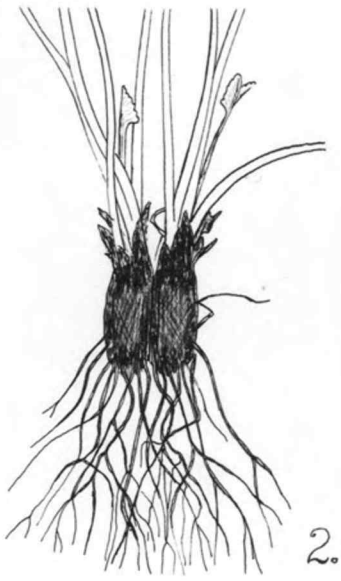
PLATE 4

Freehand drawing showing the method of grafting strawberry plants together.

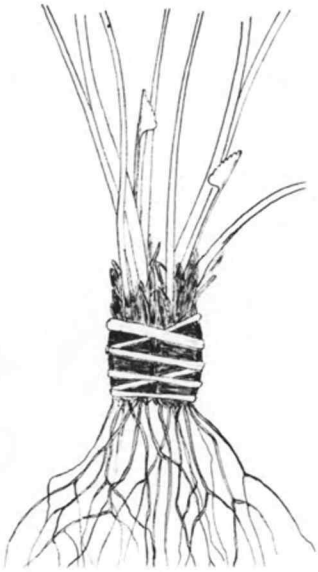
1. Plants with section cut from the side of the crown, and just through the vascular ring.
2. Plants fitted together.
3. Plants tied with raffia.
4. Plants covered over with "Tree-seal" and ready to be planted.



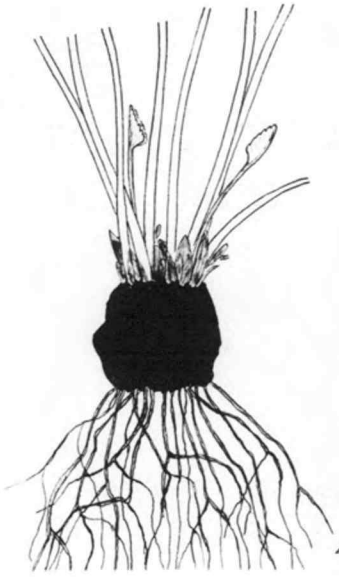
1.



2.



3.



4.

PLATE 5

Washington Certified Marshall plants grown in the greenhouse under identical environmental conditions. Both plants had aphids colonized on them; the aphids on the plant at the left were viruliferous, those on the plant at the right were non-viruliferous. The plant on the left shows typical crinkle symptoms, the other remained healthy.