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Crinkle Disease of Strawberry

By

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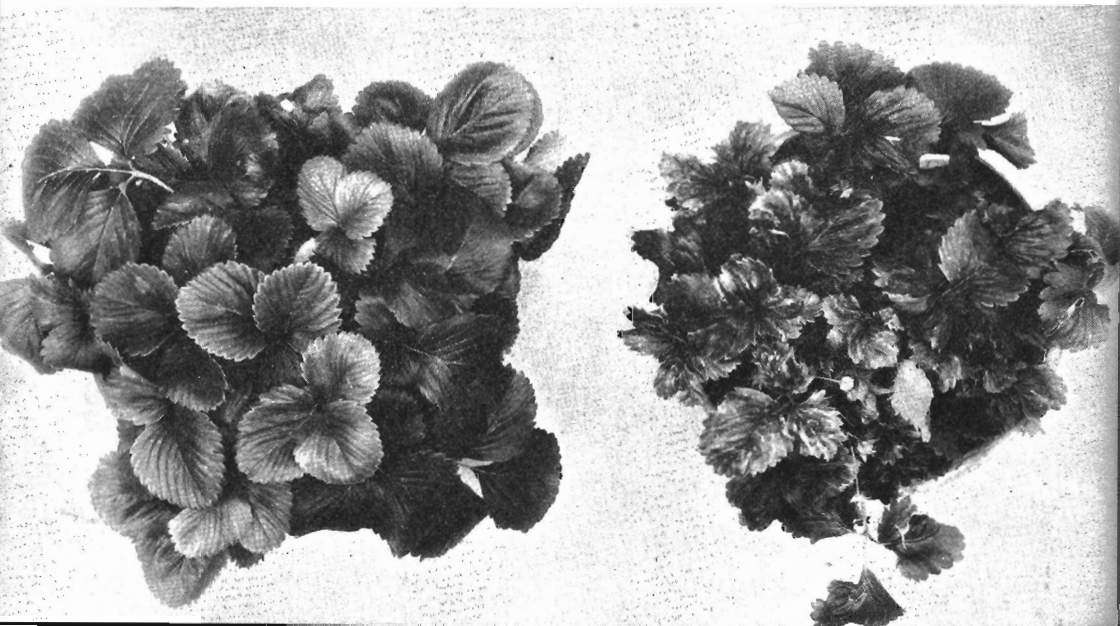
CORVALLIS

Figure 1. A and B, eleven-months-old Marshall strawberry plants from the same parent. A, *left*, healthy. B, *right*, inoculated with crinkle when six months old.



SUMMARY

1. A study has been made of the virus disease of strawberry which has become commonly known in the Pacific Coast states as "crinkle." This bulletin is a semi-popular presentation of essential facts concerning the disease.

2. The disease has caused the gradual degeneration of the Marshall variety of strawberry, and is a serious factor in the propagation of the Corvallis and Ettersburg 121. It is also known to affect the Magoon, Missionary, Nick Ohmer, Norwood, and Clarks Seedling varieties, as well as the wild field strawberry (*Fragaria cuneifolia*) and the beach strawberry (*F. chiloensis*).

3. Affected plants yield less than 50 per cent as much crop as that produced by healthy plants, and are more easily winter-killed.

4. The disease is described as a mosaic-like, systemic disease, causing at first yellowish, pin-point spots in the leaves, which soon become crinkled and unevenly streaked and spotted with yellowish tissues. The disease spreads from the mother to the runner plants, which perpetuate the disease in planting stock. Symptoms are usually masked during the first few months after planting.

5. The disease is transmitted and disseminated by the strawberry leaf louse (*Myzus fragaefolii*). A single aphid may transmit the disease from diseased to healthy plants, but for experimental purposes six to ten were used to obtain certain transmission. The virus is not carried over from agamic females to the young offspring.

6. Strawberry plants produced from seed from crinkle-infected plants were healthy until inoculated.

7. The elimination of the disease from planting stock is best brought about through the selection of outstanding healthy plants in plantings a year or more old. Runners from these are planted in an isolated propagation plot according to a plant-unit system.

8. A system is described for demonstrating the absence of crinkle in supposedly healthy stock by artificial inoculation of a few individuals selected from the same generation of mature runners from the healthy stock

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INTRODUCTION

THE "crinkle" disease of strawberry is a disorder which has been under observation in plantings of the Marshall variety since 1925. It was first noticed by C. E. Schuster and the writer, and the term "crinkle"[1] was applied to it in the field as a designating term. Since 1925 the term "crinkle" has come into rather common use in Oregon, Washington, and California. The disease was originally described in 1932,[2] sometime after it was first considered of economic importance.

DISTRIBUTION, OCCURRENCE, AND ECONOMIC IMPORTANCE

In the Pacific Coast states the disease is wide-spread in the Marshall type of strawberry. Stock of this variety having relatively low percentages of the disease is rarely found in any quantity. Some other varieties as a rule are quite free from it, but usually they may in time show symptoms if planted in close proximity to diseased plants. Besides the Marshall variety (which also goes under such names as Oregon, Improved Oregon, Oregon Plum, Admiral Dewey, and Banner) the following other varieties and species have been proved by inoculation experiments to harbor the disease. These are the Corvallis, Magoon, Missionary, Nick Ohmer, Norwood, Ettersburg 121, and Clarks Seedling varieties, and the two native species, the beach strawberry (*Fragaria chiloensis* Duch.) and the wild field strawberry (*F. cuneifolia* Nutt.). Of these, the Corvallis, Ettersburg 121, and Marshall have been found to have high percentages of the disease in commercial stocks. Other varieties in which similar symptoms have been noted are Dunlap, Fairfax, Gene, Sear's La Grange, Narcissa, O.S.C. No. 7, Howard 17 (Premier), Redheart, U.S.D.A. Nos. 227-A, 400, and 682.

For the most part, the effects of the disease have not been severe enough to arouse the concern of strawberry growers except that in general growers have observed that the Marshall variety in particular has been gradually "running-out" over a period of years. Affected plants are not killed, but continue to yield, although the quantity and quality of crop is not up to standard. In the Agricultural Experiment Station plantings in 1933, 20 two-year-old plants of the Marshall variety with crinkle and 20 of the same variety without crinkle yielded at the rate of 3,402 pounds and 7,136 pounds per acre, respectively, or a potential loss of 3,734 pounds per acre. Assuming that there are 8,000 acres of bearing Marshalls in Oregon and an estimated average of 20 per cent diseased plants this would indicate an annual loss (at 5¢ per pound) of approximately $298,720 due to crinkle

[1]Oregon Agr. Exp. Sta., Director's Bienn. Rept. **1924-1926**: 94. 1926.
[2]Zeller, S. M., and E. K. Vaughan. Crinkle disease of strawberry. Phytopathology **22**: 709-713. *illus.* 1932.

in the Marshall variety alone. These figures are perhaps too conservative, for in the writer's surveys more plantings have shown above 20 per cent diseased plants than below that figure. On the other hand, 1933 was a poor year to take yield records. The previous winter was very severe on strawberry plants in Oregon and at the Oregon Agricultural Experiment Station plantings with crinkle were more severely injured by the cold weather than were disease-free plants and the loss in yield doubtless included the effects of the low temperature as well as of the virus.

Since the plants are not killed outright the disease probably does not rank with root weevil, crown borer, or Rhizoctonia for immediate destructiveness. Nevertheless, since the disease becomes an inherent factor in planting stock, it is distinctly more serious than these other diseases in one respect; namely, a progressive reduction of the vigor of runners. Its general appearance and behavior are distinct from those of other pests and diseases under like conditions.

Crinkle has been proved to be a virus disease[3] having many of the general appearances and behaviors of other diseases of this nature. It seems to be more nearly like the yellows (xanthosis)[4] described from California and "yellow-edge"[5] described from England than any other strawberry diseases. From our present knowledge, however, crinkle appears to be different from these two diseases.

In his reported occurrence of yellows in Oregon,[4] Plakidas may have been mistaken. It seems more and more probable as we continue to study conditions in Oregon plantings that the disease observed and reported by him was, in fact, crinkle. Yellows is evidently quite restricted to California and in some scattered stocks originating from that state. It does not occur generally in Oregon, but has been seen in a few cases where planting stock had been introduced from California. These cases have been cleaned up. Crinkle, on the other hand, is widely distributed in the Pacific Northwest and also in California wherever the Marshall (Banner) variety is grown. Its origin is unknown.

SYMPTOMS

Although no one person has studied crinkle throughout 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.

Leaf symptoms. The two most characteristic symptoms are the crinkled condition and yellowish areas of the leaves. The crinkled condition is undoubtedly due to the uneven distribution of the chlorotic (yellowed), retarded areas in the early stages of development. The wrinkled condition of the leaf surface seems to follow the yellowed areas with no distinct pattern. This is illustrated in the cover illustration (Figure 1, B).

These yellowish areas at first are extremely localized, starting in small developing leaves as mere pin-point areas, and enlarging somewhat with

[3]Vaughan, E. K. Transmission of the crinkle disease of strawberry. Phytopathology 23:738-740. *illus.* 1933.

[4]Plakidas, A. G. Strawberry xanthosis (yellows), a new insect-borne disease. Jour. Agr. Res. 35:1057-1090. *illus.* 1927.

[5]Harris, R. V. The strawberry "yellow-edge" disease. Jour. Pom. & Hort. Sci. 11:56-76. *illus.* 1933.

leaf expansion. The central youngest leaf in Figure 2 shows these small yellowish areas. They are the *primary symptoms* of the disease as it first shows up in runner plants or in older plants just after (about two weeks) the plant has been infected with crinkle. By transmitted light these lighter green or yellowish areas in the leaves show up plainly. Often the extremely yellowed centers of these spots soon begin to die, at first reddened and then brownish dead tissue resulting. This condition may be found at any time of year, but it is not uncommon to find the smaller spots with many of these small dead areas during the less favorable growing conditions from September to March. Besides this stippling or pin-point mottling some leaflets exhibit most uneven chlorosis (yellowing). This is especially true in advanced stages of crinkle. As a rule, such 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," or yellowed and translucent. This may extend even into the finely netted veins. Veins so affected become stunted in growth as do all of the yellowed tissues. Together with the resultant shortening of veins, there may be more or less normal growth in the neighboring green tissues, producing various degrees of crinkled leaf surface.

With the uneven distribution of growth there results an uneven margin of the leaflets. The normal, more or less regular, dentation becomes a deeper crenation and an unnatural, wavy lobing of the margins.

Symptoms of the plant as a whole. During any season of the year the whole of a mature plant affected with crinkle is a lighter shade of green than normally. In the greenhouse or in the field during late fall and winter, 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 some affected plants may grow out of most of the severe symptoms and yet usually retain some characters to distinguish them from healthy plants. The leaves 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 upward at the margins. Since some plants show more severe symptoms than others under like environmental conditions, we are led to believe that there may be separable components of the virus, one producing more severe symptoms, and another what might be termed a "mild crinkle." Experiments along this line are yet inadequate for a definite understanding.

Symptoms of runner plants. In late fall and during the winter the runner plants may show symptoms of crinkle as characteristically as the parent plant. Especially is this true where the runner plant is still attached to the parent by a living stolon (runner) and is not too well rooted to become entirely independent of the mother. This is not always true in very fertile soils where the independence of the runner plant comes about more rapidly.

When runner plants with crinkle were cut from the parent and potted into fertile soil in the greenhouse usually the leaves produced for a time subsequent to potting were without symptoms, but in a few weeks the symptoms appeared on the leaves produced later. Whether this temporary recovery from symptoms is entirely due to soil fertility or to some other

factor is not known. Figures 2 and 3 illustrate this behavior in runner plants. These two runner plants were from mother plants which after inoculation in the greenhouse had shown severe symptoms of crinkle which remained at the time when these photographs were taken. In Figure 3 the earliest leaf shows decided crinkle symptoms, but the three leaves produced after the plant was well rooted in fertile potting soil show no crinkle symp-

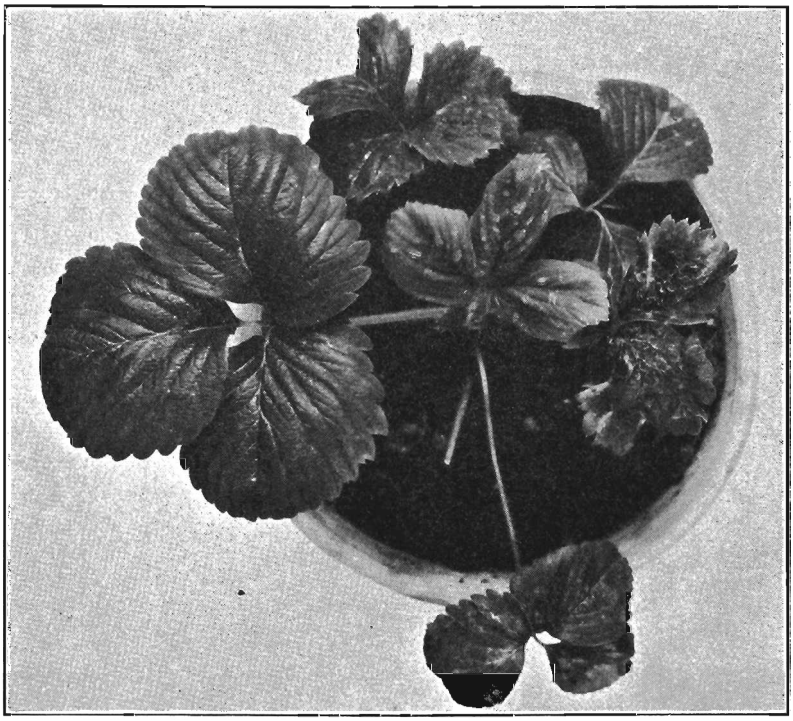

Figure 2. Runner plant potted while still attached to mother having crinkle. Symptoms on first leaves are severe; when well-rooted, a leaf (largest) was produced without symptoms, but the youngest leaf showed primary symptoms as the plant became pot-bound.

toms. These symptoms will inevitably appear, however, on later leaves. Figure 2 is an example where the masking of and the reappearance of symptoms both show on the same plant. The earliest leaves show more or less severe crinkle; then, after potting, one leaf (the largest) was produced *without symptoms*, but primary symptoms reappeared on the youngest central leaf.

This temporary masking or failure of symptoms to appear is a type of behavior which is readily observed in commercial plantings of such varieties as Marshall and Corvallis. This is especially true in the better strawberry soils and has a very practical bearing on the selection of planting stock in the late fall. In plantings less than a year old one cannot be sure to recognize the disease, while in older plantings at least the mother

plants will show some symptoms. This indicates that where autumn selections of disease-free plants are to be made in young plantings, it is desirable to plant the previous fall and not in the spring of the current year. This is also desirable where roguing is to be practiced in stock selected as a foundation for a disease-free planting stock.

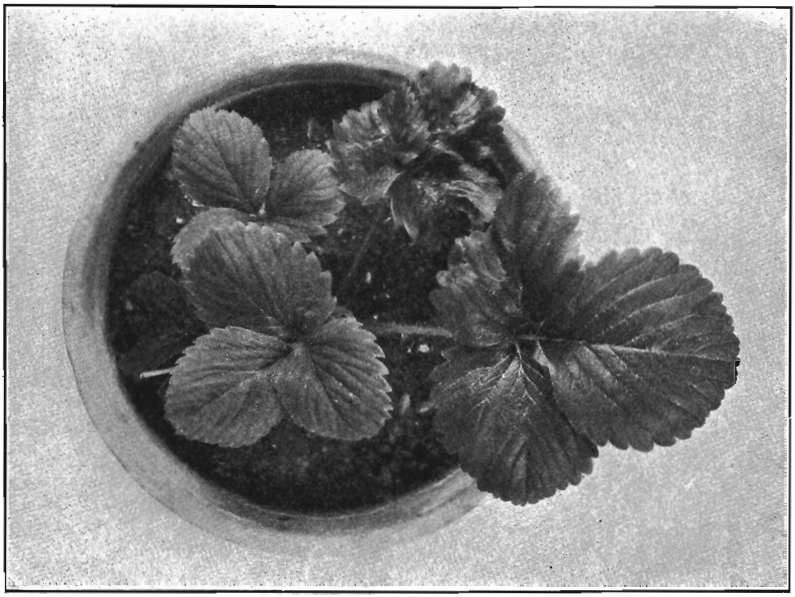

Figure 3. Runner plant potted while still attached to mother having crinkle. While still dependent on mother plant through the runner, symptoms were characteristic, but as soon as it became independent on its own root system, leaves without symptoms were produced.

Variation of symptoms as to varieties affected. The symptoms as they have been discussed above apply primarily to the Marshall or Oregon variety and although they are strikingly similar in other varieties there are some outstanding differences in certain cases.

In the CORVALLIS variety the whole affected plant is much lighter green than normally and although the primary symptoms are very much like those described for the Marshall the later symptoms are mostly characterized by marginal sectors of the leaf yellowing deeply in toward the mid-vein and by a downward, twisted curving of the latter.

The ETTERSBURG 121 and the CLARKS SEEDLING have much less pronounced symptoms than either the Corvallis or Marshall. Seldom in these varieties do they advance beyond the primary pin-point yellowing or slight mottling of the leaves. In a very few cases in plantings of the Clarks Seedling individuals with severe symptoms have been found, but these plants may have been "rogue" varieties.

There are occasional plantings of the WILSON and GOLD DOLLAR varieties in Oregon but no crinkle symptoms have ever been observed in these two varieties nor in the wild woodland strawberry (*Fragaria californica*).

Crinkle-infected plants of the wild field strawberry (*Fragaria cuneifolia*) seldom show any symptoms of the disease. When they do appear for very short periods in the field or greenhouse, they are the merest suggestions of the primary pin-point chlorosis, which even disappear in the leaves showing them. This species becomes virtually a symptomless carrier of the disease. It is not

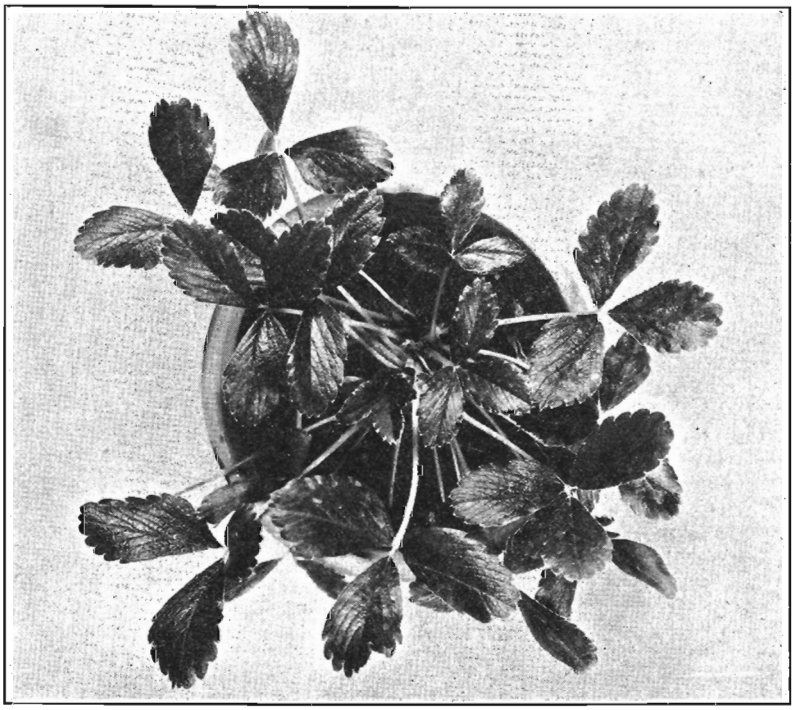

Figure 4. Beach strawberry (*Fragaria chiloensis*) infected with crinkle. Note the pin point, yellowed spots.

yet known how wide-spread the disease may be in this wild strawberry which is extremely common in most pasture and open cut-off timber lands of Western Oregon.

One crinkle-infected clone of the beach strawberry (*Fragaria chiloensis*) was discovered at Brookings, Oregon, by G. M. Darrow of the U. S. Bureau of Plant Industry. The clone covers an area of perhaps 900 square feet and seems to exhibit primary symptoms of the disease the year round. Figure 4 is a greenhouse-grown potted plant from this infected clone. Notice the typical pin-point yellowish spots, especially on the youngest leaves.

Spittle-bug injury confusing. Spittle-bug injury may be confused with crinkle symptoms until one becomes familiar with the fact that these bugs produce a crinkling of the leaves with a dark green color. Usually, also, one may find the remains of the dried spittle on the under side of the leaves

for some time after the bugs have disappeared. Spittle-bug injury is not a permanent inherent property of the plant.

NATURE OF THE DISEASE

Investigations of the cause of crinkle of strawberry were undertaken at the Oregon Agricultural Experiment Station. In August 1931 and again in 1932, diseased plants were sent to the U. S. Department of Agriculture, Office of Nematology, for examination, but no parasitic nematodes were consistently found in the leaves, buds, or roots. For several years it had been realized that the disease was spread in the field and in the greenhouse, for some of the new hybrids distributed from the U. S. Department of Agriculture had contracted the disease in Oregon. These hybrids originated at Glenn Dale, Maryland, where, so far as known, crinkle does not occur. This stock was first planted near diseased Marshall plants on the State College farms near Corvallis and later some of these hybrids at Corvallis and elsewhere in the state have developed crinkle-like symptoms. In commercial fields the disease is much more prevalent than a few years ago, sometimes more than half of the plants being infected by the third year. Because of the disease there is a definite "running-out" of the Marshall variety. If it were not for the fact that most of the thrifty growers of strawberries always select planting stock from the most vigorous mother plants regardless of crinkle this "running out" undoubtedly would have been much more apparent. Another limiting factor in the perpetuation of diseased stock is the winter-killing of crinkle-infected plants. In the plots where this disease is studied, at the Oregon Agricultural Experiment Station, 31 per cent of the crinkle-infected Marshall plants were killed in the winter of 1932–33, contrasted with 10.5 per cent in the healthy plots.

Such running-out diseases have proved for the most part to be caused by viruses transmitted by insects. In 1931 Mr. E. K. Vaughan, working at the Oregon Station, proved that the strawberry leaf aphid (*Myzus fragaefolii* Cockerell) carries the disease from diseased to healthy plants.[6] By means of these aphids he was able to transmit the crinkle from diseased to healthy Marshall and from diseased Ettersburg 121 to healthy Marshall. Vaughan also demonstrated that (1) in a small percentage of cases plants may recover after the appearance of primary symptoms immediately following inoculation and (2) the virus does not pass from the adult aphids to the young offspring.

Since then, the writer has continued by transmission experiments the study of the nature of the disease. These studies have included (1) vectors and their efficiency in transmission, (2) intervariety and interspecies transmission, and (3) non-transmission to seedlings.

VECTORS

As stated above, the strawberry leaf-louse or aphid (*Myzus fragaefolii*) has been proved to be a carrier of crinkle. Preliminary experiments with the spittle bug (*Philaenus spumarius* L.), red spider (*Tetranychus telarius* L.) and the greenhouse white fly (*Trialeurodes vaporariorum*) indicate they are perhaps not factors in the transmission of the disease. Notes on another

[6]Vaughan, E. K., *loc. cit.*

species of aphid which transmits the disease to some extent will be published later provided more complete knowledge of its efficiency as a carrier is obtained.

Efficiency of strawberry leaf-louse as a vector. In Vaughan's experiments 20 aphids were transferred from a diseased Marshall plant to each healthy plant, but in most of the transmission experiments conducted by the writer since then only 10 individual aphids have been used for each transfer. In order to learn whether this number was sufficient for maximum transfer of the disease the following experiment was conducted using Marshall strawberry plants in aphid-proof cages. Each cage was placed over two healthy plants in the field early in the spring (March). On June 15, 1933, a large colony of the strawberry-leaf aphis was caged on two plants having severe symptoms of the crinkle disease, and a similar colony was caged on two healthy Marshall plants. The original colony had previously been proved non-viruliferous in the greenhouse. On June 30, aphids from the caged crinkle plants were transferred to caged healthy plants in varying numbers as given in Table I. As a check, 10 aphids from the healthy plants were caged on each of ten healthy plants. All transfers of aphids have been made by picking them from the plant by means of a moist camel's-hair brush and in every case immature aphids have been used to transmit crinkle.

In greenhouse experiments it had previously been determined that primary symptoms usually appear in 12 to 15 days after inoculation. For this reason ample time was allowed before checking the inoculated plants for infection. On July 28, the inoculated plants showed the results presented in Table I.

TABLE I. SHOWING THE EFFICIENCY OF THE STRAWBERRY LEAF-LOUSE AS A VECTOR OF THE CRINKLE DISEASE ON MARSHALL STRAWBERRY PLANTS

Number of aphids placed on each healthy plant	Number of healthy plants treated	Number of plants showing crinkle four weeks after receiving aphids	Percentage of infection
			%
Viruliferous			
1	10	1	10.0
2	8	3	37.5
3	8	2	25.0
4	8	5	62.5
5	8	7	87.5
6	8	8	100.0
Total	64	37(Av'age)	57.8
Non-viruliferous			
10	10	0	.0

In a previous experiment in the greenhouse six viruliferous aphids were caged on each of 14 healthy Marshall plants on March 17. On March 24 these plants were each carefully examined throughout for the presence of aphids. On 11 of the plants aphids were found to be active and multiplying, but on the remaining three plants there were no aphids to be found. Whether these were all killed by brushing in the transfer is not known. At any rate, on April 1, primary symptoms appeared on the 11 plants, but

symptoms have not yet (September 28) appeared on the other three plants nor on 35 uninoculated plants under the same conditions. The 11 plants have had severe symptoms of crinkle since about April 20. Since for some reason the aphids died on three plants the transfer by six aphids in this experiment was also considered 100 per cent and as a result no more than six aphids were used in the experiment reported above (Table I).

It appears from Table I that a single vigorous, immature aphid is capable of transmitting crinkle from a diseased plant to a healthy plant, but the chance of transfer of disease is more certain as the number of aphids involved in the transfer is increased. This seems to be true until six or more aphids are involved, above which number 100 per cent infection may confidently be expected. The checks show that aphids which do not harbor the virus do not cause crinkle in the healthy plants they feed upon.

From the foregoing experiments it is readily seen that *Myzus fragaefolii* (strawberry-leaf aphis) in its immature stages is an efficient carrier of crinkle. Spread undoubtedly takes place in the field, but it is not known whether this is due to the flight of a winged stage of this aphid or to some mechanical or climatic agency, such as wind, causing the distribution of the immature stages. The time of year when the winged form of this aphid appears in Oregon has not been discovered, but this point is now under investigation.

Intervariety transmission. Plants of several varieties of strawberry have been noticed with symptoms more or less like those of crinkle-infected Marshalls. Experiments have been carried out in a number of cases to determine whether or not these symptoms in other varieties are actually expressions of crinkle. The experiments were conducted in each case essentially as reported previously, some in the greenhouse and some in the field. In every case the diseased and healthy plants were caged and ten aphids were transferred. The results of these experiments are given in Table II.

TABLE II. SHOWING THE TRANSFER OF CRINKLE FROM ONE VARIETY OR SPECIES OF STRAWBERRY TO ANOTHER BY MEANS OF TEN IMMATURE APHIDS (*MYZUS FRAGAEFOLII*)

Variety from which aphids were transferred —plants showing symptoms	Variety to which aphids were transferred— plants healthy	Number of healthy plants to which transferred	Number of plants showing crinkle after inoculation	Incubation period from inoculation until primary symptoms show
				Days
Marshall	Nick Ohmer	4	3	14–18
Nick Ohmer	Marshall	4	4	12–14
Corvallis	Marshall	6	5	12–16
Magoon	Marshall	4	4	12–15
Marshall	Magoon	4	2	18–20
Missionary	Marshall	4	3	12–16
Norwood	Marshall	4	4	12
Clarks Seedling	Marshall	4	2	15–16
Ettersburg 121	Marshall	4	1	14
Fragaria chiloensis	Marshall	6	4	13–16
F. cuneifolia	Marshall	6	5	12–15

In each case the disease was transmitted to the Marshall variety, in which typical symptoms of crinkle were produced. The fact that at least a

few plants of all of these varieties have been found to harbor the crinkle virus is proof that they are, to some degree, susceptible to the disease, but surely in some cases, such as the Magoon, Nick Ohmer, and Clarks Seedling, they cannot be highly susceptible or undoubtedly plantings of these sorts near Marshall plantings would carry higher percentages of infection.

Interspecies transmission. In Table II, transmission of crinkle from the beach strawberry (*F. chiloensis*) and the wild field strawberry (*F. cuneifolia*) to the Marshall variety is reported. The distribution of crinkle in these wild species of strawberry has been discussed earlier in this bulletin. The presence of crinkle in the wild field strawberry may be of considerable importance in the spread of the disease to commercial plantings.

CRINKLE-FREE SEEDLINGS FROM CRINKLE-INFECTED PLANTS

One hundred and twenty-two seedlings were raised in the greenhouse from seed obtained from crinkle-infected Marshall plants. These were grown to a stage where they began to produce runner plants and were quite pot-bound. In no instance have they shown symptoms of crinkle until inoculated by means of viruliferous aphids. Ten such seedlings were each inoculated by means of ten viruliferous aphids and after the usual incubation period the ten plants showed typical symptoms of crinkle. Thus the infective principle is probably not transmitted through the seed. This is a very important and encouraging fact for the plant breeder, since he may know that the original clone of a newly selected seedling variety starts crinkle-free.

VEGETATIVE PERPETUATION OF CRINKLE

Thus far only the transmission of crinkle by aphids has been discussed. Vaughan unsuccessfully attempted its transmission by several other means, such as lateral graftage of crowns of diseased on to those of healthy plants, pricking through diseased leaves directly into healthy, and the injection of juice expressed from diseased leaves into the tissues of healthy plants. Besides the transfer of the disease by aphids as vectors there is the natural perpetuation of the disease in planting stock through the stolons (runners). This characteristic and the relation of the behavior of symptoms in runner plants to the problem of controlling the disease has been quite adequately discussed above.

It might be said here, however, that the disease is entirely systemic, so that when a mother plant is diseased all of the runner plants derived from it will always be diseased although for quite a period of weeks or even months the runner plants may not show symptoms after being planted independent of the mothers in fertile soil. This condition in new plantings interferes greatly with the successful selection of crinkle-free plants. Until plants in the field are nearly a year old it seems almost impossible as a rule to be sure whether they are crinkle-free or not. For experimental purposes, however, greenhouse tests may be made to prove this point satisfactorily.

CONTROL

The control of virus diseases must involve either (1) the elimination of the disease from planting stock, (2) the possibility of preventing its dissemination by means of insect vectors, or (3) the production of varieties resistant or immune to the disease.

The U. S. Department of Agriculture in cooperation with the Oregon Agricultural Experiment Station at Corvallis is now breeding new varieties of strawberries in order to obtain, not only desirable sorts for particular uses, but varieties which may possess resistance or immunity to the crinkle disease. Since the disease is so prevalent in commercial plantings in Western Oregon, its elimination from planting stock is of much more consequence than the control of the insect carrier. In fact, elimination of the disease is of prime importance to combat degeneration and to maintain desirable varieties, such as the Marshall and Corvallis, now under cultivation.

The elimination of crinkle from planting stock must be brought about by (1) *roguing out* the diseased plants or (2) the *selection* of healthy plants.

Roguing. Our experience with mass roguing of old fields with various percentages of crinkle has been rather limited. The impracticability of this procedure has been previously reported.[7] If, however, there is reasonable assurance that a planting has a very low percentage of crinkle-infected plants, satisfactory results doubtless could be obtained by roguing. When selections of disease-free plants have been made first and the plants set out in isolated plots or in the greenhouse, later roguings are always advisable and yield good results when carefully conducted.

Selection. The selection of healthy plants yields the best returns in healthy planting stock. These selections are made from fields more than a year old by choosing during the spring or fall outstanding plants with smooth leaves and without any of the symptoms of crinkle. A *few* of these plants are marked with a stake at each selected hill. From time to time these few marked hills are inspected and the stakes removed from any plants which develop symptoms through the season. Just before the runners start, other plants around each marked hill are cleared away so the runner plants will not mix with neighboring diseased plants. As early in the fall as possible the runner plants are lifted, keeping those from each plant segregated by themselves, in order that they may be planted according to a plant-unit system. The new plot of ground for these plants is selected with care. It should be located at least 300 feet from any wild or cultivated strawberries. The runner plants from each mother plant are now lined out and separated from those of the next plant unit by a skip in the row or preferably by a stake. Then the following year this plot is rogued, removing immediately the whole plant unit whenever symptoms appear in any of the plants of that unit. Such a procedure, if very carefully pursued, should soon yield a high-grade foundation stock for certification for freedom from disease.[8]

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[7]Zeller, S. M. Betterment of strawberry planting stock. Ore. State Hort. Soc., Rept. 24:106-110. 1932.

[8]McWhorter, O. T., and Zeller, S. M., Strawberry-plant certification plan. Ore. State Agr. Coll. Ext. Bul. 448:1-3. 1932.

Freedom from crinkle experimentally proved. After careful field selections had been made and several plants which showed no symptoms of crinkle had been obtained in the greenhouse, the runner plants from 9 outstanding mother plants selected from them were potted separately in ten-inch pots in September, 1932. These plants were grown in the pots until they were thoroughly pot-bound and the soil supposedly well depleted of fertility. Under these circumstances, if field observations were correct, the potted plants should show crinkle symptoms if diseased. After six months, however, the whole group were smooth-leaved and much healthier appearing than field-run plants which had been potted much more recently. Fourteen of these plants were inoculated on March 17 and in fifteen days the crinkle symptoms showed strikingly on 11 of them. (The detailed results of this experiment are given on page 10.) Since the remaining plants from the same 9 mother plants kept under identical conditions show *no* symptoms of crinkle whatever, the test clearly indicates that they are undoubtedly crinkle-free. The front cover illustration of this bulletin is from a photograph of two of these mature runner plants from the same healthy mother stock, one having been inoculated with crinkle by means of six viruliferous aphids. For experimental purposes this sort of procedure provides a satisfactory proof of freedom from crinkle in any given stock of selected Marshall plants. In this particular instance the test demonstrated the health of the stock in the third generation of runner plants in the greenhouse after more than two years of selection. The procedure described above is a slow one but may ultimately form the foundation for strawberry certification as to freedom from virus disease, just as tuber-indexing has paved the way for high-standard seed potatoes.

ACKNOWLEDGMENTS

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W. H. Dreesen, Ph.D. ..... Agricultural Economist

Farm Management

H. D. Scudder, B.S. ..... Economist (Farm Management)
H. E. Selby, M.S. ..... Associate Economist (Farm Management)
G. W. Kuhlman, M.S. ..... Associate Economist (Farm Management)
A. S. Burrier, M.S. ..... Associate Economist (Farm Management)

Division of Animal Industries

Animal Husbandry

O. M. Nelson, M.S. ..... Animal Husbandman
A. W. Oliver, M.S. ..... Assistant Animal Husbandman

Dairy Husbandry

I. R. Jones, Ph.D. ..... Associate Dairy Husbandman

Poultry Husbandry

A. G. Lunn, B.S. ..... Poultry Husbandman
F. L. Knowlton, M.S. ..... Poultry Husbandman
F. E. Fox, M.S. ..... Associate Poultry Husbandman

Veterinary Medicine

B. T. Simms, D.V.M. ..... Veterinarian
W. T. Johnson, B.S., D.V.M. ..... Poultry Pathologist
J. N. Shaw, D.V.M. ..... Assistant Veterinarian
R. Jay, D.V.M. ..... Associate Veterinarian, Bur. of Anim. Ind.*
E. M. Dickinson, D.V.M. ..... Assistant Poultry Pathologist
F M. Bolin, D.V.M. ..... Assistant Veterinarian, Agricultural Experiment Station; Cooperative Agent*
O. H. Muth, D.V.M. ..... Assistant Veterinarian, Agricultural Experiment Station, Cooperative Agent*
O. L. Searcy, B.S. ..... Technician in Veterinary Medicine

Division of Plant Industries

G. R. Hyslop, B.S. ..... Agronomist; In Charge, Division of Plant Industries

Farm Crops

E. N. Bressman, Ph.D. ..... Agent, Division of Drug and Related Plants
H. A. Schoth, M.S. ..... Associate Agronomist; Forage Crops and Disease Investigation*
D. D. Hill, M.S. ..... Associate Agronomist
B. B. Robinson, Ph.D. ..... Assistant Plant Breeder*
Grace Cole Fleischman, AB. ..... Assistant Botanist, Division of Seed Investigations*

Horticulture

W. S. Brown, D.Sc. ..... Horticulturist
A. G. B. Bouquet, M.S. ..... Horticulturist (Vegetable Crops)
E. H. Wiegand, B.S.A. ..... Horticulturist (Horticultural Products)
H. Hartman, M.S. ..... Horticulturist (Pomology)
C. E. Schuster, M.S. ..... Horticulturist*
W. P. Duruz, Ph.D. ..... Horticulturist (Plant Propagation)
G. F. Waldo, M.S. ..... Assistant Pomologist
B. F. Dana, M.S. ..... Pathologist (Horticultural Crops and Diseases)
J. C. Moore, M.S. ..... Assistant Horticulturist (Pomology)
T. Onsdorff, B.S. ..... Assistant Horticulturist (Horticultural Products)

Soil Science

W. L. Powers, Ph.D. ..... Soil Scientist
C. V. Ruzek, M.S. ..... Soil Scientist (Fertility)
M. R. Lewis, C.E. ..... Irrigation and Drainage Engineer, Bur. of Agric. Engineering
R. E. Stephenson, Ph.D. ..... Associate Soil Scientist
E. F. Torgerson, B.S. ..... Assistant Soil Scientist (Soil Survey)

Other Departments

Agricultural Chemistry

J. S. Jones, M.S.A. ..... Chemist in Charge
R. H. Robinson, M.S. ..... Chemist (Insecticides and Fungicides)
J. R. Haag, Ph.D. ..... Chemist (Animal Nutrition)
D. E. Bullis, M.S. ..... Assistant Chemist (Horticultural Products)
M. B. Hatch, B.S. ..... Assistant Chemist

Agricultural Engineering

F. E. Price, B.S. ..... Agricultural Engineer
C. Ivan Branton, B.S. ..... Assistant Agricultural Engineer

Bacteriology

G. V. Copson, M.S. ..... Bacteriologist in Charge
J. E. Simmons, M.S. ..... Associate Bacteriologist
W. B. Bollen, Ph.D. ..... Assistant Bacteriologist

Entomology

D. C. Mote, Ph.D. ..... Entomologist in Charge
A. O. Larson, M.S. ..... Entomologist (Stored Products Insects)*
B. G. Thompson, M.S. ..... Assistant Entomologist
F. G. Hinman, M.S. ..... Entomologist (Stored Products Insects)*
S. C. Jones, M.S. ..... Assistant Entomologist
K. W. Gray, B.S. ..... Field Assistant (Entomology)
W. D. Edwards, B.S. ..... Field Assistant (Entomology)

Home Economics

Maud M. Wilson, A.M. ..... Home Economist

Plant Pathology

H. P. Barss, S.M. ..... Plant Pathologist
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F. D. Bailey, M.S. ..... Associate Plant Pathologist*
L. N. Goodding, B.A., B.S. ..... Associate Pathologist*
F. P. McWhorter, Ph.D. ..... Pathologist
P. W. Miller, Ph.D. ..... Associate Pathologist*
G. R. Hoerner, M.S. ..... Agent*
T. Dykstra, M.S. ..... Assistant Plant Pathologist*
A. R. Sprague, Jr., Ph.D. ..... Assistant Pathologist*
H. H. Millsap ..... Agent, Bureau of Plant Industry*

Publications and News Service

C. D. Byrne, M.S. ..... Director of Information
E. T. Reed, B.S., A.B. ..... Editor of Publications
D. M. Goode, B.A. ..... Associate Editor of Publications
J. C. Burtner, BS ..... Associate in News Service

Branch Stations

D. E. Stephens, B.S. ..... Superintendent Sherman County Br. Expt. Sta.; Senior Agronomist* (Moro)
L. Childs, A.B. ..... Superintendent Hood River Br. Expt. Station, Hood River
F. C. Reimer, M.S. ..... Superintendent Southern Oregon Br. Expt. Station, Talent
D. E. Richards, B.S. ..... Superintendent, Eastern Oregon Br. Expt. Station, Union
H. K. De.an, B.S. ..... Superintendent, Umatilla Br. Expt. Station, Hermiston
O. Shattuck, M.S. ..... Superintendent Harney Valley Br. Expt. Station, Burns
A. E. Engbretson, B.S. ..... Superintendent John Jacob Astor Br. Expt. Sta., Astoria
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Arch Work, B.S. ..... Associate Irrigation Engineer, Bureau of Agricultural Engineering*
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