BULLETIN No. 20. V. P. P.—72.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

B. T. GALLOWAY, Chief.

PEACH LEAF CURL:

ITS NATURE AND TREATMENT.

BY

NEWTON B. PIERCE,

In Charge of Pacific Coast Laboratory, Santa Ana, California.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1900

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

SCIENTIFIC STAFF.

B. T. GALLOWAY, *Chief of Division.*
ALBERT F. WOODS, *Assistant Chief.*

ASSOCIATES.

ERWIN F. SMITH,
MERTON B. WAITE,
NEWTON B. PIERCE,
HERBERT J. WEBBER,
M. A. CARLETON,
P. H. DORSETT,
OSCAR LOEW,
WM. A. ORTON,
ERNST A. BESSEY,
FLORA W. PATTERSON,
MARCUS L. FLOYD.*

IN CHARGE OF LABORATORIES.

ALBERT F. WOODS, *Plant Physiology.*
ERWIN F. SMITH, *Plant Pathology.*
NEWTON B. PIERCE, *Pacific Coast Laboratory.*
HERBERT J. WEBBER, *Plant Breeding.*
OSCAR LOEW,† *Plant Nutrition and Fermentation.*

*Detailed as tobacco expert, Division of Soils.
†In charge of tobacco fermentation investigations, Division of Soils.

LETTER OF TRANSMITTAL

U. S. Department of Agriculture,
Division of Vegetable Physiology and Pathology,
Washington, D. C., February 20, 1900.

Sir: I respectfully transmit herewith a report on peach leaf curl, prepared by Mr. Newton B. Pierce, who has charge of the work of this Division on the Pacific coast, and recommend that it be published as Bulletin No. 20 of the Division. The report embodies the results of investigations and experiments carried on for a number of years, and shows conclusively that peach leaf curl can be controlled by comparatively simple and inexpensive treatment.

Respectfully,

B. T. Galloway,
Chief of Division.

Hon. James Wilson,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

PACIFIC COAST LABORATORY,
Santa Ana, Cal., December 15, 1899.

SIR: I herewith submit a report of investigations on the nature and treatment of peach leaf curl. The experiments described were conducted under the most varied conditions of soil, climate, etc., in all the leading peach centers of the United States, and it is believed that the recommendations for treatment here given are equally applicable wherever peaches are grown.

Respectfully,

NEWTON B. PIERCE,
In Charge of Pacific Coast Laboratory.

MR. B. T. GALLOWAY,
Chief, Division of Vegetable Physiology and Pathology.

CONTENTS.

ILLUSTRATIONS.

PLATES.

FIGURES.

DESCRIPTION OF PLATE I.

Curl-infested peach shoot from Biggs, Cal. Leaves of this character are badly infested with *Exoascus deformans*. The greatly broadened and distorted leaves, which are characteristic of this disease, are shown, and the whitened, spore-covered surface of some of the more elevated portions of the upper surface may be distinguished. The petioles of the affected leaves are greatly enlarged, the branch is much bent and distorted, and the internodes of the diseased portion of the branch are greatly shortened. A branch thus badly diseased is apt to die during the year unless conditions for growth are very favorable. It is in shoots of this character that the mycelium occurs in greatest abundance, but the hyphæ have been seen to spread only a short distance beyond the parts showing the hypertrophy. (Compare with Pls. V and VI.)

PEACH LEAF CURL: ITS NATURE AND TREATMENT.

By Newton B. Pierce.

CHAPTER I.

PRIMARY CONSIDERATIONS RELATIVE TO PEACH LEAF CURL.

INTRODUCTION.

This bulletin has been prepared to place before the peach growers of the United States the results of experiments conducted during several years past for the prevention of peach leaf curl. The losses arising from this disease frequently amount to several millions of dollars annually, and it is believed that a wide dissemination of the results obtained by the experiments here outlined will lead to a large saving to the peach industry. During the progress of the Department's work over one thousand six hundred peach growers in all peach-growing States have been requested to test the preventive measures here recommended. A large number have done so, and some of the more important results of their work are also given. From conservative data it has been estimated that the experimental work thus widely set on foot by the Department has saved to the country in a single year the sum of three-fourths of a million dollars. This is but a fraction, however, of what may easily be saved in the future, when all growers have obtained a more thorough understanding of the disease and its prevention.

The obscure views held by many growers in the past upon the true nature of peach leaf curl, and the total lack of preventive measures up to a recent date, make it desirable to thoroughly consider the subject at this time and to record the detailed work upon which the conclusions reached are based. These conclusions are that peach leaf curl may be prevented with an ease, certainty, and cheapness rarely attained in the treatment of any serious disease of plants, and that there is no longer a necessity for the losses annually sustained from it in the United States.

GENERAL CHARACTERISTICS OF THE DISEASE.

The disease of peach trees here considered is variously known in different regions and languages. In the United States it is commonly know as peach leaf curl, or curl leaf of the peach; in England and all British possessions, as leaf blister, leaf curl, or curly leaf; in France, as cloque du pêcher; in Germany, as Kräuselkrankheit; in Italy, as Fillorissema, etc.

Peach leaf curl is a disease which seriously affects the leaves, flowers, tender shoots, and fruit of the peach. Its action is most severe in the spring of the year, shortly after the leafing of the trees, and the greatest injuries are caused in wet seasons and in humid localities. The leaves become enlarged, thickened, much curled, and distorted. As the disease progresses the healthful green of the foliage is changed to a yellowish, sickly appearance. The leaves soon fall, and the newly formed fruit ceases to grow, yellows, wilts, and likewise falls. The total loss of foliage and crop is common in seasons favorable to the disease. A second growth of leaves develops more or less rapidly, according to the severity of the disease and the favorable or unfavorable soil and atmospheric conditions prevailing at the time. If the soil and atmosphere are dry and the temperature high, new foliage may appear slowly and much of the terminal growth may die throughout the orchard. In severe attacks young trees are frequently killed. The second crop of leaves, appearing on affected trees after the spring defoliation, usually remains comparatively free from curl for the rest of the season. The amount of disease which will appear upon this later crop of foliage depends largely upon the humidity or dryness of the atmosphere, excessive moisture favoring a continuance of the trouble. The action of the disease upon spring branches causes them to enlarge, become curved and distorted in various ways, and often to dry up and die.

GEOGRAPHIC DISTRIBUTION.

Peach leaf curl exists in most peach-growing countries. Its distribution in the United States extends from the Gulf of Mexico to Canada and from the Atlantic to the Pacific. The centers of greatest prevalence, and where the greatest losses are sustained from this cause, are in the leading peach-growing districts bordering the Great Lakes, especially in Michigan and western New York; in the central, northern, and coast regions of California; and west of the Cascade Mountains in Oregon and Washington. The disease is less serious, or is of minor importance, in those peach-growing counties of New York most distant from the lakes, in Pennsylvania, Ohio, Indiana, Illinois, and in southern California. Still less injury is reported from New Jersey, Delaware, Connecticut, Rhode Island, Massachusetts, Maryland, Virginia, West Virginia, Kentucky, Tennessee, North Carolina South Carolina, Arkansas, Oklahoma, Louisiana, Mississippi, Alabama, and Florida, but in most of these regions occasional serious outbreaks are reported in seasons favorable to curl or in particular localities. It prevails rather more seriously in portions of Georgia, Kansas, and Missouri. In Texas, New Mexico, Arizona, and Colorado it has occasioned but little loss and is not widely known. Reports from Utah and Nevada are meager, but it is probable that the disease prevails to a limited extent in both States. The more northern States not mentioned here have either failed to report the prevalence of the disease or are properly included within that portion of the United States unsuited, by rigor of climate, to successful peach culture.

In Canada both Ontario and British Columbia, which are the leading peach-growing provinces, are favorably situated for the serious development of peach leaf curl in wet seasons. Mr. John Craig, horticulturist of the Central Experimental Farm, Ottawa, writes that the disease "obtains in Canada in all the peach-growing districts, including British Columbia and the Province of Nova Scotia." It is known to cause considerable losses of fruit in some sections.[1]

Peach leaf curl exists also in some if not all the peach-growing countries of South America. In Chile the peach is widely grown, being planted from the snow line of the Andes to the Pacific Ocean, and from Copiapo south as far as Valdivia, a distance of 800 miles. Mr. C. T. Ward, Jr.,[2] of the Hacienda Loreto, Department of Limache, says that the parasite of peach leaf curl "exists all over the country where the peach grows," but that no satisfactory method of control is yet practiced there.

In Europe Dr. R. Sadebeck[3] records the disease from Denmark, Germany, Austria, Switzerland, and Italy. He states that in central Germany it prevails more extensively than in the vicinity of Hamburg.[4] Among the many German scientists who have written upon this

[1] Mr. L. Woolverton, secretary of the Fruit Growers' Association of Ontario, said, in 1890, in a paper entitled, Points on Peach Growing in the Niagara District, published in the Annual Report of the Society for that year, pp. 56 and 57: "The peach has its share of enemies and diseases, chief among which are the curl, curculio, the borer, and the yellows. For the curl I know no remedy. It is not often severe, but sometimes with the diseased leaves the fruit also drops." Mr. John Craig, in writing from Ottawa under date of October 7, 1897, says, relative to the disease in Ontario: "It is only severely injurious here during years of unusually heavy rainfall. This year it was very bad."

[2] Letter of March 22, 1896, to Mr. J. M. Dobbs, U. S. Consul at Valparaiso, Chile.

[3] Sadebeck, Dr. R., Die parasitischen Exoasceen. Eine Monographie, Hamburg, 1893, p. 94.

[4] Sadebeck, Dr. R., Untersuch. über die Pilzgattung Exoascus, Hamburg, 1884, p. 115.

disease and its cause are Sadebeck,[1] Winter,[2] De Bary,[3] von Tavel,[4] Hartig,[5] Zopf,[6] Tubeuf,[7] Ludwig,[8] Sorauer,[9] Frank,[10] Kirchner,[11] Fuckel,[12] and others. Winter says (l. c.) that the fungus of this malady causes great damage by early defoliation of the trees, and that it even kills the diseased trees by its repeated occurrence.

In Great Britain peach leaf curl has been common for a great many years. In 1821 it was accurately described by an English gardener under the name of "blight." He says:[13] "Under this denomination [blight] are frequently confounded two varieties of disease materially different in their appearance, and which I shall distinguish by the appellation of *blister* and *curl*. The former is generally confined to such peach trees as have glandular leaves, which are mostly subject to it in the months of April and May, and when attacked it is not until the latter part of the season, if at all, that they become healthy. The leaves so attacked are crisp, and assume a swollen, crumpled, and succulent appearance; the shoots themselves are affected by it in the same manner, and never produce either good blossom or healthy wood." Berkeley[14] has described the fungus causing this disease, and it has been mentioned by Bennett and Murray[15] and many other English writers. (Consult a popular article on Peach Blister, by W. G. Smith, *Gardeners' Chronicle*, Vol. IV, pp. 36, 37.)

---

[1] Sadebeck, Dr. R., see locations cited; also Einige neue Beobachtungen und kritische Bemerkungen über die Exoascaceæ, Bot. Ges., 1895, Band XIII, Heft 6.

[2] Winter, Dr. Georg, Die durch Pilze verursachten Krankheiten der Kulturgewächse, Leipzig, 1878, p. 47; also Rab. Krypt. Flora, 1885, II, p. 6.

[3] De Bary, Prof. A., Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria, English edition, Oxford, 1887, p. 265; see also in the same volume various other references to the arrangement and position of the Exoascus group.

[4] Tavel, Dr. F. von, Vergleichende Morphologie der Pilze, Jena, 1892, pp. 55, 56.

[5] Hartig, Dr. Robert, Lehrbuch der Baumkrankheiten, Berlin, 1889, p. 118; also the English edition, Text-book of the Diseases of Trees, London, 1894, p. 132.

[6] Zopf, Dr. Wilhelm, Die Pilze in morphologischer, physiologischer, biologischer, und systematischer Beziehung, Breslau, 1890, pp. 236, 282.

[7] Tubeuf, Dr. Karl Freiheer von, Pflanzenkrankheiten durch kryptogame Parasiten verursacht, Berlin, 1895, pp. 167–188.

[8] Ludwig, Dr. Friedrich, Lehrbuch der Niederen Kryptogamen, Stuttgart, 1892, p. 205.

[9] Sorauer, Dr. Paul, Handbuch der Pflanzenkrankheiten, Zweiter Theil, Die parasitären Krankheiten, Berlin, 1886, p. 278.

[10] Frank, Dr. A. B., Die Krankheiten der Pflanzen, Band II, Die Pilzparasitären Krankheiten, Breslau, 1896, pp. 249, 250. Edition of 1880–81, Vol. II, p. 526.

[11] Kirchner, Dr. Oskar, Die Krankheiten und Beschädigungen unserer landwirtschaftlichen Kulturpflanzen, Stuttgart, 1890, pp. 324, 407.

[12] Fuckel, L., Symbolæ mycologicæ, 1869, p. 252.

[13] See quotation in Report of Michigan Pomological Society for 1873, pp. 16, 17.

[14] Berkeley, M. J., Introduction to Cryptogamic Botany, 1857, p. 284, and Outlines of British Fungology, London, 1860, pp. 376, 444, tab. 1, fig. 6.

[15] Bennett, A. W., and Murray, George, A Handbook of Cryptogamic Botany, London, 1889, p. 379.

Tulasne,[1] Prillieux,[2] and others (Cours complète d'agriculture, T. XV, p. 255, art. Pêcher) have studied this disease more or less carefully in France, where it often develops in a serious form. In June, 1890, the writer saw the peach trees near the Mediterranean, particularly about Montpellier, in anything but a healthy condition. On the 3d of June leaf curl was bad, and the ends of branches were seen to be dying in some cases. In Italy Briosi and Cavara,[3] Berlese,[4] and Comes[5] are among those who have described this malady. The disease varies in its prevalence through Italy in accordance with its habits elsewhere. The trees of northern Italy appeared more healthful than in the south of France during the visit of the writer in 1890, but considerable gummosis, perhaps due to the same cause, was observed in both regions. In western Sicily, near Palermo, leaf curl was again encountered in severe form. The situation in Spain and Portugal is not known, but in the more humid coast regions it should not be materially different from the condition found in Italy. In Greece, as stated by Prof. P. Genardius,[6] the disease rarely causes any damage of importance, because of the dryness of the climate, and for this reason, he states, no treatment has been tried. In Austria-Hungary the situation respecting leaf curl is much the same as in Italy. Dr. Johann Bolle, director of the Institute of Experimental Agricultural Chemistry, at Gorizia, writing from the island of Cherso, under date of October 25, 1897, states that in rainy weather the disease appears some years with great intensity and causes great damage. In Roumania the situation is much the same. Prof. Wilhelm Knechtel, of the Agricultural School of Herestrau, states in a letter dated Bucharest, October 17, 1897, that in that country leaf curl of the peach is also a troublesome and destructive disease to which the trees are subject in many years. He states that Roumania has in the region of the lower Danube almost a steppe climate—in summer very hot and dry, in winter cold, with very abrupt temperature changes, so that the variations of temperature within twenty-four hours not infrequently amount to from 10° to 15° R. (22.50° to 33.75° F.). When such changes of temperature occur in the spring at the time of leaf development the disease is certain to appear. The growth of the vegetation, which has been favored through the preceding warm days, is checked during succeeding days of lowered temperature, when

[1] Tulasne, L. R., Ann. d. Sci. Nat., 1866, ser. 5, T. V, p. 128.

[2] Prillieux, Ed., Bull. de la Soc. Bot. de France, 1872, T. XIX, pp. 227–230; Compt. Rend. 3; also Maladies des Plantes Agricoles, Paris, 1895, T. I, pp. 394–400.

[3] Briosi, G., and Cavara, F., Fungi Parassiti d. Piante Coltiv. od Utili, essicc., delin. e descr., 1891, fasc. 5, No. 104.

[4] Berlese, A. N., I Parassiti Vegetali d. Piante Coltiv. o Utili, Milano, 1895, pp. 124–126.

[5] Comes, O., Crittogamia Agraria, Napoli, 1891, pp. 163, 165–167, 549.

[6] Letter dated Athens, Sept. 12, 1895.

the development of the fungus begins, so that in June all leaves at the ends of the young branches are curled and deformed and perhaps all the blossom buds fall off. If the more developed leaves at the base of the young shoots prove more resistant to the fungous action, then fresh shoots are formed in June, even if not in normal condition, but yet somewhat healthy, so that the tree remains intact. In the more protected hill regions of the vineyards, at the foothills of the Carpathian Mountains, this disease is also troublesome, but less intense than in other parts of the country.

Peach leaf curl exists in South Africa, and probably also throughout Algeria and other peach-growing portions of the continent. Professor MacOwan, of the department of agriculture of Cape Colony, has written of the disease in South Africa, giving his views as to the proper manner of treating the same.[1] He also writes that it is "a great plague at the Cape."[2]

A peach grower of Drysdale, Frere, Natal, in writing to the Cape Colony agricultural department under date of October 31, 1893, says that he has a good many peach trees of the yellow, white, and St. Helena varieties, and that they are all affected with the discolored and curled-up leaves characteristic of this disease; that several of his neighbors are complaining that their peach trees are suffering like his; and that the disease seems to be spreading. The young trees were similarly affected.[3]

Perhaps no foreign country has suffered more from peach leaf curl than New Zealand. Mr. W. M. Maskell, of Wellington, writes as follows:[4] "The curly blight has been for many years prevalent in this country—so much so that whereas in the early days peaches were exceedingly luxuriant and fine, they have dwindled to comparatively very small and poor trees and in many parts of the colony almost died out. In the last two or three years the people have been advised to employ remedies, and have done so to some extent, so that there is a marked improvement in the peach orchards. * * * I can myself recollect, early in the sixties, when the most splendid peaches used to grow wild in the warm northern districts, where now scarcely a tree is seen; and the curly blight has been a dreadful curse all over the colony."

Australians report peach leaf curl among their serious plant diseases. In South Australia it "has been known quite twenty years,"[5] and probably longer, and occasions considerable losses in seasons favoring it. The situation is much the same in New South Wales.

---

[1] MacOwan, Prof. P., Agricultural Journal, published by the department of agriculture of Cape Colony, 1892, Vol. V, pp. 252, 253.

[2] Letter dated Cape Town, Oct. 26, 1895.

[3] Agricultural Journal, Cape Colony, Vol. VI, No. 23, p. 451.

[4] Letter dated Wellington, New Zealand, December 24, 1895.

[5] Observations of Mr. A. Molineux, general secretary for the agricultural bureau of South Australia, letter dated Adelaide, February 11, 1895.

Prof. N. A. Cobb,[1] pathologist for the agricultural department of that colony, has described the malady quite fully, and although he fails to specify particular localities, it is probable that his descriptions are drawn from observations made in the colony for which he writes. He says that in the most severe cases of the disease "the fruit falls about three weeks after setting, and not a peach is left to ripen. This occurs on trees on which the disease is chronic and severe. * * * Such trees are worthless, nay, worse than worthless; they are a constant menace to the peach trees in the neighborhood. The sooner they are cut down and burned, and thus utterly destroyed, the better it will be for the peach industry. * * * I have now described the disease in its worst form, a form in which it is not common. The milder forms of the disease are much more frequent."

Peach leaf curl also prevails in Victoria, where it has been placed; according to Mr. D. McAlpine,[2] pathologist for Victoria, among the specified diseases in the vegetable diseases bill, recently passed in that colony. Mr. McAlpine also says that according to Mr. George Neilson, chief inspector under the vegetation diseases act, it has been known in Victoria since 1856, and affected peach trees were just as bad then as now. Mr. McAlpine adds: "The disease is distributed all over the colony. In the cooler districts it is generally more severe than in the northern and warmer districts, and it is generally more prevalent in a moist and cool spring than in a dry, warm one."

The situation in Japan has been learned through the obliging and careful inquiries of Prof. K. Miyabe,[3] of the Sapporo Agricultural College. He writes that *Exoascus deformans* is at present a serious pest to the peach trees at Sapporo, north island, and states that his attention was first called to its presence in that place some three or four years since, but that there is no doubt of its existence from the time of the first introduction of American peach trees, about twenty-three years ago. The Japanese flowering (double red) peach trees and nectarines were introduced at Sapporo by a florist about six or seven years ago from Echigo Province in the northern part of the main island or Honsiu. These varieties were found to be attacked to some extent during these few years. American varieties are now most seriously affected, and many persons have been obliged to cut down their trees on account of the disease. Respecting the distribution throughout Japan, Professor Miyabe says: "As to the rest of Hokkaido [the northern island] I found the fungus in 1890 at Mombetsu, a farming village on Volcano Bay, settled about twenty-seven years ago by the people from Sendai. I could not tell whether the peach trees cultivated there were of American or Japanese origin. In Honsiu, or

[1] Cobb, Prof. N. A., paper in the Agricultural Gazette, 1892, Vol. III, pp. 1001-1004.
[2] Letters dated Melbourne, Australia, July 14, 1896, and Oct. 12, 1897.
[3] Letter dated Sapporo, Hokkaido, Japan, Nov. 22, 1897.

Main Island, the peach curl seems to be prevalent only in the northern provinces. * * * I sent letters of inquiry relating to this question to the graduates of our college, who studied especially about the parasitic fungi in our laboratory, and whose opinions I can trust. From Mr. Y. Takahashi, at Morioka, in Rikuchu Province, I received the following answer: 'Peach curl is very prevalent in this town. Almost every tree is more or less attacked by the fungus. I saw some trees entirely attacked. At the end of summer [spring?] all the diseased leaves fell to the ground and new leaves were produced.'" In the southern island, Kumamoto, a correspondent reported to Professor Miyabe that the disease had not been seen there by him. From Tokyo Professor Shirai, of the College of Agriculture, reports that he has not yet found the disease in that section of the main island.

In China, as the writer is informed, peach leaf curl prevails to a very large extent, and the losses are probably considerable from this cause.[1]

ORIGIN OF THE DISEASE.

The country of origin of peach leaf curl is not positively known. It was hoped that the inquiry as to distribution would develop positive information respecting this point, but such has not been the case. That seedling peaches are remarkably susceptible to the disease, and that the Chinese Saucer peach is among those most subject to it, appears to indicate that the home of the peach is the source of the disease, and that the two may have come to us together from a common point of origin. Recent studies have been constantly tending to reduce the number of species of plants once thought to be subject to curl. At present it is believed that it is confined almost wholly to the peach or its derivatives, as the nectarine and peach-almond. The exceptions to this, where the disease has been noted on the plum, almond, etc., are rare, and not sufficiently numerous or general to materially affect the evidence that the peach is the natural host of the fungus. Thus far, however, it has been impossible to learn if the peach in the interior of China, its supposed home, is affected by this trouble, though in the coast regions it is said to prevail extensively. Such information as has been obtained from Japan indicates the recent introduction of the disease in that country, and that the United States is probably its source rather than the near-by continental coast. In Australia, however, this may properly be questioned, for, as already mentioned, Mr.

[1] Letter from Augustus White, Esq., forwarded April 3, 1896, through the kindness of Mr. Rufus S. Eastlack, then U. S. Deputy Consul-General at Shanghai, China. Mr. White says, in concluding his statements, that the Chinese, ignorant of the use of the knife in pruning, trust solely to an annual inspection of the trees at the time the blossoms set, when they carefully pick off all excess of fruit, and with it all diseased leaves, etc., but allow these to fall to the ground and remain under the trees to rot or reproduce the plague, as nature thinks best.

George Neilson, chief inspector under the vegetation diseases act of that colony, states that peach leaf curl has been known in Victoria since 1856. This dates the presence of the disease in Australia back to a time when its importation from America to that country would be doubtful. Its European origin, however, may not be improbable.

The severity of the disease in the gardens of China and the fact that the peach probably reached Europe and America from the East make it still desirable to learn if the trouble is prevalent among the wild or escaped peach trees in the interior of the Chinese Empire.

It may be pertinent to state, in view of the fact that Darwin holds the peach to be derived from the almond, that none of the many widely cultivated varieties of the almond in California, either of local or foreign origin, are subject to peach leaf curl, even when growing beside peach orchards denuded by it. Trees which are apparently the result of almond and peach crosses are somewhat affected, however, and several of the nectarines, which are derived from the peach, are quite subject to it. Seedling peaches, as stated, are very commonly attacked, but of some forty to fifty varieties of seedling almonds examined by the writer none has thus far shown the disease.

LOSSES FROM THE DISEASE.

The direct annual losses to the peach interests of the United States from peach leaf curl are very large, and are usually much greater than is suspected by the growers themselves, as the nature and action of the disease are misunderstood by them, and its effects frequently attributed to other causes. In case an orchard is so affected that it fails to hold the crop, or sets but a partial crop, the grower has but little ground for an opinion as to what the yield would have been had curl not prevailed, hence the estimates of losses made by growers are frequently very unsatisfactory. In case curl occurs after a severe cold spell in spring, as is quite commonly the case, the orchardist is apt to charge the loss of fruit to the low temperature rather than to the disease. The preventive spray work conducted by the Department has shown, also, that the loss estimates are nearly always too low.

By preventing the disease upon a portion of the trees of an orchard the amount of injury sustained by the untreated trees has been determined most accurately by direct comparison. Such comparative work has now been conducted for several years in many of the leading peach-growing centers of the country, and these tests enable the writer to state that the losses sustained by the peach industry are probably not overdrawn in the following estimates: Of a large number of peach growers who replied to a circular letter sent them in 1893, there were 251, living in 35 peach-growing States and Territories, who stated whether or not their orchards were affected by curl.

Sixty-three per cent of these (158 growers) reported that their orchards were affected, and 37 per cent (93 growers) reported that their trees had not been troubled by it. Of the 158 whose trees were affected, 66 per cent (104 growers), or about 42 per cent of the 251 orchardists reporting on this disease, reported more or less loss. The growers who reported loss were residents of 21 States, and were scattered from the Atlantic to the Pacific. The losses sustained varied from a small amount of fruit to the entire crop, and in some instances many of the young trees were killed. Of the entire number of reports received as to the presence or absence of curl in the orchard of the grower, 93 came from States or sections of the country where little leaf curl prevails, as Texas, Delaware, Florida, Kansas, etc., so that the data should be strictly representative of the peach-growing country as a whole. The replies received were from Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, Tennessee, Texas, Virginia, Washington, and West Virginia.

The amount of loss sustained by the 42 per cent of the growers reporting losses is given in the replies in various ways. Some growers have reduced their loss to dollars and cents; others have indicated the loss in percentage of crop; while still others have used some term, such as "slight" loss, "small" loss, etc., as a reply to the inquiry. In estimating the true loss sustained by these growers a uniform system has been adopted. Where the loss has been stated in dollars the amount has been recorded as given. Where the loss is given in percentage of crop the cash loss has been determined from the basis used by the United States Census Bureau in determining the value of peach crops for the Eleventh Census. A full peach crop was valued at $150 per acre, and all portions of a crop at the same rate. Where the report of the grower was indefinite, the statement being that the loss was small, it has been placed at $2.50 per acre, which amounts to about 2½ cents per tree as usually planted. It is probable that this is much below the average loss in such cases, as a loss so small as this would usually escape notice. In all the calculations in these estimates an effort is made not to overrate the loss. These calculations gave a loss to the growers averaging $10.95 per acre for the acreage reported as suffering from the disease, or 42 per cent of the full area. This is equivalent to about $4.60 per acre for the entire acreage, or about 4 cents per tree. At first thought this may seem high, but this is more apparent than real. If one 10-acre orchard loses its crop from curl, valued at $150 per acre, the loss amounts to $1,500. There may be 32 other orchards of 10 acres each all about this orchard where not a peach is lost, yet the average for such a district is the same as that stated. This is perhaps a clearer manner of putting the matter than by placing an average loss for all orchards. The loss may be viewed in still another manner. If an orchardist has grown peaches for 32 years and lost only one crop during that time from leaf curl his loss for the third of a century will average as high as here calculated.

There are large sections of the country where curl is scarcely known, as in portions of Texas. For such regions the preceding estimates may appear high. On the other hand, there are other prominent sections of the country devoted to peach culture where these estimated losses will certainly be far too low.

If the preceding calculations and statements are accepted as fairly representing the situation throughout the country, the annual losses from curl in the United States may be approximated. The Eleventh Census reports the orchards of peach trees in the United States at that time (1889–90) as 507,736 acres, and from replies to our circular we are led to believe that curl was present in 63 per cent of these orchards and that 42 per cent sustained some loss from the disease.

Most of the orchards included in the 42 per cent sustained only a slight loss, but a very small percentage sustained a heavy loss, sometimes amounting to the entire crop. The average loss for the 42 per cent of the orchards is found to amount to $10.95 per acre, or about 10 cents per tree, averaging the trees at 108 per acre. The total acreage of the country being 507,736, the loss should be calculated upon 42 per cent of this, or 213,249 acres, which gives a total estimated annual loss from peach leaf curl of $2,335,076. In this estimate no account has been taken of the great injury to the growth of trees, the injury to nursery stock, the death of young orchard trees, nor the loss to succeeding crops from the reduced number or quality of fruit buds on affected trees. There is also the loss arising from the cultivation and pruning of unproductive orchards, which, if it could be determined, would probably bring the entire annual loss to the country up to $3,000,000 or more.

Since 1893, when the investigation of this disease was undertaken by the writer, a very large amount of correspondence has been conducted with peach growers in all parts of the Union who have sustained losses from curl, and this correspondence has resulted in the accumulation of a large number of facts respecting these losses. These data, however, have not been drawn upon in the above estimates, as it might be claimed that they were from growers only who have suffered from the disease, and consequently would not fairly represent the industry as a whole—a claim which can not be made against the circular letter, the basis of the estimates, which was addressed to peach growers in general in all parts of the United States. In fact there appears to have been a larger percentage of replies received from sections of the country where curl is scarce than from the more affected portions.

CHAPTER II.

NATURE OF PEACH LEAF CURL.

The study of the nature of plant diseases is intimately linked with the study of plant physiology, and the true science of vegetable pathology is largely, as Ward has defined it, the study of abnormal physiology. (Introduction to Hartig's Text-book of the Diseases of Trees.) These facts become evident when studying the etiology of peach leaf curl and the conditions attendant upon its widespread development. The direct cause of peach leaf curl has long been known as a parasitic fungus, *Exoascus deformans* (Berk.) Fuckel, but it is evident from a careful study of the disease that the injurious development of the fungus is distinctly correlated with special physiological phenomena of the peach tree itself. These conditions of the tree are in turn dependent upon such external influences as temperature, the humidity of the soil and atmosphere, and others. Such facts were foreshadowed by the theories advanced by peach growers as to the cause of the disease. Many growers have considered peach leaf curl as the direct result of excessive moisture and low temperature or sudden changes, and as these physical conditions certainly have an important bearing upon the injurious development of the disease, they are considered together with the direct relations of the parasite to its host. However, too much stress can not be placed upon the fact that the fungus alone is responsible for the injury to the tree. Without the parasite not a leaf would curl nor a peach fall on account of this malady—in fact, no such disease would exist. This is shown by the work hereafter detailed. It is fortunate that the direct cause of peach leaf curl is a parasitic fungus rather than unfavorable atmospheric conditions, for the latter could not be controlled, while the control of the fungus has been found practicable, simple, and inexpensive.

PHYSICAL CONDITIONS INFLUENCING THE DISEASE.

The influences of temperature, humidity, situation, soil, etc., upon leaf curl are often so well marked that they have frequently and in fact quite generally been mistaken for the active cause of the disease. Indeed a very large percentage of peach growers have maintained, to within the past ten or fifteen years, that sudden changes of temperature occurring in conjunction with wet weather are the sole cause of the curling and loss of foliage. Notwithstanding the number of known facts to the contrary, there are even now many growers who retain this idea to the utter and needless loss of their crops. The writer has met men who so firmly believe that leaf curl is due to uncontrollable climatic influences that they would not consider other explanations, being unwilling to visit the orchard, though the crop was being lost through curl and by so doing future crops might have been saved.

To gather the experience of peach growers in general respecting the conditions under which leaf curl develops most severely, a circular of inquiry was addressed to several hundred orchardists in November, 1893. The replies to some of the questions are presented. Among the inquiries the growers were requested to state if they had observed the disease to be more prevalent after a cold spell in the spring. To this question 97 replies were received, 89 affirmative, 6 negative, and 2 growers said they had observed no difference, which shows that the orchardists are almost unanimous in holding that a cold spell in the spring favors the development of curl.

To the second question, as to whether the trees were most affected by curl in a wet or dry season, there were 104 replies. Of these, 78 stated that peach trees were most affected in wet seasons, 8 that they were most affected in dry seasons, and 18 that there was no difference. Here again is seen a marked agreement in the replies, a great majority of the growers recognizing that wet years favor the disease.

The above-considered conditions—a cold spell in the spring and wet weather—may be explained by stating that such conditions favor, on the one hand, the serious development of the fungus causing the disease, and, on the other, they result in a much greater susceptibility of the tissues of the peach leaves to the attacks of the parasite. Where both cold and rain occur together in the spring, about the time the leaves are pushing, the disease is liable to develop seriously and few varieties can then resist it. The action of wet, cold weather upon the tissues of the peach, making them much more subject to curl than they otherwise would be, has been considered in relation to other plants in a paper by Prof. H. Marshall Ward,[1] who says that *when the combined effects of the physical environment are unfavorable to the host, but not so or are even favorable to the parasite, we find the disease assuming a more or less pronounced epidemic character.* He is not here speaking of curl, but the statement holds perfectly true for that disease. A cold, wet spell succeeding warm spring weather, has a tendency to saturate and soften the tissues of the peach, as in the case of other plants. The sudden checking of active transpiration, due to lowered temperature and saturated atmosphere, soon results in the tissues of the plant being suffused with water. "The stomata," as Ward puts it, "are nearly

[1]Ward, Prof. H. Marshall, The Relations between Host and Parasite in Certain Diseases of Plants, Croonian Lecture, Proc. Roy. Soc., Vol. XLVII, No. 290.

closed, the cell walls bounding the intercellular passages and the air in the passages themselves are thoroughly saturated with water and aqueous vapor, respectively, and the movements of gases must be retarded accordingly; turgescence is promoted, and the water contents accumulate to a maximum, owing to the disturbance of equilibrium between the amounts absorbed by the active roots in the relatively warm soil and those passing off into the cold, damp air; much more water is absorbed by the roots in the relatively warm soil than passes off as vapor in equal periods of time." Further than this, Ward states that "the low temperature, feeble light, and partially blocked ventilation system have for a consequence a depression of respiratory activity and the absorption of oxygen generally." This must give a lowered vitality and an accumulation of organic acids. The reduced light also leads to a decided reduction in the assimilative power of the leaves. "The turgid condition of the cells, and the diminished intensity of the light," Ward says, "will favor growth." If this takes place, "the tendency will be for the very watery cell walls to become relatively thinner than usual, as well as watery, because the ill-nourished protoplasm does not add to the substance of the walls in proportion. This being so, we have the case of thinner, more watery cell walls acting as the only mechanical protection between a possible fungus and the cell contents."

It is generally known that the conditions of moisture and shade, which are above shown as making the tissues of a host plant more tender and watery (more subject to fungous attacks), are also the conditions most favorable to the development of fungi. This holds equally as good for *Exoascus deformans* as for other forms. In speaking of these conditions in relation to a fungus known as *Botrytis*, Professor Ward gives some generalizations equally applicable to *Exoascus deformans* in its relation to curl. He says that just those external climatic conditions which are disturbing the well-being of the green host plant are either favorable to the fungi considered or, at any rate, not in the least inimical to their development. "Thus," he says, "the oxygen respiration of the fungus goes on at all temperatures from 0° C. to 30° C. and higher, and although we still want information as to details, experiments have shown that the mycelia flourish at temperatures considerably below the optimum for higher plants. Moreover, light, so indispensable for the carbon assimilation of the green host, is absolutely unnecessary for the development of the fungus. Then, again, the dull, damp weather and saturated atmosphere, so injurious to higher vegetation, if prolonged, because they entail interference with the normal performance of various correlated functions, as we have seen, and render the plant tender in all respects, are distinctly favorable to the development of these fungi; consequently the very set of external circumstances which make the host plant least able to withstand the entry and devastation of a parasitic fungus like *Botrytis*, at the same time favor the development of the fungus itself."

The writer thinks, as the result of observations in the field, that *Exoascus deformans* is favored in both its entrance and spread within its host by the conditions which have just been considered. It is a widely observed fact that leaf curl usually develops sparingly in a uniformly warm and dry spring, and it is also noticed that where infection has occurred a return of warm, dry weather, or even the occurrence of a hot, dry wind, will check the development of the fungus within the tissues. An infected leaf may fail to develop the spores of the fungus under such circumstances. The thin, saturated cell walls and the moist intercellular spaces thus appear to be closely correlated with the active vegetation of the fungus. The growth and consequent tenderness of the tissues is also important in this connection. Where soil, elevation of orchard, and atmospheric conditions are unfavorable to a saturated condition of the plant parenchyma, the disease is not likely to run more than a short and feeble course. Soil and elevation are here considered with atmospheric conditions, for it is found that on the same farm a difference of elevation or soil moisture may determine the degree of virulence of the disease. The influence of elevation may be of only secondary nature—that of maintaining a higher temperature—but its action on the disease is frequently well marked. Of 92 orchardists who expressed their views as to whether trees are affected by curl most on high or on low land, 48 say that trees suffer most on low land, 14 on high land, and 30 think there is no difference. While the majority claiming that trees on low land are most affected is not as large as some of the majorities obtained in replies to other questions, it represents over one-half the replies received to the question under consideration and is more than three times as great as the number who believe trees to be most affected on high land, hence is sufficient to establish confidence in its reliability, even if it were not indorsed by many published statements to the same effect.

Mr. Thomas A. Sharpe, superintendent of the experiment farm at Agassiz, British Columbia, has made several comparative reports on the action of peach leaf curl on trees planted in the valley and upon the more elevated bench lands of the farm. A few brief statements from these reports should be of value in connection with the above statements.[1] In 1892, Mr. Sharpe says, the peach trees suffered from a severe attack of leaf curl. "Only 5 varieties of those planted in the valley escaped" the disease. "The trees planted on the bench lands did not suffer so much, and appeared to recover much more rapidly than those in the valley" (l. c., p. 278). In 1893, it is said,

[1] See reports of experimental farms, Ottawa, Canada, for the years indicated.

the curl leaf in the peach and nectarine trees was worse than it had ever been before, the Malta being the only variety that was entirely healthy on level land. The varieties received from England and planted on the level land were just as badly affected as the others. The first and second bench orchards suffered alike with those on the level ground, but the orchard highest up, at an elevation of 800 feet, had no curl in any case, and the trees appeared to have suffered less from cold than those lower down (l. c., p. 342). Mr. Sharpe says that in 1896, "as heretofore, the trees on the upper benches, both nectarine and peach, escaped the curl leaf entirely" (l. c., p. 449). Again, it is said that "the peach crop on the level land this year [in 1898] was almost an entire failure. The curl leaf was very prevalent, nearly every tree being seriously affected by it." Relating to the orchard on the bench lands, it is stated that "curl leaf did not affect the foliage there; in fact, it has never injured the foliage on either peach or nectarine trees on the benches over 300 feet above the valley" (l. c., p. 403). These facts have an especial interest and value in that they were recorded by a single observer on one farm and during successive years and epidemics of curl, and they are in perfect harmony with the experience of a majority of the growers whose views are presented above.

The soil may exert its influence by abundantly or feebly supplying the transpiration stream, in accordance with the degree of accessibility of the moisture it contains, to the root hairs of the tree. It may be said, however, that as leaf curl commonly develops at the beginning of spring growth or at the close of the winter's rains, the soil will rarely be found so deficient in moisture as to greatly retard the development of the disease where other conditions are favorable. It is probably equally true that the excess of water usually found in the soil in the spring is favorable to the special development of the disease at that season in its worst form.

Besides the influence of temporary excessive humidity of the atmosphere upon leaf curl, which has already been considered, there are other atmospheric influences and relations of importance, which depend upon the local or general geographic, topographic, and climatic features of country. Some of these more prominent atmospheric influences may here be briefly considered, together with their most probable causes.

Proximity to large bodies of water, whether salt or fresh, greatly favors the development of curl. The cause for this clearly rests in the resulting greater humidity and lower temperature of the atmosphere. Plants growing in a constantly humid atmosphere have normally more succulent and tender tissues than those growing in a drier region. The reasons for this have already been alluded to for special cases of extreme atmospheric humidity and lowered temperature. Near large bodies of water spring fogs commonly occur, and these lead to the increase of the atmospheric humidity at a time when the foliage is tender and growing rapidly, thus stimulating a development of curl almost annually and over wide stretches of country. Independent of fogs, the atmosphere about large bodies of water is also much more humid than in an inland region. Instances of the influence of large bodies of water on the general prevalence and frequent occurrence of curl in a region are found in western New York, near the shore of Lake Ontario; in Ontario, Canada, near Lakes Erie and Ontario; in Michigan along the shore of Lake Michigan; in California about the bay of San Francisco and at other points along the Pacific coast; in Washington and British Columbia about Puget Sound; and in many similar situations in all portions of the world where the peach is grown. The writer believes, however, that the influence of large bodies of water upon the development of curl depends in part upon the normal spring temperature of the region, and likewise upon the source of the prevailing winds. Where the prevailing spring winds are from a dry, inland region instead of from the water, the atmosphere does not feel the influences of the latter. Moreover, where the spring temperature is high, transpiration may proceed normally even in the neighborhood of large bodies of water, and curl may not commonly prevail.

In contrast to the influences of large bodies of water are those of neighboring dry and arid plains or desert regions. In the midst of such influences peach leaf curl can rarely attain to an epiphytotic development, and then only under special favoring seasonal conditions. The atmosphere is normally too dry in such situations to exert a predisposing action upon the host, and it certainly does not favor the serious development of the parasite. Exemplifying these conditions are large areas in Arizona, New Mexico, Nevada, Utah, Colorado, Texas, Kansas, and California. Little or no curl is reported from the more arid portions of these sections of the country, its absence being due, at least in part, to the influences here considered.

Another of the broader influences affecting the general and permanent prevalence of curl over extensive regions is the normal annual rainfall. Comparisons of this kind must be made, however, between regions of approximately similar temperature. Under such conditions it may be said that the general annual prevalence of leaf curl increases with the increase of normal annual precipitation. Comparisons of this kind can hardly be justly drawn in the Mississippi Valley or on the Atlantic coast, as the temperature conditions vary too greatly in those regions from north to south. On the Pacific coast, however, owing to the modifying influence of the Pacific Ocean, the temperature prevailing from Lower California to British Columbia, a distance of about one thousand three hundred miles, presents no such great variations as are found in a like distance from south to north on the Atlantic coast, so that the relations of annual rainfall to the constant prevalence of curl may be more fairly decided.

In the following remarks on this subject I have left out of consideration the temporary influence of exceptional seasons and, as far as possible, the special influence of local features. The subject should be viewed from the broad field above pointed out. In southern California leaf curl is not recognized as a generally prevalent and serious trouble, but there is evidence which shows that its prevalence increases from San Diego northward to the San Bernardino Mountains. The average annual rainfall varies from about 10 inches at the former place to 16 inches at Los Angeles, which is not far from the mountains. In the San Joaquin Valley the prevalence of curl increases as a whole from the south central portion toward Sacramento and the north. The average annual rainfall, which is 7 inches at Tulare, 9 inches at Fresno, 11 inches at Merced, and 14 inches at Stockton, reaches 20 inches at Sacramento, about which center curl is quite prevalent. The average rainfall at Oakland is 23 inches, and curl is quite troublesome there. In the Sacramento Valley curl is frequently quite prevalent, and the rainfall varies from 20 inches at Sacramento and Chico to 34 inches at Redding. About Ashland, in southern Oregon, the rainfall is 23 inches, and the disease is about as in the Sacramento Valley. Farther north in Oregon curl becomes decidedly more prevalent and injurious at the west of the Cascade Mountains, and increases as Portland is approached. The rainfall is 35 inches at Roseburg, 46 inches at Albany, and 49 inches at Portland. From Albany to Portland the peach industry has been greatly injured by curl, and on its account many growers in this region have considered peach culture a failure.

Curl, it seems, was introduced into the central part of the Willamette Valley, Marion County, nearly half a century ago. Prior to that time the peach was successfully grown in that region in spite of the humidity of the climate. In the Patent Office Report for 1855, p. 298, there is a statement of the situation in Polk and Marion counties from 1852 to 1855. This statement was from Mr. Amos Harry, of Farm Valley, Polk County, Oreg., and is of special interest in this connection. Mr. Harry says: "The peach in this county has been affected with a disease known as the 'curled leaf,' which threatens to destroy the trees. It made its appearance at Mill Creek, in Marion County, in 1852, and extended considerably on that side of the river (Willamette River) in 1853, but had reached most parts of the valley in 1854–55. Some trees seem to escape it much more than others, but if the malady increases for two years to come as it has for two past, I fear we shall come entirely short of this delicious fruit. Some think it is owing to cold, wet weather, and recommend shortening all the limbs as a remedy, and some experiments seem to favor this idea. Others think it is produced by an insect, and that no remedy will save the trees unless it can be applied to the whole surface of the leaves."

The rainfall at Portland, as already said, is 49 inches, and curl is commonly prevalent and severe. At Umatilla, east of the Cascade Mountains, but about the same distance north as Portland, the rainfall is only 10 inches, while on that side of the mountains the peach industry is extensive and everywhere prosperous, leaf curl being much less prevalent and of secondary importance. This shows that it is not the distance north and the consequent lower temperature which makes curl more severe at Portland than at Los Angeles for instance, but that it is the excess of rainfall, for at the east of the mountains, near Umatilla, the temperature goes equally as low or lower than at Portland, and curl is of little importance there. In the Puget Sound region peach culture has never developed extensively, the general prevalence of curl and its injurious action being one of the chief reasons. The rainfall is 50 inches at Seattle and 56 inches at Olympia. It is only 7 inches at Kennewick and 9 inches at Ellensburg, on the east side of the Cascade Range. The peach orchards of North Yakima and neighboring sections on the east side of the Cascades and near Ellensburg, where this rainfall is taken, are noted for their extent, thrift, and general health, and curl is not a serious trouble. This case is parallel with that of Portland, already considered. The rainfall at the west of the mountains is 50 to 56 inches or more, while at the east it is only 7 to 9 inches. In the former region peach growing is not listed by the Washington Board of Horticulture as one of the horticultural industries, but in the latter region the peach is a leading fruit, being extensively and successfully grown. The winter temperature east of the mountains should range fully as low where the peaches are grown as at the west of the range. The contrast in peach culture in the two situations results from the difference of rainfall, and the heavy rainfall at the west of the Cascades results in a development of curl almost prohibitive to peach growing.[1]

In replying to a circular letter sent to the peach growers of Maryland, November, 1893, Mr. T. C. Stayton, of Queen Anne, makes some statements which bear directly on the matter here considered and are of much interest as resulting from personal observation. After speaking of the conditions in Maryland, Mr. Stayton says: "I was in Washington State during the months of April, May, June, etc., this year, and I find they can not grow peach trees west of the Cascade Mountains or in western Washington, as that part of the State is called, as that is a very wet part of our country." He adds that this was especially true in 1893, and continues: "About all the young trees that had been planted in that part of the State died from curl leaf, or so nearly so that they were worthless, but over in eastern Washington I did not notice any curl leaf, the climate being dry."

[1] For a full and accurate account of the rainfall conditions prevailing on the Pacific coast, see Report of the Rainfall on the Pacific Slope for from Two to Forty Years, Washington, 1889; also other reports of the Weather Bureau.

Peach leaf curl appears to be more prevalent in late than in early springs. This is probably due to the lower temperature and greater rainfall usually accompanying the former. Of 80 growers who gave their experience in relation to this matter, 43 stated that curl affects trees most in late springs, 23 believed it affects them most in early springs, and 14 had noticed no difference.

The question as to whether peach leaf curl affects trees most after a cold or warm winter was submitted to the growers, and of the 67 who replied, 27 stated that trees were most affected after a cold winter, 21 that they were most affected after a warm winter, and 19 growers had observed no difference.

The question of the influence of heavy dews on curl was also submitted to the orchardists, and the views expressed in their replies exhibit a remarkable agreement, 47 out of the 58 expressions of opinion received stating that the disease is no worse after a series of heavy dews. To the writer it appears probable that these answers are in perfect accord with the facts. Heavy dews can exert but slight influence upon the tissues of the peach, as they occur at night, when transpiration from the leaf is largely checked by the reduced light and lowered temperature of the atmosphere, resulting in the stomata being nearly closed. With the return of light and warmth the dew evaporates with the resumption of transpiration, and can have but little influence upon the tissues of the leaf. It might seem that dew would have a direct action on the germination of the spores of the fungus and in that way lead to a serious development of the disease after one or more heavy dews. This view, however, is not supported by observations either in the field or in the laboratory. In regions having little cloudy weather, with exceptionally clear sky, as in many portions of the Southwest, the heat of the soil radiates rapidly after sunset. In such sections of the country the days are hot and the nights cool or cold in comparison, the range of temperature between night and day being often considerable. In such regions dew is common and often heavy, but it is here that least curl occurs.

Relative to the action of dew on the germination of the spores of *Exoascus deformans*, it may be said that something more than dew is required for such germination. The writer has tested this matter most thoroughly, not only with dew, but with many forms of culture media at various temperatures and with varying supplies of oxygen. Brefeld has also shown that moisture alone is not sufficient for germination, he having utterly failed to induce germination in a single instance after months of work with culture media in liquid form. Budding of the spores is easy to obtain in all liquids, and is more abundant and continuous in suitable nourishing cultures than in dew or rain water. Fifty-eight growers replied to an inquiry on this subject, 47 stating that the disease is no worse after a series of heavy dews, 7 that it is worse, and 4 that no difference was observed.

THE FUNGUS CAUSING THE DISEASE.

The fungus causing peach leaf curl, now known as *Exoascus deformans* (Berk.) Fuckel, is a member of the subfamily of fungi known as *Exoasceæ*. The *Exoasceæ* are low or simple *Ascomycetes*, or fungi bearing their spores in cases or asci.

The classification of the *Exoasceæ* which now lays greatest claim to scientific permanence is that outlined in the recent writings of Sadebeck, who has given careful study to these forms.[1]

Of the five genera which he recognizes, only the last directly concerns us at this time, as it is to this genus (*Exoascus*) that the peach curl fungus belongs, as well as numerous other species injurious to horticulture. In considering this genus Sadebeck[2] has grouped thirty of its species according to certain characters of development. He recognizes the following characters of the genus:

EXOASCUS Fuckel.

A. The mycelium is perennial in the inner tissues of the axial organs.

a. The development of the hymenium occurs only in the floral leaves of the host plant. Eight species.

b. The development of the hymenium occurs only in the foliage leaves of the host plant. Seven species, including *E. deformans*.[3]

c. The development of the hymenium occurs upon the leaves as well as upon the fruits. One species.

B. The mycelium is perennial in the buds of the host plant and develops only subcuticularly in the leaves.

---

[1] Sadebeck, Dr. R., Die parasitischen Exoasceen, Hamburg, 1893, p. 43.

Sadebeck recognizes five genera in the *Exoasceæ*, which he arranges and characterizes in the following manner:

EXOASCEÆ: Ascomycetes whose asci are not united in a fruit body.

A. The asci arise as swellings at the end of the branches of the mycelial threads.

1. *Endomyces* Tulasne. Four-spored asci, no conidia within the same; the sterile threads develop chlamydospores and oïdia.

2. *Magnusiella* Sadebeck. Parasitic. Asci with more than four spores; usually conidia formations in the ascus. Oïdia and chlamydospores wanting.

B. The asci take their origin from a more or less loose hymenium.

3. *Ascocorticium* Bref. Saprophytic on bark. The ascus layers are arranged in a loose hymenium upon the mycelium.

4. *Taphrina* Fries. Parasitic. Without perennial mycelium. In the formation of the ascogenous cells differentiations of material occur. Forming leaf spots.

5. *Exoascus* Fuckel. Parasitic. With perennial mycelium. In the formation of the asci no differentiations of material appear. The subcuticular mycelium changes directly to ascogenous cells. Causing sprout deformations.

[2] Sadebeck, Dr. R., Einige neue Beobachtungen und kritische Bemerkungen über die Exoascaceæ, pp. 277, 278, reprint from den Ber. d. deutsch. bot. Ges., 1895, Bd. XIII.

[3] Dr. von Derschan has described the occasional fruiting of *Exoascus deformans* in the blossoms of the peach. The figures given by this author do not show the normal development of ascogenous cells in the blossoms which are so common in the leaf blade of the peach. His figures show the asci as arising from lateral branches of a continuous mycelial hypha, and this mycelium is situated beneath the epidermal cells instead of between the cuticle and epidermis (Landw. Jahrb., Berlin, 1897, pp. 897–901, and Table XLI).

a. The development of the hymenium occurs only in the floral leaves of the host plant. Three species.

b. The development of the hymenium occurs only upon the foliage leaves. Ten species.

c. The resting mycelium extends intercellularly in the deformations of the leaves. One species.

It may be seen under A *b* of this arrangement that *Exoascus deformans* is said to possess perennial mycelium, inhabiting the inner tissues of the axial organs, and that the development of the hymenium occurs only in the foliage leaves of the host plant. As will be seen in another part of this bulletin, it is perhaps a perennial nature of the mycelium of *E. deformans* which makes it difficult to thoroughly rid an orchard of curl by means of spray treatment, but this matter requires further careful consideration.

The synonymy of *Exoascus deformans* (Berk.) Fuckel has been given by numerous writers. Sadebeck[1] gives it as follows:

Ascomyces deformans Berk. Intro. to Cryptogamic Botany, 1857, p. 284.

Ascosporium deformans Berk. Outlines, 1860, p. 449.

Taphrina deformans Tul. Ann. Sci. Nat., 1866, V. Sér., t. 5., p. 128.

Exoascus deformans Fuckel. (*a*) *Persicæ* Fuck. Symbolæ Micolog., 1869, p. 252.

This fungus has been very commonly observed and frequently described by botanists since Berkeley called attention to it in 1857. It has thus been known as the cause of curl for a little less than half a century. The peculiar behavior of peach foliage under its action has been observed by horticulturists, however, for a much longer time. The disease was well described in England in the early part of the present century.

In spite of the very common appearance of *Exoascus deformans* upon peach foliage in peach-growing countries, the descriptive literature relating to its life history is not free from conflicting statements. Several species of *Exoasceæ* have been confounded with this species in some instances, and subsequent writers have perpetuated the confusion.

Some earlier writers believed this species inhabits a considerable number of host plants, thus resulting in the description and distribution of several distinct species as *Exoascus deformans*. To avoid such confusion it would be best to confine remarks upon this species to the fungus as it develops upon the peach (*Prunus persica* L.), which if not its only host, is certainly its most common one.

At least two modes of infection of the peach tree by *Exoascus deformans* are said to exist—(1) by means of perennial mycelium, and (2) by means of the spores of the fungus.

Sadebeck[2] is authority for the statement that the mycelium winters over in the youngest portions of the one-year-old branches of the host

[1] Sadebeck, Dr. R., Die parasitischen Exoasceen, Hamburg, 1893, p. 53.

[2] Idem, l. c.

plant, and may be seen in the primary cortex, in the medulla, and in the medullary rays of the first shoots of each period of vegetation, but has not been observed in the soft bast. With the beginning of the new season of growth the mycelium, according to Sadebeck, extends into the leaves of the young shoots, penetrates first the inner tissue of the leaves, and finally progresses to the development of the subcuticular hymenium. From what foundation of experimentation Sadebeck has arrived at these views respecting this particular species, I am unable to state, but he has given the outlines of his investigations upon other species.[1]

The facts given by De Bary[2] can not be cited here, for this work was done upon the Exoascus infesting the cherry tree, and which is now considered to be distinct from *E. deformans*.

The general acceptance of the view that spring infection of the peach foliage is largely due to the extension of the internal perennial mycelium into the new shoots and leaves from the shoots of the previous summer, has probably considerably retarded the progress of preventive treatment. Pathologists have thought it improbable that any considerable amount of disease could be prevented after a tree was once generally affected, as the perennial mycelium, being internal, could not be readily reached by external sprays. Prillieux,[3] writing in 1872, advises the gathering of the diseased leaves and the cutting away and burning of the diseased branches. Frank[4] has made like recommendations in both editions of his work on plant diseases. Assuming the mycelium to be perennial, he says that the curing of the disease might be aimed at through cutting back of the diseased branches and the prevention through quick removal of the diseased leaves. Winter[5] suggests a somewhat similar line of treatment, with the additional recommendation that the trees be protected from rain during the unfolding of the leaves. Dr. Cobb,[6] as late as 1892, after speaking of the perennial mycelium of this fungus, discusses preventive and curative measures, such as the destruction of diseased leaves, prunings, etc., while in the more severe cases he says the sooner the trees are cut down and burned the better it will be for the peach industry.

---

[1] Sadebeck, Dr. R., Die parasitischen Exoasceen, Hamburg, 1893, pp. 24–28.—Das perennirende Mycel der Exoascus-Arten.

[2] De Bary, A., Com. Mor. and Biol. of the Fungi, Mycetozoa, and Bacteria, English edition, 1887, p. 266.

[3] Prillieux, Ed., Bul. de la soc. bot. de France, 1872, T. XIX, p. 230.

[4] Frank, Dr. A. B., Die Krankheiten der Pflanzen, Breslau, 1881, Part II, p. 526; second edition, 1896, Vol. II, p. 250.

[5] Winter, Dr. Georg, Die durch Pilze verursachten Krankheiten der Kulturgewächse, Leipzig, 1878, p. 47.

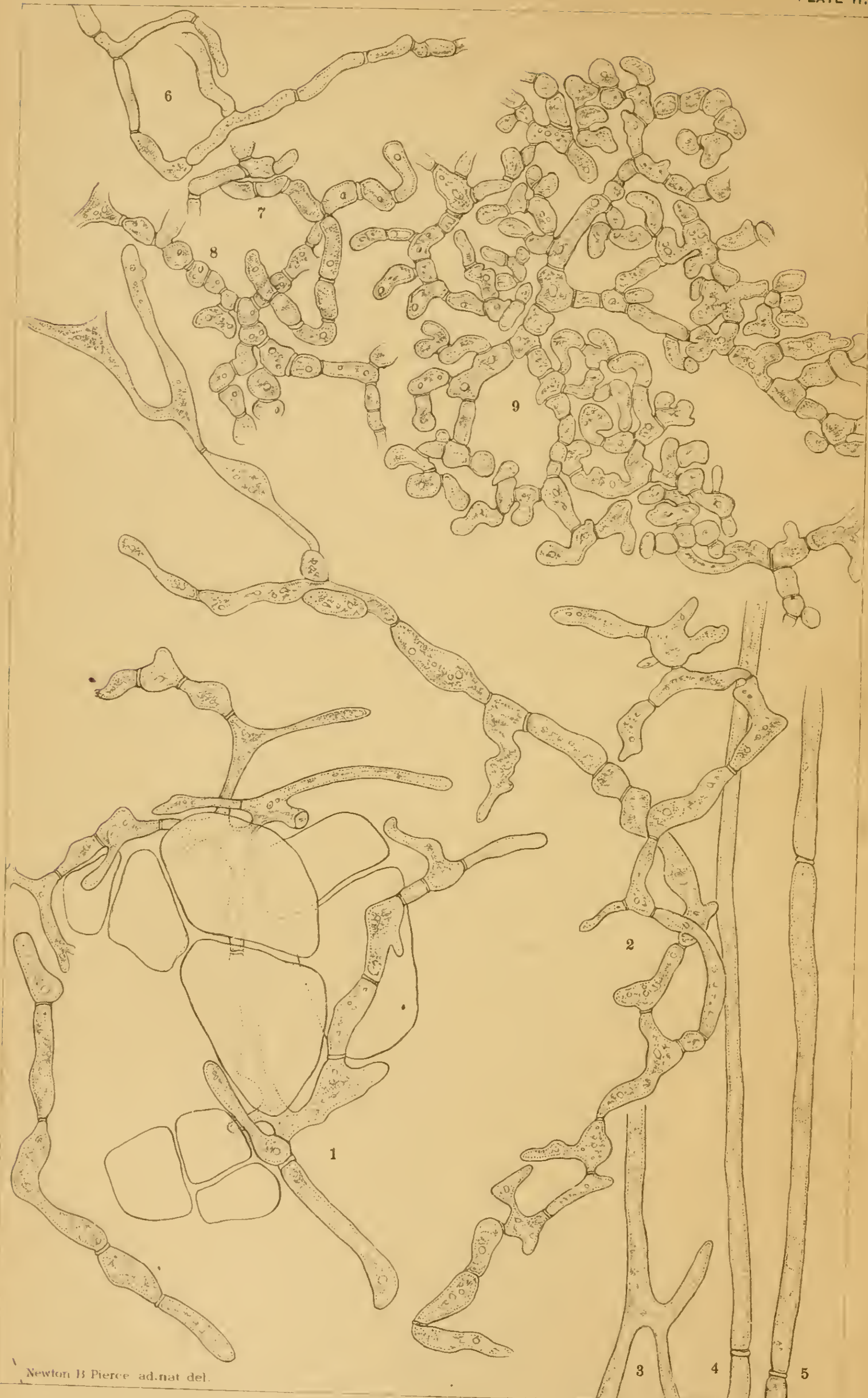
[6] Cobb, Dr. N. A., The Agricultural Gazette, Sydney, New South Wales, 1892, Vol. III, pp. 1001–1004.

Relative to the use of fungicides the same writer says: "These treatments are of doubtful value as far as the curl is concerned, and were it not that they are useful in other ways I would not mention them." It is evident that these views are the result of Dr. Cobb's belief that the perennial mycelium is responsible for the major portion of the spring infection of the tree. The writings of others to the same effect could be cited, but the views of the workers already named are sufficient to show that their recommendations for treatment have been based upon the hypothesis that the spring infection could not be prevented by treatment with fungicides, as it arose mainly from internal mycelium rather than from the germination of external spores. That this view has held back the preventive treatment of the disease, as already claimed, can not be doubted, and that a perennial mycelium is not responsible for more than a very small percentage of the spring infections seems evident from the results of the present experiments; in fact it may even be questioned if such infection takes place except under exceptionally favorable conditions. Our experiments have demonstrated that as high as 98 per cent of infections may be prevented by a single thorough application of a suitable fungicide. This is as high a percentage of control as is often obtained in the treatment of fungous diseases where no perennial mycelium exists, and it seems probable that the infections by this means may not commonly exceed 5 per cent of each spring's infections. Were this not the case we would be forced to assume that the spray has a direct effect upon the hibernating mycelium, which certainly would be unusual and scarcely to be expected.

The second mode of spring infection—that by means of spores—is probably much more general and important in this disease than has been supposed. That 90 to 98 per cent of the infections of the tree are prevented by a single spraying suggests that at least such percentage of the infections is by means of spores.

The mycelium of *Exoascus deformans* as found in the peach, shows great differences in the form and appearance of its hyphæ. These differences depend upon the stage of development of the fungus and the various functions of the mycelium. The writer recognizes three types of hyphæ, which may be termed vegetative, distributive, and fruiting.

The vegetative hyphæ are found most commonly in the leaf parenchyma, but are also met with in the leaf stalk and cortical parenchyma of badly diseased and distorted branches. These hyphæ may be most distinctly seen, and are most highly developed, in infested leaves which have not yet formed the hymenium of ascogenous cells, but in which the parasite has been present a sufficient time to entirely alter the character of the palisade tissue and cause the loss of the chlorophyll. In the leaf blade the palisade tissue first shows the serious action of



MYCELIUM OF EXOASCUS DEFORMANS, THE FUNGUS CAUSING PEACH LEAF CURL.

A.Hoen & Co. Lith Baltimore

DESCRIPTION OF PLATE II.

Mycelium of *Exoascus deformans* (600/1). Figs. 1 and 2, normal vegetative hyphæ, as found in the leaf parenchyma, showing characteristic septation, modes of branching, etc.; figs. 3, 4, and 5, usual type of distributive hyphæ found in swollen branches in the cortical parenchyma and medulla; figs. 6, 7, 8, and 9, fruiting hyphæ, showing successive stages in the development of ascogenous cells from the subcuticular mycelium (6) to the half-formed ascogenous cells (9). (See Pl. III for further stages in the development of the ascogenous cells and asci.)

the vegetative hyphæ, which are usually found somewhat later among the cells of the spongy parenchyma, below the vascular network. The loss of chlorophyll from the two classes of leaf parenchyma commonly preserves the order here given. The form of the vegetative hyphæ is very irregular, and their elements, or cell members, are often of different size, length, and shape. The cells vary greatly in diameter from one end to the other, are frequently much curved and twisted, and oftentimes appear triangular in cross section. The branches may arise from greatly enlarged triangular bifurcations, or in other instances directly from the sides of the cells. These vegetative hyphæ are all intercellular so far as observed, but are commonly found adhering closely to the cell walls of the host, frequently wrapping about the parenchyma cells. The walls of the hyphæ are semitransparent but firm, commonly having a slight yellowish cast. The septa present peculiar characters. Two adjoining cells of a hypha have the appearance of being separately closed at the end and united with each other by means of an intervening plate, which if it should be dissolved or lost would leave the cells separated but closed. These peculiar septa are remarkably refractive and characteristic. They are well shown in the drawings of Sadebeck (Die parasitischen Exoasceen, Hamburg, 1893, Tab. II, figs. 7, 8). The predominating characters of the vegetative hyphæ are shown in Pl. II, figs. 1 and 2, of this bulletin. The hyphæ there shown were carefully separated from the leaf parenchyma and drawn under the camera. The vegetative hyphæ of the branch are much like those of the leaf, and have been seen most commonly among the looser parenchyma cells of the cortex just exterior to the bast fiber bundles. Thus far they have never been found by the writer in the cambial tissues. Sadebeck states that the mycelium has been found in the pith and medullary rays.

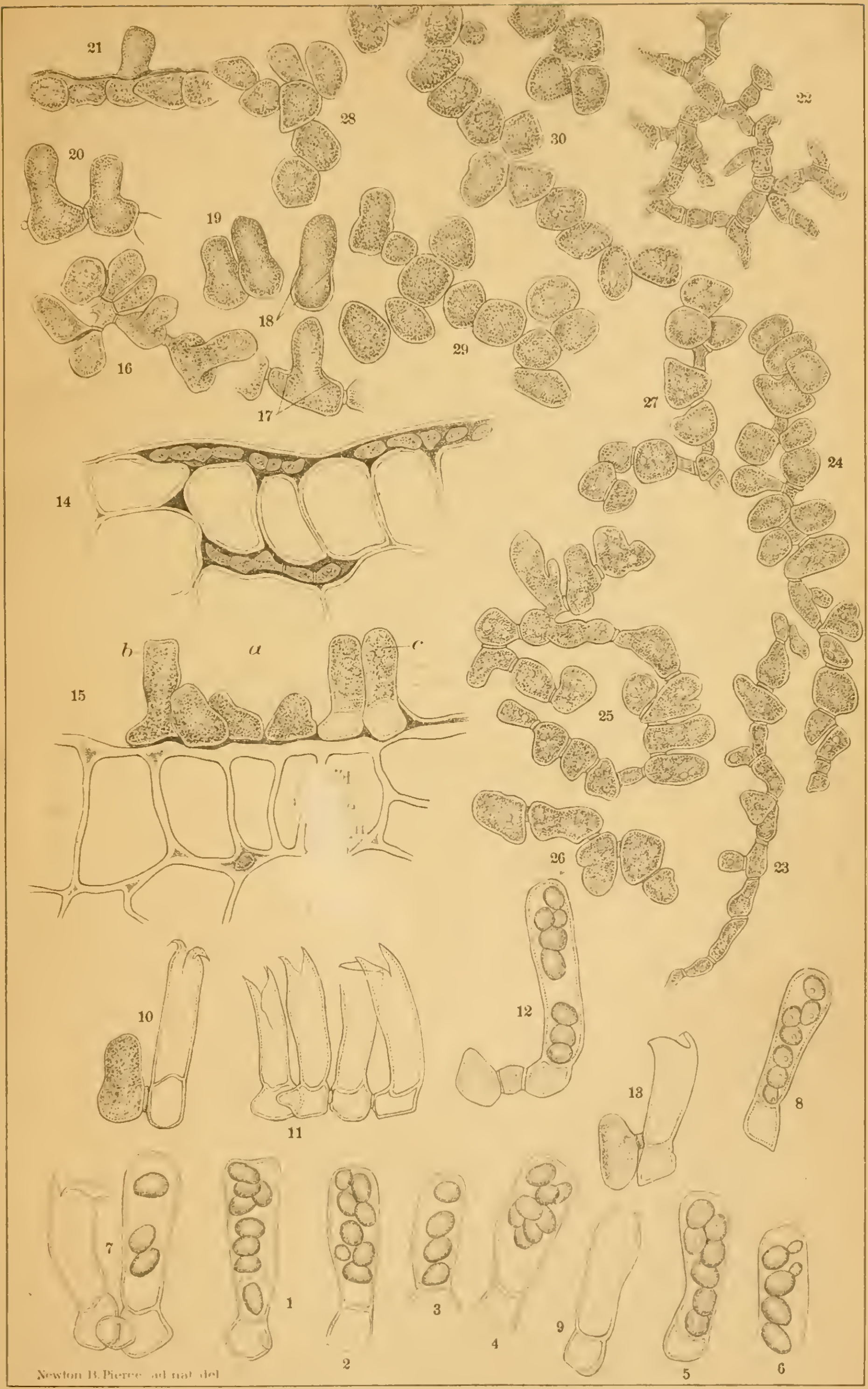
The distributive hyphæ are shown in Pl. II, figs. 3, 4, and 5. They have been found by the writer in the tissue lying close beneath the epidermal cells of diseased peach twigs, and in great abundance in the pith. They are occasionally found in groups of several hyphæ but slightly separated from each other and following a course parallel to the longitudinal axis of the shoot. The cells composing these hyphæ are much longer than either the vegetative or the fruiting forms, while they are nearly straight and of more uniform diameter. The septa are characteristic of those found in the other forms of the mycelium of this fungus. Such distributive hyphæ have been followed for some little distance in the swollen portions of the peach twig, and the name has been given them from their apparent function of spreading the fungus in the branch. Such hyphæ branch by bifurcation, the branches commonly assuming a course parallel to the parent hypha and the direction of the peach limb.

The fruiting hyphæ have been seen to arise in *Exoascus deformans* from the vegetative hyphæ after the latter have become well developed in the parenchyma of the leaf. Large, well-nourished vegetative hyphæ commonly develop just below the epidermal cells of the upper leaf surface.[1] From these hyphæ arise branches which penetrate between the cells of the epidermis, and press themselves between the epidermis and the cuticle. Such hyphæ may be seen both in section and surface view. These subcuticular hyphæ now branch freely, and follow with more or less regularity the triangular space formed by the juncture of two adjoining and somewhat rounded epidermal cells with the cuticle. This is presumably the line of least resistance to the advance of the hyphæ. By opening and following these channels the mycelium assumes the outlines of a quite uniform network beneath the cuticle. While this manner of following the line of juncture of adjoining epidermal cells with the cuticle is common, it is not invariably the practice of the fungus, cases occurring where apparently no such agreement exists. Series of straight and parallel hyphæ, at regular distances apart, are sometimes met with beneath the cuticle as the precursors of the hymenial layer. These send off lateral branches on either side, which by enlarging, branching, and curving eventually occupy most of the surface of the epidermis between the main hyphæ. It is probable that the path followed by the first subcuticular hyphæ depends largely upon the firmness with which the cuticle is attached to the epidermal cells, and which may largely depend upon the amount of water in the tissues and upon the age and rapidity of their growth. With the leaf tissues full of water and making a rapid growth, the hyphæ could naturally pursue a more direct course beneath the cuticle than under contrary conditions. After the establishment of a much-branched filamentous network of subcuticular hyphæ, the cells of which are usually slender, of medium length, thin-walled, and of comparatively uniform diameter (Pl. II, fig. 6), these cells begin to distend, and are shortened by the formation of new transverse septa (Pl. II, fig. 7, and Pl. III, fig. 22). About this time all septa become much more distinct. At a later stage the cells become still more distended and subspherical (Pl. II, fig. 8). As these enlarged cells

[1] Miss E. L. Knowles (Bot. Gaz., Vol. XII, No. 9, p. 217) has called attention to the fact that Winter's statement that "the asci break through the lower side of the leaf" does not hold good for the peach (Kryp. Flora, Asco., p. 6, and Krank. Kultur-Gewächse, Leipzig, 1878, p. 47). Winter is not alone in stating that the asci of *E. deformans* arise on the under surface of the leaves. Robinson says: "The asci are borne on both sides of the leaf, but in greater numbers upon the lower surface" (Robinson, B. L., Notes on the Genus Taphrina, Ann. Bot., Nov., 1887, Vol. I, No. 11, p. 168). Atkinson also says: "The asci are developed on both surfaces of the leaf" (Atkinson, Geo. F., Leaf Curl and Plum Pockets, Cornell Agr. Exp. Sta. Bull. No. 73, 1894, p. 325). These and other like statements have probably arisen from a study of other foliage than that of the peach, and of other species of *Exoascus*, and qave been perpetuated through insufficient reference to nature.

DESCRIPTION OF PLATE III.

Fruiting stages of *Exoascus deformans*. Figs. 1 to 13 (600/1), various stages and conditions of the asci and ascospores of the fungus. Fig. 14, section of peach leaf, showing subepidermal and subcuticular mycelium, the latter already partially differentiated into ascogenous cells. Fig. 15, section of peach leaf showing three successive stages in the formation of the asci from the ascogenous cells: *a*, the pushing of the ascogenous cells; *b*, the ascus nearly full-formed, but with the contents still connected with the ascogenous cell; *c*, the asci separated by a septum from the ascogenous cell, which now forms the stalk cell of the ascus. Figs. 16 to 20 (600/1), the first stages in the formation of the asci from the ascogenous cells, the latter being ruptured above and the asci pushing upward. [illegible] 21, the pushing of a forming ascus through the leaf cuticle (600/1). Figs. 22 [illegible] (600/1), various stages in the formation of ascogenous cells from subcuticular [illegible]um. (For several early stages in this process see Pl. II, figs. 6 to 9). Figs. 28 [illegible] (600/1) show fully developed ascogenous cells as seen from above.



FRUITING STAGES OF EXOASCUS DEFORMANS.

A Hoen & Co. Lith. Baltimore

spread out between the epidermal cells of the leaf and the cuticle they are much distorted, curved, and lobed, the branches and lobes eventually filling, in a quite uniform and continuous manner, the entire space between the elevated cuticle and epidermis, so that a more or less perfect and continuous hymenial layer of ascogenous cells is formed (Pl. II, fig. 9; Pl. III, figs. 23, 24, 25, 26, and 27). At this time the cells become well rounded and heavy-walled, and they may or may not become loosened and separated from each other (Pl. III, figs. 28–30). These are now the fully developed ascogenous cells of the hymenium, and they are fully stored with nutritive materials for the development of the asci. In their compact, continuous, and rounded condition they resemble, when viewed from the surface, the stones in the pavement of an old Roman highway.

The various phases of the development of the hymenium of ascogenous cells may often be observed at one time in a single infected leaf. The center of a swollen spot frequently shows the fully developed hymenium, while at the margin of the spot the first filamentous hyphæ are just spreading beneath the cuticle. In such instances nearly all stages in the development of the ascogenous cells may be studied in a single well-prepared specimen. The development of a subcuticular hymenium has been observed in the petiole as well as in the blade of the leaf.

The formation of the asci from the fully developed ascogenous cells has been carefully followed in the study of a large number of preparations. Thus far no sexual phenomena have been observed in connection with the formation of the ascogenous cells or with the development of the asci. As already said, the walls of the ascogenous cells are heavy. The early steps in the development of the asci from these cells (the development of a papilla-like elevation on the upper surface of the cells) cause the rupture or dissolution of the heavy wall where the elevation occurs. The phenomenon is that of the germination of a heavy-walled spore, or, perhaps, more properly, the outgrowth or prolongation of an endospore through the rupture of the epispore (Pl. III, figs. 17, 18, etc.). The fact to be noted is the perfect resting condition into which the ascogenous cells may pass before the development of the ascus, as shown by the marked delimitation between the thin wall of the forming ascus and the heavy wall of the ascogenous cell. The entire isolation of single ascogenous cells or groups of cells from all sources of vegetative supply indicates that the ascus is entirely dependent for its nourishment upon the stored materials of the cell from which it arises. The pushing of the ascus after the complete development of the ascogenous cell instead of in direct continuation of the development of the latter, also points to a probable cessation and renewal of the reproductive activity of the ascogenous cell.

In view of these facts, it seems possible that the ascogenous cells may be capable of enduring, under especially favorable conditions, a resting period of considerable time. Such resting ascogenous cells have been sought for upon the swollen branches of the peach, however, without success. Further research along this line is desirable. As the fungus is already known to fruit upon the blade and petiole of the leaf and upon the blossom, and a vegetative mycelium is found growing thriftily in the swollen branches, there seems to be no good reason why the parasite may not fruit upon the infected twigs.

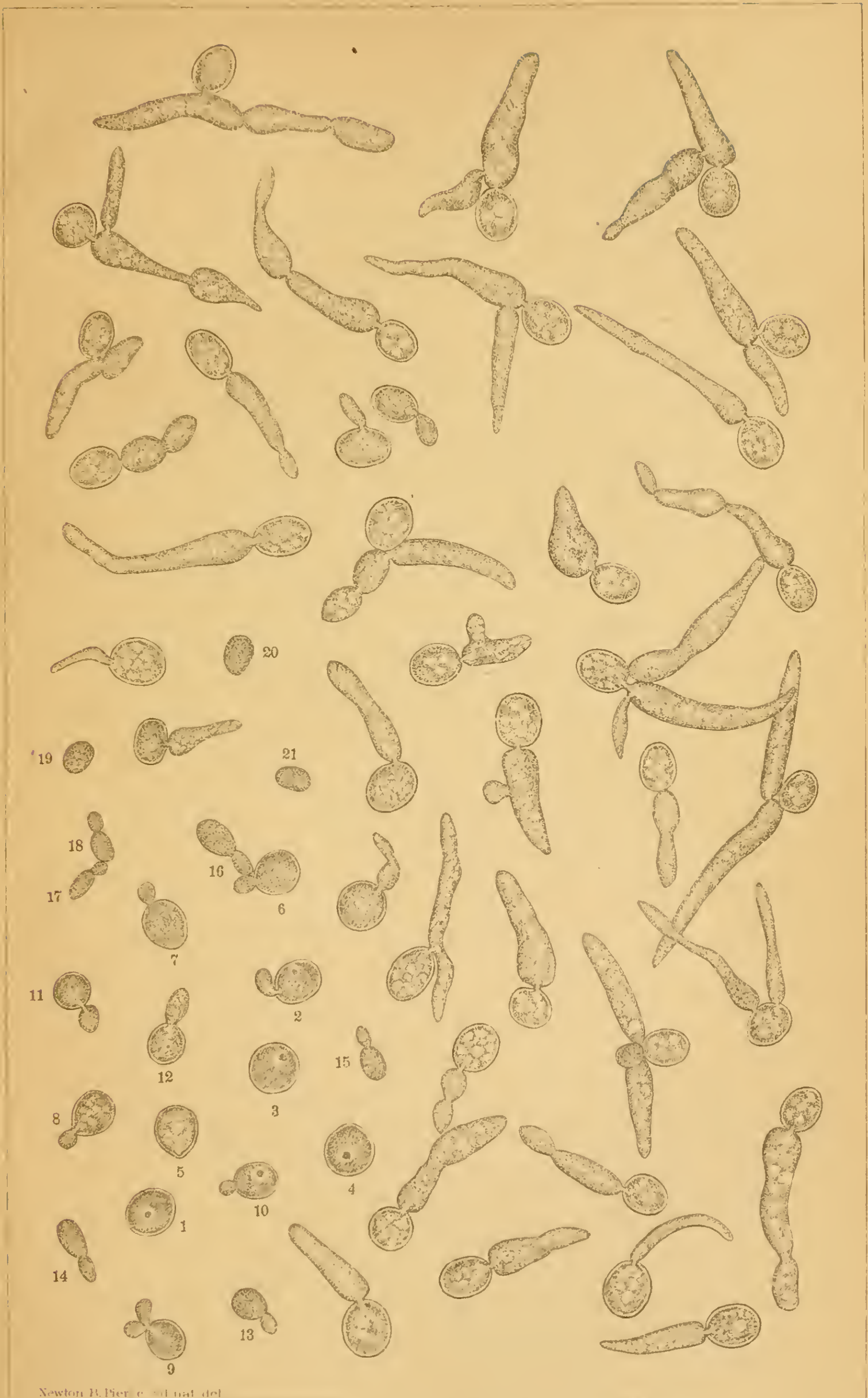
The perpendicular growth of the developing asci in the leaf soon ruptures or pierces the cuticle, and where large numbers of asci develop at the same time the cuticle is lifted, torn, and lost, the asci forming a more or less continuous plush-like surface growth. Isolated asci press through the cuticle so as to form separate perforations (Pl. III, fig. 21). The contents of the forming ascus are finely granular, and as the ascus elongates these contents crowd into the upper portion and a septum is formed across the basal part in such a manner as to cut off the now emptied ascogenous cell as a stalk cell for the ascus (Pl. III, fig. 15). When fully developed the asci are usually broader at the top than at the base, and often somewhat clavate in form. A series of asci measured varied in length from 34 to 44 μ, the average being 38 μ; the width of the asci ranged from 10 to 12 μ, and the height of the stalk cells varied from 8 to 13 μ, the average being slightly over 10 μ (Pl. III, figs. 1–13).

The formation of the ascospores in *Exoascus deformans* has not been carefully studied by the writer. Sadebeck has shown, however, for *E. turgidus*, that mitotic nuclear division occurs in the ascus in connection with spore formation (Untersuch. über die Pilzgattung Exoascus, Hamburg, 1884, Pl. III, fig. 20). The ascospores developed in the asci of *E. deformans* vary in number from 3 to 8, the latter being the full and typical number. When mature they are surrounded by a moderately firm cellulose wall, which is rather inconspicuous, owing to its transparency. The spores are usually somewhat oval in form, being longer than broad, but occasionally some are seen which appear nearly or quite spherical. Fresh ascospores sometimes show distinct nuclear phenomena. This has been observed with spores still within the ascus, as well as in many which have escaped. The nucleated appearance seems less common in budding or germinating ascospores than in those in a resting condition (Pl. IV, figs. 1, 2, 3, 4, and 10). The average length of the ascospores measured was $7\frac{9}{11}$ μ, the length varying from 6 to 9 μ, and the average width was $6\frac{3}{10}$ μ, varying from 5 to 7 μ. The ascospores escape from the ascus through an apical rupture of the latter.

Germination of the ascospores has been observed by the writer to proceed in two ways: (1) By means of budding or conidia formation; (2) by means of stocky germ tubes, often one branched and resembling promycelia.

DESCRIPTION OF PLATE IV.

Germination of the ascospores and conidia of *Exoascus deformans*. Figs. 1 to 12 (about 800/1), ascospores, of which five show nuclear phenomena and several are budding. Figs. 13 to 21 (800/1), thin-walled conidia, several of which are producing buds; the remaining spores, unnumbered, show various modes of promycelium formation or mycelial germination.



GERMINATION OF THE SPORES OF EXOASCUS DEFORMANS.

A. Hoen & Co. Lith. Baltimore.

Budding of the ascospores occurs either before or after the escape of the spores from the ascus. In the formation of the bud conidia the process may take place from the ascospore direct, one conidium after another being produced, or the contents of the ascospore may pass into a thin-walled conidium nearly or quite equal in size to the ascospore, this large conidium then assuming the function of bud production. Ordinarily the ascospore buds at one point only, but bud formation at two points has been seen. Budding occurs most commonly at one end of the ascospore, but occasionally lateral buds are observed. In the early stages of budding the ascospore sometimes shows a nipple-like swelling at one end, reminding one of the germinating end of the sporangium in the *Peronosporeæ*. The successive primary conidia budding from an ascospore may become loosened and turned to one side by the following conidium, which swells from the same germ pore of the ascospore. In other cases several conidia may remain united with each other, but when this condition is observed it is frequently the result of the secondary or tertiary budding of the primary conidium, several orders or generations of buds remaining united. When the process of primary conidial budding can no longer take place the empty ascospore may or may not become separated from the last primary conidium. With the exception of the case above referred to, the different orders or series of conidia (primary, secondary, tertiary, etc.) when grown in pure water, are each smaller than the preceding, and the conidia are considerably elongated in form, sometimes almost cylindrical. The walls of the conidia are more delicate than those of the parent spore. In a suitable nourishing fluid, as the extract of malt, the conidia take up nourishment and increase in size, thus enabling them to continue the budding process for considerable periods of time, as in the yeasts (Saccharomyces). Whether the conidia of *Exoascus deformans* are able to induce an alcoholic fermentation through their growth in saccharine culture media is not known, but Sadebeck states that the conidia of other species of this genus certainly possess this fermenting power.

The second method of germination of the ascospore of *Exoascus deformans*, that is, the pushing of germ tubes, is rarely met with except upon the host plant itself. Such mode of germination is shown in Pl. IV. The germ tube produced from the ascospore is usually much swollen near the spore and tapers considerably toward the extremity, though not infrequently considerable constrictions occur at one or more points in its course. It seems probable that this tube is in many cases capable of directly infecting the host, probably through a stoma, as observed by Sadebeck in *Exoascus tosquinetii*, and that its function is not wholly the abjointing of sporidia. Such separation of sporidia, in fact, has not thus far been observed. The germ tube, or promycelium, is connected with the spore by a very narrow and short tube, with straight and parallel walls. The same mode of connection is also observable in the formation of the bud conidia, and reminds one of the sterigmata bearing the sporangia of *Phytophthora infestans*.

Thus far efforts to induce filamentous germination of the bud conidia or of the ascospores of *Exoascus deformans* in culture media have proved unsuccessful. Brefeld has worked with this problem for months, and the writer has frequently attempted to obtain this form of germination.[1] Budding occurs, as already indicated, quite readily in various nutrient solutions, and short promycelia from the ascospores have been found in some cultures. In nearly if not all cases, however, the ascospores showing promycelia or short mycelial germination have shown that this germination occurred under natural conditions upon the peach leaf, the germinated spores being transferred from the leaf to the culture in preparing the latter. It may be added here that the bud conidia are also formed in vast numbers upon the surface of the infested leaf after the maturing of the ascospores. It is largely these conidia which give the infested leaf the marked white appearance commonly observed at the height of the disease. The leaf appears as if covered with flour or a heavy white bloom.

RELATIONS OF THE FUNGUS TO THE HOST.

Under a previous heading in this chapter the physical conditions which influence the serious development of peach leaf curl have been considered in accordance with the light which we now have relative to such influences, and there remain to be taken up at this time the more intimate and direct relations of the host and parasite. These relations include the action of the fungus upon the cell contents, the cell walls, and the cellular tissues of the host; the probable mode of infection and the spread of the parasite within the tissues; the wintering of the fungus upon the tree; etc.

---

[1] A very considerable number of cultural experiments have been tried. The cultures of ascospores and conidia have been subjected to temperatures much below the freezing point and to various degrees of heat in the thermostat. Sudden changes of temperature have been tried. Increased and diminished amounts of oxygen, as contrasted with that of the normal atmosphere, have been tested. Even a chamber filled with nearly pure oxygen has produced no apparent effect. Water from various sources, such as rain water, dew, ice water, distilled water, tap water, etc., has been tested. Solutions of the various sugars, malt extract, sterilized beer, plum extract, etc., were tried. Hanging drop cultures of various nutrient media and plate cultures of potato-peptone-sugar gelatin have not shown germination. Drops of various nutrient solutions placed upon newly forming leaves dissected from unopened peach buds and these held in moist chambers have given only negative results. The same is true for peach pits brought near to germination and the cotyledons treated with a weak solution of diastase, the spores placed between them and held at various temperatures in moist chambers. Sections of such cotyledons with spores placed upon them were also prepared in moist chambers. A brief treatment of the spores with ether was tested without bringing about germination.

Prillieux states that attempts to artificially infect the leaves or shoots have not thus far succeeded (Mal. d. Plantes Agr., Vol. I, p. 399).

As already indicated, the writer's work with sprays seemed to show that not more than a small percentage of each year's infections ordinarily arise from a perennial mycelium. In the Lovell orchard, where the personally conducted work was carried out, it would appear that not to exceed 2 to 3 per cent of the infections could have arisen from that cause. On the other hand it would seem that at least 95 per cent of the infections arose from spores, for, as already stated, 95 to 98 per cent of the spring infections could be prevented by a single spraying, and this was actually accomplished where the spraying was done with sufficient thoroughness. It is believed by the writer, however, that these percentages will vary within moderate limits in different localities, with different varieties, and in different seasons. The following observations will explain these views.

The mycelium of diseased leaves is found to be connected through the leaf petiole with the mycelium of the infected limb. From the writings of Sadebeck and many others it might be supposed that the leaves were infected from the perennial mycelium in a majority of cases, and that the mycelium met with in the petiole of the leaf originated from the perennial mycelium of the branch. That such spring infection really occurs from the wintering mycelium of the branch should perhaps be admitted, but that such is the common mode of infection of the leaves is certainly doubtful. The writer's studies have shown that the mycelium in the branch close to a cluster of infected leaves diminishes in amount as it passes upward or downward in the branch from such leaves. This fact is as obvious from microscopic studies of the infested tissues as from the external hypertrophies observable to the eye. A macroscopic examination of diseased and swollen branches will show that the enlarged parts may extend upward or downward along the branch from the base of the petioles of the leaves, which seem to represent the center of infection. In a majority of cases these swollen ridges terminate before reaching another leaf bud, though in some instances they are seen to extend along the branch throughout the entire length of one or more internodes, and in such cases it is fair to suppose that the mycelium may have infected the young leaves of a second or third bud in its course. It should be remembered, however, that this mycelium, in a great majority of instances, indicates no connection with a previous year's mycelial growth, but has evidently just entered the branch from one or more infected leaves. The microscopic evidence supports these conclusions, which are, to some extent, in harmony with Benton's observations, to be hereinafter considered, but the writer is scarcely prepared to admit the large percentage of spring infections arising from new mycelium entering the branch which the observations of that writer seem to imply.[1] The microscope shows that the hyphæ which pass away from

[1] Pacific Rural Press, Aug. 2, 1890, p. 88.

the base of the leaf petiole gradually decrease in numbers as they recede from the leaves, and they appear to be wholly lost at a short distance from the point of entrance into the shoot. As a rule, little or no mycelium has been found extending more than 1 or 2 inches beyond a point where external macroscopic evidence of disease exists.

The preceding facts lead to the belief that where mycelial infection of foliage takes place from the branch it is usually done in the spring from hyphæ arising from spore-infected leaves of the same season, and that this occurs only in comparatively few instances or in bad cases of disease. They also indicate that living perennial mycelium which succeeds in accomplishing spring infection, is comparatively rare. Badly infested and swollen branches are apt to die and dry out, thus affording no living tissue for the support of the infesting mycelium. Such branches, even if living until the following spring, are not apt to produce much growth, and frequently produce none whatever. Furthermore, the badly swollen mycelium-infested branches are comparatively few, and it is believed that the infested winter buds of these branches very rarely exceed 2 to 3 per cent of the total number of buds upon the tree. Most branches appear to suffer from the disease only in an indirect manner, that is, by the fall of affected foliage. It seems probable to the writer, therefore, that the swollen branches, in which the swelling is apparent to the eye, constitute the true and almost exclusive home of the perennial mycelium, and therefore supply the only possible source of spring infection by the wintering hyphæ, and consequently the only source of infection not controllable by sprays. This is in harmony with the results of widespread orchard treatment. All but 2 to 3 per cent of infections have been prevented by a single spraying. (See the results of work on half-sprayed trees.) That such spraying did not prevent the spread of the mycelium in the inner tissues of the host is shown by the fact that when it is delayed until the leaves have fairly started and have become infested, the treatment is ineffective and the disease will continue to develop and both foliage and crop may be lost. It is not the checking of the spread of the mycelium from the branch to the new leaves, therefore, that results from spraying, but the prevention of the early spore infections from without; and as all but 2 to 3 per cent of the year's infections may be thus prevented, all of such infections must be considered as arising from spores.

The limitation of the perennial mycelium of *Exoascus deformans* to the swollen branches or branch parts, as here held, is in harmony with observed facts respecting other species of *Exoasceæ*. It is not understood, for instance, that trees developing witches' brooms are infested in all their branches, but that the branch-infesting mycelium is limited in its distribution to those centers which develop the abnormal multiplication of shoots, the swellings and other external manifestations of disease. (See Pls. I, V, and VI, and descriptions, in connection with

DESCRIPTION OF PLATE V.

Terminal peach twigs badly affected by curl. The mycelium of the fungus has entered the growing end of these shoots, and the conditions being favorable, it has developed to such an extent as to prevent further elongation of the twig, thus forming a compact head, with greatly shortened internodes. It is in shoots of this character that the mycelium is found, and its extent is nearly coincident, so far as observed, with the swollen portions of the branch. Such swollen branches constitute a striking feature of the disease, but rarely involve more than 2 to 3 per cent of the buds of a tree. Specimens were collected at Santa Ana in the spring of 1899 and photographed natural size. (Compare with Pls. I and VI.)

PEACH TWIGS AND LEAVES AFFECTED BY CURL.

The distributive mycelium of the fungus is found in such swollen branches.

DESCRIPTION OF PLATE VI.

Sprayed and unsprayed branches of Lovell peach trees in the experiment block at Biggs, as they appeared in 1895. The sprayed branches at the left show the large amount of fruit and healthy foliage on the sprayed trees; the unsprayed branches at the right have lost most of their foliage and all the fruit from curl. These unsprayed branches show the typical and common effects of curl. Hypertrophy of the branch is not shown, and it is probable that these branches carry little if any perennial mycelium. Thorough winter treatment of such branches with proper fungicides will prevent 98 per cent of the spring infections and conduce to the development of foliage and fruit, as shown on the branches at the left. All these trees were equally infected by the fungus in 1893, when the orchard suffered severely from curl, and had the branches at the left not been sprayed before the leaf buds opened in the spring of 1895, they would have been in the same condition as those at the right of the plate. (Compare with Pls. I, V, and VII.)

TREATED AND UNTREATED PEACH BRANCHES.

At the right is shown the usual defoliating action of curl without hypertrophy of the branch; branches at left were treated.

the present remarks on infested and noninfested branches.) It seems probable, therefore, (1) that most of the spring infections of the peach occur from spores which have wintered on the tree and about the newly formed buds; (2) that most of the infected leaves fall off without infecting the branch which bears them; (3) that the mycelium of badly diseased leaves sometimes infects the branch through the leaf petiole; (4) that such mycelium after entering the branch may pass upward or downward, and in some instances may follow the branch for the length of one or at most a few internodes, and possibly infect one or two adjoining buds; (5) that badly infested branches usually die during the year; while in comparatively few instances they may support a living mycelium capable of inducing spring infection of opening buds; (6) that most infected branches show by external hypertrophy the presence of the parasite, which may commonly be removed by pruning off the hypertrophied parts at a point a few inches below the swelling; (7) that seasons, atmospheric conditions, localities, and varieties may have a limited bearing on the extension of the mycelium in the branch and upon the amount of mycelium wintering in an active state, although the results of spraying in many parts of the country, continued for several years, have shown the variation in these respects to be confined within comparatively narrow limits.

The direct infection of the peach leaf by means of the spores of *Exoascus deformans* has not been seen. The efforts made to observe the germination and penetration of the fungus have already been touched upon. One thing seems certain, viz. that under ordinary conditions this form of infection occurs at a very early period in the development of the leaf, but evidently not before the opening of the leaf buds. Very young leaves are found to be already infected, but spraying just before the buds expand will prevent this infection, i. e., infection may be prevented by the treatment of closed buds, which would scarcely be true if a perennial mycelium were within. If we may judge by analogy, the germ tube of the fungus enters the leaf through a stoma. Sadebeck reports that such was his observation in *Exoascus tosquinetii*, in which species the germ tube creeps for a short distance on the leaf surface, and then enters a stoma, much as in the germination of the conidium of *Phytophthora omnivora*.

The major portion of the spring infection of foliage occurs while the latter is young and tender, but it is observed that new infections may take place for a considerable time if the various influencing conditions continue favorable to the fungus. These conditions act chiefly in suddenly retarding the transpiration of the host, and some of them have already been discussed. On the other hand, a short period of spore infection may be expected when external influences are such that transpiration is rapid and normal. The longer or shorter course of the disease in spring may be said to depend largely, therefore, upon the greater or less susceptibility of the tissues of the host, mostly resulting from atmospheric influences. The injury which the fungus may do after infection is also dependent, where development of the fungus has not progressed too far, upon a very nice balance of the atmospheric conditions. Newly infected leaves may be greatly distorted and fall at an early date, or they may be only slightly injured by the fungus, according to the atmospheric conditions prevailing and their influence toward softening or hardening the tissues and moistening the intercellular spaces of the host. A few days favorable to the drying and toughening of the parenchyma of the infested leaf may entirely check the spread of the fungus. The action of the mycelium of *E. deformans* upon the tissues of the leaf and branch of the peach has been widely remarked. The hypertrophies of peach branches, due to this parasite, are as striking and characteristic as are the witches' brooms caused on other hosts by various *Exoasceæ*. In the case of the peach, however, there is rarely if ever any increase noted in the number of shoots, as upon the cherry, the hypertrophy manifesting itself in enlargements and twistings of the infested branch. There is often a great reduction in the length of the infested portion of the shoot and a shortening of the internodes, so that the approximated and enlarged leaves give a tufted or plumed appearance to the shoot. An examination of transverse sections of such enlarged shoots shows that the enlargement is due to a great increase in the number of cells of the cortical parenchyma, and frequently an entire separation of such cells into a network or series of chainlike cells. The structure of the infested parenchyma is altered, the cells being enlarged and much more angular than normally, while the thickness of the tissue from the bast fibers to the epidermis is frequently eight or ten times as great as usual. The parenchyma cells lose the chlorophyll and all matter which the eye can detect, becoming quite transparent. The cell walls vary much more in thickness than normally, some of them being heavier and others lighter than in healthy cells. Transverse and longitudinal sections of swollen peach twigs show that the pith cells are greatly injured along the course of the infesting mycelium. The location of the mycelium may often be detected by treating transverse sections with Bismark brown, the infested medullary tissue taking less stain than that not harboring the fungus. The walls of the healthy cells of the medulla become reddish brown, while those of the infested tissue assume scarcely more than a light yellow or yellowish brown. The cells of the infested tissue are also much more angular and irregular than those in which the mycelium does not exist, while in some instances the cells collapse.

The action of *E. deformans* on the tissues of the peach leaf has been considered by different writers, as Prillieux,[1] Knowles,[2] and others.

---

[1] Prillieux, Ed., Mal. d. Plantes Agr., Vol. II, pp. 394–400; also Bull. de la Soc. Bot. de France, 1872, T. XIX, Comp. Rend. d'Sci., 3, pp. 227–230.

[2] Knowles, Etta L., Bot. Gaz., 1887, Vol. XII, pp. 216–218, with plate.

The badly infested leaves become greatly increased in thickness and breadth and the weight is often much increased above the normal, the tissues become stiffened in a coriaceous or cartilaginous manner, the cell walls become greatly thickened, and the cells become more compressed. The cells of the palisade tissue are increased in size and number, and suffer an entire loss of chlorophyll, as in the case of the cortical parenchyma of the branch. The walls of the epidermal cells become considerably thickened and the multiplication of the parenchyma cells on either side of the midrib causes a pronounced gathering and distortion of these tissues. As the midrib does not elongate in proportion to the increased extent of the parenchyma, it acts as a gathering string passing through the leaf from end to end, and the parenchyma becomes folded upon itself. The increase in the number of cells occurs more extensively among the palisade tissue of the upper half of the leaf than among the cells of the spongy parenchyma of the under leaf surface; hence the majority of badly diseased leaves are convex above and concave below, though this appearance is often lost sight of, owing to the number and variety of folds which the leaf blade assumes.

CHAPTER III.

HISTORY OF THE TREATMENT OF PEACH LEAF CURL.

THE EUROPEAN SITUATION.

That the present outline of the gradual development of methods for the treatment of peach leaf curl in the United States may be properly appreciated, it is desirable to first show the conditions prevailing in Europe as presented by some of the leading European writers on plant diseases. Prillieux, in an interesting paper on peach leaf curl, prepared in 1872, describes the fungus *Exoascus deformans* and its action on the tissues of its host.[1] He states that the fruiting fungus should be looked upon as the center of infection, and that it is desirable to remove the diseased leaves as thoroughly as possible and to destroy them. He also states that this work should be supplemented by the cutting off and burning of diseased branches. In 1878 Winter[2] stated that the only way to prevent this disease is to destroy the fungus by carefully removing the affected leaves, and by protecting the trees from rain during the unfolding of the leaves, as rain favors the spread of the parasite. The same year Felix von Thümen wrote of *Exoascus pruni*, the fungus causing plum pockets and closely related to *Exoascus deformans* of the peach,[3] but made no recommendations for its treatment. In 1885, however, he again spoke of the plum pocket disease and pointed out that it can not be removed except by severe cutting back of the new and old wood of the affected trees.[4] In 1880–81 Frank, in the second volume of the first edition of his work on plant diseases, recommends the cutting back of the twigs as a cure for leaf curl, and the quick removal of the diseased leaves for prevention.[5]

In 1886 the well-known work of Sorauer on plant diseases[6] appeared. The treatment recommended by this author is somewhat similar to that recommended by Frank. He says, in speaking in a general way

[1] Prillieux, Ed., Bull. de la Soc. Bot. de France, 1872, T. XIX, pp. 227–230.

[2] Winter, Dr. Georg, Krankheiten der Kulturgewächse, Leipzig, 1878, p. 47.

[3] Thümen, Felix von, Die Pilze und Pocken auf Wein und Obst, Berlin, 1878, III, Fungi Pomicoli, pp. 88, 89.

[4] Thümen, Felix von, Die bekämpfung der Pilzkrankheiten unserer Kulturgewächse, Vienna, 1886, p. 71.

[5] Frank, Dr. A. B., Die Krankheiten der Pflanzen, Breslau, 1880–81, Theil II, p. 526.

[6] Sorauer, Dr. Paul, Handbuch der Pflanzenkrankheiten, second edition, Theil II, p. 281.

of the *Exoasceæ*, that it has been proved that the mycelium winters over in the youngest parts of the shoots and in the buds, and he recommends the removal of isolated slightly diseased leaves soon after the first appearance of the blister-like swellings. When through the attack of a majority of the leaves of a branch it is shown that the mycelium is already present in the axial organs, it is advised that all of the young wood of the affected branches be cut off. Hartig described peach leaf curl in 1889,[1] and again in the English edition of his work published in 1894,[2] but he leaves the subject without making any suggestions as to treatment. In 1890 Dr. Kirchner published a work on plant diseases,[3] in which he recommends the cutting off of diseased branches for the control of the disease. In 1891, Dr. Comes, in writing of this disease, states that no direct means for combating the parasite exists. He discusses the gathering and burning of diseased and fallen leaves, the cutting back of infected branches, and the application of cultural methods in their influence on the disease.[4] A most excellent work on plant diseases by Dr. Tubeuf appeared in 1895.[5] This writer groups the diseases caused by the *Exoasceæ* among those maladies which should be combated by the removal of the diseased living plants and plant parts (pp. 86, 87). The second edition of Frank's work on plant diseases appeared in 1896, fifteen years after the publication of the first edition, but the same recommendations for the treatment of curl are again made, word for word.[6] In all the preceding works there is no recognition of the methods of treatment being adopted and discussed in the United States and in Australia. The recommendations for cutting away the diseased branches so generally presented are the same as advanced by Ehrenfels nearly a century before for the control of mildew of the peach.[7]

It is hardly necessary to say here what most orchardists have learned by experience, that is, that it is impossible to eliminate the disease by ordinary cutting back of the branches, and that in the orchard it is equally impracticable to prevent the disease by the early removal of the diseased leaves.

About this time the work being done on this disease appears to have attracted the attention of Europeans. In 1894, in his work on vegetable parasites, Berlese recommends for this disease in Italy the use

[1] Hartig, Dr. Robert, Lehrbuch der Baumkrankheiten, Berlin, 1889, pp. 118, 119.

[2] Idem, The Diseases of Trees, London, 1894, pp. 132, 133.

[3] Kirchner, Dr. Oscar, Die Krankheiten und Beschädigungen unserer landwirtschaftlichen Kulturpflanzen, Stuttgart, 1890, p. 324.

[4] Comes, Dr. O., Crittogamia Agraria, Naples, 1891, Vol. I, pp. 167, 168.

[5] Tubeuf, Dr. Karl Freiherr von, Pflanzenkrankheiten durch kryptogame Parasiten verursacht, Berlin, 1895, pp. 86, 87, and 184.

[6] Frank, Dr. A. B., Die Krankheiten der Pflanzen, second edition, Breslau, 1896, Bd. II, pp. 249, 250.

[7] Ehrenfels, J. M. Ritter von, Ueber die Krankheiten und Verletzungen der Frucht- oder Gartenbäume, Breslau, 1795, p. 225.

of Bordeaux mixture in the spring, although he adds, as if doubting its utility, that the mycelium of the parasite winters over under the cortex of the branches.[1]

In France, in 1895, Prillieux published the first volume of a work on plant diseases, devoting several pages to the consideration of peach leaf curl.[2] In this work the recommendations for treatment appearing in his paper in 1872 are not given, but instead it is stated that treatments with the salts of copper seem sometimes to produce good results in preventing the multiplication by spores; but, as in the case of Berlese, he adds, as if in doubt of the value of such treatments, that they are without effect upon the perennial mycelium hidden in the tissues.

By the year 1898 the true idea of the preventive treatment of curl had been grasped in Germany. Professor Weisz, in his paper on plant diseases,[3] published that year, cites the present method of controlling curl. After renewing the older recommendations to cut off and burn the affected twigs, he says that the trees should be sprayed with copper-soda or copper-lime solution (eau celeste or Bordeaux mixture), the first time *before* the buds open. That these recommendations are not the results of work done by Weisz, however, appears probable, for his description of the disease is evidently quoted, as he falls into the error of Winter, Frank, Kirchner, and other writers in stating that the bloom produced by the fruiting of the fungus appears upon the under surface of the leaves. Had he worked upon this disease in the field he would not have been apt to follow the above authors in their erroneous description of the fruiting habits of the parasite.

DEVELOPMENT OF THE PRESENT METHODS OF TREATMENT.

The successful treatment of peach leaf curl dates from the time when fungicides were first applied to dormant peach trees. So far as learned, this treatment was first practiced in California, being introduced by the winter application of sprays for the destruction of the San José scale (*Aspidiotus perniciosus*). This insect was first discovered in the Santa Clara Valley about 1870, but some time had elapsed between the date of its introduction and the use of the stronger winter sprays for its control.

Caustic soda and potash were early tested against this insect, and afterwards sulphur was added, the sulphides of potassium and sodium being used by many growers. Somewhat later whale oil soap and sul-

[1] Berlese, A. N., I Parassiti Vegetali delle Piante Coltivate o Utili, preface dated 1894, pp. 124–126.

[2] Prillieux, Ed., Mal. d. Plantes Agr., Paris, 1895–97, pp. 394–400.

[3] Weisz, J. E., Die schädlichsten Krankheiten unserer Feld-, Obst-, Gemüse- und Garten-Gewächse, München, 1898, p. 45.

phur were combined by boiling, and still later a caustic spray containing lime was tested. All the above chemicals, even the milk of lime, were applied to dormant trees, and they are all known to possess sufficient fungicidal action to control peach leaf curl to a large extent if applied to the trees shortly before they bloom.

While many growers were using these caustic and sulphide sprays, another spray containing much larger quantities of sulphur was being used, and proved of much greater power, both as a fungicide and insecticide. This was a spray containing sulphur and lime, or a sulphide of calcium, and the history of its introduction is of special interest and is inseparable from the early history of the treatment of curl. Mr. Alexander Craw, quarantine officer of the California State Board of Horticulture, has published an account of the introduction of this spray in a recent number of the Pacific Rural Press,[1] but the following facts were gleaned from those who were the first to use and introduce the spray.[2] Mr. A. T. Covell, who first applied this spray to dormant peach trees, near Fresno, Cal., does not supply exact dates relative to the work, but Mr. N. W. Motheral, of Hanford, and Mr. I. H. Thomas, of Visalia, agree in placing its first use as a spray in the year 1880 or 1881. The writer is informed by Mr. Motheral that the lime, sulphur, and salt solution was originally used as a sheep dip in Australia, where it was known as the "Victoria lime-and-sulphur-dip" for scab. He states that it was recommended by a Dr. Rowe, and officially indorsed for a sheep dip in that country. This dip, it is also said, was introduced in California by Mr. Charles Hobler, of Hanford, and Mr. Hobler claims to have first recommended it to Mr. Covell, then living near Fresno, for the treatment of his infested peach trees. Mr. Covell disputes this claim, but holds that he (Covell) first used this solution as a spray upon his trees with success in the control of the San José scale. As soon as this spray was found to be a practical success, Mr. Covell, Mr. Thomas, and Mr. Motheral worked for its general adoption in the treatment of scale. Mr. Thomas states that he sprayed his own orchard the winter after seeing the action of the spray on Mr. Covell's trees, and about this time the facts were given to the press. Mr. Thomas writes that this spray was in general use in and about Visalia as early as 1883, 1884, and 1885, and in Mr. Motheral's section, near Hanford, at the same time. It may here be stated, however, that lime and sulphur had been united by boiling in water and used as early as 1852, at least in hothouses, for controlling the diseases of plants. (See Revue Horticole, 1852, p. 168, and Gardeners' Chronicle, 1852, p. 419.)

---

[1] Pacific Rural Press, July 29, 1899, p. 68.

[2] Letters from I. H. Thomas, Visalia, Cal., Sept. 6, 1899; N. W. Motheral, Hanford, Cal., Sept. 6, 1899; and A. T. Covell, Woodbridge, Cal., Oct. 13, 1899.

It will be seen by the preceding outline that strong fungicidal sprays were in general winter use upon peach trees throughout much of California in the years 1880 to 1885, during which time the peach orchards of many portions of the State were badly affected by curl. In a report by Mr. W. G. Klee, who inspected the orchards in many counties of California from July to September, 1886, it is stated that in Alameda County the cultivation of peaches must be confined to such varieties as are very little subject to leaf curl; in Santa Cruz County, that "peaches, of course, are subject to curly leaf, and can not, as a general thing, be considered profitable;" and that in the Santa Rosa Valley the peach is "of course subject to curly leaf."[1]

As peach leaf curl was quite prevalent throughout California in 1880–85, and as a large number of peach growers treated their dormant trees with fungicidal sprays during that period, it is not strange that they soon learned that the winter sprays prevented curl. Mr. I. H. Thomas, of Visalia, informed the writer[2] that it was about the year 1885 that he noticed that the orchards sprayed with the lime, sulphur, and salt solution were entirely free from leaf curl, while orchards contiguous were affected so badly that all the foliage fell off.

In 1886 Mr. W. G. Klee said,[3] when speaking of an inspection he made of the orchard of Mr. A. Block, of Santa Clara, Cal.: "A treatment of peaches affected with curly leaf attracted my attention. Trees not subjected to this treatment were in very poor condition, while the others, favored with it, were in fine, healthy bearing." Mr. Block says respecting this work[4] that he was making experiments for the destruction of scale insects when he detected a perceptible difference in the amount of curl on the treated and the untreated trees. He thinks this was one or two years before Mr. Klee had seen his trees in 1886. After having noticed the action of the sprays applied for scale in the prevention of curl, he went to work to ascertain what particular ingredient caused the prevention of the fungous disease. These direct experiments, Mr. Block states, were carried out on a row of 23 trees in his orchard. Among the chemicals tested were caustic soda, caustic potash, carbolic acid, tobacco, and sal soda, all more or less combined with whale oil. Among the numerous sprays used, Mr. Block thinks that a strong solution of caustic soda gave the best results. All these sprays were applied while the trees were dormant.[5] The stronger

[1] Klee, W. G., Reports and Papers by the Inspector of Fruit Pests, read at Sacramento, November, 1886, Rept. Cal. State Bd. Hort., 1885–86, pp. 344, 347, 349, 350.

[2] Letter dated Visalia, Cal., Sept. 6, 1899.

[3] L. c., p. 347.

[4] Letters dated Santa Clara, Cal., Sept. 1 and 10, 1899.

[5] It may be noted that whale oil soap was thus used by Mr. Block with success against curl in 1885 and 1886. Prof. L. R. Taft, in a letter dated Agricultural College, Mich., Aug. 31, 1899, says that he had good results in the treatment of curl with limewater, lye, and whale oil soap. (See also records of experiments by the writer with milk of lime, etc.) Mr. F. M. Webster reports satisfactory results with whale

caustic spray recommended by Mr. Block consisted of 1 pound of 98 per cent caustic soda to 6 or 7 gallons of water. The same year, 1886, Mr. Sol. Runyon, of Courtland, Cal., reported that he had met with success in controlling a "blight" of peach trees, the name of the disease not being known to him. This blight had previously caused all the leaves to fall from every tree he had, especially the young ones. He used a caustic spray on the dormant tree, as did Mr. Block, and states that the trees which he treated were not affected by the blight at all, while the untreated trees, right beside the treated ones, were badly affected.[1] There is little doubt that Mr. Runyon was treating curl, as it is a very serious trouble in that section of the State. After the leaves had fallen in the autumn of 1886 and during the winter of 1886–87, Mr. Runyon sprayed many of his peach trees with a spray composed of 2 gallons fish oil, 10 pounds of caustic soda (98 per cent), and 5 pounds of copper sulphate to 100 gallons of water. This spray, as applied, was certainly a preventive of curl, and as a portion of his peach trees were left untreated the contrast should have been marked. Unfortunately, however, I have been unable to get further details of this early work with copper sulphate, as Mr. Runyon is no longer living.[2]

In November, 1888, Mr. W. G. Klee stated at the Chico meeting of the California State Board of Horticulture, that an experienced and successful fruit grower in San José had used successfully for the purpose of killing scale insects, the so-called sal soda and whale oil wash, and that he maintained that ever since he had been using that wash he had been free from leaf curl in his orchard.[3] Mr. Joseph Hale, of Stockton, Cal., reports[4] that he sprayed his peach trees, while dormant, in the years 1888, 1889, and 1890, as well as in subsequent years, and that as a result he sustained no loss from curl during these years. He used the lime, sulphur, and salt spray. Mr. G. W. Ramsey, of Lotus, Cal., states that he began spraying his orchard with lime, sulphur, and salt in 1890 or possibly in 1891. In 1895, in writing of his past spray work, he states that his trees had not been affected in the least by leaf curl since he had been using the above wash. He says: "It completely exterminated the scale the first two years I used it, but I continue to apply it to my trees once a year to prevent leaf curl." He further states that this wash must be applied when the buds are dormant, and that it is generally applied in February in his section.

---

oil soap (South Australian Journal of Agriculture, March, 1899, Vol. II, No. 8, p. 630); see also the results reported by Henry Rofkar and W. V. Latham & Son, of Catawba Island, Ohio, as reported by A. D. Selby, Bull. No. 104, pp. 208, 209, Ohio Agr. Exp. Sta., March, 1899.

[1] Rept. Cal. State Bd. Hort., 1885–86, p. 221.

[2] Ibid., 1887–88, p. 93.

[3] Rept. Cal. State Bd. Hort., 1889, p. 172.

[4] Reply to circular letter of Nov. 25, 1893.

As early as 1890 the effectiveness of lime, sulphur, and salt against curl appears to have been observed in Oregon. Mr. J. D. Whitman, of Medford, Oreg., who was horticultural commissioner for the third district of that State, wrote under date of January 27, 1894, that four years' observation as commissioner had demonstrated beyond a doubt that a spray of lime, sulphur, and salt is an effectual remedy for leaf curl. He states that the application in every instance was made for the purpose of destroying the San José or pernicious scale, and generally on only a portion of the orchard, the other portion showing the curl as usual.

The first practical experiments with copper sprays on dormant trees for the control of curl, after the sprays applied by Mr. Sol. Runyon in 1886 and 1887, were conducted, so far as learned, in the year 1890. The summer use of these sprays had been tested in Australia, and probably elsewhere, for several years, but with slight success in the control of curl.

About the 1st of December, 1889, Mr. L. E. Benton, then of Berkeley, Cal., wrote to the United States Department of Agriculture for information relative to the nature and treatment of curl. These inquiries were answered at length, the literature on *Exoascus deformans* being quite fully cited. No method of controlling this disease was then known at Washington, and as winter spraying had not yet reached its present importance, the recommendations for treatment were necessarily inadequate, and were based upon the then accepted views respecting the strict perennial nature of the mycelium of the fungus, and the consequent difficulty of controlling the parasite by sprays.

After gathering such information as he desired, Mr. Benton instituted a series of spraying experiments in the university orchard at Berkeley in the spring of 1890. The work done by Mr. Benton, although limited in extent, was of the utmost practical importance, as well as of great theoretical interest. A summary of his results was published in August, 1890.[1] Three copper sprays were tested, the ammoniacal copper carbonate, basic copper acetate solution, and Bordeaux mixture. The ammoniacal copper carbonate was applied on February 28, 1890, before the opening of the buds. All three of the sprays mentioned were also tested soon after the leaves started. The results demonstrated that winter treatment of the trees with the salts of copper will effectively control the disease, but that summer treatment will not control it, and also that infection of the spring growth by perennial mycelium was the exception and not the rule with this disease—facts of the utmost practical importance for the orchardist. Mr. Benton's studies likewise led him to the view that the mycelium, passing from infected leaves to the stem, is able to infect new foliage

[1] Pacific Rural Press, Aug. 2, 1890.

by following close behind the growing point of the stem. His observations seemed to point to this young mycelium, resulting from the first spring infections, as the source of the later infections through the branches rather than the perennial mycelium of the previous year. He says that not only does the fungus live in the leaf of the peach, but it at once pushes its way into the young growing stem, following the growing point as fast as it lengthens and passing into the leaves as fast as they appear. On this account he concludes that no external applications can stop such a fungous growth, and spraying after the buds burst and the fungus has become established will have little effect. It may be added that several years' observation in large blocks of trees sprayed after the foliage had started has shown the writer that the disease can not thus be controlled, and that Mr. Benton's conclusions are correct. Whether this failure is due to the causes pointed out by Mr. Benton, however, or simply to the lack of the prevention of the infection by spores, or to both sources of infection, should be given further study. Mr. Benton states that in the spring of 1890, the time his experiments were undertaken, "no remedy was known: since, some practical growers have found successful means of combating it, and these experiments now deserve no further credit than that they were intentional and not a matter of chance." It is now known that curl had been controlled by numerous growers in widely separated regions in California through the use of various sprays many years prior to 1890. Mr. Benton says he was unaware of these facts when he began his work, and his experiments are worthy of full credit, not alone for the enterprise shown in undertaking them, but for the results of unquestioned value to which they led.

In 1891 the copper treatment for peach leaf curl was independently discovered and clearly demonstrated in Australia. The successful results of this work were observed in November and December, 1891, and were published in the South Australian Register of March 30, 1892. At a meeting of the Nuriootpa branch of the South Australian Agricultural Bureau, held in Angaston during November, 1890, the subject of fungous diseases affecting fruit trees was discussed and the appointment of a committee to conduct preventive experiments was considered. At a subsequent meeting Messrs. F. C. Smith, W. Sage, and A. B. Robin were selected for this work. During the interval before spraying, Mr. Smith corresponded with those in charge of the pathological departments in Australia, England, California, and Washington. The report in the South Australian Register says that among the replies received was a series of valuable reports from Professor Galloway, showing that up to 1889 modified eau celeste, ammoniacal copper carbonate, and Bordeaux mixture had proved most successful in the United States. "These were therefore selected by the committee for their experiments." Mr. Smith, of this committee, informed the writer that their work was based largely upon that of Prof. E. S. Goff on Fusicladium.[1]

The spray work was begun in July, before the trees leafed out, the main object being to control apple scab and the shot-hole fungus on the apricot. The sprayed apricot trees belonged to Mr. Trescowthick, and were treated with Bordeaux mixture. In the block was one peach tree, which was sprayed when the apricots were treated. This tree had suffered severely from curl, so much so, in fact, that it had not borne for four or five years, but after spraying it yielded eight cases of fruit of 50 pounds each, or 400 pounds, the curl being almost entirely prevented. Mr. Smith writes, respecting this work, that when applying Bordeaux mixture from July to October, 1891, for the various diseases with which they were coping he had not the slightest idea that this or any of the fungicides would have any effect whatever on curl leaf, and the members of the committee were the more surprised to see its marvelous effects in January and February. "It was the most conclusive of all our tests," it was stated.[2]

The work was continued the following season, and some contrasts obtained on the place of Messrs. Sidney Smith & Son, of Yalumba, are of interest in this connection. In an article published at that time it is stated that the effects of spraying with Bordeaux mixture upon both peaches and apricots were very noticeable. On one side of the fence was seen a healthy set of trees, well clothed with fruit and dark green foliage, and with no curled leaves, while on the other side, where spraying had not been done, was a block of apricots, among which were a few peach trees very badly attacked by leaf curl. At this time the orchard of Mr. A. B. Robin, of Nuriootpa, secretary of the committee for experiments, was inspected by Mr. Molineaux, general secretary of the South Australia Agricultural Bureau, and by several prominent horticulturists, and was found to have a splendid crop of fruit, nearly all the apricot and peach trees having been sprayed. One peach tree had been sprayed on only one side with the Bordeaux mixture, and on this side the foliage was clean and healthy, while on the unsprayed side it was curled. "Here again," says the reporter of this examination, "was absolutely conclusive evidence of the preventive effect of spraying for curl leaf."

In the United States, in 1892, the use of both the sulphur and copper sprays on dormant trees was much more common. The control of curl was a new discovery to several growers who had not heard of the published experiments. Mr. George Woolsey, of Ione, Cal., had been considerably troubled by a shot-hole fungus affecting peach twigs—a common trouble in the northern portion of the State. A bundle of the affected twigs was sent to Professor Woodworth, of Berkeley, who

[1] Letter dated Angaston, South Australia, Feb. 11, 1895.

[2] Letter dated Angaston, South Australia, Apr. 6, 1895.

advised the use of Bordeaux mixture; but as this fungus is active in the spring before the trees leaf out, Mr. Woolsey sprayed the trees while dormant. He says, in relation to his results, that he found Bordeaux mixture corrected the trouble with the twigs, and at the same time acted as a specific for the leaf curl.[1] His work for the control of curl in the following year was strikingly conclusive as to the effectiveness of this spray. Mr. D. W. Sylvester, of Geyserville, Cal., conducted some spraying experiments in 1892 with the direct object of controlling curl. His spray was composed of 12 pounds of copper sulphate and 20 pounds of lime to 100 gallons of water, and was applied to the dormant trees. Mr. Sylvester states that having formed the opinion that the disease was of fungous nature, and knowing of the value of copper sulphate as a fungicide, he determined to test it against curl. He believed better results would be obtained by killing the "germ" than by waiting until the disease appeared, and this, he says, induced him to make the application to the dormant trees. For the experiment he selected a row of 10 trees, spraying 5 and leaving 5 unsprayed for comparison. He states that the 5 sprayed trees held their leaves and fruit and bore a crop, but the others shed every leaf and every peach, and for more than a month looked as if a fire had gone over them. In spite of this experience, Mr. Sylvester neglected to spray in 1893, when, he states, the trees shed all their leaves and nearly all their fruit through curl,[2] and adds that the best time to spray is just as the buds begin to swell. A portion of the peach trees on the Rio Bonito ranch at Biggs, Cal., were sprayed with the lime, sulphur, and salt spray in 1892, the spray being applied to the dormant trees as elsewhere. The contrast that season between the sprayed and unsprayed trees was well marked, the unsprayed trees being much affected by curl, while those treated were practically free from it. These observations were made at the time by Mr. McDonald, the foreman, and by others on the ranch.

The preceding examples could be greatly extended if necessary, as winter spraying was a common practice in California after 1885. By 1892 the San José scale had also become more widely distributed in Oregon, and was being quite generally treated by winter sprays in that State. Mr. A. H. Carson, of Grants Pass, Oreg., began spraying his orchard about this time. In reply to a communication sent to him November 25, 1893, Mr. Carson says that his knowledge as to the lime, sulphur, and salt remedy for leaf curl was gained by observing that trees on which this remedy was used to destroy the San José scale were not affected by curl, although they were varieties much subject to the disease. On the other hand, he states that unsprayed trees, with the same conditions as to exposure, altitude, etc., were badly affected. Mr. J. H. Stewart, of Medford, Oreg., writes that he sprayed his peach

[1] Letter dated Ione, Cal., Aug. 26, 1899.

[2] Letters dated Geyserville, Cal., Nov., 1893, and Sept. 18, 1899.

trees in 1892.[1] He says he used a spray in 1892, 1893, and 1894, which was effectual against scale and most fungi. This spray was composed of lime, sulphur, and sulphate of copper, and was applied in the winter.

In the East, about this time, mildew, brown rot, black spot, rust, and curl were attracting the attention of peach growers and causing serious losses in some sections, and a good many growers were trying summer sprays for the control of one or more of them. Mr. F. P. Herr, of Ridgely, Md., writes[2] that for three successive years prior to 1895 he sprayed with limewater, Bordeaux mixture, and arsenical mixtures, and that everything he used produced absolutely negative results, except the arsenites, which injured both foliage and fruit. It would appear probable from these results that the sprays were applied too late to be effective against curl. Mr. L. B. Geiger, of Hoffman, Pa., writes[3] that he was formerly troubled with leaf curl in his orchard, but has had very little of late years. The reason of this, he thinks, is the fact that he has sprayed his peach trees with Bordeaux mixture several times each year since 1892. He states that at least 75 per cent of the crop of one variety was thus saved. Whether the spray work was done in the winter, or whether, owing to the number of applications made, the summer spray persisted in its action through the following winter, is not known.

It was in 1892 that Prof. L. R. Taft, of the Michigan Agricultural Experiment Station, first obtained the idea that peach leaf curl could be controlled by the application of winter sprays. This gentleman has supplied the leading facts respecting his work.[4] He says: "In 1892 I was making a series of experiments with Bordeaux mixture and solutions of copper sulphate to learn the strength that could be used upon various plants and trees without injury. These materials were applied at different times, the sprayings being at intervals of about four weeks, from April to July, and while some trees received but one application, others were sprayed two, three, and four times. It was noticed, the trees sprayed in April with either copper sulphate or Bordeaux mixture had no curled leaves, while unsprayed trees and those that were not sprayed until June or July were seriously injured by leaf curl.

"From the marked difference in the injury from the leaf curl to the sprayed and unsprayed trees, I felt very confident that the disease could be held in check to a large extent by the use of fungicides, and in writing Bulletin 92, in December, 1892 (published in March, 1893), I make the statement that 'it is quite certain that the disease can be, to some extent, held in check by their use,' in referring to the effect

[1] Letters dated Medford, Oreg., Dec. 14, 1894.
[2] Letter dated Ridgely, Md., Feb. 15, 1895.
[3] Letter dated Hoffman, Pa., Mar. 18, 1895.
[4] Letter dated Agricultural College, Mich., Aug. 31, 1899.

of fungicides in preventing the development of leaf curl on peach trees."

It would seem that the work in Australia, as well as that of the preceding ten years in California, had not come under the notice of Professor Taft at the time of his observations in 1892, and that the same was true at the close of the succeeding year's experiments. In his article on curl, published in the American Agriculturist for February, 1894, he says,[1] in speaking of the treatment of curl prior to his work in 1893: "Although there were some vague suggestions as to the possible value of some of the fungicides as remedies for this disease, nothing was really known until the past season."

May 20, 1893, while working on plant diseases at Yuba City, Cal., in company with Mr. R. C. Kells, then horticultural commissioner of Sutter County, that gentleman told the writer of a peach orchard in the vicinity where peach leaf curl had been controlled by the previous winter's sprays. The orchard was that of Mr. W. H. Campbell, of Yuba City, and was at once examined by the writer in company with Mr. Kells. The trees were of the Orange Cling variety, and had been sprayed with lime, sulphur, and salt up to the base of the smaller branches of the main limbs, for the purpose of killing the San José scale upon the older wood, the spraying of the tops of the trees not being necessary. The result of this treatment was to protect the lower half of the trees from the attack of curl, while the tops were left unprotected. Curl developed seriously in the Sacramento Valley that spring, and as a consequence these trees were badly diseased and stripped of foliage down to the line where the limbs had been sprayed for San José scale. The resulting appearance was most striking, and showed the advantages of spraying in a marked degree. The lower half of the trees was well supplied with normal green foliage, while the upper half was either bare or the leaves present were yellow and badly curled. Photographs of these trees were taken on May 21, 1893.

May 22, 1893, the writer visited the Riviera orchard, at Live Oak, Cal. This orchard is situated on the Feather River bottom and is under the management of Mr. A. D. Cutts, of Live Oak, one of the proprietors. In this orchard was found a most striking case of the prevention of curl by the use of winter sprays. In the winter of 1892–93 one block of trees was thoroughly sprayed for San José scale with lime, sulphur, and salt. After this work was completed the weather became unfavorable for further spraying. The soil was so wet from rains that a 40-acre block of Crawfords Late trees could not be sprayed, and it was so late in the winter before the work could be done that Mr. Cutts feared it might injure the fruit buds if he sprayed the trees entire. He therefore had the trees in this block examined, and rags were tied upon the limbs of those which appeared to most need a thorough

[1] The Curl of the Peach, American Agriculturist, Feb., 1894, pp. 71, 72.

spraying for scale. These marked trees were scattered, here and there one, throughout the entire 40-acre block. In February the marked trees were very thoroughly sprayed over all parts, as much as two gallons of spray being applied to each tree. After this work was completed the entire block, with the exception of the trees already treated, was sprayed as high as the forks of the main limbs, thus avoiding any injury to swelling buds. As before stated, curl developed seriously in the Sacramento Valley in the spring of 1893, and the result was that the unsprayed trees, as well as those sprayed only on the main limbs, were nearly denuded by the disease, while the scattered trees which had been sprayed throughout were in full and vigorous foliage and growth. In the writer's notes upon the examination of this orchard on May 22, 1893, it is stated that the trees fully treated in this block were loaded with fruit and in full leaf, while the trees sprayed only to the forks of the limbs were nearly bare and almost wholly destitute of fruit on the unsprayed parts. Such fruit as was found on the unsprayed branches was inferior in size and quality. It is further stated that the absence of fruit on the untreated branches as compared with the abundant yield of the treated branches gives such a striking contrast as to be almost beyond belief.[1]

Mr. William N. Runyon, of Courtland, Cal., treated a large acreage of peach trees with lime, sulphur, and salt in the winter of 1892–93. He states that the trees sprayed once while dormant were practically free from curl, while trees of the same variety not sprayed were badly affected.[2] He also gives an observation of interest in connection with the habits of the fungus, and one since indorsed by the writer, that is, that the disease "will not spread from an unsprayed to a sprayed tree." In letters from Mr. Runyon[3] relative to this work, he remarks that although he had heard that a mixture of lime, sulphur, and salt was beneficial in controlling curl, he had no idea that the result would be so nearly a complete prevention. He says that it was only when curl leaf had become quite prevalent on unsprayed trees that he noticed its almost total absence on those that had been sprayed. The most striking instance, he states, was where about 50 three year old nectarine trees stood in rows adjoining about a dozen full-grown trees of the same variety that had shown curl for years. The young trees, not having shown any scale, were left unsprayed, and were a mass of curl, while the old trees, which were given the regular treatment, were almost entirely free. In this orchard about 60 acres of peach trees were also sprayed, the work being done about the 1st of

[1] For further notes and tabulated records of some of this work of the spring of 1893 the reader is referred to Chapter VII under Notes on the Auxiliary Experiments in California.

[2] Answer to circular letter of Nov. 25, 1893.

[3] Letters dated Courtland, Cal., Jan. 31, and Mar. 8, 1894.

February, and 40 acres of young trees left unsprayed. In the Santa Clara Valley the sulphur sprays were in general use by the leading growers in 1893. Mr. A. B. Elder, of Santa Clara, writes, in reply to a circular letter of November 25 of that year, that this spray is giving good satisfaction for the control of curl and "is used by large growers of peaches." Mr. John Rock, of Niles, Alameda County, Cal., writes, under date of December 28, 1893, that a mixture of lime, sulphur, and salt is a preventive of curl if applied before the flower buds expand.

Bordeaux mixture was used in the winter of 1892–93, in the Carmel Valley, near Old Monterey, with the express purpose of controlling curl. Mr. Daniel Snively, of Gubserville, Cal., writes[1] that his brother used Bordeaux mixture for the control of this disease, and that its action is "so certain that any twig not touched is sure to curl." Mr. George Woolsey, of Ione, Amador County, Cal., sprayed his orchard with Bordeaux mixture in the winter of 1892–93, for the express purpose of controlling curl, and as a result of his experiments in the winter of 1891–92, to which reference has already been made. Relative to his work in the spring of 1893, Mr. Woolsey says[2] that he sprayed all of his apricot trees, but as time pressed he found that he would not be able to spray all of his peach trees, so he sprayed the most valuable portion, i. e., the young lower growth, and left the top unsprayed. He states that the season of 1893 was damp, and leaf curl very prevalent in his neighbors' orchards, but on his place all the trees and parts of trees sprayed were exempt, all the others being badly affected by curl and the crop on them almost a failure. A healthy growth on the lower sprayed part of the trees, and the branches denuded of foliage on the upper unsprayed part, formed "a most striking object lesson," and, Mr. Woolsey adds, has made him "an enthusiast on Bordeaux mixture." A few demonstrations such as he obtained in the season of 1893, he remarks, would convince the growers of the profitableness of the work.

Many peach orchards were sprayed in Oregon in the winter of 1892–93. A favorite spray was a combination of the sulphur spray with copper sulphate, although the former was used separately by some growers. The object of the combined spray was to unite, as far as possible, the insecticidal qualities of the sulphur spray with the fungicidal qualities of the copper salts.[3] The winter application of ammoniacal copper carbonate was tested in Oregon also, by Mr. M. O. Lownsdale, of Lafayette. In reply to the circular letter dated November 25, 1893, Mr. Lownsdale says he had fair success in preventing curl with lime, sulphur, and salt applied in the winter, followed

[1] Reply to circular letter of Nov. 25, 1893.

[2] Letter dated Ione, Cal., Mar. 26, 1894.

[3] See results of the tests of combined sprays made by the writer, pp. 84, 86, 117, 118.

by three applications of ammoniacal copper carbonate after the appearance of the foliage. He had better success, however, from ammoniacal copper carbonate applied in late winter, before the swelling of the buds, followed by three applications of a weaker solution upon the foliage. "This," he says, "was a complete success."

In Michigan the work in 1893 was very satisfactory. Mr. Charles Youngreen, of Whitehall, sprayed one row of peach trees before they leafed out in the spring. He states[1] that not one of the sprayed trees showed curl, while the unsprayed trees were all affected. The following year he sprayed the entire orchard and not a tree suffered from the disease. At Shelby, Oceana County, several growers sprayed with Bordeaux mixture with good success. Mr. R. Morrill, of Benton Harbor, stated at a meeting of the Michigan Horticultural Society held at Shelby, June 14 and 15, 1893, that he found there, in four or five cases, that men had sprayed peach trees with Bordeaux mixture, and the effect in decrease of leaf curl was plain to be seen.[2] Mr. Morrill fails to state, however, whether the first spraying was done while the trees were dormant. The effects of curl at Shelby at that time were marked, the same gentleman remarking that in one morning he had seen enough damage done by it to pay for spraying all the orchards within five miles.

Professor Taft reports his work in 1893 as follows:[3] "In order to secure definite knowledge upon the subject [treatment of curl], I arranged for a series of experiments, and in the fall of 1892 had a number of peach trees sprayed with a solution of copper sulphate (1 pound in 25 gallons), and in a similar experiment at South Haven Bordeaux mixture was used as soon as the leaves dropped in November, 1892. During the first half of April, 1893, the same trees were again sprayed with similar mixtures, and other trees were treated that had not been sprayed in the fall of 1892. The result was that where fully 50 per cent of the leaves and all of the fruit dropped from the unsprayed trees, there was little injury to the same varieties that were treated in both fall and spring or that were sprayed only once, in April; but where they were not sprayed until after the leaves had come out only a slight benefit was secured. The results were given in Bulletins 103 and 104 of the Station. On June 14, 1893, I gave the results, up to that time, at the meeting of the State Horticultural Society."

The orchards of the Michigan Agricultural Experiment Station at South Haven, in charge of Mr. T. T. Lyon, had suffered severely from curl in 1890, 1891, and 1892.[4] Mr. Lyon says, respecting the spray

---

[1] Letter dated Whitehall, Mich., Sept. 6, 1899.

[2] Rept. Mich. State Hort. Soc., 1893, p. 68.

[3] Letter dated Agricultural College, Mich., Aug. 30, 1899.

[4] See Repts. Mich. Hort. Soc., 1890, p. 144; 1891, p. 228; 1892, pp. 160, 161.

work done in the winter of 1892-93,[1] that as the apparent result of the fall and spring sprayings, there was almost a total absence of leaf curl, although it had usually been quite prevalent there in early spring, and was present in 1893 in neighboring orchards, causing many of the leaves and fruits to drop. He says[2] further, that to him "the effect of the spray upon leaf curl in particular was a revelation." The work of Professor Taft in this orchard in 1893 was reported on several occasions during 1893 and 1894.[3]

The work of the writer began in Michigan by the publication, in the fruit belt of that State, in the latter part of July, 1893, of notices of the work done in California,[4] and of requests for the names of peach growers who had sustained losses from this disease. In August, plans for experiments at Shelby and Ludington were in progress, and in November a circular letter, stating that leaf curl had been successfully prevented in California, was addressed to the peach growers of all the leading peach centers of the country. In this circular it was stated that "It is proposed to carry on during the coming season some work in different parts of the United States." The circular reached many of the leading peach growers of Michigan. During the winter, that of 1893–94, plans for the testing of winter sprays for the control of curl were undertaken by growers, at the request of this Department, at Whitehall, Albion, Ganges, Beulah, Riverside, Benton Harbor, St. Joseph, Kalamazoo, Covert, Hawkhead, South Haven, Ludington, Shelby, Douglas, Millgrove, Custer, Amber, Mears, Hart, Gobleville, Ortonville, Monterey, Fenville, Saugatuck, Allegan, Wayland, Bradley, Peach Belt, etc. During the winter of 1894–95 the above list was greatly extended. Within these two years over 400 Michigan peach growers were sent full instructions for controlling curl. Each grower was requested to make his tests according to an experiment sheet sent him, leaving unsprayed trees for comparison. In this way many striking object lessons were obtained, aiding materially in the early and widespread introduction of the methods of treatment recommended. Reports of a few of these experiments are given in a subsequent chapter.

The Department's tests in Ohio were instituted through a circular letter in November, 1893, announcing to a large number of peach growers in that State the successful treatment of curl in California, and stating that experiments would be undertaken in the East. As a result of replies to this circular, full instructions for controlling curl

---

[1] Mich. Exp. Sta. Bull. No. 104, pub. Feb., 1894, pp. 64, 65.

[2] Letter dated South Haven, Mich., Dec. 16, 1897.

[3] Paper read at Shelby, June 14, 1893, Rept. Mich. Hort. Soc., 1893, pp. 66, 67, and 79; article in Allegan Gazette, July 1, 1893; Mich. Exp. Sta. Bull. No. 104, p. 64; pub. Feb., 1894; American Agriculturist, Feb., 1894, pp. 71, 72.

[4] Ludington (Mich.) Appeal, issue of July 20, 1893, quoted by Shelby Sentinel, etc.

were sent to a number of orchardists in the peach-growing centers of Ohio in the winter of 1893–94. During this and the succeeding winter over fifty orchardists, located in twenty-five different peach-growing centers of the State, received carefully prepared instructions for winter spraying for curl. The instructions for both winters were planned in the usual manner of experimental work, a number of unsprayed or control trees being left for comparison with the trees to be treated with each spray to be tested. The object in thus planning the work was the same as for that in Michigan and elsewhere—that is, to obtain such striking contrasts between sprayed and unsprayed trees that they would form long-remembered object lessons for all who should chance to see them.

The spray work of the Ohio Agricultural Experiment Station after 1890 was quite extensive; but the treatment of peach leaf curl is not mentioned in the bulletins on orchard spraying published by that station in December, 1891, and February, 1893,[1] although in the latter (Bul. No. 48, p. 12) the spraying of peach trees for other diseases is considered. In the spring of 1893, however, Prof. W. J. Green sprayed a considerable number of young peach trees, just planted, the object being "to determine the truthfulness of the statements that had been made concerning the effect of spraying upon peach trees." In relation to curl, Professor Green says that he "did not see any effect until the season of 1894," during which and in 1895 "there was some effect noticeable." He says further, in this connection: "I am aware that other work in this direction had been done before I commenced, because I received my suggestions from some other source, but I can not now recall the particular case." (Letter dated September 30, 1899.)

Upon these results obtained by Professor Green, and supported by the work of Benton in California and Taft in Michigan, were based the subsequent experiments of Prof. A. D. Selby in the orchard of William Miller, of Gypsum, Ohio.[2] These experiments were begun, according to Professor Selby, in April, 1895,[3] but no results with leaf curl were obtained until 1896,[4] as in 1895 there was no difference between sprayed and unsprayed trees in the amount of curl developing, it being so insignificant as to be without evident effect. The curl which developed in 1896 enabled Mr. Selby to obtain some contrasts between sprayed and unsprayed trees, but these contrasts were not as

---

[1]Green, W. J., The Spraying of Orchards, Ohio Agr. Exp. Sta. Bul. No. 9, Dec., 1891, Vol. IV, second series; Bul. No. 48, Feb., 1893, p. 12; and a letter from Professor Green, dated Wooster, Ohio, Sept. 30, 1899.

[2]Letter from Prof. A. D. Selby, dated Wooster, Ohio, Sept. 13, 1899.

[3]L. c.; also Ohio Agr. Exp. Sta. Bul. No. 92, March, 1898, pp. 237–245.

[4]Ohio Agr. Exp. Sta. Bul. No. 92, March, 1898 p. 245; also Thirtieth Ann. Rept. Ohio State Hort. Soc., pp. 87.

marked as they would have been had the disease developed seriously.[1] As it was light in 1895 and 1896, no gain in fruit was shown by sprayed over unsprayed trees these years. In 1897 the work was continued, and owing to the serious development of curl the desired contrasts in foliage were obtained. Unfortunately, however, the fruit buds had been killed by cold and no fruit records were obtainable. The first contrasts in fruit on sprayed and unsprayed trees in Mr. Miller's orchard were reported to Mr. Selby in 1898, and they are both valuable and conclusive.[2]

The announcement of the Department's work on leaf curl was sent to the growers of peaches in Illinois, Indiana, and Pennsylvania at the same time that it was sent into Ohio and other States of the East, viz, in November, 1893; and during the winters of 1893–94 and 1894–95, 135 peach growers in Pennsylvania, 81 in Indiana, and 36 in Illinois were requested to spray for the control of curl and report to the Department. A complete plan for these tests, control trees being provided for in every case, was sent to each of the growers. So far as reported, where instructions were followed, the results of this work were satisfactory in all cases where curl developed and where frost did not prevent the obtaining of results.

Winter spraying for the control of curl began in New York, so far as known to the writer, in the winter of 1893–94, during which and the following winter over seventy peach growers of the State received from the writer full instructions for the treatment. These instructions were sent out through personal correspondence with orchardists in over twenty of the peach-growing centers, and by means of carefully prepared circulars. Among others, Mr. W. T. Mann, of Barkers, undertook spray work for the Department in the winter of 1893–94. Carefully planned experiments were carried out by him in his young orchard, the spraying being done on April 9, and before growth started, and alternate rows being left untreated for comparison. Mr. Mann reported the results of this work as satisfactory, and they are elsewhere given in this bulletin. Mr. James A. Staples, of Marlboro, also conducted spray work for the Department in 1894, 1895, and 1896, and where the instructions were carried out respecting the time of first spraying his results were fully satisfactory. Prof. L. H. Bailey[3] reported the work of Mr. Henry Lutts, of Youngstown, for the spring of 1894; and Mr. A. D. Tripp, of North Ridgeway, reports excellent results from his work.

---

[1] Ohio Agr. Exp. Sta. Bull. No. 92, pp. 246, 247.

[2] Ohio Agr. Exp. Sta. Bull. No. 104, March, 1899, p. 210; also Rept. Ohio State Hort. Soc., 1898, p. 13.

[3] Bailey, L. H., Impressions of the Peach Industry in Western New York, Cornell Agr. Exp. Sta. Bull. No. 74, Oct., 1894, pp. 382, 383.

A bulletin of the Cornell Agricultural Experiment Station, by George F. Atkinson,[1] which appeared in September, 1894, treats of leaf curl and plum pockets. Respecting the treatment of leaf curl, Mr. Atkinson says that some experiments had been made in various places by spraying the trees with Bordeaux mixture for the prevention of the disease. Some of the experimenters regard it as certain, he states, that the disease can to some extent be checked by this method, and adds: "It is quite likely that, in some cases at least, another disease is confused with leaf curl, and this fact might account in those instances for the results claimed." The doubts here expressed as to the results of the work in New York do not appear to have been supported by any field work of the station, and may have arisen from Mr. Atkinson's understanding of the perennial habits of the fungus causing the disease. There seems to have been no winter spraying for curl by the Cornell Station before the spring of 1898, and the results then obtained are in perfect accord with those obtained in 1894 by growers cooperating with the Department. In the spring of 1898 several experiments were instituted and carried out by B. M. Duggar and H. P. Gould. The results of this work are given in a bulletin by Mr. Duggar, published in February, 1899.[2]

The efforts to control peach leaf curl by winter sprays in Canada, so far as concerns the work of the Canadian Government, appear to have begun nearly simultaneously in Ontario and British Columbia.

At the experiment farm at Agassiz, British Columbia, the peach orchard had suffered severely from curl prior to the introduction of winter spraying. The superintendent, Mr. Thomas A. Sharpe, reported for 1892 that of the large number of peach varieties at that time on the farm—about 116—only 5 escaped leaf curl, and the attack was severe.[3] In the report for 1893 it is said that leaf curl was worse that year than ever before. Of about 129 varieties on the farm the Malta was the only variety on the level land that was entirely free.[4] In the spring of 1894 the trees were sprayed with strong Bordeaux mixture when the leaves were partly expanded, but no leaf curl developed that year, even the unsprayed orchards not being troubled by it.[5] It should be stated here, however, that the work done was too late to have given good results had curl developed, and that it did not properly constitute a preventive spraying. Whether this late spraying was owing to the nature of the season, or whether it was supposed that such treatment would control the disease, is not known to the writer.

---

[1] Atkinson, Geo. F., Leaf Curl and Plum Pockets, Cornell Agr. Exp. Sta. Bull. No. 73, Sept., 1894, pp. 324–326.

[2] Duggar, B. M., Peach Leaf Curl, etc., Cornell Agr. Exp. Sta. Bull. No. 164, Feb., 1899, pp. 377–384.

[3] Rept. Exp. Farms, 1892, p. 278.

[4] Rept. Exp. Farms, 1893, pp. 342, 343.

[5] Rept. Exp. Farms, 1894, p. 404.

In 1895 Mr. Sharpe reports that the peach trees at Agassiz were sprayed with Bordeaux mixture before leafing out, and again when the leaves were nearly full grown. He states that the sprayed trees had very little curl, and made a very strong and healthy growth, while on a few unsprayed trees of several varieties the leaves were nearly all destroyed by curl, and the trees themselves made a very feeble growth.[1]

This treatment, so far as known, is the first successful experiment for the control of curl by the Canadian Government. Leaving control trees for comparison added greatly to the value of the work, which was also strengthened by the results at Agassiz the following year, 1896.[2] The writer regrets to add, however, that unfavorable results attended the spray work at Agassiz in 1898.[3] The reasons for this failure are not apparent.

In Ontario the early results were not so satisfactory as at Agassiz, owing to the nondevelopment of the disease in Ontario. Mr. John Craig, horticulturist of the Central Experimental Farm, at Ottawa, planned the Ontario work. He states that the work on peaches in 1894 was planned to prevent the rotting of fruit and injury from insects, and that the first spraying was not given until May 1.[4] Mr. Craig's work on leaf curl began in 1895, by the application of winter sprays,[5] but owing to the absence of the disease that year no conclusive results were obtained. Later work, I am informed by Mr. Craig, has given more conclusive and satisfactory results.[6] The variable results reported in Bulletin No. 1, second series, leads the writer to wonder, however, if the early spray work was done with sufficient thoroughness. Mr. W. M. Orr, of Fruitland, Ontario, met with very convincing and satisfactory results from winter spraying in 1898.[7] The same is true for the experiments of Mr. A. H. Pettit, of Grimsby, Ontario, who carried on work in 1898 and 1899, the results of the latter year, when one row of trees was left untreated for comparison, being very striking.

The work of this Department in extending the use of sprays for the control of curl on the Pacific coast began in the spring of 1893. In the fall of that year a circular letter on the subject was addressed to many Pacific coast growers, and this was closely followed by requests that growers undertake preventive spray work in the winter of

[1] Rept. Exp. Farms, 1895, p. 396.

[2] Rept. Exp. Farms, 1896, p. 449.

[3] Rept. Exp. Farms, 1898, p. 403.

[4] Rept. Exp. Farms, 1894, pp. 110, 111.

[5] Peach Culture in Canada, Bull. No. 1, second series, pp. 35–37; Central Exp. Farm, Dept. of Agr., Ottawa, Canada, Sept., 1898.

[6] Letter dated Ottawa, Oct. 7, 1897.

[7] Canadian Horticulturist, Jan., 1899, pp. 18–20.

1893–94. During the winters of 1893–94 and 1894–95 the writer sent full instructions for preventing curl by winter sprays to over two hundred and seventy California peach growers, and requests to carry on spraying experiments, with similar instructions, to more than one hundred growers in Oregon, and to many in Washington. In all of this work for the extension of spraying an effort was made to introduce it in as large a number of leading peach-growing centers as possible, especially in those sections of the coast where leaf curl had been most prevalent. The results of some of these experiments are given in Chapter VII. and the facts gathered and experiments conducted under the direct charge of the writer in 1893, 1894, and 1895 are detailed in full in other portions of this bulletin, and require no discussion here.

CHAPTER IV.

PLAN OF PREVENTIVE SPRAY WORK CONDUCTED BY THE DEPARTMENT.

PRELIMINARY PLANS FOR THE WORK.

The partial control of peach leaf curl in the spring of 1893, in a few orchards of the Sacramento Valley in which the trees had received a winter spraying for the control of the San José scale (*Aspidiotus perniciosus*), showed to the writer the importance of conducting careful experiments for the prevention of curl. As a foundation for experimental work a circular of inquiry was sent to some 1,500 peach growers of the United States in the fall of 1893. The facts thus obtained were of much value, but the general lack of accurate knowledge respecting both the nature and control of the disease, as well as the heavy losses reported from this cause in different sections of the country, strikingly emphasized the need for widespread and thorough preventive experiments.

After careful consideration it was concluded to inaugurate two series of experiments. The first, which had been planned before the sending out of the circular, was to be conducted in California under the direct supervision of the writer, and the second, planned somewhat similarly, though on a more limited scale, was to be carried out by the growers themselves in various peach-growing sections of the country. The personally conducted work is described here, while the results of the cooperative work are given farther on.

Observation and correspondence had already shown which sections of California were most subject to frequent and serious recurrences of the disease. Facts thus gathered led to the opening of correspondence with Mr. George F. Ditzler, the manager of the Rio Bonito orchard, situated in the Sacramento Valley, in the bottom lands of the Feather River, near Biggs, Cal. This orchard is the property of the Hatch & Rock Orchard Company, and comprises some 1,600 acres, several hundred of which have as fine peach trees as any in the State. Among the varieties of peaches in this orchard is a large acreage of Lovell trees. The Lovell, it was learned, while presenting as thrifty growth as any variety in the orchard during years when curl did not prevail, had been especially subject to it in seasons favorable to its development, the crop of this variety, which would amount to several thousand dollars, having been largely lost in 1893. After a brief correspondence Mr. Ditzler kindly offered to allow the Department to select from the orchards of Lovell peaches a block of several hundred trees of exceptionally uniform and vigorous growth and especially suited to the purposes of the experiments planned, and no finer or more uniform block of trees has ever been seen by the writer than that eventually selected and assigned to this experimental work. It consisted of nearly 600 trees at the southwest corner of a 40-acre block of Lovells, and was nearly level. The soil was sandy loam—deep, rich, and almost uniform in quality. The trees had been set in orchard less than five years, were 25 feet apart each way, and had grown so vigorously that before pruning the branches met between the rows in many cases, thus presenting tops of exceptional size for trees so young.

The experiments planned included a rectangular block of the orchard, 20 trees wide from east to west by 29 trees long from north to south. The tract selected was 500 feet east and west by 725 feet north and south, or nearly 8½ acres in extent. At the south of these Lovells is an almond orchard of the same age; at the west a young apple orchard.

Through the center of the experiment tract, extending from south to north, was planned a driveway, thus dividing the trees into two long rectangular blocks, each block being 10 trees wide from east to west, and 29 trees long from north to south. Each cross row of 10 trees was numbered. The south 10 trees, forming the south east-and-west row on the east side of the driveway, was designated 1; the second row from the south, 2; the third row, 3; etc., the north row on the east of the driveway being row 29. On the west of the driveway the south row was 30, the second row 31, etc., the north row being 58. This arrangement gave 580 trees, divided into 58 rows of 10 trees each, one-half of these, rows 1 to 29, being east of the driveway and the other half, rows 30 to 58, west of the same. This arrangement may be fixed more clearly in the mind by the diagram on page 69.

This diagram, in addition to showing the arrangement of the rows, as already described, is planned to represent and distinguish the rows which were to be treated with sprays from those which were to be left untreated as check or control trees in each experiment. The trees of the rows to be treated are represented by a star (*) and the trees to be left unsprayed are shown by a circle (°), with the exceptions to be noted. It may thus be seen that each row of 10 trees intended for treatment has at its side 10 untreated trees as a check or control row. With the exception of rows 29 and 58 each control row serves for comparison with two sprayed rows, one on either side. This method of contrasting each control row with a sprayed row on either side admitted of the planning of 38 experiments in the block of 58 rows, each experiment comprising 20 trees—10 sprayed and 10 unsprayed, in two immediately adjoining and parallel rows.

After locating and numbering each of the 38 experiments to be tested the block was carefully examined to determine if any of the trees were missing or so injured as not to represent entire trees. The results of this examination are also embodied in the plat. Where trees were missing the fact is shown by a cipher (0) in the place of the

North.

Drive-way.

Row numbers. (West.)	10	9	8	7	6	5	4	3	2	1	10	9	8	7	6	5	4	3	2	1	Row numbers. (East.)
58	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	29
57	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	28
56	*	*	*	*	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	27
55	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	26
54	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	25
§53	*	*	*	*	*	*	*	*	6	*	*	*	*	*	*	*	*	*	*	*	24§
52	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	23
51	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	22
50	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21
49	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	20
48	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	19
47	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	18
46	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	17
45	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	16
44	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	15
43	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	14
42	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	13
41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4	*	*	12
40	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	11
39	*	*	*	*	*	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	10
38	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	9
37	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	8
36	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7
35	*	*	*	*	o	*	+	6	*	*	*	*	*	*	*	*	*	*	*	*	6
34	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	5
33	*	*	*	*	*	8	*	*	*	*	*	*	*	*	*	8	*	*	*	*	4§
32	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3
31	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	5	o	o	o	o	2
30	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1

Tree numbers. Tree numbers.

South.

* Sprayed in 1894 and 1895, except where noted.
○ Unsprayed in 1894 and 1895.
§ Sprayed in 1894 and left unsprayed in 1895.

tree, but it was found that only two trees, both from row 39, were wanting in the block. The cross (+) in row 35 represents a nectarine tree, omitted in results of work. In cases where main limbs had been broken off or the tree otherwise injured, the proportion of the tree remaining is expressed in numerals, i. e., 8 in the place of a tree indicates that the tree was eight-tenths perfect, 5 that it was five-tenths perfect, etc. As will be seen, however, there were very few imperfect trees.

In all the following calculations of fruit, etc., these few discrepancies in the number of trees are carefully taken into account in arriving at results intended for comparison with other rows. The amounts produced by the trees of each row are first divided by the number of trees actually in the row to obtain the average per tree, and this amount is multiplied by 10 to obtain the amount a full row would yield at the given average. By reference to the plat it may be seen that the trees and parts of trees missing amount to but 5.8 equivalent trees for the entire block, that 51 of the 58 rows have the whole complement of 10 perfect trees, and that the missing trees or parts of trees are divided among the remaining 7 rows.

SPRAY WORK CONDUCTED IN 1894.

The spray tests conducted in the Rio Bonito orchard in 1894 included the application of sprays prepared according to 38 different formulæ, making 38 distinct experiments. Each experiment included two adjoining rows of 10 trees each, one sprayed and the other unsprayed for comparison. Of these 38 experiments 11 involved two sprayings of the trees treated and 27 a single treatment. All treatments were made during the dormant period of the trees and varied in date from February 1 to March 6. The consideration of the preparation of sprays for this work will be discussed in a subsequent chapter devoted to that subject, as will also the methods of application, which will be given for use in both small and large orchards.

The table which follows is prepared to show as concisely as possible the arrangements adopted for the experiments of 1894. The rows of trees once treated and those twice treated are shown, the date or dates of treatment and the formula or formulæ used in each case.

TABLE 1.—*Showing the formulæ of the sprays applied in 1894, dates of application, and rows treated.*

Row No.	Date of spraying.	Formulæ for 45 gallons of spray.
1	Feb. 20	15 lbs. sulphur, 30 lbs. lime, 10 lbs. salt.
2	....	Control row.
3	Feb. 24	10 lbs. sulphur, 20 lbs. lime, 7 lbs. salt.
4	Feb. 16 Feb. 28	10 lbs. sulphur, 20 lbs. lime, 7 lbs. salt. 5 lbs. sulphur, 10 lbs. lime, 3 lbs. salt.
5	....	Control row.
6	Feb. 23	5 lbs. sulphur, 10 lbs. lime, 3 lbs. salt.
7	Feb. 24	15 lbs. sulphur, 30 lbs. lime.
8	....	Control row.
9	Feb. 23	10 lbs. sulphur, 20 lbs. lime.
10	Feb. 20 Mar. 3	10 lbs. sulphur, 20 lbs. lime. 5 lbs. sulphur, 10 lbs. lime.
11	....	Control row.
12	Feb. 24	5 lbs. sulphur, 10 lbs. lime.
13	Feb. 13	20 lbs. lime, 20 lbs. salt.
14	....	Control row.
15	Feb. 13	20 lbs. lime.
16	Feb. 26 Mar. 6	45 lbs. salt (hot). 45 lbs. salt (hot).

TABLE 1.—*Showing the formulæ of the sprays applied in 1894, dates of application, and rows treated*—Continued.

Row No.	Date of spraying.	Formulæ for 45 gallons of spray.
17	....	Control row.
18	Feb. 26	3 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime.
19	Feb. 27	2 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime.
20	....	Control row.
21	Feb. 16	5 lbs. copper sulphate, 5 lbs. lime.
	Feb. 20	5 lbs. copper sulphate, 5 lbs. lime.
22	Feb. 21	4 lbs. copper sulphate, 5 lbs. lime.
23	....	Control row.
24	Feb. 6	4 lbs. copper sulphate, 5 lbs. lime.
	Mar. 1	3 lbs. copper sulphate, 5 lbs. lime.
25	Feb. 23	3 lbs. copper sulphate, 5 lbs. lime.
26	....	Control row.
27	Feb. 6	3 lbs. copper sulphate, 2 lbs. lime.
	Mar. 1	2 lbs. copper sulphate, 5 lbs. lime.
28	Feb. 26	2 lbs. copper sulphate, 5 lbs. lime.
29	....	Control row.
30	Feb. 2	2 lbs. copper sulphate, 3 lbs. ammonia.
31	....	Control row.
32	Feb. 2	4 lbs. copper sulphate.
33	...do...	2 lbs. copper sulphate.
	Mar. 2	2 lbs. copper sulphate.
34	....	Control row.
35	Mar. 3	4 lbs. copper sulphate, 5 lbs. soda, 3 lbs. ammonia.
36	Feb. 27	3 lbs. copper sulphate, 10 lbs. sulphur, 10 lbs. lime.
37	....	Control row.
38	Feb. 26	5 oz. copper carbonate, 3 lbs. ammonia.
39	Feb. 1	5 oz. copper carbonate, 3 lbs. ammonia.
	Feb. 28	5 oz. copper carbonate, 3 lbs. ammonia.
40	....	Control row.
41	Feb. 23	5 lbs. copper sulphate, 10 lbs. lime.
42	Feb. 14	6 pints spray solution.
	Mar. 3	6 pints spray solution.
43	....	Control row.
44	Feb. 24	6 lbs. copper sulphate, 15 lbs. lime.
45	Feb. 27	3 lbs. copper sulphate, 15 lbs. lime.
46	....	Control row.
47	Feb. 14	8 pints spray solution.
	Mar. 3	8 pints spray solution.
48	Feb. 14	6 pints spray solution, 3 lbs. lime.
	Mar. 6	6 pints spray solution, 10 lbs. lime.
49	....	Control row.
50	Feb. 14	8 pints spray solution, 3 lbs. lime.
51	Mar. 3	5 lbs. sulphur, 5 lbs. lime.
52	....	Control row.
53	Feb. 14	10 lbs. spray solution, 1 lb. soap (hot).
	Mar. 6	8 pints spray solution, 1 lb. soap (hot).
54	Feb. 27	3 lbs. copper sulphate, 10 lbs. lime.
55	....	Control row.
56	Mar. 6	8 pints spray solution, 2 lbs. copper sulphate, 10 lbs. lime.
57	....do...	5 lbs. sulphur, 15 lbs. lime.
58	....	Control row.

The spray work outlined in the above table was fully completed before the opening of many of the peach blossoms in the spring. Following this work, plans were laid for the preservation of records of fruit thinned from the trees, etc., should peach leaf curl develop. As the spring advanced, however, it became evident that the disease would not appear to any serious extent in that portion of the State that season, it not being sufficiently severe to produce a contrast either in foliage or fruit between the sprayed and unsprayed trees, hence the action of the sprays applied could not be determined. While this failure to arrive at the results hoped for in 1894 was much regretted, the failure, nevertheless, led to the acquisition of certain facts at a later date which are of prime importance to the orchardist wishing to combat the disease with sprays. The treatment of the trees in 1894 made it possible when the work was resumed in 1895 to ascertain if the effects of one year's treatment extended to the crop or foliage of the second year.

While peach leaf curl did not develop seriously in the Sacramento Valley in 1894, it prevailed quite extensively in other portions of the United States. This resulted in acquiring facts bearing on the experiments for 1895 in the Rio Bonito orchard. The experiments planned by the Department and carried out by growers in the East and in the north Pacific States, where leaf curl developed, showed that one thorough spraying during the dormant period of the tree was sufficient. The experiments of 1895 were consequently modified from those of 1894 in respect to the number of applications made, as well as in other respects found to be advisable.

SPRAY WORK CONDUCTED IN 1895.

In the spray work in the Rio Bonito orchard during the winter and spring of 1895, the same block of Lovell peach trees was selected as that treated the previous year, and in each case the same unsprayed or control rows were left as in 1894. In 1895 the number of experiments made in this block was 38, as in the previous year, but three of the 38 rows were not sprayed, being left without treatment for the purpose of observing the action of sprays applied in 1894 upon the crop and foliage of 1895. These three rows were numbers 4, 24, and 53, each of which had received two treatments in 1894. The facts thus learned are considered farther on. The spray work of 1895 included but a single spraying of each row designed for treatment. As already indicated, each experiment included one treated and one untreated row, each row having 10 immediately adjoining trees. By treating one row on either side of each control row the latter served as a contrast row for both sprayed rows. By referring to the plat of the block, p. 69, this arrangement may be seen. Row 1 is sprayed; row 2, unsprayed; row 3, sprayed. These three rows make two experiments—rows 1 and 2 compared make the first experiment, while rows 3 and 2 compared make the second experiment. In like manner rows 4 and 5 and 5 and 6 make two experiments. These illustrations will be sufficient, as the entire block, with the exception of the three rows already noted, was treated according to the same general plan.

In considering the application of sprays in the experiments of 1895, the nature of the sprays used, the formulæ according to which they were prepared, the location of the rows treated, and the dates of application, as well as the location of the control rows for comparison, are set forth in the table which follows. That the reader may better grasp the nature of all treatments which each row had received the previous year, the formulæ for the sprays applied in 1894 are placed at the left of the treatment given the same rows in 1895.

TABLE 2.—*Showing formulæ of sprays used in 1894 and 1895, the rows treated, and dates of application.*

Row No.	Date of spraying.	Formulæ for 45 gallons of spray as used in 1894.	Date of spraying.	Formulæ for 45 gallons of spray as used in 1895.
1	Feb. 20	15 lbs. sulphur, 30 lbs. lime, 10 lbs. salt	Mar. 1–5	15 lbs. sulphur, 30 lbs. lime, 10 lbs. salt.
2		Control row		Control row.
3	Feb. 24	10 lbs. sulphur, 20 lbs. lime, 7 lbs. salt	Mar. 1–5	10 lbs. sulphur, 20 lbs. lime, 5 lbs. salt.
4	Feb. 16 Feb. 28	10 lbs. sulphur, 20 lbs. lime, 7 lbs. salt 5 lbs. sulphur, 10 lbs. lime, 3 lbs. salt		Unsprayed, to note action of 1894 spray.
5		Control row		Control row.
6	Feb. 23	5 lbs. sulphur, 10 lbs. lime, 3 lbs. salt	Feb. 26	5 lbs. sulphur, 10 lbs. lime, 3 lbs. salt.
7	Feb. 24	15 lbs. sulphur, 30 lbs. lime	...do...	15 lbs. sulphur, 30 lbs. lime.
8		Control row.		Control row.
9	Feb. 23	10 lbs. sulphur, 20 lbs. lime	Feb. 26	10 lbs. sulphur, 20 lbs. lime.
10	Feb. 20 Mar. 3	10 lbs. sulphur, 20 lbs. lime 5 lbs. sulphur, 10 lbs lime	...do...	10 lbs. sulphur, 8 lbs. lime.
11		Control row		Control row.
12	Feb. 24	5 lbs. sulphur, 10 lbs. lime	Feb. 26	5 lbs. sulphur, 10 lbs. lime.
13	Feb. 13	20 lbs. lime, 20 lbs. salt	Mar. 1–5	20 lbs. lime, 20 lbs. salt.
14		Control row		Control row.
15	Feb. 13	20 lbs. lime	Feb. 26	6 lbs. copper sulphate, 15 lbs. lime.
16	Feb. 26 Mar. 6	45 lbs. salt (hot) 45 lbs. salt (hot)	...do...	6 lbs. sulphur, 4 lbs. lime.
17		Control row		Control row.
18	Feb. 26	3 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime	Mar. 1–5	3 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime.
19	Feb. 27	2 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime	Feb. 27	2 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime.
20		Control row		Control row.
21	Feb. 16 Feb. 20	5 lbs. copper sulphate, 5 lbs. lime 5 lbs. copper sulphate, 5 lbs. lime	Mar. 1–5	5 lbs. copper sulphate, 5 lbs. lime.
22	Feb. 21	4 lbs. copper sulphate, 5 lbs. lime	Feb. 27	4 lbs. copper sulphate, 5 lbs. lime.
23		Control row		Control row.
24	Feb. 6 Mar. 1	4 lbs. copper sulphate, 5 lbs. lime 3 lbs. copper sulphate, 5 lbs. lime		Unsprayed, to note action of 1894 spray.
25	Feb. 23	3 lbs. copper sulphate, 5 lbs. lime	Mar. 1–5	3 lbs. copper sulphate, 5 lbs. lime.
26		Control row		Control row.
27	Feb. 6 Mar. 1	3 lbs. copper sulphate, 2 lbs. lime 2 lbs. copper sulphate, 5 lbs. lime	Mar. 1–5	4 lbs. copper sulphate, 3 lbs. ammonia.
28	Feb. 26	2 lbs. copper sulphate, 5 lbs. lime	...do...	2 lbs. copper sulphate, 5 lbs. lime.
29		Control row		Control row.
30	Feb. 2	2 lbs. copper sulphate, 3 lbs. ammonia	Mar. 1–5	2 lbs. copper sulphate, 3 lbs. ammonia.
31		Control row		Control row.
32	Feb. 2	4 lbs. copper sulphate	Mar. 1–5	3 oz. copper carbonate, 2 lbs. ammonia.
33	...do... Mar. 2	2 lbs. copper sulphate 2 lbs. copper sulphate	...do...	3 lbs. copper sulphate, 15 lbs. lime.
34		Control row		Control row.
35	Mar. 3	4 lbs. copper sulphate, 5 lbs. soda, 3 lbs. ammonia	Mar. 1–5	4 lbs. copper sulphate, 5 lbs. soda, 3 lbs. ammonia.
36	Feb. 27	3 lbs. copper sulphate, 10 lbs. sulphur, 10 lbs. lime	Feb. 27	3 lbs. copper sulphate, 10 lbs. sulphur, 20 lbs. lime.
37		Control row		Control row.
38	Feb. 26	5 oz. copper carbonate, 3 lbs. ammonia	Feb. 27	5 oz. copper carbonate, 3 lbs. ammonia.

TABLE 2.—*Showing formulæ of sprays used in 1894 and 1895, the rows treated, and dates of application*—Continued.

Row No.	Date of spraying.	Formulæ for 45 gallons of spray as used in 1894.	Date of spraying.	Formulæ for 45 gallons of spray as used in 1895.
39	Feb. 1 Feb. 28	5 oz. copper carbonate, 3 lbs. ammonia 5 oz. copper carbonate, 3 lbs. ammonia	Mar. 1–5	2 lbs. copper sulphate, 3 lbs. soda, 2 lbs. ammonia.
40		Control row		Control row.
41	Feb. 23	5 lbs. copper sulphate, 10 lbs. lime	Mar. 1–5	5 lbs. copper sulphate, 10 lbs. lime.
42	Feb. 14 Mar. 3	6 pints spray solution 6 pints spray solution	...do...	8 pints spray solution, 5 lbs. lime.
43		Control row		Control row.
44	Feb. 24	6 lbs. copper sulphate, 15 lbs. lime	Mar. 1–5	20 lbs. lime.
45	Feb. 27	3 lbs. copper sulphate, 15 lbs. lime	...do...	3 lbs. copper sulphate, 10 lbs. lime.
46		Control row		Control row.
47	Feb. 14 Mar. 3	8 pints spray solution 8 pints spray solution	Mar. 1–5	8 pints spray solution.
48	Feb. 14 Mar. 6	6 pints spray solution, 3 lbs. lime 6 pints spray solution, 10 lbs. lime	...do...	12 pints spray solution, 10 lbs. lime.
49		Control row		Control row.
50	Feb. 14	8 pints spray solution, 3 lbs. lime	Mar. 1–5	6 lbs. sulphate of iron, 10 lbs. lime.
51	Mar. 3	5 lbs. sulphur, 5 lbs. lime	...do...	5 lbs. sulphur, 5 lbs. lime.
52		Control row		Control row.
53	Feb. 14 Mar. 6	10 pints spray solution, 1 lb. soap (hot) 8 pints spray solution, 1 lb. soap (hot)		Unsprayed, to note action of 1894 spray.
54	Feb. 27	3 lbs. copper sulphate, 10 lbs. lime	Mar. 1–5	3 lbs. copper sulphate, 10 lbs. lime.
55		Control row		Control row.
56	Mar. 6	8 pints spray solution, 2 lbs. copper sulphate, 10 lbs. lime	Feb. 27	5 lbs. sulphate of iron, 5 lbs. sulphur, 10 lbs. lime.
57	...do...	5 lbs. sulphur, 15 lbs. lime	Mar. 1–5	5 lbs. sulphur, 15 lbs. lime.
58		Control row		Control row.

The methods of preparing and applying the sprays used in 1895 are considered in subsequent chapters. In each case an effort was made to do thorough work in applying the sprays, but, as is true with all such work in the field, more or less variable results could not be avoided owing to the weather conditions and other influences. The treatment was given the 35 rows during the ten days immediately preceding the general opening of the flowers, that is, at the close of the dormant period of the trees, or from February 26 to March 5. In a few of the more forward trees a small percentage of the flowers had opened before the completion of the work.

GENERAL CONSIDERATION OF SPRAYS APPLIED.

Several distinct types of sprays were tested in the preventive work on curl in 1895, and these were prepared in many forms and proportions. The two fungicidal bases, copper and sulphur, which are now recognized in all countries as most valuable for this class of work, enter into the composition of a large proportion of the sprays used, in one form or another.

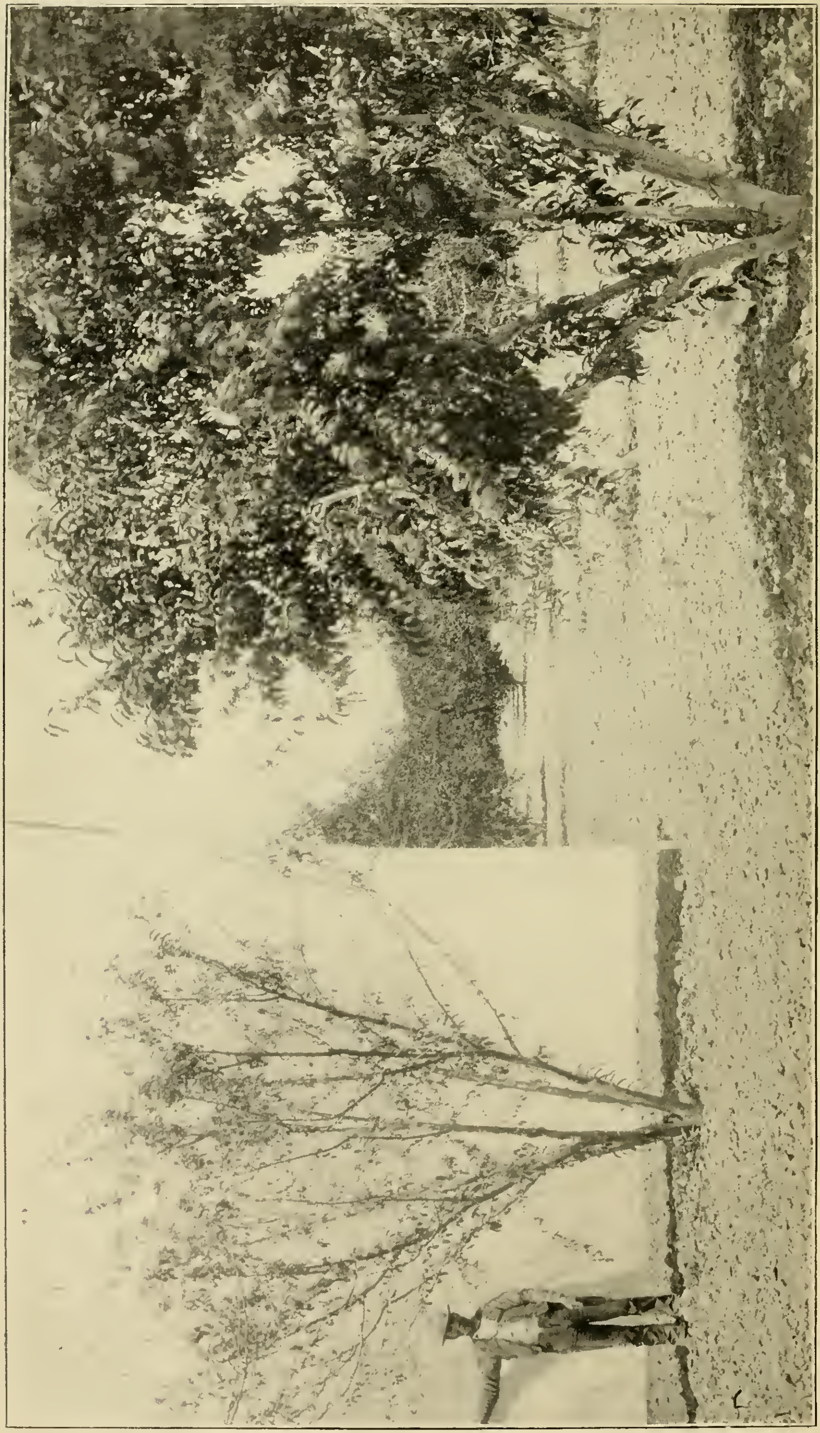
In testing sprays considerable weight was given to the fact that the peach tree is subject to the attacks of certain serious insect pests, prominent among which is the San José scale, and that a spray combining both fungicidal and insecticidal properties would often prove of greater value than one the action of which was solely fungicidal. Having these facts in mind, and knowing the demonstrated value of the sulphur, lime, and salt spray as an effective remedy for the San José scale, this spray, together with various modifications, was tested and compared (rows 1, 3, and 6). Besides quantitative modifications of the spray, tests of its constituents were made to acquire such facts respecting their value as were obtainable. The sulphur and lime united were tested in several proportions without salt (rows 7, 9, 10, 12, 16, 51, and 57). The lime and salt were tested together (row 13), and the lime was tested separately (row 44). The trial of a strong salt solution was made the previous year (row 16), but as it injured the foliage somewhat it was omitted in 1895. Other modifications of the sulphur spray were prepared by adding different fungicides, with the hope of increasing its fungicidal action without detracting from its effectiveness as an insecticide. Sulphate of copper was added in different proportions (rows 18, 19, and 36), and the addition of iron sulphate was also tried (row 56).

The copper sprays tested for leaf curl were numerous and were variously prepared and combined. As already said, copper sulphate was added to the sulphur sprays, but it was most extensively used in the preparation of the Bordeaux mixture, in which form it was applied in many experiments and of various strengths (rows 15, 21, 22, 25, 28, 33, 41, 45, and 54). Copper sulphate with ammonia (eau celeste) was tested (rows 27 and 30), as was the modified eau celeste, composed of copper sulphate, sal soda, and ammonia (rows 35 and 39). Two experiments were also conducted with ammoniacal copper carbonate (rows 32 and 38).

The action of sulphide of potassium was tested (row 47), as well as sulphide of potassium combined with milk of lime (rows 42 and 48).

Iron sulphate in connection with lime was applied in one experiment (row 50), and, as already stated, was also used in connection with sulphur and lime (row 56).

Of the three rows left unsprayed in 1895 (rows 4, 24, and 53), one (row 4) had received two applications of the sulphur, lime, and salt spray in 1894; another (row 24) had been twice sprayed in 1894 with Bordeaux mixture; and the third (row 53) had received two sprayings in 1894 with a hot saponified solution of sulphide of potassium.



TREATED AND UNTREATED CRAWFORDS LATE TREES, LIVE OAK, CAL.

Untreated tree at left shows the general denuding action of curl without hypertrophy of the branches; tree at right treated with lime, sulphur, and salt.

DESCRIPTION OF PLATE VII.

Sprayed and unsprayed Crawfords Late trees in the orchard of Mr. A. D. Cutts, Live Oak, Cal. The tree seen at the right was sprayed with lime, sulphur, and salt in February, 1893; that at the left was unsprayed and was denuded of foliage and fruit by curl. (See records of fruit of sprayed and unsprayed trees in this orchard, p. 141.) The trees were photographed in May, after most of the curled leaves had fallen from the unsprayed tree. (Compare with Pl. XX.)

CHAPTER V.

INFLUENCE OF SPRAYS ON THE VEGETATION OF THE TREES.

SAVING OF FOLIAGE FROM INJURY BY CURL.

(Pl. VII.)

The effectiveness of the winter sprays discussed in the previous chapter in saving the foliage of peach trees from injury by peach leaf curl has been carefully considered. The relative importance of this matter appears from the fact that it is the injury from the loss of foliage which is responsible for the ultimate loss of the fruit. The spray work already mentioned was completed, in 1895, about the close of the first week in March. From this time on the flowers opened rapidly, and they were soon followed by the pushing of the leaf buds and the complete resumption of the vegetative growth of the year. By the middle of April the trees were well in foliage, while peach leaf curl was nearing the height of its development. By the 22d of the month the contrast between healthy and diseased foliage on the sprayed and unsprayed trees had become so great that a careful estimate was made of the percentage of the diseased leaves upon every tree in the block.

The first estimate of the condition of the foliage was made to determine the amount and percentage of disease present on sprayed and unsprayed trees. The estimate of each tree was calculated upon the basis that the foliage present represented 100 per cent, and the amount of badly diseased leaves was taken as a certain per cent of the leaves present at that date. Badly diseased leaves were considered as those seeming to have sufficient curl present to cause their premature fall from the tree. The ultimate comparisons of sprayed with unsprayed rows are not based upon this first estimate of foliage as the disease was still progressing. The parasite was still in the vegetative state, few of the swollen leaves as yet showing the fruit of the fungus, and still fewer having fallen from the trees. The trees sprayed with the stronger sulphur preparations were injured somewhat by the sprays, many of the more tender twigs being killed. This delayed the leafing of these trees, and resulted in their showing rather a smaller percentage of diseased foliage at the time this estimate was made than would have been the case had the leaves pushed earlier. These discrepancies influence only a few of the sprayed rows. In other respects, it is believed the numerous influencing conditions would apply, so far as could be told, with equal force to all rows.

In taking the percentage estimates of disease shown in the following table, the trees were examined in north and south rows. This was done so as to work across the lines of the experiment rows rather than with them, and for the purpose of avoiding any influence which a knowledge of the sprays used on the trees estimated might be thought to exert.

TABLE 4.—*Estimated percentage of diseased leaves on trees April 22 and 23, 1895.*

Row No.	Percentage of diseased leaves estimated Apr. 22 and 23, 1895, on tree No.—										Average per cent of diseased leaves per tree in sprayed rows.	Average per cent of diseased leaves per tree in control rows.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.		
1	10	15	15	10	10	10	15	15	20	15	13.5	....
2	90	90	90	85	85	90	90	85	85	85	....	87.5
3	30	35	35	40	35	30	30	30	25	20	31.0	....
4	70	80	80	80	85	85	80	80	85	80	*a*80.5	....
5	80	80	85	85	80	90	85	90	90	85	....	85.0
6	40	60	40	50	40	45	35	40	35	30	41.5	....
7	20	25	25	30	25	35	30	30	35	30	28.5	....
8	75	85	80	85	75	70	70	75	80	80	....	77.5
9	30	34	46	42	25	27	25	29	47	45	35.0	....
10	30	32	40	40	35	27	23	30	27	36	32.0	....
11	80	90	90	85	85	85	85	80	80	80	....	84.0
12	25	47	15	35	34	50	45	50	45	47	39.3	....
13	40	45	55	40	45	50	35	50	60	35	45.5	....
14	80	80	78	78	75	76	77	80	80	80	....	78.1
15	5	11	8	13	16	16	9	12	11	13	11.4	....
16	16	35	30	45	37	31	20	20	30	25	28.9	....
17	80	90	85	85	87	78	65	80	82	90	....	82.2
18	25	30	33	40	29	32	40	31	35	60	35.5	....
19	8	15	13	16	25	23	35	20	23	36	21.4	....
20	80	90	90	90	90	90	90	90	90	90	....	89.0
21	7	11	16	26	17	10	11	10	10	9	12.7	....
22	8	10	15	9	16	9	10	10	12	8	10.7	....
23	82	85	80	85	85	80	85	80	90	85	....	83.7
24	80	80	80	85	85	85	80	85	85	80	*a*82.5	....
25	8	12	12	18	27	15	9	11	15	10	13.7	....
26	80	80	85	90	90	85	85	85	90	85	....	85.5
27	17	20	17	21	21	15	24	26	23	17	20.1	....
28	20	21	21	30	26	24	30	31	15	19	23.7	....
29	85	90	90	90	90	87	87	90	88	90	....	88.7
30	8	5	15	15	10	15	15	15	20	15	13.3	....
31	85	80	85	85	90	85	80	85	80	85	....	84.0
32	25	35	30	35	30	30	30	35	35	30	31.5	....
33	10	10	10	10	5	10	10	10	10	5	9.0	....
34	90	90	85	90	90	85	90	90	90	85	....	88.5
35	20	15	15	20	12	10	8	15	12	10	13.7	....
36	25	15	10	10	15	10	15	20	12	10	14.2	....
37	75	75	70	75	75	75	65	60	65	65	....	70.0
38	50	45	40	35	25	19	17	25	24	10	29.0	....
39	27	35	18	....	....	15	20	15	15	18	20.3	....
40	78	85	80	80	82	80	75	80	85	78	....	80.3
41	9	14	12	13	20	18	18	23	13	17	15.7	....
42	50	45	50	55	55	65	55	60	55	60	55.0	....
43	85	80	80	85	88	85	87	85	85	85	....	84.5
44	13	27	16	30	30	35	31	28	30	25	26.5	....
45	14	12	12	12	10	11	18	12	12	13	12.6	....
46	85	85	90	90	80	90	85	80	85	85	....	85.5
47	70	70	60	50	65	70	70	75	75	75	68.0	....
48	30	40	40	38	37	38	30	40	28	42	36.3	....
49	90	87	85	85	85	80	87	85	85	85	....	85.4
50	35	40	40	50	45	42	45	43	35	33	40.8	....
51	30	26	28	25	32	30	35	22	35	28	29.1	....
52	85	80	80	80	80	85	80	85	85	80	....	82.0
53	85	80	80	80	85	85	85	85	80	85	*a*83.0	....
54	17	10	11	12	12	20	15	15	16	18	14.6	....
55	85	75	80	80	85	80	85	85	82	87	....	82.4
56	30	22	30	25	22	9	20	18	19	13	20.8	....
57	26	31	31	32	21	20	18	16	15	11	22.1	....
58	90	89	85	90	85	87	88	90	90	88	....	88.2

a Rows sprayed in 1894 but left unsprayed in 1895.

General consideration of the above table develops some striking contrasts. By adding the figures corresponding to the average percentage of diseased leaves on the trees of the control rows, and dividing this amount by the number of rows, we find that in the entire block, containing 200 control trees, 83.6 per cent of the leaves were badly diseased at the date of this estimate. In contrast to this, the total of the average percentages of disease shown by the trees of the sprayed rows, divided by the number of sprayed rows in the block, shows the average amount of disease in the sprayed rows to have been 26.2 per cent. Evidently this average is much above the percentage of disease shown at that date by many separate rows, as it included the rows treated with noneffective sprays as well as those giving the best results. Adding the averages of rows 4, 24, and 53 and dividing the amount by 3 gives 82 per cent of disease as the average of the three rows. As noted in the table, these rows were not sprayed in 1895, but were left in order to ascertain the effects of the sprays applied to them in 1894, and the average of disease is seen to be practically as great as upon rows never sprayed.

From the date of this first estimate the progress of the disease in the orchard was very marked. Within the next two weeks the fungus fruited quite generally upon the swollen leaves, and a large percentage of the worst diseased leaves had fallen from the trees. By May 9 the contrast between sprayed and unsprayed trees had quite generally reached its highest point, and any irregularities of special trees, etc., could no longer be considered. On May 9 a second careful estimate of the foliage was made. In this work, however, it was impossible to estimate the amount of disease on the trees as compared with the total amount of foliage present, as had first been done, for much of the diseased foliage had already fallen. To avoid this difficulty a new method of estimating was adopted. From the entire block of trees were selected two rows, Nos. 21 and 22, which showed only from 4 to 6 per cent of disease, and were in other respects in perfect foliage. A careful study of these rows was made to get a clear idea of the condition of a tree in full foliage at that date, and with these types in mind each tree of the entire block was carefully examined. An estimate was made for each tree, based on the twenty typical trees studied, to determine the per cent of perfect foliage upon it, taking the amount which should be upon the tree at that date, if no disease existed, as 100 per cent. The following table gives the results of this work. The percentages in the last column represent the gain in leaves of sprayed trees over the average of all control trees in the block. The manner of obtaining these percentages is discussed on page 85.

TABLE 5.—*Estimated percentage of healthy foliage on the sprayed and unsprayed trees May 9, 1895, as compared with the amount a healthy tree should have at that date.*

Row No.	Percentage of healthy foliage compared with the amount the tree should have, estimated May 9, 1895. Tree No. —										Average per cent of healthy leaves per tree in sprayed rows.	Average per cent of healthy leaves per tree in control rows.	Gain in leaves of sprayed trees over average of all control trees, expressed in per cent.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.			
1	92	93	93	92	94	95	92	92	93	87	92.3	....	607
2	9	10	12	9	15	10	8	13	10	5	....	10.1	....
3	90	85	80	82	85	85	85	80	90	85	84.7	....	549
4	15	8	15	10	15	20	18	20	12	15	*a*14.8	....	13
5	10	12	12	10	18	15	15	25	10	18	....	14.5	....
6	85	65	87	80	85	60	83	78	80	65	76.8	....	488
7	95	85	90	85	83	84	87	85	90	70	85.4	....	554
8	10	10	13	9	12	10	12	25	20	20	....	14.1	....
9	88	75	87	80	90	80	88	80	85	78	83.1	....	536
10	90	80	88	83	90	82	87	85	89	80	85.4	....	554
11	9	8	10	20	11	20	10	10	12	18	....	12.8	....
12	92	80	88	85	80	80	78	72	80	75	81.0	....	520
13	87	87	75	85	65	86	85	80	70	75	79.5	....	509
14	8	10	15	10	20	13	20	20	12	15	....	14.3	....
15	95	89	95	90	90	88	92	88	93	80	90.0	....	589
16	92	65	80	80	86	87	85	85	85	75	82.0	....	528
17	20	11	12	10	8	13	10	22	10	12	....	12.8	....
18	92	85	90	85	88	86	83	80	85	68	84.7	....	549
19	90	85	90	91	85	85	77	84	75	70	83.2	....	537
20	10	9	9	8	9	10	10	10	20	12	....	10.7	....
21	97	95	97	89	92	99	96	98	98	98	95.9	....	634
22	96	96	96	90	90	98	95	96	90	98	94.5	....	624
23	8	10	14	10	8	10	8	20	9	25	....	12.2	*b*39
24	8	9	11	9	9	9	10	7	8	14	*a*9.4	....	....
25	89	90	92	85	88	87	96	92	85	94	89.8	....	588
26	10	10	9	8	10	12	11	8	9	35	....	12.2	....
27	91	92	97	87	92	91	89	85	98	90	91.2	....	598
28	87	88	96	88	85	92	84	86	95	92	89.3	....	584
29	9	10	12	10	8	13	9	8	8	10	....	9.7	....
30	96	95	92	91	90	96	90	95	82	95	92.2	....	606
31	11	18	20	20	15	22	21	23	23	20	....	19.3	....
32	65	50	55	60	65	45	45	45	45	50	52.5	....	302
33	92	92	94	94	90	90	85	95	92	95	91.9	....	604
34	9	9	16	20	16	14	15	15	10	18	....	14.2	....
35	86	90	88	92	92	90	98	95	93	94	91.8	....	603
36	65	80	85	90	75	80	50	90	75	92	78.2	....	499
37	10	13	10	12	15	15	12	12	12	17	....	12.8	....
38	65	45	68	70	70	75	80	75	70	85	70.3	....	438
39	73	82	93	(*c*)	(*c*)	92	85	86	78	78	83.4	....	539
40	15	10	10	12	10	12	15	11	10	18	....	12.5	....
41	93	92	95	85	85	80	90	78	87	85	87.0	....	566
42	45	25	45	28	45	50	45	45	48	40	41.6	....	219
43	10	12	15	10	15	18	10	18	22	15	....	14.5	....
44	78	75	80	55	65	55	40	65	40	35	58.8	....	350
45	89	89	80	90	90	95	75	87	75	87	85.7	....	556
46	11	16	13	15	25	20	8	18	15	18	....	15.9	....
47	40	40	40	45	28	45	50	45	30	25	38.8	....	197
48	70	75	55	70	65	50	45	50	50	50	58.0	....	344
49	9	10	20	18	20	15	10	12	15	12	....	14.1	....
50	70	65	50	60	40	50	45	65	65	60	57.0	....	336
51	80	70	75	70	70	65	55	70	65	65	68.5	....	424
52	9	10	10	10	18	12	18	10	18	15	....	13.0	....
53	20	15	18	8	15	15	10	10	15	22	*a*14.8	....	13
54	85	87	90	70	82	85	85	80	88	70	82.2	....	529
55	9	14	10	9	15	15	10	9	10	12	....	11.3	....
56	85	80	70	75	65	90	60	75	68	90	75.8	....	480
57	70	83	65	60	75	87	80	70	70	88	74.8	....	473
58	8	10	11	10	12	12	11	8	10	10	....	10.2	....

a Trees sprayed in 1894, but unsprayed in 1895.
b Gain of control row over row sprayed in 1894.
c Tree missing.

The comparison of some of the general facts brought out in the estimates of foliage April 22 and 23 and May 9, 1895, shows the progress of the disease during that time.

TABLE 6.—*Comparative percentage of diseased foliage on sprayed and unsprayed trees April 22 and 23 and May 9, 1895.*

Trees examined.	April 22 and 23, 1895.	May 9, 1895.
Average per cent of disease on the trees of all control rows	83.6	86.9
Average per cent of disease on the trees of all sprayed rows	26.2	21.2
Average per cent of disease on the trees of the three rows sprayed in 1894, but left unsprayed in 1895	82.0	87.0

These comparisons show 3.3 per cent more diseased foliage on the control trees May 9 than April 22. The percentage of foliage of the sprayed trees showing disease had decreased, however, 5 per cent. Of the total foliage of the trees sprayed in 1894, but left unsprayed in 1895, 5 per cent more was diseased at the second date than at the first. These figures indicate that the divergence in the percentage of disease on sprayed and unsprayed trees was still increasing just prior to the second estimate. The second estimate may thus be considered as taken before any of the trees had begun to recover from the effects of the disease. The time of maximum contrast was the true time to make the estimates, and it is believed the date of this second estimate was certainly not too late to fully comply with this requirement. This belief was substantiated by a third partial estimate made a week later, which gave in general very similar results to those obtained May 9. It should also be said that the decrease in the percentage of disease on the sprayed trees between the dates of the first and second estimates did not indicate that the second estimate was made too late, or after the trees had begun to recover, but merely that the leaf buds had not fully pushed at the time of the first estimate. This is further shown by the fact that the percentage of disease was still increasing on unsprayed trees up to that time.

Before considering the action of individual sprays in saving the foliage from curl, the following comparisons are given of the action of the classes of sprays used:

TABLE 7.—*Percentage of healthy foliage on trees differently sprayed.*

Percentages of healthy foliage shown by trees sprayed with different classes of sprays. Estimated April 23 and May 9, 1895.	Percentage of healthy foliage Apr. 22 and 23, 1895.	Percentage of healthy foliage May 9, 1895.	Gain in per cent of foliage from Apr. 23 to May 9, 1895.	Loss in per cent of foliage from Apr. 23 to May 9, 1895.
Average of 30 trees sprayed with sulphur, lime, and salt	71.4	84.6	13.2	....
Average of 70 trees sprayed with sulphur and lime	69.3	80.0	10.7	....
Average of 100 trees sprayed with the two preceding sulphur sprays	70.3	82.3	12.0	....
Average of 90 trees sprayed with Bordeaux mixture	86.2	89.6	3.4	....
Average of 20 trees sprayed with eau celeste	83.3	91.7	8.4	....
Average of 20 trees sprayed with modified eau celeste	83.0	87.6	4.6	....
Average of 130 trees sprayed with the three preceding copper sprays	84.2	89.6	5.4	....
Average of 20 trees sprayed with ammoniacal copper carbonate	69.8	61.4	....	8.4

TABLE 7.—*Percentage of healthy foliage on trees differently sprayed*—Continued.

Percentages of healthy foliage shown by trees sprayed with different classes of sprays. Estimated April 23 and May 9, 1895.	Percentage of healthy foliage Apr. 22 and 23, 1895.	Percentage of healthy foliage May 9, 1895.	Gain in per cent of foliage from Apr. 23 to May 9, 1895.	Loss in per cent of foliage from Apr. 23 to May 9, 1895.
Average of 30 trees sprayed with copper sulphate, sulphur, and lime (*a*)	76.3	82.0	5.7	....
Average of 10 trees sprayed with iron sulphate and lime	59.2	57.0	....	2.2
Average of 10 trees sprayed with iron sulphate, sulphur, and lime	79.2	75.8	....	3.4
Average of 10 trees sprayed with sulphide of potassium	32.0	38.8	6.8	....
Average of 20 trees sprayed with sulphide of potassium and lime	54.3	49.8	....	4.5
Average of 10 trees sprayed with milk of lime	73.5	58.8	....	14.7
Average of 10 trees sprayed with milk of lime and salt	54.5	79.5	25.0	....

a Compare text.

The table shows the average of healthy foliage on the trees sprayed with the sulphur sprays (sulphur, lime, and salt, 30 trees; sulphur and lime, 70 trees) to have been 82.3 per cent May 9. The average on the trees sprayed with the leading copper sprays (Bordeaux mixture, 90 trees; eau celeste, 20 trees; modified eau celeste, 20 trees) was 89.6 per cent. The average amount of healthy foliage saved on trees sprayed with a combination of these two leading classes of sprays (Bordeaux mixture added to the sulphur and lime sprays, 30 trees) was no greater than the average saved by all sulphur and lime sprays alone, being 82 per cent as against 82.3 per cent for the sulphur sprays. This result was a surprise, but by carefully looking into the reason it would seem that the low average in the case of the combined sprays was due to the low average of the single row 36, while the high average of the sulphur sprays arose from including in the average the results of those sprays which contained much more sulphur than was used in the combined sprays. Notes on the spray applied to row 36 show that considerable sulphur was precipitated in cooking, probably through overheating, and for this reason it would be as well to omit this row in determining the average saving of the combined sprays. The two remaining rows, 18 and 19, sprayed with combined sprays, showed 84.7 and 83.2 per cent of healthy foliage, respectively—an average of 83.9 per cent. The formula for each of these experiments contained 5 pounds of sulphur. In the experiments with uncombined sulphur sprays there were four formulæ containing 5 pounds of sulphur each. The average per cent of saving of these four experiments was 75.3. These facts show that when the amount of sulphur was equal there was an average gain of 8.6 per cent in healthy foliage resulting from the addition of Bordeaux mixture to the sulphur sprays.

The average percentage of foliage saved by the use of the ammoniacal copper carbonate (20 trees) was, May 9, 61.4. As the ammoniacal copper carbonate sprays used contained much less basic copper carbonate than the other copper sprays applied, their comparatively low effectiveness against curl is fully accounted for, and for this reason they were not included when calculating the average action of the copper sprays in general. They were outclassed by the amount of copper used in the other sprays.

The foliage saved by the use of iron sulphate and lime (10 trees) was but 57 per cent May 9. This shows a much less satisfactory action than either the copper or the sulphur sprays. The iron sulphate combined with the sulphur and lime sprays showed a saving of foliage May 9 of 75.8 per cent. While this is a good showing, the beneficial action was evidently due to the sulphur of the spray and not to the iron, and the result was even below the average obtained by the sulphur sprays alone, or equal to those having the same amount of sulphur.

One experiment (10 trees) was made with sulphide of potassium, but the average percentage of foliage saved by this spray was, May 9, only 38.8. Sulphide of potassium combined with milk of lime (20 trees) showed a greater saving of leaves, being 49.8 per cent, but as the sulphide alone gave a saving 11 per cent lower, and as milk of lime saved as high as 58.8 per cent, it is questionable if the lime was not the more active agent in the combination. As already stated, the milk of lime applied as a spray (10 trees) showed a saving of 58.8 per cent of the leaves, which was quite satisfactory for a spray containing none of the standard fungicides. The spray prepared from lime and salt (10 trees) gave a high record, the healthy foliage May 9 being 79.5 per cent. While it is possible that the fungicidal action of this spray may be somewhat higher than that of milk of lime alone, it is perhaps more probable that the results noted arose from another influence. It was learned in the previous year's work that a solution of salt injured the new growth and tender leaves, and it is thought likely that in the present case the earliest growth and that which first showed disease was destroyed by the spray, and that the foliage estimated was a new and somewhat later growth, showing much less disease than the first foliage would have shown. It would be well, however, to repeat this test.

Some interesting facts are brought out by the preceding table in relation to the continued action of the fungicides used. By comparing the first column, the percentages of healthy foliage taken April 22 and 23, with the second column, the percentages taken May 9, it will be seen that the percentage of healthy foliage on all trees sprayed with the sulphur or copper sprays increased decidedly between the two dates of estimate, as shown in the third column. On the other hand, the action of the weaker sprays was overcome by the disease, and the percentage of healthy foliage May 9 was much less than April 23, as shown in the fourth column. These weaker sprays checked the action of the fungus at first, but were not sufficiently active or persistent to prevent its gradual increase upon the trees. An apparent exception to this in the case of the sulphide of potassium appears to arise from the fact that the disease was never greatly checked by this fungicide, the amount of healthy foliage being only 32 per cent April 23. Another and more marked exception is seen in the trees sprayed with lime and salt in solution. It is thought, however, that the true explanation of this exception is that given in the preceding paragraph.

What has been stated will be sufficient to indicate the comparative value of the main classes of sprays used in these experiments. It is shown that the highest degree of effectiveness in saving foliage is possessed by the copper sprays, that the sulphur sprays also possess a high degree of fungicidal activity, and that where Bordeaux mixture is added to the sulphur sprays the effectiveness of the latter is somewhat increased. It is also made clear that sulphide of potassium, sulphate of iron, and several other sprays, as tested, are of secondary value in this work. It should be noted that the average saving obtained from the use of the sulphur sprays is sufficiently high to well warrant the use of these sprays, either in combination with Bordeaux mixture or alone, in cases where it is desired to use a spray having both fungicidal and insecticidal qualities.

It will now be advantageous to briefly consider the leading individual sprays composing the classes of sprays already discussed, in respect to their action on peach foliage and peach leaf curl. The following table gives a compact presentation of the number and nature of these sprays, as well as their action in controlling curl:

TABLE 8.—*Nature and composition of sprays applied.*

Row No.	Classes and formulæ of sprays applied.	Average per cent of healthy foliage May 9, 1895.	Net gain per cent of healthy foliage over average per cent of all control trees.	Percentage of color, texture, and size of uninfected leaves.
	Sulphur, lime, and salt:			
1	15 lbs. sulphur, 30 lbs. lime, 10 lbs. salt	92.3	607	80
3	10 lbs. sulphur, 20 lbs. lime, 5 lbs. salt	84.7	549	60
6	5 lbs. sulphur, 10 lbs. lime, 3 lbs. salt	76.8	488	60
	Sulphur and lime:			
7	15 lbs. sulphur, 30 lbs. lime	85.4	554	60
9	10 lbs. sulphur, 20 lbs. lime	83.1	536	60
10	10 lbs. sulphur, 8 lbs. lime	85.4	554	60
16	6 lbs. sulphur, 4 lbs. lime	82.0	528	80
57	5 lbs. sulphur, 15 lbs. lime	74.8	473	60
12	5 lbs. sulphur, 10 lbs. lime	81.0	520	60
51	5 lbs. sulphur, 5 lbs. lime	68.5	424	60
	Bordeaux mixture and sulphur sprays combined:			
36	3 lbs. copper sulphate, 10 lbs. sulphur, 20 lbs. lime	78.2	499	70
18	3 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime	84.7	549	80
19	2 lbs. copper sulphate, 5 lbs. sulphur, 10 lbs. lime	83.2	537	80
	Bordeaux mixture:			
15	6 lbs. copper sulphate, 15 lbs. lime	90.0	589	100

TABLE 8.—*Nature and composition of sprays applied*—Continued.

Row No.	Classes and formulæ of sprays applied.	Average per cent of healthy foliage May 9, 1895.	Net gain per cent of healthy foliage over average per cent of all control trees.	Percentage of color, texture, and size of uninfected leaves.
33	3 lbs. copper sulphate, 15 lbs. lime	*91.9	*604	80
41	5 lbs. copper sulphate, 10 lbs. lime	87.0	566	100
45	3 lbs. copper sulphate, 10 lbs. lime	85.7	556	90
54	3 lbs. copper sulphate, 10 lbs. lime	82.2	529	80
21	5 lbs. copper sulphate, 5 lbs. lime	95.9	634	100
22	4 lbs. copper sulphate, 5 lbs. lime	94.5	624	100
25	3 lbs. copper sulphate, 5 lbs. lime	89.8	588	80
28	2 lbs. copper sulphate, 5 lbs. lime	89.3	584	80
	Eau celeste:			
27	4 lbs. copper sulphate, 3 pints ammonia	91.2	598	80
30	2 lbs. copper sulphate, 3 pints ammonia	†92.2	†606	†100
	Modified eau celeste:			
35	4 lbs. copper sulphate, 5 lbs. sal soda, 3 pints ammonia	91.8	603	80
39	2 lbs. copper sulphate, 3 lbs. sal soda, 2 pints ammonia	83.4	539	80
	Ammoniacal copper carbonate:			
38	5 ounces copper carbonate, 3 pints ammonia	70.3	438	80
32	3 ounces copper carbonate, 2 pints ammonia	52.5	302	60
	Iron sulphate and lime:			
50	6 lbs. iron sulphate, 10 lbs. lime	57.0	336	40
	Iron sulphate, sulphur, and lime:			
56	5 lbs. iron sulphate, 5 lbs. sulphur, 10 lbs. lime	75.8	480	40
	Potassium sulphide solution:			
47	8 pints potassium sulphide solution	38.8	197	40
	Potassium sulphide solution and lime:			
48	12 pints potassium sulphide solution, 10 lbs. lime	58.0	344	50
42	8 pints potassium sulphide solution, 5 lbs. lime	41.6	219	40
	Lime and salt:			
13	20 lbs. lime, 20 lbs. salt	79.5	509	60
	Lime:			
44	20 lbs. lime	58.8	350	50

* Exceptional, see p. 87. † Outside row, next to driveway.

The above table is planned to give for each experiment the following facts: (1) The number of the row to which the spray was applied; (2) the nature and amount of the ingredients used in each case; (3) the average per cent of healthy foliage shown by the trees of the row May 9, 1895; (4) net gain in healthy foliage above the average per cent of healthy foliage produced by all of the control trees of the block (200 unsprayed trees), and which is expressed in per cent; (5) thrift of uninfected leaves in color, texture, and size. The figures under the fourth head were obtained in the following manner: The average percentage of healthy foliage of all the trees of each control row was first ascertained. These amounts were added together and divided by the number of rows (20) to obtain the average percentage of healthy foliage of all control trees of the block. This average was 13.06. From the average percentage of each sprayed row was then subtracted the average of all control trees to obtain the gain in healthy foliage of each sprayed row. This net gain was then divided by the 13.06 per cent of the control trees to obtain the net gain per cent of each sprayed row. For example, take row 1: 92.3 % − 13.06 % = 79.24 % gain; 79.24 % ÷ 13.06 % shows the net gain to be $\frac{607}{100}$ = 607 % of the average amount of healthy foliage of the control trees. The fifth subject, thriftiness of leaves, is discussed in the next general head of this chapter.

In considering the saving of foliage induced through the use of the sulphur, lime, and salt sprays (rows 1, 3, and 6) in comparison with the average saving of sprays containing an equal amount of sulphur but no salt (rows 7, 9, 10, 16, 57, 12, and 51), there appears to be a slight gain in favor of the former sprays. The average saving from both classes, taken together or separately, is in proportion to the amount of sulphur contained in the spray. With 15 pounds of sulphur the average net gain in healthy foliage was 580 per cent; with 10 pounds, 547 per cent; with 6 pounds, 528 per cent; and with 5 pounds, 480 per cent.

In considering the combined sulphur and copper sprays (rows 18, 19, and 36), it is well to omit comparisons of row 36, on account of the injury caused to the effectiveness of the spray applied to it through the precipitation of a portion of the sulphur in boiling, as has already been noted. Rows 18 and 19, containing 3 pounds and 2 pounds of copper sulphate, respectively, and each containing 5 pounds of sulphur and 10 pounds of lime, show a gain in healthy foliage of 549 per cent and 537 per cent, or an average gain of 543 per cent. The average gain from the sulphur sprays, which contained the same amount of sulphur but no copper, was, as already stated, 480 per cent. This shows the advantage of adding the copper to the sulphur sprays.

In the table the experiments with the Bordeaux mixture are arranged according to the amount of copper and lime used in each. The results obtained in the 9 experiments bring out some valuable facts respecting the most desirable proportions of copper and lime to be used. Of the 9 experiments with Bordeaux mixture, 2 formulæ contained 15 pounds of lime each, 3 formulæ 10 pounds each, and 4 formulæ 5 pounds each.

By comparing rows 15 (6 pounds copper sulphate, 15 pounds lime), 41 (5 pounds copper sulphate, 10 pounds lime), and 21 (5 pounds copper sulphate, 5 pounds lime), it will be seen that there was a gain in healthy foliage of 589 per cent, 566 per cent, and 634 per cent, respectively. Dividing these gains by the number of pounds of copper in the respective formulæ, which may be fairly done, owing to the nearly equal amounts of copper contained in each, the following results will be obtained:

	Per cent.
Row 15 (6 pounds copper sulphate, 15 pounds lime = 1 pound copper to 2.5 pounds lime) shows a gain of foliage per pound of copper sulphate of	98
Row 41 (5 pounds copper sulphate, 10 pounds lime = 1 pound copper to 2 pounds lime) shows a gain of foliage per pound of copper sulphate of	113
Row 21 (5 pounds copper sulphate, 5 pounds lime = 1 pound copper to 1 pound lime) shows a gain of foliage per pound of copper sulphate of	127

These comparisons indicate a decided increase in activity of the sprays as the percentage of lime is lessened—the total amount of copper remaining the same, at least to that point where the number of pounds of copper sulphate and lime are equal. The formulæ containing 3 pounds of copper sulphate can not all be compared as justly as the above formulæ have been, owing to a difference in the make of copper sulphate used on row 33. However, rows 45 and 54, each having been sprayed with a formula containing 3 pounds copper sulphate and 10 pounds lime, may be compared with row 25, which was treated with 3 pounds of copper sulphate and 5 pounds of lime. The average saving of foliage per pound of copper sulphate in the former two experiments (10 pounds lime) was 180 per cent. The saving per pound of copper sulphate in the latter experiment (5 pounds lime) was 196 per cent. These comparisons also show most gain in foliage per pound of copper sulphate where least lime was used.

That no misconception may be formed from the preceding comparisons, it is well to consider that the sprays were applied in these cases immediately before the opening of the buds, so that prompt action of the copper was of greater importance than the enduring qualities of the sprays. As will be elsewhere shown, however, the endurance of sprays upon the trees is largely increased with the increase of the amount of lime they contain. A large increase of lime above the absolute requirements for the Bordeaux mixture is not necessary when the spray is applied so near the date of the opening of the buds that its action can not be delayed without loss in effectiveness. On the other hand, if the spray is applied at an earlier date, so that it is required to withstand weathering for a longer period, a considerable increase in the amount of lime may be an advantage in increasing its enduring quality.

The amount of copper sulphate used in the preparation of the Bordeaux mixture varied from 2 to 6 pounds for 45 gallons of spray. Of the nine formulæ tested, that containing 5 pounds of copper sulphate and 5 pounds of lime (row 21) gave the highest gain in foliage over the average healthy foliage of the control trees, or 634 per cent. There was an actual average saving of 95.9 per cent of the spring foliage of the 10 trees sprayed, consequently the average loss of foliage in this experiment was only 4.1 per cent. The next best results were obtained with the spray containing 4 pounds copper sulphate and 5 pounds lime (row 22). This spray gave a gain in foliage above the average produced by the control rows of 624 per cent. The average amount of foliage saved on the 10 trees was 94.5 per cent, showing that all but 5.5 per cent of disease had been prevented. While row 33 shows the next highest saving in foliage, these results, as already indicated, are exceptional, as shown by comparison. The yield of fruit which this row produced also shows the foliage records to be exceptional, and they may properly be omitted in these comparisons.

The results obtained by the use of eau celeste and modified eau celeste were very satisfactory, but in no case was as high a percentage of foliage saved by them as in the better tests with Bordeaux mixture. The exceptionally high percentage of foliage saved on row 30 with but 2 pounds of copper sulphate may be in part due to the fact that the row was an exterior one of the block and next to a driveway, where the trees may have been better nourished than those of interior rows. By comparing the formula used on row 27 with that used on row 35 (each containing 4 pounds of copper sulphate) it will be seen that the saving of foliage was about equal with eau celeste and modified eau celeste. Comparison of these results with those shown by row 22, which was sprayed with Bordeaux mixture containing the same amount of copper, will show that the latter saved the highest percentage of foliage.

Ammoniacal copper carbonate gave less satisfactory results than the preceding sprays, probably owing to insufficient copper. The various results given by the other sprays tabulated require no special comment.

Another fact is made evident by the preceding table. Of two formulæ of the same class, as the Bordeaux mixtures, one containing more of the fungicide than the other, the percentage of foliage saved for each pound of fungicide will be the greater in the weaker spray. Each of the Bordeaux mixtures used in spraying rows 21, 22, 25, and 28 contained 5 pounds of lime, but the amounts of copper sulphate used were 5, 4, 3, and 2 pounds, respectively. The total net amount of foliage saved by these sprays and the net saving per pound of copper sulphate each contained may be thus shown.

Row 21: 5-pound formula, 634 per cent saved; per pound of copper sulphate, 127 per cent.

Row 22: 4-pound formula, 624 per cent saved; per pound of copper sulphate, 156 per cent.

Row 25: 3-pound formula, 588 per cent saved; per pound of copper sulphate, 196 per cent.

Row 28: 2-pound formula, 584 per cent saved; per pound of copper sulphate, 292 per cent.

These figures show a gradual decrease of the total per cent of foliage saved as the amount of the fungicide is decreased, but a decided increase in the percentage of foliage saved per pound of fungicide.

COMPARISONS OF WEIGHT AND COLOR OF FOLIAGE FROM SPRAYED AND UNSPRAYED TREES.

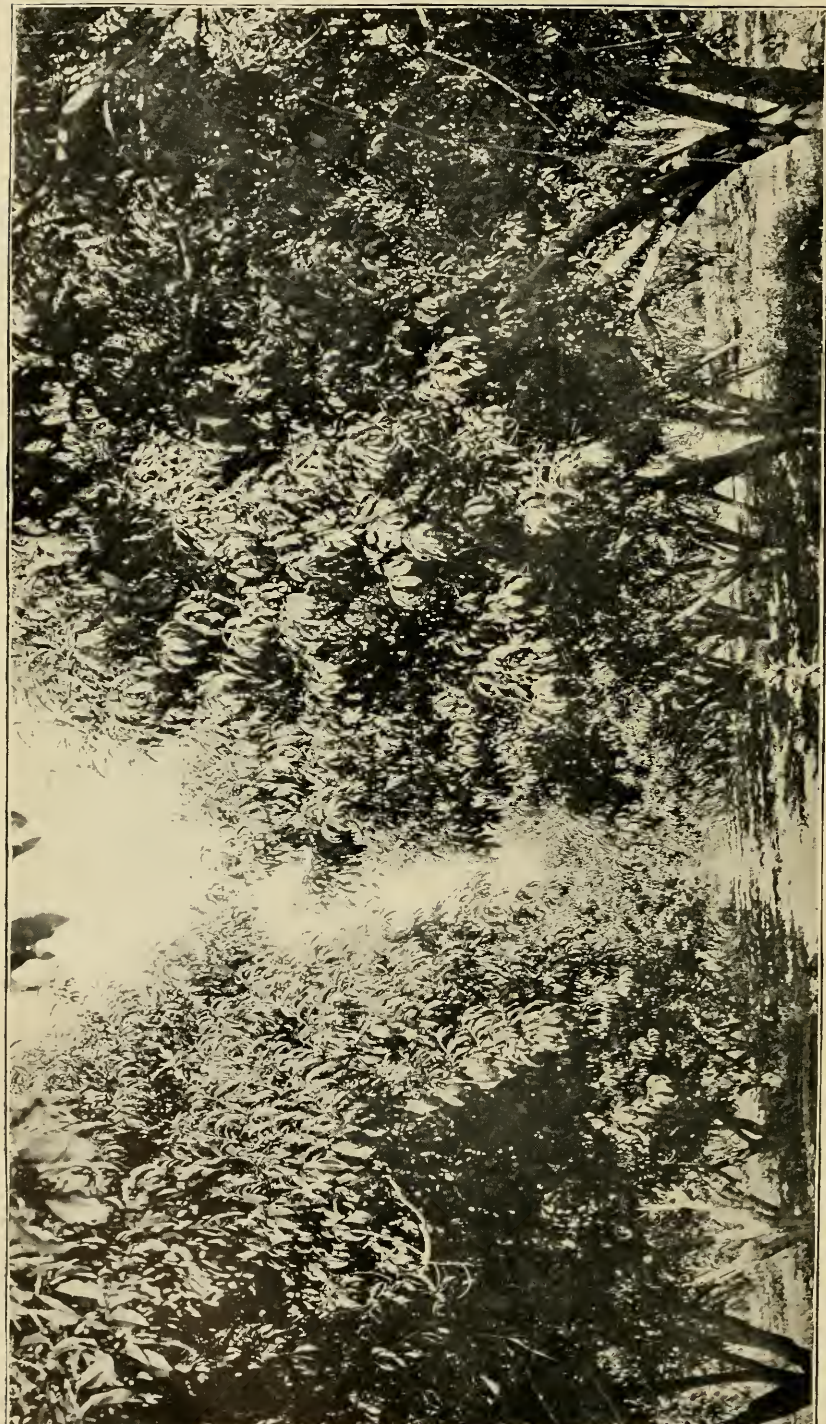
Besides the direct loss of leaves through infection by *Exoascus deformans*, there is an indirect loss through the retarding of growth of such foliage as has not been directly infected by the fungus. A limited examination of this matter was made May 17 and 18, 1895. Two typical trees were selected in adjoining rows, one of which had been

UNTREATED TREES IN LOVELL ORCHARD, BIGGS, CAL.

(Compare with Plate IX.)

DESCRIPTION OF PLATE VIII.

Experiments at Biggs, Cal. (Unsprayed.) Looking north through the Lovell trees from row 28 of the experiment block, showing the unsprayed trees on both sides as they appeared May 15, 1895, in the unsprayed orchard. These should be contrasted with the two sprayed rows, 21 and 22, shown in Pl. IX.



This row, No. 22, set 21,478 peaches; the adjoining unsprayed row set only 2,127.

TREATED TREES IN LOVELL ORCHARD.

(Compare with Plate VIII.)

This row, No. 21, set 22,163 peaches; the adjoining unsprayed row set only 1,911.

DESCRIPTION OF PLATE IX.

Experiments at Biggs, Cal. (Bordeaux mixture.) Looking east between rows 21 and 22, May 15, 1895. Row 21 was treated before blooming with 5 pounds copper sulphate, 5 pounds lime, and 45 gallons of water, and row 22 with 4 pounds copper sulphate, 5 pounds lime, and 45 gallons of water. Row 21 matured 4,443 pounds of fruit, and row 22, 4,421 pounds, while row 20, unsprayed, just south of row 21, matured only 648 pounds, and row 23, unsprayed, just north of row 22, matured only 712 pounds. Row 21 set 22,164 peaches, and row 22 set 21,478, while row 20 set only 1,911, and row 23 only 2,127; or, in other words, row 21 set eleven times as many peaches as row 20, and row 22 ten times as many as row 23 (p. 111). (Compare with Pl. VIII.)

sprayed and the other not. These were trees No. 10 of rows 20 and 21. Tree No. 10 of row 21 was sprayed the first week in March, 1895, with Bordeaux mixture (5 pounds copper sulphate, 5 pounds lime). Tree No. 10 of row 20 had not been sprayed. From each of these trees was gathered 2 pounds of healthy foliage. Careful measurements were made of the length of the branches of 1894 growth necessary to yield this weight of healthy leaves, and it was found that on the unsprayed tree it required 186 feet 2 inches, while on the sprayed tree it required only 49 feet 4 inches. The work was done as similarly as possible on both trees. The 2 pounds of foliage from the sprayed tree contained 2,428 leaves, and the 2 pounds from the unsprayed tree 2,546. In other words, 118 more healthy leaves were required from the unsprayed tree than from the sprayed tree to equal 2 pounds in weight, or 59 more leaves per pound. This result is due to the indirect rather than the direct action of the disease. The leaves from the unsprayed trees, being healthy, should average as great in weight as those from the sprayed trees, were it not for the retarding and impoverishing action of the disease upon the general growth of the tree. In comparing diseased with healthy leaves, however, this ratio would be reversed. The number of diseased leaves required for a given weight would be much less than the number of healthy leaves required. The diseased leaves are greatly curled and distorted through the irritation or stimulative action of the fungus present in the tissues, and in many instances they also become enormously increased in width, thickness, and weight.

The contrast observed in the color and general appearance of the leaves of the sprayed and unsprayed trees was very marked. The foliage of the trees treated with the stronger copper sprays, especially the Bordeaux mixtures, presented the finest appearance. On May 8, 1895, two months after the spray work was completed, and at the height of the disease, the foliage on trees thus sprayed presented the greatest perfection. It was so abundant and so dense as to throw very dark shadows beneath the trees, making it difficult to obtain good photographs among them. This dense foliage existed upon both the lower and the upper branches. The leaves were of a very dark and rich green color, long, soft, and beautiful. Upon the unsprayed trees comparatively few leaves presented the appearance of full health, and much of the diseased foliage had already fallen, leaving many trees nearly bare. The color of much of the remaining foliage was yellow and sickly. Many of the uncurled leaves were small and light colored on both the lower and the upper limbs. What growth these trees had made up to that date was largely terminal, very little healthy or comparatively healthy growth being apparent from lateral buds. (Compare Pls. VIII and IX.)

The influence of the various sprays on the thriftiness of the leaves was especially examined. This examination was confined to such foliage as was free from infection by the fungus, but was extended to sprayed and unsprayed trees alike, and to all rows of the block. In recording the comparative thrift of uninfected foliage, attention was given to the depth of the green color, to the softness of texture, and to the size of the leaves. These features of the foliage were considered collectively and recorded on the scale of 100; for instance, the most thrifty foliage was recorded at 100 per cent of thrift, and the less thrifty at a lower percentage. This method enables one to distinguish at a glance those sprays giving the best results in color, texture, and size of leaves—in other words, in functional ability. The records for each row and formula are given in the general table under the preceding head of this chapter, to which the reader is referred. It will there be seen that the trees of 5 rows produced foliage of the highest quality in spite of the presence of disease. These rows were all sprayed with the copper sprays, and all but one with Bordeaux mixture. Owing to the fact that row 30, showing first-quality foliage, was an outside row, it may be well to omit it in comparisons. The remaining 4 rows, Nos. 15, 41, 21, and 22, were all sprayed with Bordeaux mixture, containing 6 pounds, 5 pounds, 5 pounds, and 4 pounds of copper sulphate, respectively. Smaller amounts of copper sulphate did not give equally high results.

The average results shown by the different classes of sprays are as follows:

	Per cent.
Sulphur, lime, and salt (3 rows)	67
Sulphur and lime (7 rows)	63
Bordeaux, sulphur, and lime combined (3 rows)	77
Bordeaux (9 rows)	90
Bordeaux, 4, 5, and 6 pound formulæ (4 rows)	100
Eau celeste (2 rows)	90
Modified eau celeste (2 rows)	80
Ammoniacal copper carbonate (2 rows)	70
Iron sulphate and lime (1 row)	40
Iron sulphate, sulphur, and lime (1 row)	40
Potassium sulphide (1 row)	40
Potassium sulphide and lime (2 rows)	45
Lime and salt (1 row)	60[1]
Lime (1 row)	50
Trees sprayed in 1894, but not in 1895 (3 rows)	20
Control trees (19 rows)	20[2]

The Bordeaux mixture is here shown to give the best average results as to thrift of foliage. The excellence of texture, color, and size of the leaves on rows sprayed with the stronger Bordeaux mixtures would be hard to surpass.

[1] First leaves probably injured by spray.

[2] One exceptional row, showing 40 per cent, omitted; perhaps benefited by wind-borne spray.

GROWTH OF BRANCHES AND LEAF BUDS ON SPRAYED AND UNSPRAYED TREES.

Besides knowing the action of the disease and of the sprays upon foliage, it is desirable to ascertain their action on leaf buds and the growth of branches. Two months after growth started—from May 10–14, 1895—a study was made of the growth of 20 trees in the experiment block, 10 sprayed and 10 unsprayed. The rows selected for this work were Nos. 20 (unsprayed) and 21 (sprayed). These rows were types of the injurious action of the disease and of the beneficial action of the spray applied, which was 5 pounds of copper sulphate and 5 pounds of lime. Much time was given to making measurements of the new growth and recording the results, the time being equally divided between the 10 sprayed and the 10 unsprayed trees. Typical limbs were measured upon both the lower and upper portions of the trees, and the length and comparative health of the new growth was recorded. The length of 1894 growth and that which was older was first ascertained, and was followed by careful measurements of all spring growth of 1895 arising from wood of 1894 or from that which was older. The results of this work are shown in the following table:

TABLE 9.—*Records of measurements of healthy and diseased wood on unsprayed and sprayed trees, taken May 10–14, 1895.*

Tree No.	Row 20, unsprayed trees.					Row 21, sprayed trees.				
	Length of wood of 1894.	Length of spring growth of 1895—				Length of wood of 1894.	Length of spring growth of 1895—			
		On wood of 1894.		On wood more than 1 year old.			On wood of 1894.		On wood more than 1 year old.	
		Healthy.	Diseased.	Healthy.	Diseased.		Healthy.	Diseased.	Healthy.	Diseased.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1	1,422	492	249	76	91	674	1,189	11	194	2
2	1,614	570	229	219	131	664	908	6	494	14
3	1,364	301	251	83	22	592	768	4	46	....
4	1,304	557	301	234	29	666	1,580	6	330	....
5	1,576	499	326	85	41	702	1,100	3	45	....
6	1,886	298	257	182	11	976	1,259	4	325	1
7	1,366	527	230	18	32	998	1,348	4	183	....
8	1,758	686	516	53	2	1,068	2,751	2	195	....
9	1,986	977	550	120	8	938	2,100	....	84	....
10	1,912	670	582	56	2	982	1,869	....	220	....
Total	16,188	5,577	3,494	1,126	402	8,260	14,872	40	2,116	17

From the footings in the preceding table it appears that the total length of 1894 wood measured upon the unsprayed trees was nearly twice as great as that measured on the sprayed trees. This arose from the scarcity of new growth on this unsprayed wood, hence an equal time given to taking measurements upon each tree included more old wood upon unsprayed than upon sprayed trees.

On the unsprayed trees, prior to the middle of May, the total amount of new growth on 16,188 inches of 1894 wood, including the older wood from which this arose, was 10,599 inches. On the sprayed trees the new growth amounted to 17,045 inches during the same time (two months) on 8,260 inches of 1894 growth, including the older growth from which the latter arose. This was a net gain of 215 per cent, length of old wood considered, over the growth produced by the unsprayed trees. Otherwise stated, the unsprayed trees had averaged a new spring growth of 7.85 inches per running foot of 1894 wood and older, while the sprayed trees had produced a growth of 24.75 inches per foot of 1894 wood and older during the same time. This shows a gain in growth on the sprayed trees during these two months of 16.90 inches per foot of old wood. The importance of this matter will appear to all growers who have peach orchards situated where the spring growth represents the major part of that of the season, as is true in many peach-growing regions. In such orchards this would frequently represent a reduction of 25 per cent in the annual growth. In the peach, the growing wood of one year is the bearing wood of the next, hence the amount of wood produced would have added significance.

Considering the total growth of the spring of 1895 from wood grown prior to 1894—the pushing of dormant or quiescent buds—an analysis of the table shows a net gain by the old wood of sprayed trees of 173 per cent above the growth produced from like wood of unsprayed trees. This action of spray enables the grower to renew bearing wood on the lower portions of his trees, which is an advantage where trees are old or close set and tending to grow upward, or where curl or other causes have tended to denude the lower limbs of young and productive wood. This tendency of Bordeaux mixture to aid in the forcing and active growth of dormant buds was especially well marked in the case of a tree sprayed very thoroughly on one side (6 pounds copper sulphate, 4 pounds quicklime, 45 gallons of water) and left unsprayed on the other. From the base of the main limbs on the sprayed side there arose 13 shoots from dormant buds during the first two months of spring growth, while the unsprayed limbs produced practically none. The 13 shoots on the sprayed side had made the following growth to May 17, growth beginning about the close of the first week in March:

Shoots.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	Total.
Length in inches	36	44	29	37	46	21	36	36	36	46	22	21	23	36 feet 1 inch.

As shown by the table, the growth coming from 13 dormant buds at the base of the main limbs of the sprayed side of the tree during the first two months of spring growth amounts to 36 feet and 1 inch, or an average of over 33 inches for the 13 shoots. That this astonishing pushing of new basal buds was not due to injury of the top by the spray was shown by the immense amount of dark green foliage the sprayed half of the tree produced and from the amount and perfection of the fruit it bore. It was evidently an aided or stimulated basal growth. In table 9 is shown the comparative health or disease of the spring wood measured. Where shoots had suffered from disease to such an extent that they were enlarged, crooked, or otherwise distorted or injured by the disease, they were classed as diseased; when not so injured, they were classed as healthy. In respect to this classification the table gives the following facts: On the unsprayed trees the new shoots measured on growth of 1894 or older amounted to 10,599 inches, of which 6,703 inches was of healthy wood and 3,896 inches of diseased wood, or, in other words, 63 per cent of the wood was healthy and 37 per cent diseased. On the sprayed trees the total length of new shoots measured on 1894 growth or older was 17,045 inches; of this, 16,988 inches was of healthy wood and only 47 inches of diseased wood, or 99⅔ per cent was healthy and ⅓ per cent diseased.[1]

Many peach orchards are cultivated under conditions of moisture and nourishment that enable the trees to grow throughout the entire summer. In such situations trees badly diseased in the spring are apt to so far recover before frost that there is little apparent difference between them and the trees saved from curl by the use of sprays. That this recovery is not entire, however, is shown by actual comparisons. In the Riviera orchard, Live Oak, Cal., were obtained the following records, in February, 1894, fron 10 sprayed and 10 unsprayed Crawfords Late peach trees. The trees are fully described under the following heading of this

[1] These comparative records of the length of healthy and diseased branches upon sprayed and unsprayed trees fully serve the purpose of comparison for which they are here intended. There is another phase of the matter, however, which should not be overlooked or misunderstood at this time. A branch classed as diseased does not mean that it was diseased or swollen throughout its entire length, but that external signs of a diseased or injured condition were noted at some point in its course. If it be supposed that one-third of the injuries noted were dead ends or other imperfections not due to the infecting of the branch by the fungus, but indirect injuries arising from the loss of foliage, there remain two-thirds of the injuries which may be properly assumed to be due to the infection of branches by means of mycelium coming from diseased leaves. There would then appear to be 25 per cent of the cases which might be classed as diseased from mycelium infection. As already indicated, however, this does not mean that these branches are infected throughout their entire length, but show one or more points of infection at the buds. It is thought by the writer that not more than 1 bud in 10 is actually infected in these diseased branches. If this estimate is approximately correct, the number of infected buds on the unsprayed trees would be represented by one-tenth of 25 per cent, or 2.5 per cent of the buds on the tree. In brief, it is believed that it is rare for more than 3 per cent of the buds of a badly diseased tree to become infected by the mycelium from diseased leaves—in other words, that rarely more than this percentage of buds of one year carry a perennial mycelium to the next spring.

chapter, and it will here be sufficient to state that the growth on the sprayed and unsprayed trees could be fairly compared. The sprayed trees were treated with the sulphur, lime, and salt spray in the winter of 1892-93. Leaf curl developed seriously in the orchard in the spring of 1893. The sprayed trees saved their foliage and bore a full crop of fruit in 1893, while the unsprayed trees, everywhere surrounding those that were sprayed, lost the spring foliage and most of the fruit. All trees stood upon moist, deep, rich river bottom land, where growth could continue throughout the season. In the fall of 1893 the unsprayed trees had apparently largely overtaken the sprayed trees in growth, as the former had carried little crop, while those that were sprayed had matured a full crop. That the unsprayed trees were not, however, fully abreast of the sprayed trees when growth ceased in 1893, is shown by the measurements recorded in February, 1894 (table 11). These measurements were made on various sides of each tree, and on lower and upper limbs, and as a week was devoted to the work, the measurements are believed to be sufficiently extensive to give reliable results.

TABLE 10.—*Gain in number of lateral shoots and spurs from old wood on sprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees....	8,255	7,363
Number of lateral shoots and spurs that pushed from old wood in 1893.......	2,922	2,300
Number of lateral shoots and spurs per inch of old wood..........	0.3539	0.3124
Gain in favor of sprayed trees..........per cent..	13	....

The above table shows that 13 per cent more buds had pushed into shoots and spurs on the sprayed trees, in the summer of 1893, than on the unsprayed trees. All represented new growth from old wood.

The following table shows that the length of the new growth for the entire season of 1893 on the sprayed trees was 6.4 per cent more than that produced on the unsprayed trees. This was in spite of the facts that the unsprayed trees were so situated that growth could continue until frost and that they had not carried a crop of fruit as had the sprayed trees:

TABLE 11.—*Gain in length of new growth in favor of sprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees....	8,255	7,363
Length of new branches..........	18,174	16,390
Length of spurs, estimated at 2 inches per spur..........	2,692	1,100
Total length of new growth in inches..........	20,866	17,490
Inches of new growth per inch of old wood..........	2.527	2.375
Gain in new growth in favor of sprayed trees..........per cent..	6.4	....

The number of leaf buds produced on the sprayed and unsprayed trees per lineal inch or foot of old wood did not greatly differ. There was, however, a gain of 1 per cent in favor of the sprayed trees, as shown below:

TABLE 12.—*Gain in number of leaf buds in favor of sprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees	8,255	7,363
Number of leaf buds	5,403	4,763
Average number of leaf buds to inch of wood	0.654	0.647
Gain in favor of sprayed trees ... per cent	1	....

The tendency of the new growth to send out lateral branches and spurs was much more marked upon the sprayed than upon the unsprayed trees, the gain in this case being 109 per cent. This is a decided advantage, for the tree is thus enabled to bear a heavier and more equally distributed crop than where such laterals are few.

TABLE 13.—*Gain in number of lateral shoots and spurs from new wood on sprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of new wood, measured in inches, on sprayed and unsprayed trees	18,174	16,390
Number of lateral shoots and spurs from new wood	640	276
Number of lateral shoots and spurs per inch of new wood	0.0352	0.0168
Gain in favor of sprayed trees ... per cent	109	....

A complete tabular presentation of the data from which the four preceding tables have been drawn will be found under the following heading.

THE DEVELOPMENT OF NEW FRUIT BUDS AND FRUIT SPURS FOR THE YEAR FOLLOWING AN ATTACK OF CURL.

In February, 1894, while the action of the sulphur sprays was being considered in the Riviera orchard, the question arose as to the relative ability of sprayed and unsprayed trees to produce fruit buds and fruit spurs for the year following a severe attack of curl. Many trees in this orchard had been sprayed with the sulphur sprays in the winter of 1892–93 for the destruction of the San José scale (*Aspidiotus perniciosus*). The manner in which this work was done furnished an excellent opportunity to ascertain the facts desired respecting the development of fruit buds. It was noted during the early part of the winter that individual trees, scattered through a 40-acre block of 4-year-old Crawfords Late, had become infested with San José scale. A careful examination of this part of the orchard was then made, and each tree found to be infested with the scale was marked for spraying.

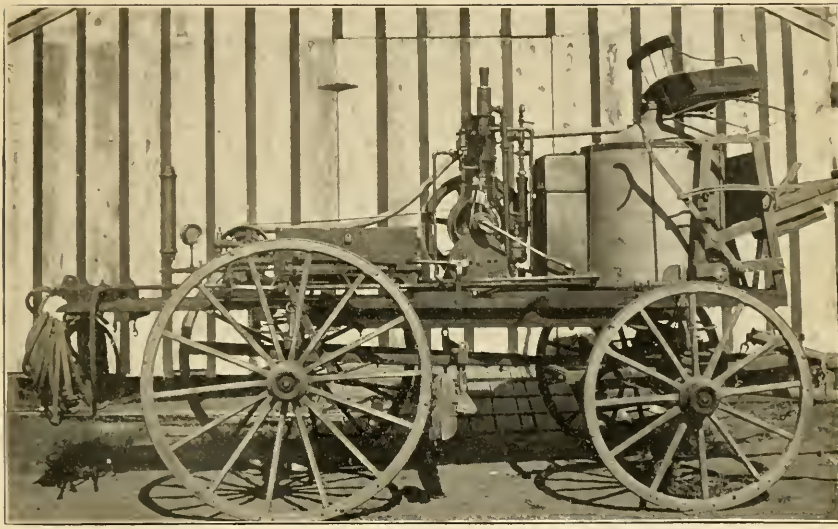
Later in the winter Mr. A. D. Cutts, one of the proprietors and the superintendent of the orchard, had these marked trees thoroughly sprayed with sulphur, lime, and salt, the formula used being as follows: Sulphur 15 pounds, lime 30 pounds, salt 10 pounds, water 60 gallons.

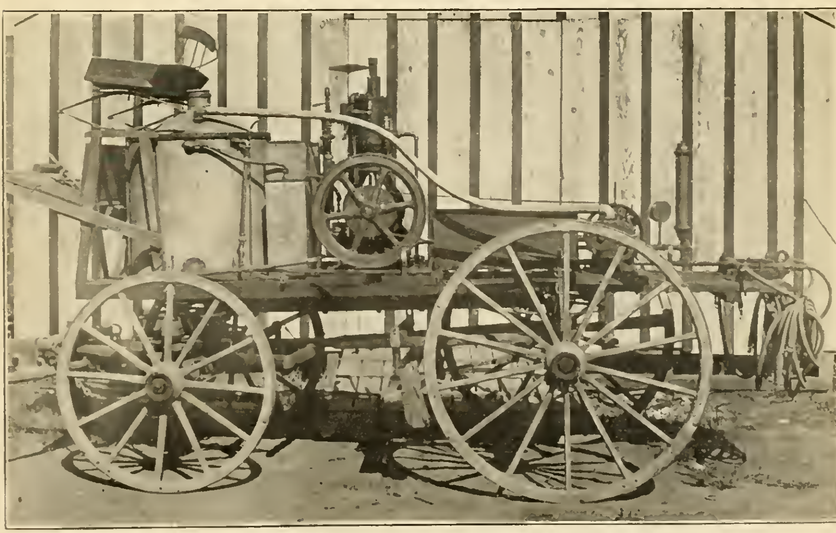
While this spray was known to be effective against San José scale, it also proved very effective against curl, which developed seriously in the orchard in the spring of 1893. The result of the spraying was to produce a most striking effect. When the disease developed, the unsprayed trees, which represented the major portion of this 40-acre orchard, were almost wholly denuded of foliage and largely of fruit, while the sprayed trees, scattered through the block, were in full foliage and fruit. This orchard was selected as a very suitable place in which to study the relative thrift and number of fruit buds and spurs produced on sprayed and unsprayed trees for the year following, and for this purpose 20 trees were selected from this block in February, 1894. Ten of these trees had been sprayed in the winter of 1892–93, and had thus escaped serious injury from curl in the spring of 1893, while 10 of them had not been sprayed and had suffered considerably from the disease. These 20 trees were all Crawfords Late, 5 years old in the winter of 1893–94, and similar in other respects, the soil, situation, etc., being the same.

The work of counting and grading buds upon these sprayed and unsprayed trees was begun about the middle of February, 1894, and continued for a week, an equal amount of time being given to each tree. To make all records as representative as possible of all portions of the trees studied, the limbs were measured and the buds counted and classified upon different sides of each tree and upon both lower and upper limbs. In the selection and measurement of limbs, as well as in the counting and classification of the buds, an effort was made to correctly represent the conditions existing in all parts of each tree, and of all trees alike. After the selection of a limb for study, all wood grown prior to 1893 was measured and the length recorded. Following this all the shoots and spurs of 1893 growth, and arising from the old wood measured, were counted and the number set down. All these new shoots, with the exception of fruit spurs 4 inches or less in length, were then measured. Records were kept of the length of the new shoots, the number of well-developed fruit buds, the number of poorly developed fruit buds, and the number of leaf buds they bore. A record of the number of lateral shoots and fruit spurs from the growth of 1893 was also preserved. The results of this work are brought together in the two tables which follow:

DESCRIPTION OF PLATE XXX.

Views of the right and left sides of the Gunnis power sprayer of San Diego, Cal. This sprayer is one of the lightest, most compact, and most practical power sprayers in use for general orchard work. It supplies 2 or 4 lines of hose, as may be desired. A tender is commonly used to carry the spraying materials to the orchard, where an extra rotary pump, worked by the same power as the spray pump, rapidly transfers the spray to the tank of the spray wagon. Such an outfit is adapted to extensive orchard work. Mr. H. R. Gunnis, San Diego, Cal., is the owner and operator of this machine.





RIGHT AND LEFT VIEWS OF POWER SPRAYER, SAN DIEGO, CAL.

TABLE 14.—*Records of fruit buds and leaf buds produced on given lengths of branches on 10 sprayed trees (Crawfords Late) after a severe attack of leaf curl in the spring of 1893.*

Tree No.	New wood.												New growth from old wood.					
	Lower limbs.						Upper limbs.						Lower limbs.			Upper limbs.		
				Fruit buds.						Fruit buds.								
	Number of spurs.	Laterals, number of shoots.	New wood (length in inches).	Well developed.	Poorly developed.	Number of leaf buds.	Number of spurs.	Laterals, number of shoots.	New wood (length in inches).	Well developed.	Poorly developed.	Number of leaf buds.	Number of spurs.	Number of shoots.	Old wood (length in inches).	Number of spurs.	Number of shoots.	Old wood (length in inches).
1	3	21	673	397	333	220	21	22	824	454	273	192	126	45	297	79	79	339
2	......	3	597	504	202	192	2	13	998	804	375	215	27	53	288	44	151	573
3	2	3	810	448	358	276	12	22	922	603	426	304	77	67	483	69	116	490
4	5	10	664	407	346	264	19	54	1,112	590	528	385	68	63	347	86	96	483
5	2	3	731	581	273	238	23	34	938	689	405	221	24	72	426	28	80	304
6	......	......	517	456	198	151	7	25	1,157	744	489	281	78	74	409	76	103	516
7	4	6	822	458	389	198	14	108	1,507	802	692	511	28	113	428	29	68	295
8	1	5	693	600	259	218	16	41	1,189	688	449	275	90	80	535	49	111	341
9	......	4	820	641	295	253	25	60	1,181	819	510	411	66	87	554	36	63	265
10	7	8	883	619	390	177	8	27	1,136	745	592	421	59	112	440	36	114	442
Total	24	63	7,210	5,111	3,043	2,187	147	406	10,964	6,938	4,749	3,216	643	766	4,207	532	981	4,048

TABLE 15.—*Records of fruit buds and leaf buds produced on given lengths of branches on 10 unsprayed trees (Crawfords Late) after a severe attack of leaf curl in the spring of 1893.*

Tree No.	New wood.												New growth from old wood.					
	Lower limbs.						Upper limbs.						Lower limbs.			Upper limbs.		
	Number of spurs.	Laterals, number of shoots.	New wood (length in inches).	Fruit buds. Well developed.	Fruit buds. Poorly developed.	Number of leaf buds.	Number of spurs.	Laterals, number of shoots.	New wood (length in inches).	Fruit buds. Well developed.	Fruit buds. Poorly developed.	Number of leaf buds.	Number of spurs.	Number of shoots.	Old wood (length in inches).	Number of spurs.	Number of shoots.	Old wood (length in inches).
1	1	4	475	155	266	123	1	12	589	240	389	214	6	30	151	17	60	236
2	1	1	479	281	245	95	12	12	787	538	375	230	34	50	202	20	66	305
3		6	597	308	274	176	3	13	1,002	558	488	381	27	67	253	15	97	454
4			715	221	436	197	5	6	934	483	620	267	34	62	250	18	121	513
5	2	19	983	374	582	275	10	23	1,166	485	714	421	13	49	206	2	94	319
6	1	3	498	397	247	117	4	8	746	737	303	210	34	71	291	44	114	494
7			646	405	390	157	19	31	1,188	616	648	408	12	122	348	8	116	425
8	2	26	806	416	479	168	5	12	1,260	572	858	393	60	114	408	23	130	576
9	3	3	719	402	372	193	3	4	937	636	545	262	19	82	319	49	161	727
10		5	702	459	348	166		16	1,161	644	621	310	24	100	380	19	116	506
Total	10	67	6,620	3,418	3,639	1,667	62	137	9,770	5,509	5,561	3,096	263	747	2,808	215	1,075	4,555

In the preceding tables, the number of shoots and spurs of 1893, which arose from wood of 1892 or earlier (old wood), as well as the length of the old wood itself, are classed under the general head of new growth from old wood. The measurements of the growth of 1893, and the number of lateral shoots and fruit spurs, as well as the number of fruit and leaf buds the new growth produced, are classed under the head of new wood. The buds were counted in a uniform manner upon all growth measured, except the buds borne by fruit spurs, which are estimated at 3 buds per spur in the tabulated calculations which follow. The fruit buds have been divided into two classes—well developed and poorly developed.

In considering the information given in the preceding tables, only those facts having a direct bearing on the fruit buds of the sprayed and unsprayed trees will be taken up under this heading. Those relating to length of new growth, number of new shoots, and number of leaf buds have already been considered under the preceding heading of this chapter.

The following digest from the general tables shows that 23,879 fruit buds of all kinds were produced by the new growth arising from 8,255 linear inches of old wood on 10 sprayed trees in 1893—an average of 2.892 buds per inch of old wood. The average number of buds per inch of old wood on the 10 unsprayed trees, obtained in a similar manner, was 2.686. These figures show that the sprayed trees produced $7\frac{2}{3}$ per cent more fruit buds of all kinds in the summer of 1893 than were produced by the unsprayed trees. These were fruit buds for the crop of 1894, and upon trees bearing a full crop in 1893, while the contrasted unsprayed trees bore very little.

TABLE 16.—*Gain in total number of fruit buds on sprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees	8,255	7,363
Total number of fruit buds of all kinds	23,879	19,777
Average number of same to inch	2.892	2.686
Gain in favor of sprayed trees ... per cent	$7\frac{2}{3}$	....

The percentage of gain in the gross number of fruit buds shown by the sprayed trees is considerable, but it represents only partially the advantages derived from the spray. Examinations of the unsprayed trees showed that a large percentage of the fruit buds they had produced in 1893 were imperfect, many of them being so poorly developed that fruit could not be expected from them. The following table shows the average number of imperfectly developed fruit buds on the sprayed trees to be 0.944 per linear inch of old wood, while on the unsprayed trees the average per inch of old wood was 1.249. This shows 32 per cent more imperfect fruit buds on the unsprayed than upon the sprayed trees at the close of the growing season of 1893.

TABLE 17.—*Excess of imperfectly developed fruit buds on unsprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees	8,255	7,363
Number of imperfectly developed fruit buds	7,792	9,200
Average number of imperfectly developed fruit buds to inch of wood	0.944	1.249
In favor of unsprayed trees ....per cent..	....	32

In comparing the number of well-developed fruit buds which were produced in 1893 by the sprayed and unsprayed trees, independent of the number of spur buds, it was learned that the number upon the sprayed trees was 20 per cent greater, as shown in the following table, than the number produced by the unsprayed trees.

TABLE 18.—*Gain in well-developed fruit buds, exclusive of spurs, on sprayed over unsprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees	8,255	7,363
Number of well-developed fruit buds, exclusive of spur buds	12,049	8,927
Average number of well-developed fruit buds to inch of wood	1.459	1.212
Gain in favor of sprayed trees ....per cent..	20	....

Taking the aggregate of all well-developed fruit buds, including the spurs, at an average of 3 buds each, the sprayed trees make a still better showing when contrasted with the unsprayed. The average number of all well-developed buds on the sprayed trees was 1.949 per linear inch of old wood, and on the unsprayed trees 1.437 per inch of old wood. This shows a gain of 35 per cent in well-developed fruit buds in favor of the sprayed trees. These facts are shown in tabular form as follows:

TABLE 19.—*Gain in spur buds and other well-developed fruit buds on sprayed over unsprayed trees.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees	8,255	7,363
Aggregate of spur buds and of other well-developed fruit buds	16,087	10,577
Average number of same to inch	1.949	1.437
Gain in favor of sprayed trees ....per cent..	35	....

One of the most striking contrasts shown by the data obtained in these field studies is that existing between the number of fruit spurs and spur buds produced by the sprayed and unsprayed trees in 1893. There was a net gain in the number of fruit spurs and spur buds on the sprayed trees of 118 per cent above the number produced by the unsprayed trees, a fact that should certainly appeal directly to the business faculties of every grower of peaches. It should also be remembered that these sprayed trees had carried a crop while producing these fruit spurs for the following year, while the unsprayed trees had borne but few peaches. The facts here discussed are shown in the table that follows.

TABLE 20.—*Gain in number of spur buds on sprayed over unsprayed trees.*

Records.	Trees. Sprayed.	Trees. Unsprayed.
Length of old wood, measured in inches, on sprayed and unsprayed trees	8,255	7,363
Total number of spurs	1,346	550
Number of spur buds, estimated at 3 buds per spur	4,038	1,650
Average number of spurs per inch	0.163	0.075
Average number of spur buds per inch	0.489	0.224
Gain in favor of sprayed trees ... per cent	118	....

Besides comparing the number of fruit buds produced in 1893 by the sprayed and unsprayed trees, it is desirable to contrast the bud-producing abilities of the upper and lower portions of these trees. It is generally conceded as desirable that the crop of a peach tree should be borne as largely as possible upon the lower limbs, and anything tending to this result may prove of value. Peach leaf curl, being due to a fungous parasite, has a tendency to do more injury to the lower than to the upper portions of the trees affected. The atmospheric conditions are more favorable for the germination of spores and to fungous growth in the lower and more shaded portions of the tree, and the lower branches accumulate greater numbers of fungous spores than the upper branches. In the following table it is shown that the total number of fruit buds produced by the lower limbs of the sprayed trees was 7 per cent greater than the number produced by the upper limbs, comparing equal lengths of new wood in each case. On the unsprayed trees, however, the upper limbs produced 5 per cent more fruit buds per linear unit of new wood than the lower limbs. This shows a difference of 12 per cent in favor of the sprayed trees. The tabulated figures are as follows:

TABLE 21.—*Gain in total number of fruit buds on lower limbs of sprayed trees over those of unsprayed trees, as compared with upper limbs of each, respectively.*

Records.	Trees. Sprayed.	Trees. Unsprayed.
Length of new wood, measured in inches, on upper limbs	10,964	9,770
Length of spurs, estimated at 2 inches per spur	1,358	554
Total length of new wood on upper limbs	12,322	10,324
Length of new wood, measured in inches, on lower limbs	7,210	6,620
Length of spurs, estimated at 2 inches per spur	1,334	546
Total length of new wood on lower limbs	8,544	7,166
Total number of fruit buds on upper limbs	13,724	11,901
Total number of fruit buds on lower limbs	10,155	7,876
Average number of fruit buds per inch on upper limbs	1.114	1.153
Average number of fruit buds per inch on lower limbs	1.189	1.099
Gain in favor of lower limbs on sprayed trees ... per cent	7	....
Gain in favor of upper limbs on unsprayed trees ... do	....	5
Difference in favor of sprayed trees ... do	12	....

By contrasting only the well-developed and spur fruit buds it is learned that there was 14 per cent in the number of buds in favor of the lower limbs on the sprayed trees and 4 per cent in favor of the upper limbs on the unsprayed trees. This showed a difference of 18 per cent in favor of the lower limbs of the sprayed trees. The entire comparison is given in the table which follows:

TABLE 22.—*Gain in number of well-developed and spur fruit buds on the lower limbs of sprayed over unsprayed trees, as compared with upper limbs of each, respectively.*

Records.	Trees.	
	Sprayed.	Unsprayed.
Length of new wood, measured in inches, on upper limbs	10,964	9,770
Length of spurs, estimated at 2 inches per spur	1,358	554
Total length of new wood on upper limbs	12,322	10,324
Length of new wood, measured in inches, on lower limbs	7,210	6,620
Length of spurs, estimated at 2 inches per spur	1,334	546
Total length of new wood on lower limbs	8,544	7,166
Number of well-developed and spur fruit buds on upper limbs	8,975	6,340
Number of same on lower limbs	7,112	4,237
Average number of same per inch on upper limbs	0.728	0.614
Average number of same per inch on lower limbs	0.832	0.591
Gain in favor of lower limbs on sprayed trees ...per cent..	14	
Gain in favor of upper limbs on unsprayed trees ...do...		4
Difference in favor of sprayed trees ...do...	18	

CHAPTER VI.

INFLUENCE OF SPRAYS ON THE FRUITING OF THE TREES.

THINNING THE FRUIT OF SPRAYED TREES.

The general discussion of the spray work conducted in the Rio Bonito orchard will be found in Chapter IV, and it is therefore not necessary to review these matters here. As soon as growth was well started in this orchard in the spring of 1895, it became evident that the fruit would have to be thinned on a portion of the Lovell trees comprising the experiment block. The peaches were setting thickly on both sprayed and unsprayed trees, but as leaf curl developed, the young fruit upon the control trees began to fall, while that upon the sprayed trees remained firmly attached and grew rapidly.

When the young peaches had reached the size of hickory nuts, and the pits were forming, the danger of dropping from curl had passed, and the thinning of fruit on overloaded trees was then undertaken. To enable the writer to make just comparisons of the merits of the various sprays in saving fruit, it became necessary to carefully record the amount and number of peaches thinned from all trees in the experiment block. Thinning fruit is an equalizing process, and to equalize the crop upon sprayed and unsprayed trees or upon trees treated with different sprays, would be to destroy the contrast in the amount of fruit arising from the use of different formulæ. This would result in the loss of the very facts which it was hoped to obtain from the experiments, unless records of the fruit thinned off were preserved. For the preservation of such records the following plan was adopted: Canvas sheets of large size, commonly used in the harvest of the almond crop in the same orchard, were spread beneath the trees to be thinned. The young peaches were allowed to fall upon the canvas as picked, and the canvas was moved as necessary. The fruit thus thinned was poured from the canvas into picking boxes beneath the tree from which it was thinned. By this plan the fruit thinned from each tree was kept by itself. After an experiment row of 10 trees had been thinned, the fruit picked from each tree was separately weighed and the weight recorded. From 3 trees of the row sufficient fruit was now taken to amount to 25 pounds. The peaches in this 25 pounds were then counted, the number entered with the other records of the row, and on this basis the average number of small peaches per pound for the row was determined. By multiplying the number of pounds of young peaches thinned from each tree by the average number of peaches per pound, as above obtained, the writer was able to determine quite accurately the number of peaches thinned from each tree of the row.

When the work on one experiment row was completed, the fruit from a second row of 10 trees was gathered, weighed, and counted in like manner, and this process was followed for each row of the block which required thinning.

From the field records thus gathered two tables have been carefully compiled, the first showing the actual weight of young peaches picked from each tree thinned in the block, and the second the computed number of peaches which these weights represent, as determined by the above-described method.

TABLE 23.—*Weight of peaches thinned from the sprayed Lovell peach trees in the experiment block of the Rio Bonito orchard in the spring of 1895.* (*a*)

Row No.	Actual weight in pounds of thinned peaches from trees Nos.—										Total weight of peaches in row.	Number of peaches in 25 pounds.	Average number of peaches per pound.	Total number of peaches per row.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.				
											Pounds.			
1	15	16½	18	33	20¼	22½	27	45	50	35	282¼	482	19.28	5,442
2	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	27	22	15	20	22½	21	30½	16½	29	16	219½	550	22.00	4,829
4	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	18	2	15	6	15	3	21½	5	19	16½	121	486	19.44	2,352
7	17	25	11	7½	12	9½	15	6	5½	8½	117	484	19.36	2,265
8	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	36	21	15	13½	18½	25	36	6½	6	7½	185	522	20.88	3,863
10	30	30½	24	10	17	25	40	19½	17	20½	233½	466	18.64	4,352
11	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	31	13	3	10	6	16½	1½	19½	10½	22½	133½	511	20.44	2,729
13	23½	14½	2	2½	18	13½	7½	2½	3½	5½	93	495	19.80	1,841
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	82	44	27	31	24	40	45	23	29½	22	367½	528	21.12	7,762
16	20½	6	15	3½	9½	5	17	17½	14	13	121	496	19.84	2,401
17	....	....	....	....	....	....	....	....	....	....	....	....	....	....
18	32	17	26	16	17	8	10	6	14	4	150	504	20.16	3,024
19	24	35	29	16	25	14	13	11	7	12	186	486	19.44	3,616
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....
21	68	48	26	28	48½	49	58	21	29½	61½	437½	484	19.36	8,470
22	33	51	35	21	35	58	41	22	29	60	385	472	18.88	7,269
23	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	....	....	....	....	....	....	....	....	....	....	....	....	....	....
25	42	20	22	18	28	21	37	38	43	51	320	449	17.96	5,747
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....
27	34	34	35	11	14	35	30	22	21	23	259	495	19.80	5,128
28	18	21	32	29	31	33	34	30	63	50	341	421	16.84	5,742
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	55	49	42	43	60	43	41	35	70	86	524	487	19.48	10,208
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....
32	31	15	18	20	22	18	27	8	....	....	159	514	20.56	3,269
33	47	51	34	40	22	39	33	29	39	47	381	483	19.32	7,361
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....
35	62	63	23	....	57	42	46	57	54	62	466	522	20.88	9,730
36	23	35	14	10	11	31	26	31	28	46	255	480	19.20	4,896
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....
38	15	6	6	8	10	22	26	17	15	25	150	553	22.12	3,318
39	40	26	39	....	....	37	34	29	34	27	266	547	21.88	5,820
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....
41	54	52	27	24	26	12	27	8	35	28	293	508	20.32	5,953
42	....	....	....	....	....	....	....	....	....	....	....	....	....	....
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....
44	6	8	11	5	6	....	....	....	....	....	36	537	21.48	773
45	25	23	21	11	22	17	20	16	27	14	196	504	20.16	3,951
46	....	....	....	....	....	....	....	....	....	....	....	....	....	....
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....
48	7	6	3	5	....	....	....	....	8	4	33	511	20.44	675
49	....	....	....	....	....	....	....	....	....	....	....	....	....	....
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....
51	15	22	8	12	11	12	12	13	18	17	140	533	21.32	2,985
52	....	....	....	....	....	....	....	....	....	....	....	....	....	....
53	....	....	....	....	....	....	....	....	....	....	....	....	....	....
54	30	34	44	18	17	27	30	21	36	17	274	508	20.32	5,568
55	....	....	....	....	....	....	....	....	....	....	....	....	....	....
56	22	40	44	18	17	27	30	21	36	17	272	520	20.80	5,658
57	21	35	16	20	11	19	20	29	32	37	240	547	21.88	5,251
58	....	....	....	....	....	....	....	....	....	....	....	....	....	....

a For plat of orchard see p. 69; for sprays applied see p. 73.

By referring to the above table it will be seen that only those rows which were sprayed in the spring of 1895 were thinned, and that a portion of these required but little thinning. The reasons for this lie in the severe action of the disease upon the unsprayed rows and those sprayed with weak or unsatisfactory sprays, in which cases the fruit fell from disease. The table shows the weight of thinned peaches per tree, the total weight of peaches thinned from the row, the number of peaches contained in 25 pounds, the average number of peaches per pound, and the total number of peaches thinned from the row.

In the table which follows the pounds have been reduced to show the number of peaches, the reduction being made according to the method already described. Comparison of the total number of peaches thinned from the separate rows, as given in the two tables, will show slight variations in the units column in several cases. These variations arise from the gain or loss in fractions resulting from the use of the different methods which it was necessary to employ in obtaining the figures shown in the two tables.

TABLE 24.—*Number of peaches thinned from the sprayed Lovell peach trees in the experiment block of the Rio Bonito orchard in the spring of 1895.* (*a*)

Row No.	Number of peaches thinned from sprayed trees Nos.—										Total.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
1	289	318	347	636	390	434	521	868	964	675	5,442
2											
3	594	484	330	440	495	462	671	363	638	352	4,829
4											
5											
6	350	39	292	117	292	58	418	97	369	321	2,353
7	329	484	213	145	232	184	290	116	106	165	2,264
8											
9	752	438	313	282	386	522	752	136	125	157	3,863
10	559	569	447	186	317	466	746	363	317	382	4,352
11											
12	634	266	61	204	123	337	31	399	215	460	2,730
13	465	287	40	50	356	267	148	50	69	109	1,842
14											
15	1,732	929	570	655	507	845	950	486	623	465	7,762
16	407	119	298	69	188	99	337	347	278	258	2,400
17											
18	645	343	524	323	343	161	202	121	282	81	3,025
19	467	680	564	311	486	272	253	214	136	233	3,616
20											
21	1,316	929	503	542	939	949	1,123	407	571	1,191	8,470
22	623	963	661	396	661	1,095	774	415	548	1,133	7,269
23											
24											
25	754	359	395	323	503	377	665	682	772	916	5,746
26											
27	673	673	693	218	277	693	594	436	416	455	5,128
28	303	354	539	488	522	556	573	505	1,061	842	5,743
29											
30	1,071	955	818	838	1,169	838	799	682	1,364	1,675	10,209
31											
32	637	308	370	411	452	370	555	164	....	....	3,267
33	908	985	657	773	425	753	638	560	753	908	7,360
34											
35	1,295	1,315	480	....	1,190	877	960	1,190	1,128	1,295	9,730
36	442	672	269	192	211	595	499	595	538	883	4,896
37											
38	332	133	133	177	221	487	575	376	332	553	3,319
39	875	569	853	....	....	810	744	635	744	591	5,821
40											
41	1,097	1,057	549	488	528	244	549	163	711	569	5,955
42											

a For plat of orchard see p. 69; for sprays applied see p. 73.

TABLE 24.—*Number of peaches thinned from the sprayed Lovell peach trees in the experiment block of the Rio Bonito orchard in the spring of 1895*—Continued.

Row No.	Number of peaches thinned from sprayed trees Nos.—										Total.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
43											
44	129	172	236	107	129						773
45	504	464	423	222	444	343	403	323	544	282	3,952
46											
47											
48	143	123	61	102					164	82	675
49											
50											
51	320	469	171	256	235	256	256	277	384	362	2,986
52											
53											
54	610	691	894	366	345	549	610	427	732	345	5,569
55											
56	458	832	915	374	354	562	624	437	749	354	5,659
57	459	766	350	438	241	416	438	635	700	810	5,253
58											

GATHERING FRUIT OF SPRAYED AND UNSPRAYED TREES.

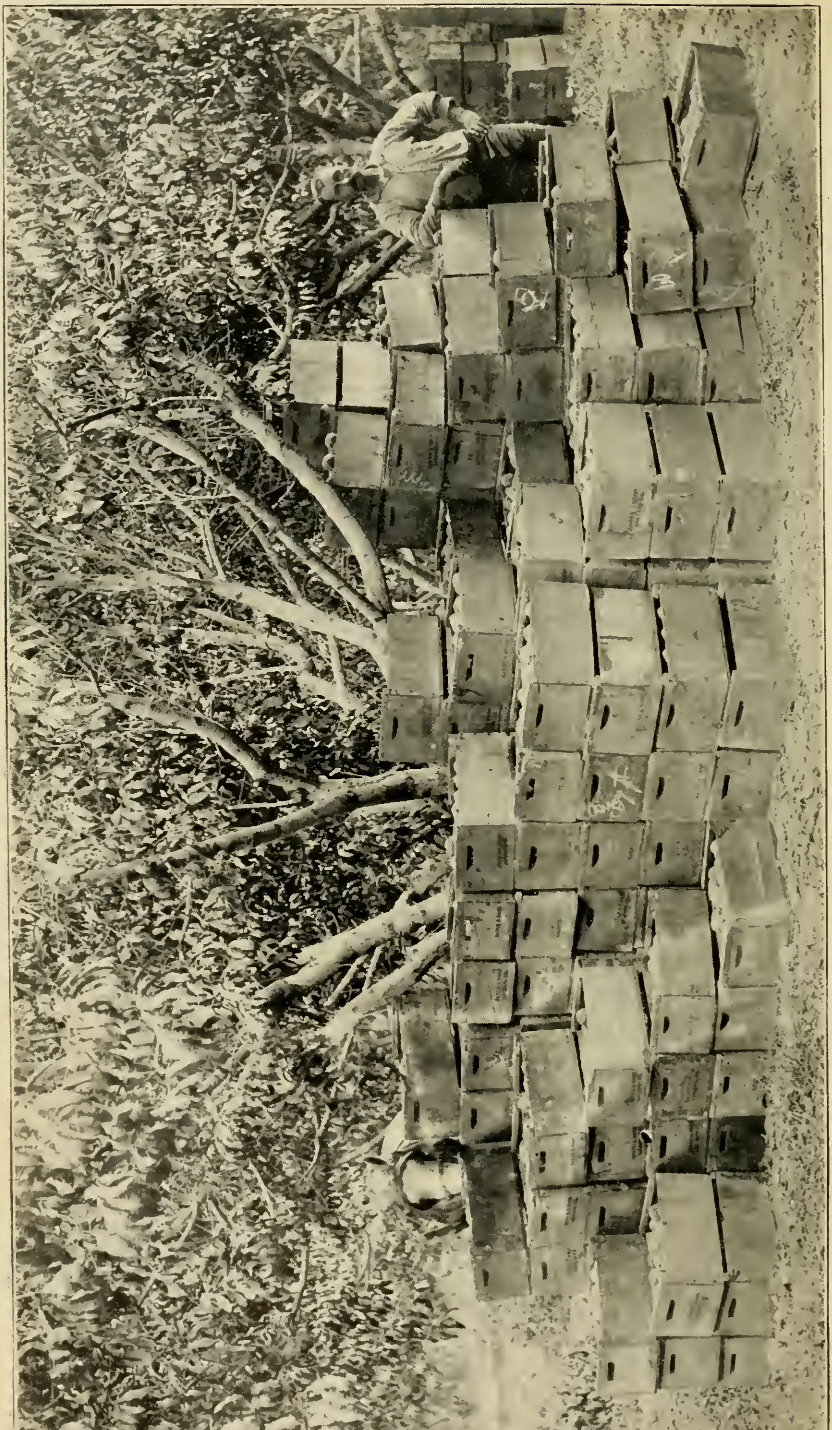
The fruit of the Lovell variety ripened rapidly in the Sacramento Valley after the middle of August, 1895. On the experiment trees a large portion of the crop was sufficiently matured for shipment to the canneries by the 20th of that month. By that date the plans had been made for the gathering of the crop, which work was completed before the 1st of September. The fruit was gathered at two pickings, the second picking beginning shortly after the close of the first. The crop was marketed in three ways:

(1) All perfect peaches above a standard size adopted by the canneries, and sufficiently firm to bear shipment by rail from Biggs to Oakland, Cal., a distance of about 140 miles, were sold to a firm at the latter point at $30.80 per ton, f. o. b. cars at Biggs. This fruit comprised about 54 per cent of the yield of the experiment block.

(2) All perfect peaches of canning size which were too mature to bear the delay and long shipment by rail to Oakland were shipped to a cannery at Chico, Cal., a distance of about 30 miles. This fruit brought $30 per ton, f. o. b. cars at Biggs. It comprised about 30 per cent of the yield of the experiment block.

(3) Such fruit as was below cannery size, overmature, or imperfect in any respect was sent to the drying ground to be dried. In the calculations of the present work this fruit is valued at three-fourths of a cent per pound in the green state. This is less than the equivalent of dried fruit was worth at the time of curing after allowing for the cost of drying. The fruit sent to the drying ground represented about 16 per cent of the yield of the experiment block.

The work of gathering, weighing, and grading the crop of the experiment rows was carefully systematized. As before shown, the experiment block was 20 trees wide from east to west, and through the center from north to south a driveway was made, so that the rows



FRUIT PRODUCED BY TREATED TREES OF ROW 15, EXPERIMENT BLOCK, BIGGS, CAL.

The fruit produced by the trees of the adjoining unsprayed row (14) is shown in the boxes in the background at the extreme right.

DESCRIPTION OF PLATE X.

Experiments at Biggs, Cal. (Bordeaux mixture.) Fruit gathered from row 15 of the experiment block of the Rio Bonito orchard in the summer of 1895. The formula for the spray used on this row was 6 pounds copper sulphate, 15 pounds quicklime, 45 gallons of water. The 10 trees of the row matured 4,351 pounds of fine peaches, which are shown in the picking boxes. The trees of the adjoining unsprayed row, No. 14, bore only 928 pounds. The value of the fruit matured on row 15 was $60.02; on row 14 it was $13.24, a net gain from spraying 10 trees of $46 after allowing for the cost of spraying. This gain resulted after more than one-third of the peaches had been thinned from the sprayed row, while none had been thinned from row 14. The total number of peaches set by the trees of row 15 was 21,272, by those of row 14 it was 2,855. The comparative average net gain shown by the spray used on row 15 was 619 per cent.

on either side were 10 trees long from east to west. One picker was assigned to each tree of the row across the block, thus making ten pickers on each side of the drive, or twenty in all, and an extra man was assigned as superintendent of the twenty pickers, to see that all instructions were carefully carried out. Every man was instructed to leave all fruit he picked beneath the tree from which it was gathered, picking boxes having been previously distributed for this purpose.

The work of picking began at the south end of the experiment block. When the fruit which was sufficiently matured had been gathered and placed in the boxes beneath a tree, the picker proceeded to the next tree north, thus following the same north-and-south row until he had passed entirely through the block, and when each man had thus completed his north-and-south row the entire block had been picked over, the fruit being beneath the trees from which it came. The first and second pickings were conducted in this manner, but the second was not begun until after the first was completed and the gathered fruit had been removed from beneath the trees.

The process of collecting the fruit of the first picking began as soon as the pickers had completed an east-and-west row and had proceeded to the next row toward the north. Four men were employed to collect and weigh the peaches—two to collect the fruit in the orchard and two to weigh, count, and keep the records. The fruit was brought from the east and from the west to the central driveway on a low platform wagon drawn by one horse. The boxes of fruit gathered from the 10 trees of each experiment row were piled at the side of the driveway, close to the last tree of the row. The boxes of fruit from each tree were also distinguished by means of cards bearing the number of the tree from under which the boxes were taken (Pl. X).

The weighing began as soon as the fruit from the 10 trees of an experiment row had been piled at the side of the central drive. Platform scales were placed on a level base close to the fruit boxes, and the fruit from each tree of the row was weighed separately. The gross weight was recorded for each tree, as well as the number of picking boxes. The average weight of the picking boxes used was afterwards carefully determined, and from these data the net weight of fruit was ascertained and tabulated for each tree of each row of the block. After the weight of fruit for each tree of an experiment row was thus learned, 100 pounds of peaches were weighed out from typical boxes of several trees of the row. The number of peaches in this 100 pounds of fruit was then ascertained by counting, the number being recorded with the other data for the row. The fruit of all the experiment rows was weighed and the average size of the peaches determined by counting, as here indicated.

Following close after the weighers came five or six sorters. These men graded the fruit, according to the requirements already outlined, into three classes—one for an Oakland cannery, one for a Chico cannery, and a third class for drying. These three classes constituted really but two qualities of fruit—a first quality for canning, and a second quality for drying. After the fruit of a row was graded a careful count of the number of picking boxes of each class of fruit was made, and the numbers recorded. From these figures were determined the proportions of the total yield of the row which belonged to the different classes of fruit. The same process of picking, collecting, weighing, counting, grading, and recording was followed for the second picking as for the first.

In the following table are shown the net weights of fruit gathered at the first picking from each tree of the entire block of 58 experiment rows, with the total weight for each row.

TABLE 25.—*Weight of peaches of first picking from the Lovell trees of the experiment block of the Rio Bonito orchard, gathered in the fall of 1895.*

Row No.	Weight of fruit, in pounds, gathered at first picking from trees Nos.—										Total net weight of fruit in row.	Number of trees in row.	Average weight per tree.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.			
											Pounds.		*Pounds.*
1	75	109	142	207	147	118	262	190	180	140	1,570	10	157
2	51	89	122	137	54	111	90	140	165	48	1,007	9.5	106
3	164	121	140	147	157	179	289	241	200	49	1,687	10	168.7
4	69	71	129	31	57	120	87	74	69	34	741	9.8	75.6
5	42	74	36	56	73	140	159	100	64	66	810	10	81
6	190	75	193	175	228	97	212	212	237	204	1,813	10	181.3
7	88	267	139	169	181	183	180	222	169	110	1,708	10	170.8
8	93	29	22	11	39	151	115	39	53	16	568	10	56.8
9	259	271	162	202	218	248	233	234	153	121	2,101	10	210.1
10	216	275	332	89	219	240	249	297	467	169	2,553	10	255.3
11	65	71	30	86	83	107	114	41	166	70	833	10	83.3
12	229	166	111	191	304	154	247	168	240	147	1,957	9.4	208.2
13	232	192	200	70	161	203	209	187	145	77	1,676	10	167.6
14	121	55	114	109	47	114	91	114	47	32	844	10	84.4
15	492	357	538	253	474	474	573	340	453	273	4,227	10	422.7
16	157	112	303	87	298	216	451	235	291	198	2,348	10	234.8
17	133	56	55	52	88	119	58	89	44	21	715	10	71.5
18	383	241	322	242	341	233	296	144	288	119	2,609	10	260.9
19	251	324	365	144	331	364	245	201	189	180	2,594	10	259.4
20	61	99	110	109	32	27	32	22	23	59	574	10	57.4
21	426	438	470	405	498	431	617	252	343	427	4,307	10	430.7
22	384	524	539	257	544	556	469	324	332	346	4,275	10	427.5
23	22	80	88	54	62	95	75	38	105	53	672	10	67.2
24	65	50	65	48	43	52	48	56	24	96	547	10	54.7
25	380	236	386	180	426	424	565	459	285	430	3,771	10	377.1
26	70	121	71	16	19	62	109	96	49	45	658	10	65.8
27	345	400	438	116	166	425	513	290	206	217	3,116	10	311.6
28	313	385	573	298	400	489	489	379	421	379	4,126	10	412.6
29	29	36	98	64	60	90	33	95	25	46	576	10	57.6
30	188	198	237	258	323	219	296	318	236	342	2,615	10	261.5
31	71	152	127	134	149	179	111	199	215	215	1,552	10	155.2
32	177	139	132	252	315	218	209	298	299	243	2,282	10	228.2
33	283	271	159	401	250	373	428	429	387	208	3,189	9.8	325.4
34	87	128	94	53	107	148	79	133	127	146	1,102	10	110.2
35	393	291	237	.....	563	491	597	590	424	448	4,034	8.6	469
36	298	213	129	144	188	354	365	365	315	310	2,681	10	268.1
37	80	96	69	27	198	84	127	163	138	143	1,125	10	112.5
38	246	91	140	166	273	234	284	341	274	403	2,452	10	245.2
39	283	154	330	.....	.....	384	439	461	339	414	2,804	8	350.5
40	135	123	65	59	69	49	53	47	114	222	936	10	93.6
41	412	268	274	451	430	200	410	305	314	400	3,464	10	346.4
42	287	176	128	157	179	145	223	119	299	211	1,924	10	192.4
43	92	85	108	32	32	45	97	28	52	84	655	10	65.5
44	171	150	246	163	70	164	139	231	182	226	1,742	10	174.2
45	328	220	296	222	510	324	413	363	326	286	3,288	10	328.8
46	52	87	64	107	90	56	42	73	103	53	727	10	72.7
47	130	149	139	118	228	116	105	169	190	228	1,572	10	157.2
48	97	155	137	106	117	79	182	142	151	181	1,347	10	134.7
49	77	91	61	95	78	60	86	41	74	32	695	10	69.5
50	250	284	214	147	107	120	118	229	295	350	2,114	10	211.4
51	264	330	277	263	247	207	251	193	299	310	2,641	10	264.1
52	162	99	126	135	147	84	25	63	94	132	1,067	10	106.7
53	140	68	62	105	54	63	44	73	90	54	753	9.6	78.4
54	337	457	449	443	311	421	392	408	294	285	3,797	10	379.7
55	93	166	97	80	45	153	137	67	92	94	1,024	10	102.4
56	336	361	314	415	294	181	244	381	268	504	3,298	9.5	347.1
57	330	400	277	359	254	282	313	399	327	471	3,412	10	341.2
58	91	64	99	92	86	195	83	46	51	52	859	10	85.9

At the side of the total column in the preceding table is given a column showing the number of trees in each row. The total amount of fruit gathered at the first picking from each row has been divided by the number of trees in the row, giving the average amount of fruit picked per tree for each row of the block. This average is shown in the right-hand column.

In the table which follows is given the net weight of fruit gathered at the second picking from each tree of the block not picked clean at the first picking.

TABLE 26.—*Weight of peaches of second picking from the Lovell trees of the experiment block of the Rio Bonito orchard, gathered in the fall of 1895.*

Row No.	Weight of fruit, in pounds, gathered at second picking from trees Nos.—										Total net weight of fruit in row.	Number of trees in row.	Average weight per tree.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.			
											Pounds.		*Pounds.*
1	54	121	41	133	112	127	132	112	242	168	1,242	10	124.2
2	25	6	12	99	.....	.....	25	41	67	68	343	9.5	36.1
3	79	124	33	151	151	88	26	162	108	187	1,109	10	110.9
4	12	.....	44	39	.....	45	4	26	34	51	255	9.8	26
5	.....	.....	13	90	61	12	.....	.....	23	37	236	10	23.6
6	49	8	60	32	83	20	109	10	38	43	452	10	45.2
7	60	9	99	28	120	.....	31	.....	30	140	517	10	51.7
8	11	10	8	.....	.....	.....	27	13	18	20	107	10	10.7
9	31	16	26	14	96	.....	82	.....	26	66	357	10	35.7
10	29	10	25	16	19	87	76	.....	63	90	415	10	41.5
11	7	5	5	11	.....	.....	31	28	18	31	136	10	36.6
12	11	12	.....	.....	.....	13	41	.....	15	54	146	9.4	15.5
13	23	13	21	.....	23	.....	35	.....	14	55	184	10	18.4
14	19	6	.....	8	.....	.....	8	13	12	18	84	10	8.4
15	33	6	18	.....	.....	.....	7	.....	22	38	124	10	12.4
16	20	11	18	.....	.....	.....	11	28	6	58	152	10	15.2
17	11	.....	11	.....	.....	.....	5	.....	7	9	43	10	4.3
18	23	10	.....	14	.....	.....	.....	.....	14	30	91	10	9.1
19	10	6	16	.....	31	.....	14	11	13	17	118	10	11.8
20	7	3	15	.....	22	.....	4	.....	5	18	74	10	7.4
21	12	8	13	5	.....	.....	12	.....	53	33	136	10	13.6
22	11	28	19	.....	.....	.....	.....	.....	8	80	146	10	14.6
23	6	.....	.....	13	.....	.....	7	.....	2	12	40	10	4
24	6	6	.....	.....	.....	.....	5	18	4	13	52	10	5.2
25	23	11	28	.....	32	.....	24	29	.....	70	217	10	21.7
26	5	.....	.....	.....	.....	.....	6	.....	3	.....	14	10	1.4
27	.....	9	8	.....	.....	.....	.....	16	16	51	100	10	10
28	.....	19	.....	.....	17	.....	.....	.....	39	62	137	10	13.7
29	.....	3	1	.....	5	12	.....	.....	.....	5	26	10	2.6
30	270	191	295	267	201	199	138	141	439	385	2,526	10	252.6
31	40	107	33	85	27	103	27	23	193	148	786	10	78.6
32	200	145	150	81	10	113	107	30	90	210	1,136	10	113.6
33	113	192	212	126	3	104	14	19	81	218	1,082	9.8	110.4
34	8	62	62	.....	.....	.....	13	6	14	57	222	10	22.2
35	89	251	63	.....	30	52	35	94	146	80	840	8.6	97.6
36	6	75	119	42	11	15	.....	72	.....	53	393	10	39.3
37	12	31	.....	55	44	27	8	24	.....	44	245	10	24.5
38	23	62	80	77	63	27	24	.....	31	37	424	10	42.4
39	26	142	108	.....	.....	67	23	14	30	29	439	8	54.8
40	15	32	30	48	.....	25	.....	.....	.....	23	173	10	17.3
41	47	103	149	48	.....	62	15	21	21	100	566	10	56.6
42	21	73	23	.....	.....	38	13	5	.....	25	198	10	19.8
43	7	.....	9	14	.....	13	7	12	.....	22	84	10	8.4
44	16	18	60	43	.....	41	15	9	31	32	265	10	26.5
45	19	16	18	.....	24	17	17	26	33	33	203	10	20.3
46	3	12	.....	.....	.....	7	2	9	.....	14	47	10	4.7
47	10	11	9	.....	.....	32	6	9	25	.....	102	10	10.2
48	11	.....	18	30	.....	15	.....	12	6	.....	92	10	9.2
49	5	.....	17	10	.....	13	9	2	5	.....	61	10	6.1
50	4	.....	.....	14	.....	10	.....	10	11	6	55	10	5.5
51	12	.....	11	25	.....	13	.....	10	15	5	91	10	9.1
52	.....	.....	9	6	.....	12	18	3	6	10	64	10	6.4
53	7	.....	10	9	.....	12	.....	9	.....	.....	47	9.6	4.9
54	19	21	92	17	.....	55	10	18	34	.....	266	10	26.6
55	.....	4	11	16	.....	18	.....	26	.....	.....	75	10	7.5
56	3	.....	32	27	.....	17	.....	.....	13	.....	92	9.5	9.7
57	1	18	.....	.....	.....	30	.....	26	.....	16	91	10	9.1
58	.....	.....	.....	.....	.....	.....	26	6	11	.....	43	10	4.3

The total yield of the trees and rows of the experiment block is shown in the following table, which was compiled from the preceding records of fruit gathered at the first and second pickings.

TABLE 27.—*Total weight of peaches of first and second pickings gathered from the Lovell trees of the experiment block of the Rio Bonito orchard in the fall of 1895.* (*a*)

Row No.	Total weight in pounds of fruit gathered at first and second pickings from trees Nos.—										
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Total.
1..........	129	230	183	340	259	245	394	302	422	308	2,812
2..........	76	95	134	236	54	111	115	181	232	116	1,350
3..........	243	245	173	298	308	267	315	403	308	236	2,796
4..........	81	71	173	70	57	165	91	100	103	85	996
5..........	42	74	49	146	134	152	159	100	87	103	1,046
6..........	239	83	253	197	311	117	321	222	275	247	2,265
7..........	148	276	238	197	301	183	211	222	199	250	2,225
8..........	104	39	30	11	39	151	142	52	71	36	675
9..........	290	287	188	216	314	248	315	234	179	187	2,458
10..........	245	285	357	105	238	327	325	297	530	259	2,968
11..........	72	76	35	97	83	107	145	69	184	101	969
12..........	240	178	111	191	304	167	288	168	255	201	2,103
13..........	255	205	221	70	184	203	244	187	159	132	1,860
14..........	140	61	114	117	47	114	99	127	59	50	928
15..........	525	363	556	253	474	474	580	340	475	311	4,351
16..........	177	123	321	87	298	216	462	263	297	256	2,500
17..........	144	56	66	52	88	119	63	89	51	30	758
18..........	406	251	322	256	341	233	296	144	302	149	2,700
19..........	261	330	381	144	362	364	259	212	202	197	2,712
20..........	68	102	125	109	54	27	36	22	28	77	648
21..........	438	446	483	410	498	431	629	252	396	460	4,443
22..........	395	552	558	257	544	556	469	324	340	426	4,421
23..........	28	80	88	67	62	95	82	38	107	65	712
24..........	71	56	65	48	43	52	53	74	28	109	599
25..........	403	247	414	180	458	424	589	488	285	500	3,988
26..........	75	121	71	16	19	62	115	96	52	45	672
27..........	345	409	446	116	166	425	513	306	222	268	3,216
28..........	313	404	573	298	417	489	489	379	460	441	4,263
29..........	29	39	99	64	65	102	33	95	25	51	602
30..........	458	389	532	525	524	418	434	459	675	727	5,141
31..........	111	259	160	219	176	282	138	222	408	363	2,338
32..........	377	284	282	333	325	331	316	328	389	453	3,418
33..........	396	463	371	527	253	477	442	448	468	426	4,271
34..........	95	190	156	53	107	148	92	139	141	203	1,324
35..........	482	542	300	....	593	543	632	684	570	528	4,874
36..........	304	288	248	186	199	369	365	437	315	363	3,074
37..........	92	127	69	82	242	111	135	187	138	187	1,370
38..........	269	153	220	243	336	261	308	341	305	440	2,876
39..........	309	296	438	....	....	451	462	475	369	443	3,243
40..........	150	155	95	107	69	74	53	47	114	245	1,109
41..........	459	371	423	499	430	262	425	326	335	500	4,030
42..........	308	249	151	157	179	183	236	124	299	236	2,122
43..........	99	85	117	46	32	58	104	40	52	106	739
44..........	187	168	306	206	70	205	154	240	213	258	2,007
45..........	347	236	314	222	534	341	430	389	359	319	3,491
46..........	55	99	64	107	90	63	44	82	103	67	774
47..........	140	160	148	118	228	148	111	178	215	228	1,674
48..........	108	155	155	136	117	94	182	154	157	181	1,439
49..........	82	91	78	105	78	73	95	43	79	32	756
50..........	254	284	214	161	107	130	118	239	306	356	2,169
51..........	276	330	288	288	247	220	251	203	314	315	2,732
52..........	162	99	135	141	147	96	43	66	100	142	1,131
53..........	147	68	72	114	54	75	44	82	90	54	800
54..........	356	478	541	460	311	476	402	426	328	285	4,063
55..........	93	170	108	96	45	171	137	93	92	94	1,099
56..........	339	361	346	442	294	198	244	381	281	504	3,390
57..........	331	418	277	359	254	312	313	425	327	487	3,503
58..........	91	64	99	92	86	195	109	52	62	52	902

a For plat of orchard see p. 69; for sprays applied see p. 73.

As already said, after the weight of fruit for each tree of a row had been ascertained and recorded, the number of peaches in 100 pounds of this fruit was determined by counting. From several picking boxes of fruit, coming from different trees of the row, was weighed out 100 pounds of peaches fairly representing the fruit of the row. The peaches of this 100 pounds were then carefully counted and the number recorded. This was done both for the first and second pickings and for the sprayed and unsprayed rows. Where less than 100 pounds of fruit was gathered the number of peaches per 100 pounds was determined by counting a less weight of fruit, usually 50 pounds. The following table gives the results of this work for both first and second pickings:

TABLE 28.—*Number of peaches per 100 pounds; weight of fruit gathered; and number of peaches thinned, gathered, and set by the trees of each row in the experiment block of the Rio Bonito orchard in 1895.* (*a*)

Row No.	Number of peaches in 100 pounds.		Pounds of fruit—		Number of peaches gathered at—		Number of peaches—		Total number of peaches set by trees of row.	Number of trees in row.	Average number of peaches set per tree.	
	First picking.	Second picking.	First picking.	Second picking.	First picking.	Second picking.	Matured by trees of row.	Thinned from trees of row.			Sprayed.	Unsprayed.
1......	259	288	1,570	1,242	4,066	3,577	7,643	5,442	13,085	10	1,308	......
2......	295	317	1,007	343	2,971	1,087	4,058	....	4,058	9.5	....	427
3......	285	310	1,687	1,109	4,808	3,438	8,246	4,829	13,075	10	1,307	......
4......	300	335	741	255	2,223	854	3,077	....	3,077	9.8	....	314
5......	303	323	810	236	2,454	762	3,216	....	3,216	10	....	322
6......	278	324	1,813	452	5,040	1,464	6,504	2,352	8,856	10	886	......
7......	280	326	1,708	517	4,782	1,685	6,467	2,265	8,732	10	873	......
8......	282	322	568	107	1,602	345	1,947	....	1,947	10	....	195
9......	288	323	2,101	357	6,051	1,153	7,204	3,863	11,067	10	1,107	......
10......	282	313	2,553	415	7,199	1,299	8,498	4,352	12,850	10	1,285	......
11......	292	316	833	136	2,432	430	2,862	....	2,862	10	....	286
12......	283	321	1,957	146	5,538	469	6,007	2,730	8,737	9.4	929	......
13......	293	312	1,676	184	4,911	574	5,485	1,841	7,326	10	733	......
14......	306	*b* 324	844	84	2,583	272	2,855	....	2,855	10	....	285
15......	309	362	4,227	124	13,061	449	13,510	7,762	21,272	10	2,127	......
16......	291	317	2,348	152	6,903	482	7,385	2,401	9,786	10	979	......
17......	296	*b* 327	715	43	2,116	140	2,256	....	2,256	10	....	226
18......	300	*b* 339	2,609	91	7,827	308	8,135	3,024	11,159	10	1,116	......
19......	289	*b* 340	2,594	118	7,496	401	7,897	3,616	11,513	10	1,151	......
20......	290	*b* 332	574	74	1,665	246	1,911	....	1,911	10	....	191
21......	308	*b* 314	4,307	136	13,266	427	13,693	8,470	22,163	10	2,216	......
22......	320	*b* 362	4,275	146	13,680	529	14,209	7,269	21,478	10	2,148	......
23......	296	*b* 344	672	40	1,989	138	2,127	....	2,127	10	....	213
24......	292	*b* 356	547	52	1,597	185	1,782	....	1,782	10	....	178
25......	284	*b* 368	3,771	217	10,710	799	11,509	5,747	17,256	10	1,726	......
26......	280	*b* 354	658	14	1,842	50	1,892	....	1,892	10	....	189
27......	276	*b* 360	3,116	100	8,600	360	8,960	5,128	14,088	10	1,409	......
28......	291	*b* 370	4,126	137	12,006	507	12,513	5,742	18,255	10	1,825	......
29......	277	*b* 360	576	26	1,596	94	1,690	....	1,690	10	....	169
30......	292	313	2,615	2,526	7,636	7,906	15,542	10,208	25,750	10	2,575	......
31......	304	326	1,552	786	4,718	2,562	7,280	....	7,280	10	....	728
32......	294	311	2,282	1,136	6,709	3,533	10,242	3,269	13,511	10	1,351	......
33......	291	335	3,189	1,082	9,280	3,625	12,905	7,360	20,265	9.8	2,068	......
34......	290	330	1,102	222	3,196	733	3,929	....	3,929	10	....	393
35......	325	345	4,034	840	13,111	2,898	16,009	9,730	25,739	8.6	2,993	......
36......	285	332	2,681	393	7,641	1,305	8,946	4,896	13,842	10	1,384	......
37......	282	330	1,125	245	3,173	809	3,982	....	3,982	10	....	398
38......	282	330	2,452	421	6,915	1,399	8,314	3,318	11,632	10	1,163	......
39......	289	328	2,804	439	8,104	1,440	9,544	5,821	15,365	8	1,921	......
40......	300	312	936	173	2,808	540	3,348	....	3,348	10	....	334
41......	284	339	3,461	566	9,838	1,919	11,757	5,953	17,710	10	1,771	......
42......	303	335	1,924	198	5,830	663	6,493	....	6,493	10	649	......
43......	293	*b* 304	655	84	1,919	255	2,174	....	2,174	10	....	217
44......	309	337	1,742	265	5,383	893	6,276	773	7,049	10	705	......
45......	309	346	3,288	203	10,160	702	10,862	3,951	14,813	10	1,481	......
46......	303	*b* 330	727	47	2,203	155	2,358	....	2,358	10	....	236
47......	289	356	1,572	102	4,543	363	4,906	....	4,906	10	491	......
48......	308	*b* 324	1,347	92	4,149	298	4,447	675	5,122	10	512	......
49......	292	*b* 312	695	61	2,029	190	2,219	....	2,219	10	....	222
50......	287	*b* 366	2,114	55	6,067	201	6,268	....	6,268	10	627	......
51......	299	*b* 356	2,641	91	7,897	324	8,221	2,985	11,206	10	1,120	......
52......	303	*b* 336	1,067	64	3,233	215	3,448	....	3,448	10	....	345
53......	300	*b* 325	753	47	2,259	153	2,412	....	2,412	9.6	....	251
54......	306	*b* 352	3,797	266	11,619	936	12,555	5,568	18,123	10	1,812	......
55......	295	*b* 334	1,024	75	3,021	250	3,271	....	3,271	10	....	327
56......	293	*b* 384	3,298	92	9,663	353	10,016	5,659	15,675	9.5	1,650	......
57......	298	*b* 370	3,412	91	10,168	337	10,505	5,251	15,756	10	1,576	......
58......	282	*b* 360	859	43	2,422	155	2,577	....	2,577	10	....	258

a For plat of orchard see p. 69; for sprays applied see p. 73.
b Number calculated from a less weight than 100 pounds, usually from 50 pounds

Following the figures in the above table which show the number of peaches in 100 pounds of fruit are those giving the number of pounds of fruit gathered at the first and second pickings. From these four columns of figures has been calculated the number of peaches gathered from the trees of each row of the block for both the first and second pickings. By adding these numbers the total number of peaches matured by the trees of each row was quite accurately determined. To this amount is now added the number of peaches thinned from the trees, where thinning was required, the grand total representing the number of peaches firmly set by the trees of each row. By dividing this grand total by the number of trees in a row it has been possible to show the average number of peaches set per tree on both sprayed and unsprayed trees, and for every row in the experiment block.

COMPARATIVE QUANTITY, QUALITY, AND CASH VALUE OF FRUIT FROM SPRAYED AND UNSPRAYED TREES.

(Pls. XI and XII.)

The actual yield in pounds of peaches, the quality, and the cash value of the fruit produced by the sprayed and unsprayed trees of the experiment rows of the Rio Bonito orchard in the season of 1895 are fully and accurately shown in the table which follows. This table gives a full record of the yield as it was taken in the orchard, and the results are of the greatest value from a practical standpoint, conveying an accurate idea of the cash gain resulting from this spray work. If the reader will compare the average value of the fruit produced by the sprayed trees of row 21, for example, with that of the fruit produced by the unsprayed trees of row 20, some conception of the possible gains resulting from thorough spraying may be obtained. In studying this table, it should be remembered that the results shown were obtained from the use of 35 different formulæ and sprays. Some of the sprays were of little value, others of medium value, etc., hence the gains shown for the entire block are far below what they would have been had the trees of each of the rows been sprayed with such sprays as those used upon rows 21, 22, or others of the better-yielding rows of the block.

DESCRIPTION OF PLATE XI.

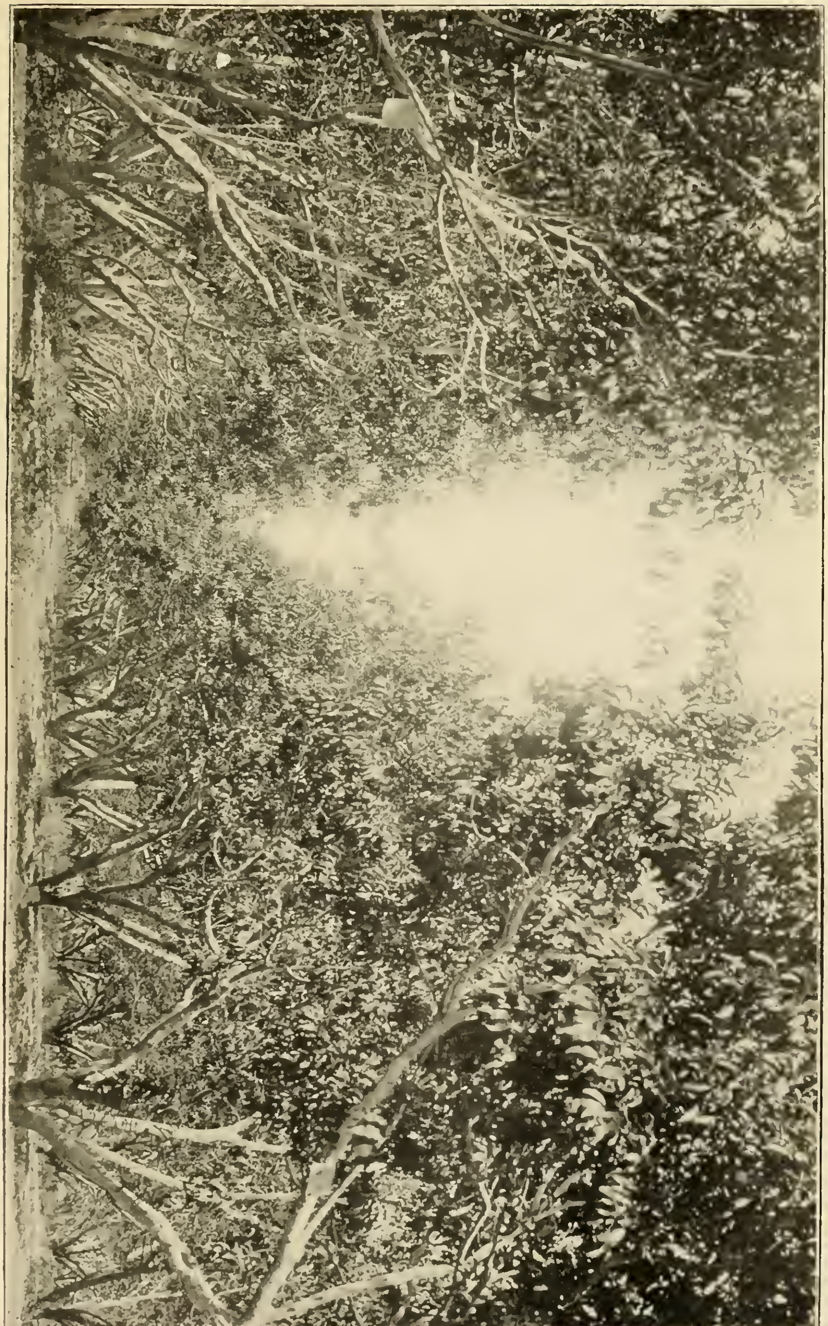
Experiments at Biggs, Cal. (Sulphur, lime, and salt.) Looking west between rows 2 and 3, May 14, 1895. Row 2 was unsprayed; row 3 was sprayed before blooming with 15 pounds sulphur, 20 pounds lime, 5 pounds salt, and 45 gallons of water. The average value of fruit matured per tree in row 2 was $1.96 and in row 3 $3.90. The spray used showed a net gain from the treatment, as determined by the comparative value of the peaches set by the trees of both rows, of 216 per cent (p. 117).

ROWS 2 AND 3, EXPERIMENT BLOCK, BIGGS, CAL.

Row 2, at left, unsprayed; row 3, at right, sprayed with sulphur, lime, and salt.

DESCRIPTION OF PLATE XII.

Experiments at Biggs, Cal. (Sulphur and lime.) Looking west between rows 9 and 10, May 14, 1895. Both rows were sprayed before blooming. Row 9 was treated with 10 pounds sulphur, 20 pounds lime, and 45 gallons of water, and row 10 with 10 pounds sulphur, 8 pounds lime, and 45 gallons of water. Row 8, adjoining row 9 at the south, and row 11, adjoining row 10 at the north, were untreated. The average value of fruit matured per tree on row 9 was \$3.35, and on row 8 only 91 cents. The average value of fruit matured per tree on row 10 was \$3.90, and on row 11, \$1.35. As determined by the comparative value of the peaches set by the trees, the spray used on row 9 showed a net gain over row 8 of 457 per cent, and that used on row 10 showed a net gain over row 11 of 337 per cent (p. 117). It may be seen that the lower limbs are not as thickly covered with foliage where the sulphur sprays are used as where the copper sprays are used. This is especially true where the former is applied too late or too strong. (See Pl. XI.)



ROWS 9 AND 10, EXPERIMENT BLOCK, BIGGS, CAL.

TABLE 29.—*Quantity, quality, and cash value of fruit produced by the sprayed and unsprayed Lovell peach trees of the experiment block of the Rio Bonito orchard in the fall of 1895.* (*a*)

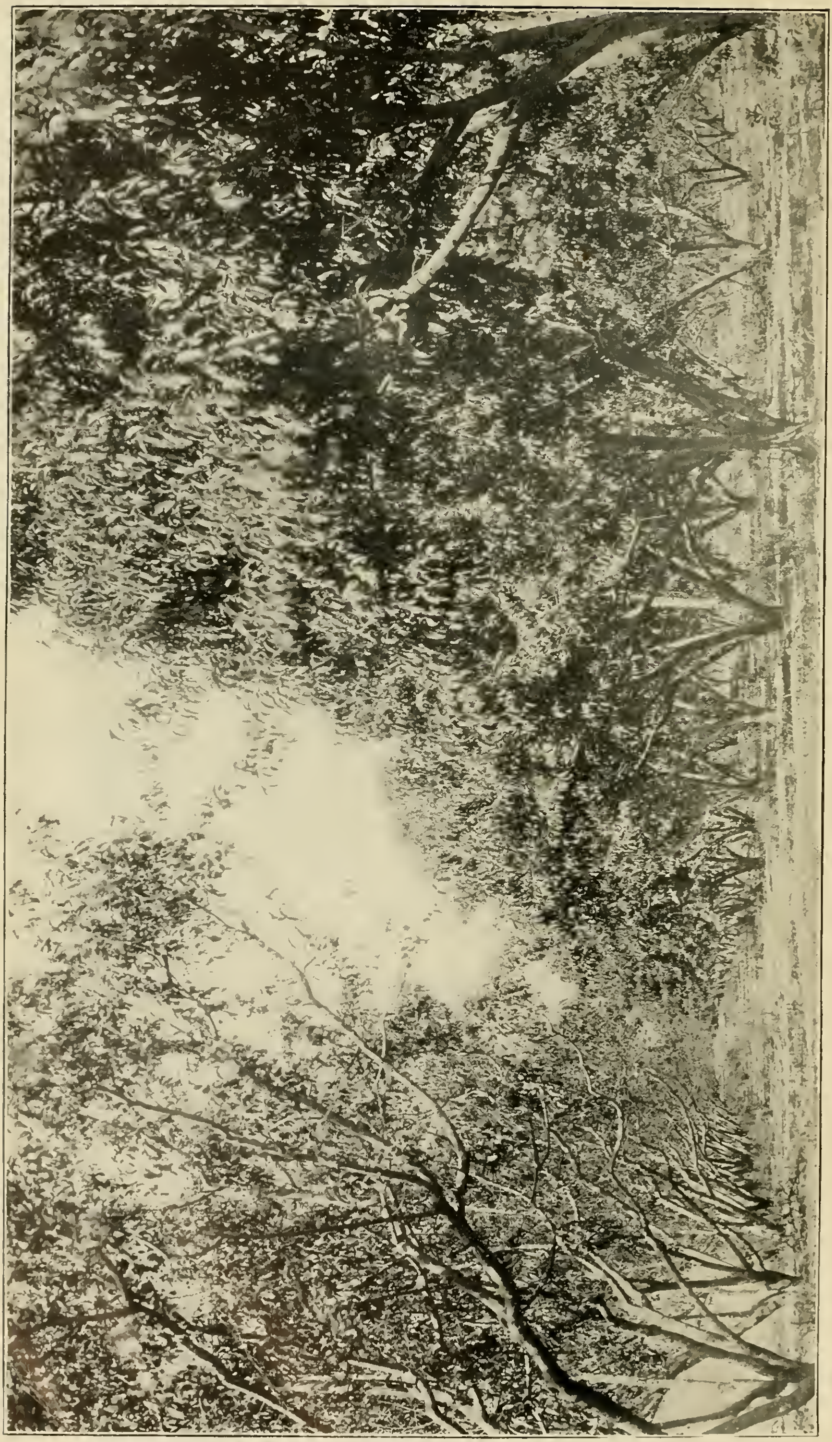
Row No.	Pounds of fruit— First picking.	Pounds of fruit— Second picking.	Total pounds of fruit. Sprayed trees.	Total pounds of fruit. Unsprayed trees.	Number of trees in row.	Average pounds of fruit per tree. Sprayed trees.	Average pounds of fruit per tree. Unsprayed trees.	Yield of fruit in pounds per row.	Classified yield. Fruit for drying.	Classified yield. Fruit for Chico cannery.	Classified yield. Fruit for Oakland cannery.	Value of fruit for drying, at three-fourths cent per pound.	Value of fruit for Chico cannery, at 1¼ cents per pound.	Value of fruit for Oakland cannery, at 1¼ cents per pound.	Total value of fruit.	Number of trees in row.	Average value of fruit per tree. Sprayed trees.	Average value of fruit per tree. Unsprayed trees.
									Lbs.	*Lbs.*	*Lbs.*	$	$	$	$		$	$
1	1,570	1,242	2,812		10	281.2		2,812	621	514	1,647	4.65	8.16	21.70	37.51	10	3.75	
2	1,007	343		1,350	9.5		142.1	1,350	214	379	757	1.60	5.68	11.35	18.63	9.5		1.96
3	1,687	1,109	2,796		10	279.6		2,796	385	837	1,574	2.88	12.55	23.61	39.04	10	3.90	
4	741	255		996	9.8		101.6	996	177	109	709	1.32	1.63	10.63	13.58	9.8		1.38
5	810	236		1,046	10		104.6	1,046	155	127	764	1.15	1.90	11.46	14.51	10		1.45
6	1,813	452	2,265		10	226.5		2,265	371	280	1,614	2.77	4.20	24.21	31.18	10	3.11	
7	1,708	517	2,225		10	222.5		2,225	400	160	1,665	3.00	2.40	24.97	30.37	10	3.03	
8	568	107		675	10		67.5	675	130	24	521	.97	.36	7.81	9.14	10		.91
9	2,101	357	2,458		10	245.8		2,458	446	356	1,656	3.31	5.34	24.84	33.52	10	3.35	
10	2,553	415	2,968		10	296.8		2,968	727	686	1,555	5.44	10.29	23.32	39.05	10	3.90	
11	833	136		969	10		96.9	969	134	299	536	1.00	4.48	8.04	13.52	10		1.35
12	1,957	146	2,103		9.4	223.7		2,103	287	599	1,217	2.15	8.98	18.25	29.38	9.4	3.12	
13	1,676	184	1,860		10	186		1,860	326	486	1,048	2.44	7.29	15.72	25.45	10	2.54	
14	844	84		928	10		92.8	928	90	362	476	.67	5.43	7.14	13.24	10		1.32
15	4,227	124	4,351		10	435.1		4,351	699	1,270	2,382	5.24	19.05	35.73	60.02	10	6.00	
16	2,348	152	2,500		10	250		2,500	449	769	1,282	3.36	11.53	19.23	34.12	10	3.41	
17	715	43		758	10		75.8	758	96	303	359	.72	4.51	5.38	10.64	10		1.06
18	2,609	91	2,700		10	270		2,700	486	979	1,235	3.64	14.68	18.52	36.84	10	3.68	
19	2,594	118	2,712		10	271.2		2,712	642	909	1,161	4.81	13.63	17.41	35.85	10	3.58	
20	574	74		648	10		64.8	648	95	291	262	.71	4.36	3.93	9.00	10		.90
21	4,307	136	4,443		10	444.3		4,443	624	1,684	2,135	4.68	25.26	32.02	61.96	10	6.19	
22	4,275	146	4,421		10	442.1		4,421	651	1,466	2,304	4.88	21.99	34.56	61.43	10	6.14	
23	672	40		712	10		71.2	712	175	298	239	1.31	4.47	3.58	9.36	10		.93
24	547	52		599	10		59.9	599	119	266	214	.88	3.99	3.21	8.08	10		.80
25	3,771	217	3,988		10	398.8		3,988	765	1,478	1,745	5.73	22.17	26.17	54.07	10	5.40	
26	658	14		672	10		67.2	672	136	315	221	1.02	4.72	3.31	9.05	10		.90
27	3,116	100	3,216		10	321.6		3,216	664	1,145	1,407	4.98	17.17	21.10	43.25	10	4.32	
28	4,126	137	4,263		10	426.3		4,263	901	1,325	2,037	6.75	19.87	30.55	57.17	10	5.71	
29	576	26		602	10		60.2	602	112	297	193	.84	4.45	2.89	8.18	10		.82

a For plat of orchard see p. 69; for sprays applied see p. 73.

TABLE 29.—*Quantity, quality, and cash value of fruit produced by the sprayed and unsprayed Lovell peach trees of the experiment block of the Rio Bonito orchard in the fall of 1895*—Continued. (*a*)

Row No.	Pounds of fruit— First picking.	Pounds of fruit— Second picking.	Total pounds of fruit— Sprayed trees.	Total pounds of fruit— Unsprayed trees.	Number of trees in row.	Average pounds of fruit per tree. Sprayed trees.	Average pounds of fruit per tree. Unsprayed trees.	Yield of fruit in pounds per row.	Classified yield. Fruit for drying.	Classified yield. Fruit for Chico cannery.	Classified yield. Fruit for Oakland cannery.	Value of fruit for drying, at three-fourths cent per pound.	Value of fruit for Chico cannery, at 1½ cents per pound.	Value of fruit for Oakland cannery, at 1½ cents per pound.	Total value of fruit.	Number of trees in row.	Average value of fruit per tree. Sprayed trees.	Average value of fruit per tree. Unsprayed trees.
									Lbs.	*Lbs.*	*Lbs.*	$	$	$	$		$	$
30	2,615	2,526	5,141	....	10	514.1	....	5,141	851	980	3,310	6.37	14.70	49.65	70.72	10	7.07	....
31	1,552	786	....	2,338	10	....	233.8	2,338	354	833	1,151	2.66	12.49	17.26	32.41	10	....	3.24
32	2,282	1,136	3,418	....	10	341.8	....	3,418	401	999	2,018	3.01	14.98	30.27	48.26	10	4.83	....
33	3,189	1,082	4,271	....	9.8	435.8	....	4,271	661	967	2,643	4.96	14.50	39.64	59.10	9.8	6.03	....
34	1,102	222	....	1,324	10	....	132.4	1,324	185	554	585	1.39	8.31	8.78	18.48	10	....	1.85
35	4,034	840	4,874	....	8.6	566.7	....	4,874	517	1,761	2,596	3.87	26.41	38.94	69.22	8.6	8.05	....
36	2,681	393	3,074	....	10	307.4	....	3,074	302	671	2,101	2.27	10.06	31.51	43.84	10	4.38	....
37	1,125	245	....	1,370	10	....	137.0	1,370	200	553	617	1.50	8.30	9.25	19.05	10	....	1.90
38	2,452	424	2,876	....	10	287.6	....	2,876	269	951	1,656	2.02	14.26	24.84	41.12	10	4.11	....
39	2,804	439	3,243	....	8	405.4	....	3,243	335	1,172	1,736	2.51	17.58	26.04	46.13	8	5.77	....
40	936	173	....	1,109	10	....	110.9	1,109	146	263	700	1.10	3.94	10.50	15.54	10	....	1.55
41	3,464	566	4,030	....	10	403.0	....	4,030	570	559	2,901	4.28	8.38	43.51	56.17	10	5.62	....
42	1,924	198	2,122	....	10	212.2	....	2,122	398	663	1,061	2.99	9.94	15.91	28.84	10	2.88	....
43	655	84	....	739	10	....	73.9	739	142	283	314	1.07	4.24	4.71	10.02	10	....	1.00
44	1,742	265	2,007	....	10	200.7	....	2,007	385	647	975	2.89	9.70	14.62	27.21	10	2.72	....
45	3,288	203	3,491	....	10	349.1	....	3,491	726	468	2,297	5.45	7.02	34.45	46.92	10	4.69	....
46	727	47	....	774	10	....	77.4	774	117	307	350	.88	4.60	5.25	10.73	10	....	1.07
47	1,572	102	1,674	....	10	167.4	....	1,674	211	861	602	1.58	12.91	9.03	23.52	10	2.35	....
48	1,347	92	1,439	....	10	143.9	....	1,439	260	237	942	1.95	3.55	14.13	19.63	10	1.96	....
49	695	61	....	756	10	....	75.6	756	142	379	235	1.07	5.68	3.52	10.27	10	....	1.03
50	2,114	55	2,169	....	10	216.9	....	2,169	446	470	1,253	3.35	7.05	18.79	29.19	10	2.92	....
51	2,641	91	2,732	....	10	273.2	....	2,732	479	1,855	398	3.59	27.82	5.97	37.38	10	3.74	....
52	1,067	64	....	1,131	10	....	113.1	1,131	230	281	620	1.73	4.21	9.30	15.24	10	....	1.52
53	753	47	....	800	9.6	....	83.3	800	160	215	425	1.20	3.22	6.37	10.79	9.6	....	1.12
54	3,797	266	4,063	....	10	406.3	....	4,063	776	760	2,527	5.82	11.40	37.90	55.12	10	5.51	....
55	1,024	75	....	1,099	10	....	109.9	1,099	259	349	491	1.94	5.24	7.36	14.54	10	....	1.45
56	3,298	92	3,390	....	9.5	356.8	....	3,390	440	1,130	1,820	3.30	16.95	27.30	47.55	9.5	5.00	....
57	3,412	91	3,503	....	10	350.3	....	3,503	465	1,519	1,519	3.49	22.78	22.78	49.05	10	4.90	....
58	859	43	....	902	10	....	90.2	902	194	378	330	1.45	5.67	4.95	12.07	10	....	1.21

a For plat of orchard see p. 69; for sprays applied see p. 73.

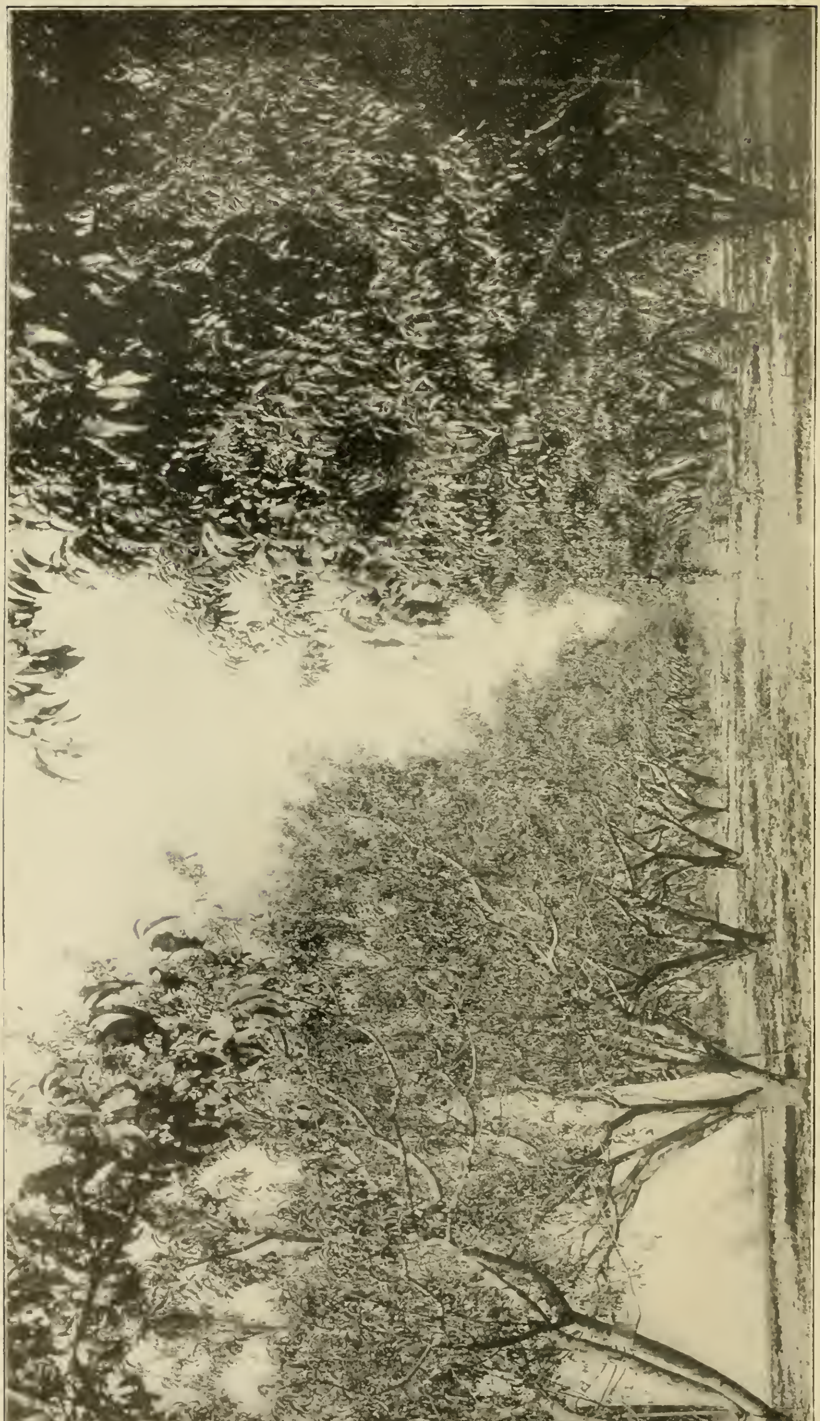


ROWS 20 AND 21, EXPERIMENT BLOCK, BIGGS, CAL.

Row 20, at left, untreated; row 21, at right, treated with Bordeaux mixture. The net gain of row 21 over row 20 in fruit set was 1,028 per cent.

DESCRIPTION OF PLATE XIII.

Experiments at Biggs, Cal. (Bordeaux mixture.) Looking west between rows 20 and 21, May 11, 1895. Row 20 was unsprayed; row 21 was sprayed before blooming with 5 pounds copper sulphate, 5 pounds lime, and 45 gallons of water. The average value of fruit matured per tree in row 20 was 90 cents; in row 21, $6.19. The spray used on row 21 showed a net gain over row 20, as determined by the comparative value of the peaches set by the trees of both rows, of 1,028 per cent (p. 117).



ROWS 26 AND 27, EXPERIMENT BLOCK, BIGGS, CAL.

Row 26, at left, untreated; row 27, at right, treated with eau celeste. Row 26 matured fruit worth $9.05; row 27 matured fruit worth $13.25.

DESCRIPTION OF PLATE XIV.

Experiments at Biggs, Cal. (Eau celeste.) Looking west between rows 26 and 27, May 11, 1895. Row 26 unsprayed; row 27 sprayed before blooming with 4 pounds copper sulphate, 3 pints ammonia, and 45 gallons of water. Average value of fruit matured per tree in row 26 was 90 cents; in row 27, $4.32. The spray used on row 27 showed a net gain over row 26, as determined by the comparative value of the peaches set by the trees of both rows, of 662 per cent (p. 117).

PLATE XV.

ROWS 34 AND 35, EXPERIMENT BLOCK, BIGGS, CAL.

Row 35, at left, treated with modified eau celeste; row 34, at right, untreated.

DESCRIPTION OF PLATE XV.

Experiments at Biggs, Cal. (Modified eau celeste.) Looking east between rows 34 and 35, May 14, 1895. Row 34 unsprayed; row 35 sprayed before blooming with 4 pounds copper sulphate, 5 pounds sal soda, 3 pints ammonia, and 45 gallons of water. The average value of fruit matured per tree in row 34 was $1.84; in row 35, $8.05. The spray used on row 35 showed a net gain over row 34, as determined by the comparative value of the peaches set by the trees of both rows, of 608 per cent (p. 118).

COMPARATIVE VALUE OF SPRAYS IN RELATION TO FRUIT.

(Pls. XIII, XIV, and XV.)

A review of the preceding table will show that no account has been taken there of the peaches thinned from the trees, and for this reason the results given in dollars and cents for the different rows can not be taken as representing the full comparative value of the sprays used. The value of a spray in controlling curl, so far as quantity of fruit is concerned, should be based upon its power to prevent the fall or loss of fruit from the disease. A spray may enable a tree to set more fruit than it can carry to maturity in a favorable season, but the value of the spray should not be decided from the amount of the crop after thinning. This will be evident from a consideration of the fact that in many years the trees may not set more peaches than can be properly matured without thinning. In such cases it would be the spray that enabled the trees to set and hold the greatest number of peaches in the presence of curl which would prove of the highest value to the grower. A less effective spray would not enable the trees to set and hold a full crop. It is thus seen that the comparative value of several sprays rests in their power to prevent the fall of the greatest number of peaches from disease, this being, of course, where other influences of the sprays are equal. Thinning is necessary only when the trees can not carry all the fruit set, or when it is desired to improve the size and quality of the fruit, and it bears no direct relation to the value of a spray in preventing curl.

In view of the preceding facts, a table has been prepared embodying those features of the fruit records by which the comparative value of all the sprays used may be determined.

To show the full comparative value of all influences of each spray upon the fruit, it has also been necessary to consider the quality as well as the number of peaches and weight of same. To obtain the ultimate comparative value of the sprays the writer has been obliged to treat the thinned peaches as if matured, assigning them the same value, in proportion to number, as the matured fruit. There is also one other calculation in the table which requires explanation. A considerable percentage of the better quality of fruit was picked while still immature. This fruit is tabulated as that for the Oakland cannery. It was necessary to gather this fruit while still hard so that it would arrive at the Oakland cannery in good condition. By weighing a large number of matured peaches and an equal number of peaches as picked for the Oakland cannery it was learned that the Oakland fruit should be increased by 11 per cent to make it equal in weight to mature fruit. This has been done, so that the quantity, quality, and full comparative value of all fruit considered could be accurately determined.

It has been possible in the manner just outlined to calculate the total comparative value of all fruit set by the trees of each row, as determined by the actual cash value of fruit of equal quality when matured. By dividing this sum by the number of trees in the row the average comparative value per tree of all fruit set is shown, both for sprayed and unsprayed rows. While these average values do not represent the money actually obtained, as in the case of the preceding table, they accurately show the average values for comparison of all fruit set by the trees, as determined by the market price of that fruit which the trees were able to bring to maturity. For these reasons the figures for the different rows may be rightly compared, and they fairly determine the comparative values of the 35 sprays tested in the block, so far as those values relate to the quantity and quality of the fruit.

To further facilitate the comparison of the values of the sprays in increasing the quantity and quality of fruit, as determined by the cash value of such fruit when matured, the results have been reduced to average net gain per cent of the sprayed trees of each treated row over those of the adjoining unsprayed row. For illustration, it may be seen that in row 30, sprayed, the average calculated value of all fruit set per tree would have been when matured \$12.62; in row 31, unsprayed, \$3.43. Deducting the calculated average value of the fruit set on the trees of row 31 from that set on the trees of row 30, there is shown an excess of \$9.19 in favor of the trees of the sprayed row, and by dividing this excess by \$3.43, the calculated average value of fruit set by the trees of the unsprayed row, there is shown to be a net gain of 268 per cent resulting from the use of the spray applied to the trees of row 30. The gain per cent has in this manner been calculated for every spray tested in the block, and it may be seen that on row 21 the spray gave a net gain of 1,028 per cent.

TABLE 30.—*The comparative value of the 35 sprays tested in the experiment block of the Rio Bonito orchard in 1895. The net gain per cent is based upon the value of all fruit set by the sprayed and unsprayed trees, as determined by the cash value of all fruit brought to maturity by the trees, both quantity and quality considered.* (*a*)

Row No.	Number of peaches— Thinned from trees of row.	Number of peaches— Matured by trees of row.	Total number of peaches set by trees of row.	Classified yield of fruit for— Drying.	Classified yield of fruit for— Chico cannery.	Classified yield of fruit for— Oakland cannery when gathered.	11 per cent weight added to Oakland fruit.	Total estimated weight of Oakland fruit when matured.	Value of— Drying fruit at ¾ cent per pound.	Value of— Chico fruit at 1½ cents per pound.	Estimated value of Oakland fruit when matured.	Total value of drying and cannery fruit when matured.	Estimated value of thinned fruit at same rate as that matured.	Total estimated value of all fruit set by trees of row.	Number of trees in rows.	Average value of fruit per tree— Sprayed.	Average value of fruit per tree— Unsprayed.	Average net gain per cent of sprayed trees over unsprayed trees.
				Lbs.	*Lbs.*	*Lbs.*			$	$	$	$	$	$		$	$	
1	5,442	7,643	13,085	621	544	1,647	181	1,828	4.65	8.16	27.42	40.23	28.64	68.87	10	6.89	....	229
2	....	4,058	4,058	214	379	757	83	840	1.60	5.68	12.60	19.88	....	19.88	9.5	....	2.09	....
3	4,829	8,246	13,075	385	837	1,574	173	1,747	2.88	12.55	26.20	41.63	24.38	66.01	10	6.60	....	216
4	....	3,077	3,077	177	109	709	78	787	1.32	1.63	11.80	14.75	....	14.75	9.8	....	1.50	....
5	....	3,216	3,216	155	127	764	84	848	1.15	1.90	12.72	15.77	....	15.77	10	....	1.58	5
6	2,352	6,505	8,857	371	280	1,614	177	1,791	2.77	4.20	26.86	33.83	12.23	46.06	10	4.61	....	192
7	2,265	6,467	8,732	400	160	1,665	183	1,848	3.00	2.40	27.72	33.12	11.60	44.72	10	4.47	....	347
8	....	1,947	1,947	130	24	521	57	578	.97	.36	8.67	10.00	....	10.00	10	....	1.00	....
9	3,863	7,204	11,067	416	356	1,656	182	1,838	3.34	5.34	27.57	36.25	19.44	55.69	10	5.57	....	457
10	4,352	8,498	12,850	727	686	1,555	171	1,726	5.41	10.29	25.89	41.62	21.32	62.94	10	6.29	....	337
11	....	2,862	2,862	134	299	536	59	595	1.00	4.48	8.92	14.40	....	14.40	10	....	1.44	....
12	2,730	6,007	8,737	287	599	1,217	134	1,351	2.15	8.98	20.26	31.39	14.27	45.66	9.4	4.86	....	237
13	1,841	5,485	7,326	326	486	1,048	115	1,163	2.44	7.29	17.44	27.17	9.10	36.27	10	3.63	....	159
14	....	2,855	2,855	90	362	476	52	528	.67	5.43	7.92	14.02	....	14.02	10	....	1.40	....
15	7,762	13,510	21,272	699	1,270	2,382	262	2,644	5.24	19.05	39.66	63.95	36.74	100.69	10	10.07	....	619
16	2,401	7,385	9,786	449	769	1,282	141	1,423	3.36	11.53	21.34	36.23	11.78	48.01	10	4.80	....	329
17	....	2,256	2,256	96	303	359	39	398	.72	4.51	5.97	11.23	....	11.23	10	....	1.12	....
18	3,024	8,135	11,159	486	979	1,235	136	1,371	3.64	14.68	20.56	38.88	14.44	53.32	10	5.33	....	376
19	3,616	7,897	11,513	642	909	1,161	128	1,289	4.81	13.63	19.33	37.77	17.29	55.06	10	5.51	....	486
20	....	1,911	1,911	95	291	262	29	291	.71	4.36	4.36	9.43	....	9.43	10	....	.94	....
21	8,470	13,693	22,164	624	1,684	2,135	235	2,370	4.68	25.26	35.55	65.49	40.51	106.00	10	10.60	....	1,028
22	7,269	14,209	21,478	651	1,466	2,304	253	2,557	4.88	21.99	38.35	65.22	33.37	98.59	10	9.86	....	917
23	....	2,127	2,127	175	298	239	26	265	1.31	4.47	3.97	9.75	....	9.75	10	....	.97	15
24	....	1,782	1,782	119	266	214	24	238	.88	3.99	3.57	8.44	....	8.44	10	....	.84	....
25	5,747	11,509	17,256	765	1,478	1,745	192	1,937	5.73	22.17	29.05	56.95	28.44	85.39	10	8.54	....	809
26	....	1,892	1,892	136	315	221	24	245	1.02	4.72	3.67	9.41	....	9.41	10	....	.94	....
27	5,128	8,960	14,088	664	1,145	1,407	155	1,562	4.98	17.17	23.43	45.58	26.08	71.66	10	7.17	....	662
28	5,742	12,513	18,255	901	1,325	2,037	224	2,261	6.75	19.87	33.91	60.53	27.78	88.31	10	8.83	....	938
29	....	1,690	1,690	112	297	193	21	214	.84	4.45	3.21	8.50	....	8.50	10	....	.85	....
30	10,208	15,542	25,750	851	980	3,310	364	3,674	6.37	14.70	55.11	76.18	50.01	126.22	10	12.62	....	268

a For plat of experiment block see p. 69; for sprays applied see p. 73.

TABLE 30.—*The comparative value of the 35 sprays tested in the experiment block of the Rio Bonito orchard in 1895, etc.*—Continued.(*a*)

Row No.	Number of peaches—		Total number of peaches set by trees of row.	Classified yield of fruit for—			11 per cent weight added to Oakland fruit.	Total estimated weight of Oakland fruit when matured.	Value of—		Estimated value of Oakland fruit when matured.	Total value of drying and cannery fruit when matured.	Estimated value of thinned fruit at same rate as that matured.	Total estimated value of all fruit set by trees of row.	Number of trees in rows.	Average value of fruit per tree—		Average net gain per cent of sprayed trees over unsprayed trees.
	Thinned from trees of row.	Matured by trees of row.		Drying.	Chico cannery.	Oakland cannery when gathered.			Drying fruit at ¾ cent per pound.	Chico fruit at 1½ cents per pound.						Sprayed.	Unsprayed.	
				Lbs.	*Lbs.*	*Lbs.*			$	$	$	$	$	$		$	$	
31	....	7,280	7,280	351	833	1,151	127	1,278	2.66	12.49	19.17	34.32	....	34.32	10	....	3.43	....
32	3,269	10,242	13,511	401	999	2,018	222	2,240	3.01	14.98	33.60	51.59	16.47	68.06	10	6.81	....	98
33	7,360	12,905	20,265	661	967	2,643	291	2,934	4.96	14.50	44.01	63.47	36.19	99.66	9.8	10.17	....	424
34	....	3,929	3,929	185	554	585	64	649	1.39	8.31	9.73	19.43	....	19.43	10	....	1.94	....
35	9,730	16,009	25,739	517	1,761	2,596	286	2,882	3.87	26.41	43.23	73.51	44.67	118.18	8.6	13.74	....	608
36	4,896	8,946	13,842	302	671	2,101	231	2,332	2.27	10.06	34.98	47.31	25.89	73.20	10	7.32	....	264
37	....	3,982	3,982	200	553	617	68	685	1.50	8.30	10.27	20.07	....	20.07	10	....	2.01	....
38	3,318	8,314	11,632	269	951	1,656	182	1,838	2.02	14.26	27.57	43.85	17.19	61.34	10	6.13	....	205
39	5,821	9,544	15,365	335	1,172	1,736	191	1,927	2.51	17.58	28.90	48.99	29.89	78.88	8	9.86	....	490
40	....	3,318	3,318	146	263	700	77	777	1.10	3.94	11.65	16.69	....	16.69	10	....	1.67	....
41	5,953	11,757	17,710	570	559	2,901	319	3,220	4.28	8.38	48.30	60.96	30.87	91.83	10	9.18	....	450
42	....	6,493	6,493	398	663	1,061	117	1,178	2.99	9.91	17.67	30.60	....	30.60	10	3.06	....	191
43	....	2,174	2,174	142	283	314	35	349	1.07	4.24	5.23	10.54	....	10.54	10	....	1.05	....
44	773	6,276	7,049	385	647	975	107	1,082	2.89	9.70	16.23	28.82	3.55	32.37	10	3.24	....	208
45	3,951	10,862	14,813	726	468	2,297	252	2,549	5.45	7.02	38.23	50.70	18.44	69.14	10	6.91	....	512
46	....	2,358	2,358	117	307	350	38	388	.88	4.60	5.87	11.35	....	11.35	10	....	1.13	....
47	....	4,906	4,906	214	861	602	66	668	1.58	12.91	10.02	24.51	....	24.51	10	2.45	....	117
48	675	4,447	5,122	260	237	942	104	1,046	1.95	3.55	15.69	21.19	3.22	24.41	10	2.44	....	128
49	....	2,219	2,219	142	379	235	26	261	1.07	5.68	3.91	10.66	....	10.66	10	....	1.07	....
50	....	6,268	6,268	446	470	1,253	138	1,391	3.35	7.05	20.86	31.26	....	31.26	10	3.13	....	193
51	2,985	8,221	11,206	479	1,855	398	44	442	3.59	27.82	6.63	38.04	13.81	51.85	10	5.18	....	218
52	....	3,448	3,448	230	281	620	68	688	1.73	4.21	10.32	16.26	....	16.26	10	....	1.63	36
53	....	2,412	2,412	160	215	425	47	472	1.20	3.22	7.08	11.50	....	11.50	9.6	....	1.20	....
54	5,568	12,555	18,123	776	760	2,527	278	2,805	5.82	11.40	42.07	59.29	26.29	85.58	10	8.56	....	459
55	....	3,271	3,271	259	349	491	54	545	1.94	5.24	8.17	15.35	....	15.35	10	....	1.53	....
56	5,659	10,016	15,675	440	1,130	1,820	200	2,020	3.30	16.95	30.30	50.55	28.56	79.11	9.5	8.32	....	443
57	5,251	10,505	15,756	465	1,519	1,519	167	1,686	3.49	22.78	25.29	51.56	25.77	77.33	10	7.73	....	513
58	....	2,577	2,577	194	378	330	36	366	1.45	5.67	5.49	12.61	....	12.61	10	....	1.26	....

a For plat of experiment block see p. 69; for sprays applied see p. 73.

COMPARATIVE SIZE OF FRUIT ON SPRAYED AND UNSPRAYED TREES.

Owing to the fullness of the records obtained relative to the weight and number of peaches gathered from the sprayed and unsprayed trees in the present experiments, it is possible to learn the comparative average weight of the fruit produced on treated and untreated trees. It might seem that the unsprayed trees, having to mature on an average 291.3 peaches per tree, would yield larger fruit than the sprayed trees, which had to mature 949.2 peaches per tree; in other words, that the increased number of peaches upon sprayed over unsprayed trees would, to a considerable extent, be counterbalanced by an increase in the size of the fruit on the lightly loaded unsprayed trees. It has been found, however, that where the conditions for vigorous growth of a tree are present, and where the fruit upon a tree is so thinned that the tree is not overloaded, the peaches of the full-bearing tree are practically as large when mature as are those of the tree which has lost much of the crop from curl. The following table has been compiled from the facts in hand upon this matter. It is shown in this table that the fruit from the sprayed trees averaged for the whole block (345.3 trees) 299.0344 peaches per 100 pounds, and the fruit from the unsprayed trees averaged for the whole block (228.9 trees) 299.0312 peaches per 100 pounds. This shows that the gain in size of peaches on unsprayed trees over those on sprayed trees, as determined by the average number of peaches to 100 pounds, is $\frac{106}{100000}$ per cent, or only about $\frac{1}{1000}$ of 1 per cent. This amounts to nothing from a practical standpoint.

TABLE 31.—*Size of fruit on sprayed and unsprayed trees as determined by the average number of peaches per 100 pounds.*

	Number of trees in block	Fruit produced by all trees of block.		Average production per tree.		Average number of peaches— Per 100 pounds.		Average number of peaches— Per tree.		Proportionate percentage yield of trees.		Average number of peaches per 100 pounds per tree.	Average percentage of gain in size of fruit on unsprayed trees over that of sprayed trees.
		First picking.	Second picking.	First picking.	Second picking.	First picking.	Second picking.	First picking.	Second picking.	First picking.	Second picking.		
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*								
Sprayed	345.3	95,094	14,504	275.4	42	293.2	337.4	807.5	141.7	86.8	13.2	299.0344	$\frac{106}{100000}$ per cent, or about $\frac{1}{1000}$ of 1 per cent.
Unsprayed....	228.9	19,035	3,257	83.2	14.2	293.6	330.8	244.3	47	85.4	14.6	299.0312	

It should not be understood by the above that a crop of 950 peaches draws no more heavily upon a tree than a crop of 300 peaches when other conditions are equal. All observation tends to show that such is not the case. A tree too heavily loaded will often produce much smaller fruit than a properly thinned tree, even upon exceedingly rich soil. The facts given in both the preceding text and table show clearly, however, that the severe attack of curl in the spring of 1895 drew upon the vitality of the unsprayed trees as heavily as did the excess of 650 peaches each on the sprayed trees. Otherwise stated, the trees averaging 300 peaches were drawn upon as heavily by the attack of curl, combined with the maturing of 300 peaches, as were the sprayed trees in maturing 950 peaches. If this had not been the case, the unsprayed trees would have better nourished their crop, and would have produced larger and heavier fruit than those which were sprayed. These facts should receive the attention of all thoughtful growers, as no one can afford to have his trees drawn upon to the extent of two-thirds of a crop of peaches without return, even when frost or other causes would not have allowed him a crop on sprayed trees. To permit trees thus to suffer from curl even in such a year would be equivalent to draining them of much vitality, even though they failed to show this drain in the reduction of wood or fruit buds for the ensuing year. But it has already been shown that a marked reduction in the number and quality of fruit buds is a result of a spring attack of curl. The soil is also certain to sustain an unnecessary drain upon its resources.

Another phase of this subject is made clearer by the above table. There are very many varieties of peaches so resistant to leaf curl that the fruit does not drop, even when a large percentage of the leaves are lost. Many growers leave such varieties unsprayed, thinking that the saving of the fruit is the all-important point, and that the loss of the spring foliage alone does not warrant the spraying of such varieties. The above facts will show the error of such deductions. When the loss of the foliage upon the Lovell is equal to the drain upon the tree brought about in maturing two-thirds of a crop, the loss of the foliage upon a semiresistant variety must be approximately the same. This drain will be apt to show also in the size and weight of the fruit, if not in the number of peaches. Certainly no grower is warranted in leaving any variety unsprayed simply because that variety holds its fruit in spite of the loss of foliage. The trees have suffered in such a case, and the orchardist can scarcely avoid feeling the loss in the reduced vigor of his trees, the reduced weight and size of his fruit, and the added drain upon his soil.

COLOR OF SPRAYED AND UNSPRAYED FRUIT.

The Lovell peach is normally a fruit of fine color, but under the action of certain of the sprays used its color was greatly heightened. In observing this action of the sprays no color scale was used, but the marked brightening on certain sprayed rows was too distinct to be mistaken by the most careless observer. This heightening of color was not due to excess or lack of crop, for it was distinct on both heavily and lightly loaded trees, where the fruit was of medium size and where it was exceptionally large, but was due to the use of the copper sprays, especially of the stronger Bordeaux mixtures applied. Here is another advantage in the use of the copper salts. This increase in color would certainly mean dollars to the grower where the fruit was placed on the market in competition with unsprayed fruit, even of the same variety. The writer regrets that a color scale could not have been used in this connection, so that the true heightening of color could be stated, but the contrast between sprayed and unsprayed fruit, where the spraying was done with the Bordeaux mixture, was observed and discussed by many who had this fruit to handle.

METHOD OF THINNING AND COST OF PICKING PEACHES.

THINNING BY HAND AND BY CURL.

An argument advanced by certain peach growers and requiring consideration is that a moderate spraying under ordinary conditions is sufficient. By avoiding too thorough work enough curl is allowed to develop to cause the dropping of one-fourth to one-half of the peaches being set by the tree. If soil conditions are favorable it is thought the trees will still retain a sufficient crop, and the expense of thinning will be avoided.

At first thought the plan here suggested might seem the easiest and cheapest way of thinning fruit. A consideration of all points involved will show, however, the faults of this method. To do effective preventive spraying against curl the spray must be applied to the dormant tree, and to judge of the severity of a coming attack of curl before growth begins is too uncertain a method to warrant the indorsement of practical growers. All influencing conditions may appear to favor a light attack of curl till after the spraying is completed, when a sudden change of temperature or a cold rain may develop a severe attack within the course of a few days. Under such conditions, incomplete or light spray work may cost the grower the major portion of his crop.

In case the severity of curl is about as presupposed, the number of peaches remaining on the tree being about what the tree should carry, it is still very probable that the grower has sustained a loss in the stoppage of growth of wood and fruit and in the fall of foliage equal to or above the expense of thinning. There is also a difference between hand-thinned trees and those thinned by curl. This disease is local in its action, not general. If one branch in the midst of diseased branches is thoroughly sprayed it will hold its fruit, while the peaches will fall from those not sprayed. This will show that the peaches of a diseased tree are not thinned evenly, as the disease is frequently not uniformly distributed over all branches of the tree. Then the fruit is for the most part nourished by the foliage of the branch which bears it, and hence if the disease is not equally distributed the foliage will be unequally distributed and the fruit unequally nourished. One portion of a tree may have an excess of fruit, even to the breaking of limbs, while another portion shows a deficiency. Besides the unequal thinning of fruit on different portions of a tree, arising from the unequal action of curl over the tree as a whole, there will also appear an unequal thinning of the fruit of individual branches. In this respect, one of the prime objects of hand thinning, the equalizing of the fruit distribution upon the branches, is lost when the thinning is caused by curl. Such fruit as remains upon the curl-thinned branches is apt to be largely toward the ends of the limbs.

The statements here made respecting the local action of the disease and the local nourishing of the fruit upon a limb or portion of a tree, are known to be correct, and have been established by a series of carefully conducted experiments on sprayed halves of trees. The details and results of this work are given in the concluding section of this chapter.

COST OF PICKING PEACHES.

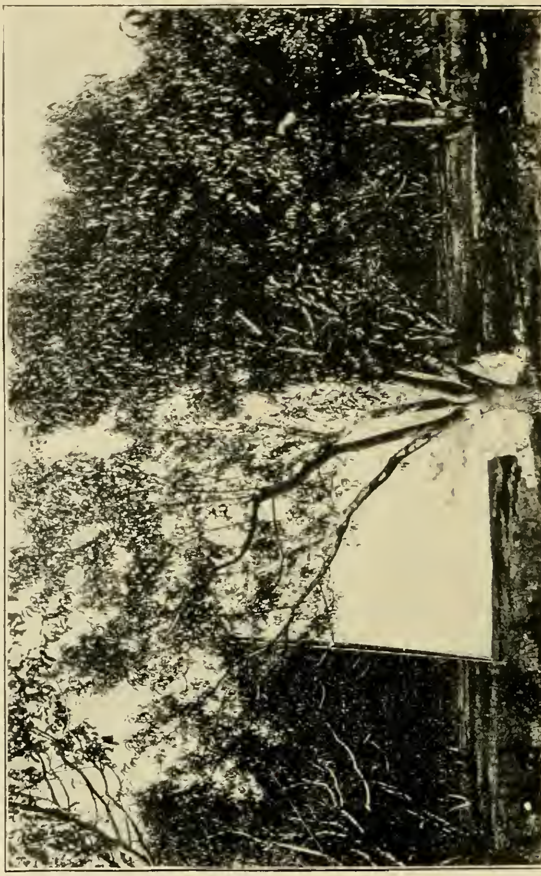
When considering the picking and sorting of peaches from sprayed and unsprayed trees a marked difference is noted in cost in favor of those sprayed. In the Rio Bonito orchard, where our experimental work was prosecuted, it has cost the proprietors $1 per ton to pick fruit from fully loaded sprayed trees. In contrast to this the cost of picking and sorting the fruit of the unsprayed trees just north of the experiment block, in the summer of 1895, was $3 per ton. This was on account of the scattered condition of the fruit on these trees, which were affected by curl in the spring like the control trees of the experiment block. This cost per ton was calculated with wages at $1 per day, the men boarding themselves, and where one sorter to five pickers was employed. We have here a difference of $2 per ton in the cost of picking and sorting fruit from sprayed and unsprayed trees. This added expense on unsprayed trees arises, of course, through the necessity of picking over a greater expanse of tree and orchard surface to obtain a given amount of fruit. It is believed that in this single item of picking the fruit enough is saved to more than cover the expense of spraying the trees and thinning the fruit.

THE LOCAL ACTION OF CURL ON FOLIAGE AND FRUIT.

RECORDS OF TREES SPRAYED ON ONE SIDE.

The study of the habits of *Exoascus deformans* and its influence upon its host led to the following investigation into the localization of the parasite upon the tree and its local rather than general effects.

2



1

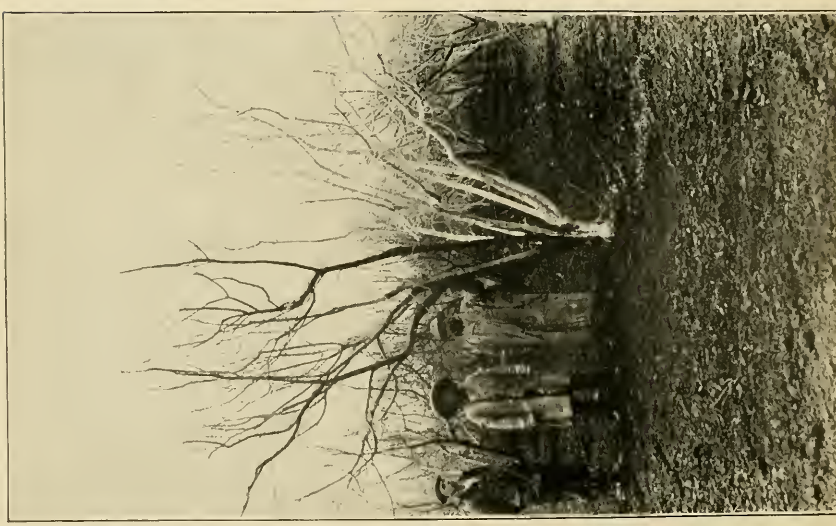


FIG. 1.—TREE TREATED ON ONE SIDE; APPEARANCE WHEN DORMANT.

FIG. 2. TREE TREATED ON ONE SIDE; APPEARANCE AFTER DEVELOPMENT OF CURL IN THE SPRING.

DESCRIPTION OF PLATE XVI.

Fig. 1 shows the condition of the trees sprayed on one side (considered in the text, p. 123). The right side of the tree shown was sprayed with Bordeaux mixture, the left side was unsprayed. (Compare with Pls. XVII, XVIII, and XIX.)

Fig. 2 shows the condition of the tree sprayed on one side after curl had largely denuded the unsprayed half at the left.

Just north of the experiment block, in the continuation of the same orchard, was selected a row of 6 trees for treatment on one side. The spray used on half of each of the first three trees from the east was the standard Bordeaux mixture recommended by the Department, viz, 6 pounds copper sulphate, 4 pounds quicklime, and 45 gallons of water. The spray used on the following three trees was lime and sulphur, consisting of 10 pounds sulphur, 20 pounds lime, and 45 gallons of water. In doing this spraying an effort was made to treat only one-half of each tree. Each tree was first examined, and, in some instances at least, a large canvas stretched through it in such a manner as to divide it as nearly as possible into two equal parts. All the branches on one side were thoroughly sprayed, the canvas preventing any of the spray reaching the limbs of the other half. In this way the half of each of three trees was sprayed with each of the above-mentioned sprays.

A photograph showing the appearance of one of these trees shortly after treatment is shown in Pl. XVI.

May 10 and 18, 1895, when curl had reached its highest development, careful estimates of the loss of foliage were made for the sprayed and unsprayed sides of the 6 trees used in the experiment. The following table shows the results of these estimates:

TABLE 32.—*Foliage lost from sprayed and unsprayed halves of trees.*

Percentage of leaves which fell from—	Trees treated with Bordeaux mixture.(*a*) Tree No.—			Trees treated with sulphur spray.(*b*) Tree No.—		
	1.	2.	3.	4.	5.	6.
Sprayed half	2	4	6	18	15	15
Unsprayed half	92	92	90	85	85	85

a Foliage estimated May 18, 1895. *b* Foliage estimated May 10, 1895.

On May 8 the trees were examined, and the notes made at that time state that the sprayed and unsprayed sides presented a striking contrast. It is said that "the foliage on the sprayed half of the trees is perfection itself in almost all cases. It is very dense and abundant, both below on the limbs and above. The leaves are of a very dark, rich green, and are long, soft, and beautiful. The growth is very thrifty, in fact, unusually so. There are probably not more than 2 to 3 per cent of the leaves curled at all on the sprayed half, and these are confined to points at the top of the branches not properly sprayed. On the unsprayed half of these trees there is very little healthy growth. Probably 95 per cent of the leaves are curled, and most of them badly curled and distorted. Probably not less than 90 per cent of those produced thus far this spring will drop. The color of the foliage is yellow and sickly. Such leaves as are not curled are small and light in color. The foliage upon both lower and upper limbs is badly affected.

What little growth there is which is thus far free from curl is terminal—very little healthy or comparatively healthy growth is seen from lateral buds. As to fruit, I may say that much is dropping from the curled side and little from the other." (Pls. XVI and XVII.)

The work of thinning the fruit from the sprayed halves of these trees was not conducted at the time the sprayed trees of the general experiment block were thinned. The writer believes that the records of the fruit thinned from these trees were not kept except for one tree sprayed on one side with Bordeaux mixture. The fruit on the sprayed half of this tree was thinned May 8, 1895, and amounted to 1,145 peaches, which weighed 23 pounds, or very nearly 50 peaches to the pound. These peaches were very uniform in size and stuck tightly to the limbs. If they could have grown to the usual size when picked in the fall they would have given 381 pounds of fruit. No peaches were thinned from the unsprayed half of this tree.

The yield of the 6 trees was carefully determined by weighing and counting the fruit from the sprayed and unsprayed sides of each tree separately. The results of this work are shown in the following table:

TABLE 33.—*Yield of sprayed and unsprayed halves of trees.*

	Bordeaux mixture, tree No.—			Sulphur spray, tree No.—		
	1.	2.	3.	4.	5.	6.
Pounds of fruit gathered from—						
Sprayed half	284.8	361.6	286.7	112.2	189.3	64.6
Unsprayed half	14.3	50.6	25.3	48.6	80.4	35.3
Number of peaches gathered from—						
Sprayed half	718	1,064	836	303	450	172
Unsprayed half	40	147	74	132	220	94

By the preceding table it is shown that the sprayed half of tree 1 bore 718 peaches, weighing 284.8 pounds, while the unsprayed half bore only 40 peaches, weighing 14.3 pounds. In this case, as in the case of the other trees of this series, the localized position and action of the fungus of curl upon a tree is shown. The unsprayed half of the tree suffered so severely from the disease that it lost 92 per cent of its foliage and all but 14.3 pounds of fruit. This severe attack on one side of the tree appeared to have no influence whatever over the sprayed limbs of the other side, as the fruit on the sprayed half was thinned of 1,145 peaches, lost but 2 per cent of its foliage, and bore 284.8 pounds of as fine peaches as any in the orchard. On the other hand, the full and healthy covering of foliage on the sprayed side of the tree appears to have had no beneficial influence over the diseased side. Had it had any well-marked beneficial influence the fruit of the unsprayed half would have been retained, which was not the case. The same local action of the disease, and the same local nourishing influence due to the assimilative action of the healthy foliage may be

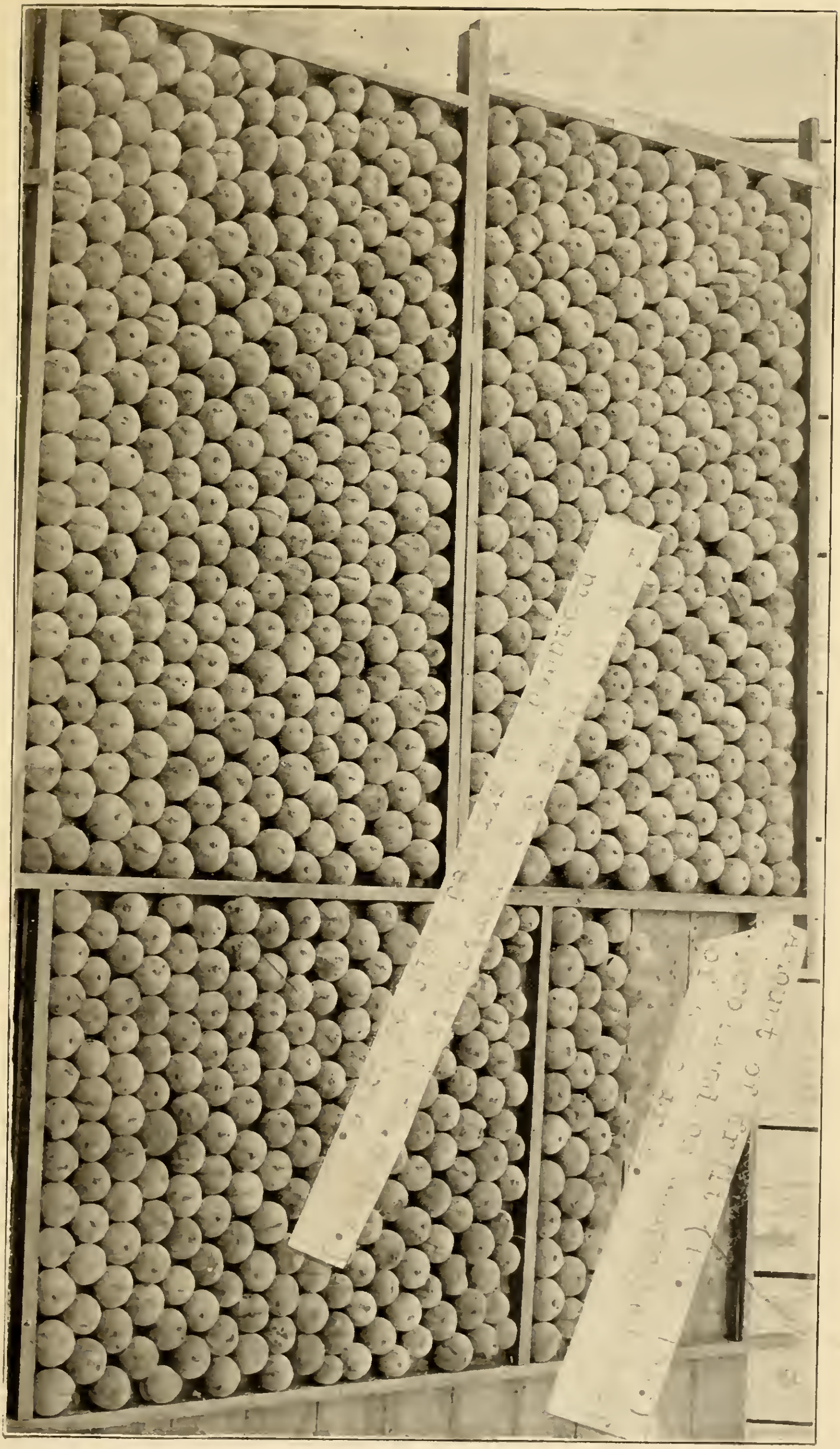
DESCRIPTION OF PLATE XVII.

This plate shows the condition of one of the trees sprayed on one side at the time of picking the fruit. The leaves have been cut away with pruning shears to enable the photograph to show the fruit upon the sprayed half (right side) of the tree, and the absence of fruit upon the unsprayed half (left side). The sprayed half matured 284.8 pounds of the finest peaches; the unsprayed half matured only 14.3 pounds. Over 1,100 peaches were thinned from the sprayed half of this tree to enable the limbs to bear the crop, while the unsprayed half was unthinned except by curl. (For records of this and other trees sprayed on one side see Chapter VI, also compare with Pls. XVI, XVIII, and XIX.)

side.

DESCRIPTION OF PLATE XVIII.

Peaches gathered from the tree sprayed on one side shown in the preceding plate. The fruit shown on the two drying trays at the left, together with that in the lower compartment of the tray at the right, was gathered from the sprayed half of this tree. The peaches shown in the upper right-hand compartment were all that matured on the unsprayed half of the same tree. The sprayed half bore 718 peaches, weighing 284.8 pounds; the unsprayed half bore only 40 peaches, weighing 14.3 pounds. (Compare with Pls. XVI, XVII, and XIX.)



FRUIT FROM TREATED AND UNTREATED SIDES OF SINGLE TREE.

DESCRIPTION OF PLATE XIX.

This is a photograph of a limb of the sprayed half of the tree shown in Pls. XVI and XVII, after the removal of the leaves with pruning shears. A good idea of the size and perfection of this fruit may be obtained from the plate. The color was strikingly high and rich. The size of the fruit is further shown by the fact that the peaches averaged 252 per 100 pounds. (See note on this work at the close of Chapter VI, p. 122; also refer to Pls. XVI, XVII, and XVIII.)

FRUITFULNESS OF LIMBS ON TREATED HALF OF TREE.

seen in the condition of the foliage and crop on the sprayed and unsprayed sides of the other trees included in these experiments.

It even appears likely, both from observation of the trees and from the general laws of use and disuse and supply and growth, that the influence of the sprayed upon the unsprayed portions of the tree, in the presence of an attack of curl, is detrimental rather than beneficial. It is probable that the half of the tree in full foliage, instead of lending material aid to the defoliated side, tends to further rob that side, at least of the crude sap coming from the roots.

For the purpose of showing the reader the striking results obtained from these trees, several photographs were made at the time the crop was matured. In order that the fruit might be seen upon the tree the foliage was carefully cut away and a screen placed behind the tree (Pl. XVII). A single limb was also photographed, as shown in Pl. XIX. The fruit gathered from the sprayed and unsprayed halves of tree 1 is likewise shown in Pl. XVIII. The unusual size and brightness of color of the fruit from the sprayed half of this tree was very marked. The peaches averaged 252 per 100 pounds. The average of peaches for the large experiment block was, as before stated, 299 per 100 pounds. There was thus a gain of 18.66 per cent in size of fruit on the sprayed half of this tree over the average for the block.

CHAPTER VII.

PREVENTIVE SPRAY WORK CONDUCTED BY ORCHARDISTS.

GENERAL CONSIDERATION OF THE AUXILIARY WORK.

While planning the experiments already detailed it seemed desirable to set on foot a similar line of work among peach orchardists in general. It was thought that several advantages could be attained from such auxiliary and coincident work: (1) It would indicate the effectiveness or noneffectiveness of the sprays recommended, in controlling curl under the various conditions of variety, situation, soil, temperature, atmospheric humidity, seasonal variations, etc., existing in the many peach-growing sections of the country. (2) It would eliminate the personal element of the other experiments being conducted, and would introduce various new conditions of orchard work, thus pointing out the efficiency or needs of the general grower and indicating what features of the work should receive special attention in offering final recommendations. (3) It would introduce the methods of treatment in many peach-growing centers, and by means of the object lessons thus set up, it would effect a much more rapid and general adoption of such spraying methods than could be hoped for otherwise.

In advance of the inauguration of this work, which was begun in the fall of 1893, correspondence was opened with over 1,600 peach growers in all peach-growing centers of the United States. To each of these growers was sent a circular describing the nature and cause of peach leaf curl, outlining a series of spraying tests which it was desirable to have conducted for its prevention, and supplying the spray formulæ known to have given good results in California. Each grower was given the facts necessary to enable him to carry out the work, and was requested to furnish the Department with the results of his experiments.

A very large number of growers expressed their willingness and desire to assist in conducting these experiments, and a very considerable number have done so in many of the peach-growing centers. It may also be said that the number of growers who have adopted annual spraying methods as a result of this introductory experimental work is large and is constantly increasing. In fact, the spraying of peach trees for curl has become very general in many of the peach-growing centers of the United States where the disease prevails.

Of the reports which have been received of work conducted by the growers, it is thought best to include a few from those regions where curl is most common. The reports given are of much value, and in numerous cases they show that the experiments were carefully carried out. Representative reports will be given from the lake shore fruit belt of Michigan, from the Willamette Valley, Oregon, where peach culture has been greatly checked by curl, and from several growers in California and elsewhere. An effort has been made to present these reports, which have been carefully tabulated, in as compact form as possible.

NOTES ON THE AUXILIARY EXPERIMENTS IN MICHIGAN.

A very considerable number of peach growers in the more northern portion of the Michigan fruit belt received from the Department a request to undertake spraying experiments in the winter of 1893–94 for the prevention of peach leaf curl. Among these orchardists was Mr. Smith Hawley, of Ludington. This gentleman, as well as several other growers of Mason and Oceana counties, entered heartily into the work, the result being that at present a very large number of orchardists are annually spraying for curl in that region. The work conducted by Mr. Hawley involved the testing of a number of sprays in early and late winter with one and two applications. It was very carefully carried out, and as the disease developed quite seriously in that region in the spring of 1894 his results are most interesting and valuable. The data supplied by his report are presented in the following table and notes:

TABLE 34.—*Experimental work conducted by Mr. Smith Hawley, of Ludington, Mich., in the spring and summer of 1894.*

Letter of formula and No. of experiment.	Formulæ.	Variety of trees.	Age of trees.	Nature of soil.	Number of trees— Sprayed.	Number of trees— Unsprayed.	Date of— First spraying.	Date of— Second spraying.	Percentage of leaves lost by— Sprayed trees.	Percentage of leaves lost by— Unsprayed trees.	Date when loss of leaves was estimated.	Pounds of fruit produced by— Sprayed trees.	Pounds of fruit produced by— Unsprayed trees.
			Years.										
(A) 1	15 lbs. sulphur; 30 lbs. lime; 10 lbs. salt; 60 gal. water	Crawfords Early	12	Heavy sand and clay loam.	10	10	Apr. 17	....	10	50	June 15 and June 22	288	99
(C) 2	5 lbs. copper sulphate; 5 lbs. lime; 45 gal. water	Hales Early	12	Sand and clay loam.	12	12	Apr. 12	....	8	50	....do	801	549
(B) 3	10 lbs. sulphur; 20 lbs. lime; 10 lbs. salt; 60 gal. water	Crawfords Early; Hales Early; Hills Chile	5	....do	21	21	Jan. 19	Apr. 17	15	50	....do	666	243
(B) 4 (C)	First spraying: 10 lbs. sulphur; 20 lbs. lime; 10 lbs. salt; 60 gal. water; Second spraying: 5 lbs. copper sulphate; 5 lbs. lime; 45 gal. water	Crawfords Early; Hales Early; Hills Chile	5	Clay loam	21	21	Jan. 19	Apr. 12	5	50	June 22	342	243
(C) 5	5 lbs. copper sulphate; 5 lbs. lime; 45 gal. water	Crawfords Early	12	Sand and clay loam.	10	10	Feb. 8	Apr. 12	3	40	June 15 and June 22	437	324
(A) 6	15 lbs. sulphur; 30 lbs. lime; 10 lbs. salt; 60 gal. water	Crawfords Early; Barnards Early	12	....do	23	23	Jan. 19	....	5; 8	50; 75	....do	991	666
(B) 7	10 lbs. sulphur; 20 lbs. lime; 10 lbs. salt; 60 gal. water	Crawfords Early	12	Clay and sand loam.	10	10	Jan. 19	....	20	50	....do	279	225
(C) 8	5 lbs. copper sulphate; 5 lbs. lime; 45 gal. water	Early Louise	15	Sand and clay loam.	18	17	Feb. 8	....	3	90	....do	1,017	63

The preceding table gives the details of eight of Mr. Hawley's experiments. The experiments are distinguished by numbers (1–8), and the formulæ used by letters (A, B, and C). Mr. Hawley's notes on these experiments were written chiefly on two dates, the first immediately after the estimates of foliage were made and the second shortly after the fruit was gathered. His statements in general are given in the following notes:

Experiment 1:

June 23, 1894.—This experiment was made under rather unfavorable circumstances, as the wind came up quite strong after I had commenced, and consequently I could not do the work as thoroughly as I wished, but the results now promise to be entirely satisfactory. The foliage is perfectly fresh and green, and apparently the peaches are going to hang on. Another thing that now appears to be well established is that the earlier spraying is the better. [See notes under experiment 2.] There is now quite a perceptible difference to be noticed between early and late spraying as regards the foliage.

October 1, 1894.—This experiment has demonstrated the effectiveness of the spray used. While the crop was not large, owing to the unhealthy state of the trees from leaf curl last year, yet it was about three times as large on the sprayed as on the unsprayed trees. The fruit was much nicer. I could easily pick out the baskets of fruit from the sprayed trees.

Experiment 2:

June 23, 1894.—This experiment has given entire satisfaction so far, as the foliage of the trees is perfect and the fruit is hanging on well. This experiment, taken in connection with the others, indicates that the blue vitriol solution, C, acts quicker than the sulphur solution. The winter sprayings seem fully as effective with the sulphur solution as with the blue vitriol, but the spring spraying is not quite as good.

October 1, 1894.—While the difference in the amount of fruit gathered from the sprayed and unsprayed trees is not as great as in some of the other experiments, yet the effect is fully as apparent, for these trees were not nearly as badly affected last year as some others, and consequently they all had a fair load of fruit. There was a far greater difference noted in the foliage than in the fruit.

Experiment 3:

The first spraying of this experiment was on January 19, and was followed by a heavy rain storm, which lasted twenty-four hours, and will undoubtedly prevent the full benefit of the work from being realized, but the work was very thoroughly done and may be effective.

June 23, 1894.—The second spraying was well done, and at this date the effect seems to show (1) that formula B is not strong enough to have the desired effect; and (2) that two sprayings are not much better than one, provided the work is thoroughly done with one spraying, and provided, also, the spraying is followed by good weather.

October 1, 1894.—This experiment has given greater satisfaction than anticipated. The proportion of sprayed to unsprayed fruit is better than expected at the time of the estimate on the loss of foliage.

Experiment 4:

June 23, 1894.—The contrast between the sprayed and unsprayed trees at this date is very decided in this experiment. The first spraying was on the same date as experiment 3, and followed by rain. The last was done April 12 with formula C, and was well done, and the trees now look fine.

October 1, 1894.—The results of this experiment are rather disappointing, as I was led to believe when I made the estimate of the loss of foliage in June that the results would be more satisfactory than with experiment 3. Whether the solutions used had the effect of neutralizing each other, or whether formula B, having been first applied, prevented any benefit from formula C, I can not tell.

Experiment 5:

June 23, 1894.—The first spraying of this lot was followed by ten hours' rain, the last spraying by good weather. The treated trees present a fine appearance, but the contrast is not so great as in some other experiments, for the control trees are an outside row and apparently not as badly affected as those farther in the orchard. I do not anticipate a very large difference in the fruit yield.

October 1, 1894.—This experiment has turned out just as I thought it would. The difference in the amount of fruit from the sprayed and unsprayed trees is not great, yet it is quite satisfactory considering the conditions.

Experiment 6:

June 23, 1894.—This experiment was thoroughly made, but was unfortunately followed by twenty-four hours of warm rain, commencing ten hours after the spraying, so that the result is not as satisfactory as desired, but the effect is so noticeable that the difference can be seen half a mile away.

October 1, 1894.—The results of this experiment are entirely satisfactory. In spite of the fact that the spraying was followed by rain and then by very cold weather, the yield of fruit was one-third more on the treated trees than on the untreated trees, but what pleases me most is the very great difference in appearance of the trees now. Those that were treated have made double the growth this season that the untreated trees have. They are holding their leaves late and have twice the buds set for another year, and are fresher and healthier in every way.

Experiment 7:

June 23, 1894.—The result of this experiment thus far seems to show that the formula used is not strong enough to accomplish the work desired. There is at this date less difference to be noted between the treated and untreated trees than in any other experiment.

October 1, 1894.—This experiment has resulted about as I thought it would, from the appearance of the trees in June. I do not think formula B is strong enough.

Experiment 8:

June 23, 1894.—I regard this as one of the most valuable experiments in the series. It has so far shown the best results. The untreated trees look as though a blight had struck them, appearing at this date as if they were going to die, while the sprayed trees look as fresh and healthy as young trees that never had any disease. One curious thing I have noticed is in relation to a branch from one of the untreated trees which reaches across to one of the treated ones. This branch, of course, got sprayed when the tree was sprayed with which it mingles, and it is as full of leaves and fruit as the treated tree, while the balance of the tree to which it belongs is bare of leaves and fruit.

October 1, 1894.—The final results of this experiment have proved what I expected. There is a greater difference in yield than in any other experiment, while the difference in appearance between the treated and untreated trees is yet very marked. The treated trees look as fresh and healthy as young trees, while the others still look very bad. These trees have always been very heavy bearers, and consequently have not attained a very large size. They were never very badly affected by leaf curl till this year.

In the eight experiments described by Mr. Hawley the percentages of net gain in fruit of the sprayed trees over the unsprayed were as follows:

TABLE 35.—*Percentages of net gain in fruit shown in eight spraying experiments conducted by Mr. Smith Hawley, of Ludington, Mich.*

Experiment No.	Formula.[a]	Net gain.	Experiment No.	Formula.	Net gain.
		Per cent.			*Per cent.*
1	A	191	5	C	35
2	C	46	6	A	49
3	B	174	7	B	24
4	B and C	41	8	C	1,424

[a] See table 34.

Owing to the fact that Mr. Hawley's experiments were conducted with different varieties of peach, an accurate comparison can not be instituted between them. From the very excellent results obtained in experiment 8, where the unsprayed trees lost 90 per cent of their leaves and the sprayed trees only 3 per cent, and where the net gain in fruit by the sprayed trees was 1,424 per cent of the yield of the unsprayed trees, the writer believes Mr. Hawley's conclusions are correct, viz, that the spray used in this experiment gave the best results. That the same spray did not give equally striking contrasts in experiments 2, 4, and 5 is probably due mainly to the fact that the trees of these experiments were not of the same variety as those of experiment 8, but were much more resistant to disease, hence no spray could have produced in the former experiments the same contrast between sprayed and unsprayed trees. That the trees of experiments 2, 4, and 5 were not as badly diseased as those of experiment 8 is shown to be a fact, for the unsprayed trees of the latter experiment lost 90 per cent of their leaves from curl, while those of the former experiments lost only 50 per cent. The same evidence is given by the fruit. The unsprayed trees of experiment 8 bore only 3.7 pounds of fruit per tree, while the unsprayed trees of experiments 2, 4, and 5 averaged 45.7, 11.6, and 32.4 pounds of fruit per tree, respectively.

From the preceding facts it appears that the most active and satisfactory spray used by Mr. Hawley was that containing 5 pounds of copper sulphate, 5 pounds of quicklime, and 45 gallons of water. This is especially interesting from the fact that this spray also gave the best results among the 35 formulæ tested by the writer in the Sacramento Valley.

The relative value of the stronger sulphur spray (formula A) and the Bordeaux mixture used by Mr. Hawley (formula C) is well brought out in an experiment conducted by him on a somewhat similar scale, but with a single variety of peach—Hills Chile. This experiment admits of very satisfactory comparisons being drawn, and is summarized in the following table:

TABLE 36.—*Experiment No. 9, conducted by Mr. Smith Hawley.*

Row No.	Formula used.	Variety of trees.	Age of trees.	Number of trees.	Date of spraying.	Total yield of fruit.	Net gain of fruit over yield of unsprayed trees.
			Years.			*Pounds.*	*Per cent.*
1	A	Hills Chile	5	6	April 12	270	328
2		do	5	6	Unsprayed	63	
3	C	do	5	6	February 8	306	354
4	A	do	5	6	January 19	189	200

The preceding experiment shows that Mr. Hawley obtained from his Hills Chile trees a net gain in fruit of 354 per cent by spraying with the Bordeaux mixture (formula C), and a net gain of 328 per cent with the stronger sulphur spray when applied on April 12 and 200 per cent when applied on January 19. These results indicate that the early winter treatment will probably not prove as effective in Michigan as a treatment of the trees shortly before the buds swell in the spring. It is probable, however, that the copper sprays will act more quickly than the sulphur sprays, on which account the latter should be allowed somewhat more time for action than the copper sprays, by applying them a little earlier in the spring. The copper sprays may be applied until the first buds begin to open, if necessary, but such a late application of the sulphur sprays would endanger the buds and new growth.

The following are Mr. Hawley's notes on this experiment:

Experiment 9:

June 23, 1894.—This experiment, although on a small scale, has been very intersting and instructive, and has been noted and admired by all who saw it. The rees stand on a slope, and a person standing on the opposite slope, only a few rods away, can see every tree, and the best possible chance is had to observe the effect of the different sprays, and to compare the treated with the untreated trees. The contrast at this time is very remarkable. The trees were quite badly affected by leaf curl last year.

October 1, 1894.—The contrast between the treated and untreated trees is very great as regards yield of fruit, and the contrast in the trees themselves at this date is quite as remarkable. The treated trees look fresh and healthy and have made a fine growth, while the untreated trees look sickly and have made very little growth, looking, in fact, a year or two younger, as regards size, than the others.

Late in the season of 1894 Mr. Hawley tested the sulphur and copper sprays to ascertain the comparative action of the same upon buds which were considerably swollen. He learned that the sulphur spray injured the buds to such an extent as to reduce the yield, while it prevented curl. The copper spray, however, prevented curl and gave a decided increase in yield. He thus reaches the conclusion that formula A is more injurious to buds than formula C. While this is true if the spray is applied at too late a date, it may be safely applied at an earlier date. It should also be mentioned that the sulphur sprays have insecticidal properties much superior to those of the copper sprays.

The Department work conducted by Mr. Hawley seems to have clearly demonstrated the possibility of controlling the most severe attacks of curl in the lake shore region of Michigan with a single spraying, when this is done thoroughly and at the proper time. In experiment 8 the untreated trees were so badly affected that, as already stated, 90 per cent of the foliage and all but 3.7 pounds of the fruit fell from the trees, but by spraying similar trees Mr. Hawley saved all but 3 per cent of the leaves—a gain of 2,900 per cent of foliage—besides increasing the yield of fruit 1,424 per cent. In other words, the sprayed trees held 30 times as much spring foliage and over 15 times as much fruit as the unsprayed trees at their side, all being of the same variety.

In the southern portion of the Michigan fruit belt a number of growers assisted the Department in conducting experiments. Among the reports received from that section is one by Mr. George Lannin, of South Haven. Mr. Lannin's work is summarized in the following table:

TABLE 37.—*Experimental work conducted by Mr. George Lannin, of South Haven, Mich., in the spring and summer of 1895.*

[Nature of soil, sandy.]

Letter of formula and No. of experiment.	Formulæ for 45 gallons of water.	Variety of trees.	Age of trees.	Number of trees—Sprayed.	Number of trees—Unsprayed.	Date of—First spraying.	Date of—Second spraying.	Percentage of leaves lost by—Sprayed trees.	Percentage of leaves lost by—Unsprayed trees.	Date when loss of leaves was estimated.	Fruit produced by—Sprayed trees.	Fruit produced by—Unsprayed trees.
			Years.								*Lbs.*	*Lbs.*
(*D*) 1	10 lbs. sulphur, 20 lbs. lime, 5 lbs. salt.	Barnard	6	10	10	Apr. 10	May 17	20	40	July 10	1,200	830
(*E*) 2	5 lbs. copper sulphate, 10 lbs. lime.	Hills Chile	6	10	10	...do..	June 25	15	35	...do..	1,300	600
(*F*) 3	2 lbs. copper sulphate, 3 pts. ammonia.	Hales Early	6	10	10	...do..	...do..	20	40	...do..	1,760	680
(*G*) 4	5 oz. copper carbonate, 3 pts. ammonia.	Crawfords Late.	6	10	10	...do..	June 8	10	30	...do..	1,800	700

The spray formulæ tested by Mr. Lannin were not included in the work of Mr. Hawley, and are therefore characterized as Formulæ D, E, F, and G. As Mr. Lannin sprayed different varieties of peach trees with 4 formulæ, the experiments can not be compared with one another to advantage. The value of all the sprays used is shown, however, by the gain in fruit obtained. The percentage of net gain in fruit was 44, 116, 158, and 157 per cent, respectively. These figures show that the eau celeste (Formula F) and the ammoniacal copper carbonate (Formula G) gave satisfactory results. The action of the disease on the foliage of the trees of experiment 3 was more severe than it was on the foliage of the trees of experiment 4. The unsprayed trees of the former experiment lost 10 per cent more of their leaves than the trees of the latter. The percentage of gain in fruit from the sprayed trees of experiment 3 was, however, fully as great as that from the sprayed trees of experiment 4. This shows that the eau celeste (Formula F) was more effective in combating the disease than the ammoniacal copper carbonate, which was applied in experiment 4.

Mr. F. N. Chesebro, of South Haven, sprayed 19 Crawfords Late and 19 Oldmixon trees in the spring of 1894, leaving 19 trees of each variety for comparison. The formula used was 15 pounds of sulphur, 30 pounds of lime, and 10 pounds of salt to 60 gallons of water. Mr. Chesebro did not report the exact yield of his trees, but stated that the sprayed trees lost 20 per cent of their foliage and the unsprayed trees 80 per cent—a saving of 60 per cent of the foliage by a single spraying. His report is as follows:

TABLE 38.—*Experimental work conducted by Mr. F. N. Chesebro, of South Haven, Mich., in the spring of 1894.*

[Variety of trees, Crawfords Late and Oldmixon Cling; nature of soil, sandy loam.]

No. of experiment.	Formula.	Age of trees.	Number of trees—		Date of spraying.	Per cent of leaves lost by—		Date when loss of leaves was estimated.
			Sprayed.	Unsprayed.		Sprayed trees.	Unsprayed trees.	
		Years.						
1	15 lbs. sulphur 30 lbs. lime 10 lbs. salt 60 gal. water	13	38	38	Mar. 7	20	80	June.

Mr. J. F. Taylor, of Douglas, Mich., reported favorably upon the spray work conducted by him in 1894. He used three different sprays, treating 50 trees with each, and leaving a like number unsprayed for comparison. The formulæ used were those designated as A, B, and C, in the spray work of Mr. Smith Hawley. Mr. Taylor says, in regard to his work:

The blossom buds had swollen somewhat when I began spraying, but the leaf buds were quite dormant. Formula A was used on March 29, Formula B on April 6, and Formula C on April 20. Blossoms began to open on the last days of April, and by the 6th of May trees were well covered with bloom. The trees sprayed were 6 years old, and of the following varieties: St. John, Barnards Early, Hinman, Switzerland, Gold Drop, and Early Freestone. Some of these varieties curled very badly last year, especially Early Freestone. The soil is quite uniformly a gravelly loam, with clay subsoil under all varieties. I made only one application with each formula. I think two applications would have been better. I sprayed 50 trees and then omitted 50 in each plat, or with each formula. I think Formula C gave as good results as any of them.[1]

After the trees were in full leaf I invited neighboring fruit men to go through the orchard and note the conditions of the trees sprayed and unsprayed. They found the foliage of trees that had been sprayed almost free from curl, while the unsprayed trees were badly curled. * * * The unsprayed trees had a larger percentage of small dead limbs through the top than those that were sprayed, and the prospect for future crops is therefore better where the trees were sprayed. * * * I hope to follow the work up more extensively next spring, and will begin the work earlier in the season, if necessary. If Formula C will continue to give as good results as it did last spring, I prefer to use it.

Mr. S. I. Bates, of Shelby, Mich., sprayed a few Stump the World trees in the spring of 1894, leaving an equal number unsprayed for comparison. The crop from the sprayed trees was double that from the unsprayed trees at their side, and a large percentage of the foliage was also saved. Mr. Bates states that the spray seems to put new life and vigor into the trees, especially young trees. With respect to the action of curl on old trees, he writes that there is an old orchard just across the road from his own which has had curl until the trees have no bearing wood left except at the extreme tops, and the owner "does nothing to prevent the disease and gets but little fruit."[2]

NOTES ON THE AUXILIARY EXPERIMENTS IN OREGON.

The climatic conditions under which peach culture is pursued in Oregon and Washington vary greatly. At the east of the Cascade Mountains the conditions approximate in many districts those prevailing in much of California. At the west of this range local influences determine the greater or less adaptation of each valley or region to the cultivation of the peach. Generally speaking, however, the humidity of the atmosphere for a major portion of the year is much in excess of that prevailing generally at the east of the Cascades or in California. In this respect also this northwest region is quite distinct from the conditions met with in most of the peach-growing regions of the East. In fact the climate of western Oregon and Washington is such as to call for separate consideration in connection with our present work. For this reason special effort has been

[1] This is the same formula that was found very satisfactory by Mr. Smith Hawley, at Ludington, Mich., and by the writer in the Sacramento Valley.

[2] There are thousands of such peach orchards in the peach districts of the United States. To those who are interested in the renewal of young and bearing wood upon lower limbs and upon old trees, the writer would refer to the data presented in Chapter V of this bulletin, where the influence of sprays on the vegetation of trees has been quite fully considered.

made to carry out spraying experiments in western Oregon, so that the needs of the growers west of the Cascades could be supplied.

The great rainfall which annually occurs on the west side of the Cascade Mountains makes the vegetation of that region especially liable to fungous diseases, and the peach is no exception to this rule. In the Willamette Valley, Oregon, along the lower Columbia, and in the basin of Puget Sound in Washington, peach leaf curl has become a great hindrance to extensive peach culture. In view of these facts, many peach growers of Oregon and Washington were requested by the Department to conduct experiments for the control of the disease, and it was taken up by a number in 1894 and again in 1895. Several of the gentlemen who conducted such work prepared reports of the same, which should prove of much interest and value to the peach growers of both States.

Among those who entered heartily into the work was Mr. M. O. Lownsdale, of Lafayette, Oreg. This gentleman conducted very extensive spraying tests according to plans supplied by the Department, both in 1894 and 1895, using in his work as many as 30 acres of young peach trees in 1894. At the close of his experimental spray work Mr. Lownsdale gave the following general facts respecting the situation in the Willamette Valley, in which Lafayette is situated, being the center of an extensive fruit-growing region of Yamhill County:

I hand you herewith my report of experiments for the prevention of peach leaf curl for the season of 1895, to which I desire to add a few words upon the status of the peach industry in the Northwest.

Peach growing has been abandoned to a great extent in the Willamette Valley because of the attacks of the shot-hole fungus and leaf curl. Growers have not understood the causes of their troubles, and have attributed them to peculiar climatic conditions, or have grouped them under the indefinite term blight; but now that the nature of these fungous troubles is better understood, and the remedies suggested have proved so efficacious, it seems that the abandonment of the industry may have been premature. The success of the preliminary experiments has restored the confidence of orchardists in a great measure, and as it becomes widely known that our fungous troubles can be controlled, increased attention will be given to peach growing.

Experiments through a series of four years on a block of 6 acres of Early Charlotte peaches indicate that it may be possible to prevent these destructive fungi from getting a foothold in an orchard. This block of trees, which was planted in dormant bud, has received an annual treatment in October and two treatments each spring with the ammoniacal copper carbonate, with the exception of the spring of 1895, when your modified Bordeaux was applied. Neither leaf curl nor shot-hole fungus has developed in this block. A fair crop of fruit was harvested this summer—the fourth from the bud—and the trees are healthy and have grown luxuriantly. If intending planters would select perfectly healthy trees—either yearling or dormant buds—and would give them one treatment in autumn, as the Department has suggested, in addition to the spring treatment for leaf curl, it is probable that peach growing would again become profitable in the Willamette Valley. I am convinced that if the efficacy of the modified Bordeaux mixture for the control of leaf curl had been known five years ago the industry would have been flourishing to-day, for with tho treatment for leaf curl, which adds so much vigor and sturdiness to the tree, as indicated by the pushing out of dormant buds on lower branches, the liability to attacks of other fungi would have been lessened, and it would then have been difficult for the great shot-hole wave to sweep over our orchards as it did in 1893 and 1894.

The quality of peaches grown in the Willamette Valley is unsurpassed. No locality in the United States can produce more delicious fruit. It seems judicious, then, to attempt to save this industry and render it profitable again. To this end it is to be hoped that the Department's methods for the prevention of these fungous attacks will be widely adopted.

The spray work conducted by Mr. Lownsdale in the spring of 1894 involved the spraying of some 1,700 young trees and the testing of 10 spray formulæ. With each of the 10 experiments was included a considerable number of unsprayed trees left for comparison, these control trees being of the same variety as the trees sprayed in the same experiment, and in each case they were so located at the sides or among the sprayed trees as to admit of just comparison. Mr. Lownsdale's report upon this extensive work is given below. All the spray formulæ prepared by him were for 45 gallons of water:

Thirty acres of peach trees were devoted to experimental work under your direction. These trees were Crawfords Early and Early Charlotte (a seedling from the Crawfords Early). In addition to these tests 10 acres were left wholly untreated as a block check against the main experiments. All these trees were 3 years old, and had curled so badly in 1893 that they had twisted into shapeless masses, though they had partially recovered later in the season. The general plan of work was to treat a block of at least 100 trees with each formula, leaving intervening check rows untreated. In some instances check rows were interspersed through the treated block, it being desirable to have all conditions as nearly alike as possible.

Formula A (10 pounds sulphur, 20 pounds lime, 10 pounds salt) was applied March 21, 1894, to 264 trees in 8 rows, with 2 control rows on each side of the block. Curl appeared in about 3 per cent of the foliage of the sprayed trees, while 60 per cent of the foliage of the untreated controls was affected.

Formula B (5 pounds sulphur, 10 pounds lime, 5 pounds salt) was applied March 23 to 204 trees in 4 rows, with 2 check rows on each side of block. About 3 per cent of foliage was affected, while untreated check rows curled very badly.

Formula C (5 pounds sulphur, 10 pounds lime) was applied to 166 trees on March 22 in a block 4 rows wide, with the customary 2 check rows. Curl developed on about 10 per cent of the foliage of the treated trees, and upon about 60 per cent of that of the controls.

Formula G (6 pounds copper sulphate, 10 pounds lime) was applied to 42 trees on March 17. About 5 per cent of foliage was affected on the sprayed trees, but the controls were so badly affected that they scarcely survived the summer.

Formula H (3 pounds copper sulphate, 5 pounds lime) was applied March 20 to 186 trees in a block 6 rows wide. About 8 per cent of the foliage of the sprayed trees was affected, while the controls were as under Formula G.

Formula I (2 pounds copper sulphate, 3 pints 26° ammonia) was applied March 20 to 26 trees with 26 check trees. About 5 per cent of curl developed on treated trees, while the check row was very badly injured.

Formula J (4 pounds copper sulphate, 5 pounds sal soda, 3 pints 26° ammonia) was applied March 20 to 26 trees, with 2 check rows of 26 trees. Curl developed on 3 per cent of the foliage of the treated trees, but the controls were almost destroyed.

Formula K (5 pounds sulphur, 15 pounds lime) was applied March 19 to 278 trees in a block 10 rows wide, with control rows of 69 trees each on each side. Curl appeared on about 2 per cent of the foliage of the treated trees, while the check rows were, as in the previous year, a mass of curled leaves and twisted branches. Formula K was also applied to 25 Salway trees and to 15 Alexanders, which had curled very badly for many years, the Salways always being defoliated completely. These trees were 8 years old. No curl appeared on either variety.

Formula L (5 pounds copper sulphate, 15 pounds lime) was applied March 13 and again March 21 to 262 trees, with 7 check rows interspersed through the block. Less than one-fourth of 1 per cent of curl appeared on the treated trees of this test, while the check rows were almost destroyed by the disease. The greater portion of these untreated trees have been dug up and replaced (February 13, 1895). Treated trees in this block made an excellent growth, though cultivated only moderately, and a great majority were absolutely free from curl.

The ammoniacal copper carbonate, Formula M (5 ounces copper carbonate, 3 pints 26° ammonia), was applied March 22 to 210 trees, 2 check rows of 69 trees being left alongside. Less than 3 per cent of curl appeared on the block, while 65 per cent of the foliage of the control trees was curled. This formula was also applied twice, at intervals of two weeks, upon 5 acres of trees upon which no curl could be found. This experiment, though remarkably successful, was not as conclusive as desired, as no control trees were left. This was upon a block of thrifty trees, of which I did not care to sacrifice any portion to an experiment. The same treatment had preserved them the previous year, and I feared a change.

All my treated trees have grown satisfactorily this year, but the 10-acre check block of untreated trees was so nearly destroyed by curl that all the trees will be dug up. Several hundred are dead, and of the remainder I think no tree has had a growth of 12 inches.

It will be seen from Mr. Lownsdale's report of the work in 1894 that several of the sprays used gave most excellent results. On May 18 of that year he wrote:

Curl has developed moderately, and everywhere the better condition of treated over untreated trees is apparent. The trees treated with 5 pounds of copper sulphate and 15 pounds of lime may be said to be absolutely free from the curl and the experiment a success. This block was sprayed twice in March. The check rows in this block and alongside are curled as badly as any trees except seedlings.

The modified eau celeste (Formula J) is also giving good results, as is the 5 pounds of sulphur and 15 pounds of lime; but I believe the copper sulphate, 5-pound formula, is in the lead. This may be attributed to more thorough work, as most of the other sprays were only applied once.

Owing to the fact that no fruit records could be obtained from Mr. Lownsdale's experiments in 1894, as the trees were yet too small, arrangements were made for the testing of some of the more valuable sprays in the spring of 1895. The experiments of 1895 show the gain in both foliage and fruit, though the yield was low, resulting from the use of 5 sprays—1 sulphur and 4 copper. The experiments were confined to the Crawfords Early variety, and in each experiment the trees received two sprayings in March. All trees were 4 years old, but rather small. Mr. Lownsdale's data on this work are presented in the following table:

TABLE 39.—*Experimental work conducted by Mr. M. O. Lownsdale, of Lafayette, Oreg., in the spring and summer of 1895.*

[Variety of trees, Crawfords Early; nature of soil, red hill.]

No. of experiment.	Formulæ for 45 gallons of water.	Age of trees.	Number of trees. Sprayed.	Number of trees. Unsprayed.	Date of— First spraying.	Date of— Second spraying.	Leaves lost by— Sprayed trees.	Leaves lost by— Unsprayed trees.	Date when loss of leaves was estimated.	Fruit produced by— Sprayed trees.	Fruit produced by— Unsprayed trees.
		Yrs.					*Per ct.*	*Per ct.*		*Lbs.*	*Lbs.*
1	10 lbs. sulphur; 20 lbs. lime; 5 lbs. salt	4	86	91	Mar. 7	Mar. 27	10	35	June 18	346	187
2	5 lbs. copper sulphate; 10 lbs. lime	4	110	68	....do....	....do...	5	35	....do...	480	62
3	2 lbs. copper sulphate; 3 pts. ammonia	4	116	87	Mar. 9	....do...	6	30	....do...	867	193
4	5 oz. copper carbonate; 3 pts. ammonia	4	268	67	Mar. 8	Mar. 28	Trifling.	30	....do...	1,264	....
5	5 lbs. copper sulphate; 15 lbs. lime	4	189	91	Mar. 9	....do...	None.	40	....do...	1,048	15

But few comments upon the preceding table are required. It makes the fact perfectly evident that two spring sprayings are sufficient to almost absolutely control leaf curl in the Willamette Valley. In a letter written June 25, 1895, Mr. Lownsdale says:

Peach leaf curl has not developed as badly in this section as it did last year. I have estimated that about 40 per cent appeared on most of my control trees. Two sprays with lime, 10 and 15 pounds, and copper sulphate, 5 pounds, were an absolute success. Lime in the amount of 15 pounds gives the best results, there being 100 per cent of healthy foliage on trees sprayed with this amount and 5 pounds of copper sulphate. Practically the same results were obtained with two applications of the ammoniacal copper carbonate. It is impossible to find a curled leaf on acres and acres of treated trees.

In the Rogue River Valley, in the southern tier of counties of Oregon, the conditions are somewhat more favorable for peach culture than in much of the Willamette Valley. The climate is somewhat intermediate in character between that of northwestern Oregon and northern California. Peach culture is quite extensive about Ashland, Medford, etc. The reports of Mr. E. F. Meissner, of Kerby, Josephine County, and of Mr. N. S. Bennett, of Medford, Jackson County, are fairly representative of those received from experiments conducted in southern Oregon. Mr. Meissner's report again shows the great effectiveness of 5 pounds of copper sulphate, 10 pounds of lime, and 45 gallons of water. With this formula he sprayed 4 Salway trees 4 years old, leaving an equal number unsprayed for comparison. Two treatments were given, the first February 22, the second March 10, 1895. From the sprayed trees 10 per cent of the foliage was lost from curl, while from the unsprayed trees 90 per cent was lost, leaving the trees nearly bare. Unfortunately, frost killed the buds, and no comparison of fruit was possible, but it is safe to say that the fall of 90 per cent of the leaves would have caused the loss of the crop, while 10 per cent loss would have occasioned little, if any, falling of fruit. Mr. Meissner writes respecting his work that the copper sulphate spray "has given far better results than the sulphur, lime, and salt," and that "the trees sprayed with the bluestone mixture look the best of any in the orchard."

Mr. Bennett used the 5-pound formula for the Bordeaux mixture as given for Mr. Meissner. He sprayed but once, on March 11, 1895. The 29 trees sprayed averaged 44 pounds of fruit per tree, while the single control tree yielded but 9 pounds, or a net gain in fruit of 388 per cent. The fact of most interest in connection with this work is, however, that the variety treated was the Elberta, which is probably more universally susceptible to leaf curl than any other variety now grown in the United States. The control of curl on this variety was almost absolute, as will be seen from the following letter from Mr. Bennett:

I send you to-day a report of the spraying for leaf curl. The experiment was an honest trial, and I feel very jubilant over the success. I have reported only the Elberta variety, as it was one of that kind which I left unsprayed. I am more than pleased with the results, and can say that a good trial is all that any man needs who has the welfare of his orchard at heart (his pocketbook as well). The peaches from the sprayed trees were first-class, clean, and sold at the highest market price. I notice a very marked difference in the general health of the trees in favor of those sprayed. The leaves lost by the sprayed trees were, perhaps, one-half of 1 per cent. The unsprayed tree was a little above an average tree in the spring. There were 29 sprayed trees, which yielded an average of 44 pounds of choice fruit to the tree, nearly half of which packed 56 peaches to the box. I sprayed 75 Wheatland trees with the same success as far as leaf curl is concerned. They are fine, healthy trees now, and bore a good crop this season. They have been bad about curling, but I left an Elberta because that variety is the worst to curl, and if spraying did them no good I intended to grub them out.

Mr. P. W. Olwell, of Centralpoint, Oreg., applied the sulphur spray to 400 Muir trees in his orchard, leaving 25 trees unsprayed for comparison. The formula used by Mr. Olwell was 15 pounds of sulphur, 30 pounds of lime, and 10 pounds of salt to 60 gallons of water. His trees were 5 years old, growing in black, loamy soil. They were sprayed March 10. The sprayed trees did not lose any foliage from disease, while the control trees lost 25 per cent. The fruit records were not reported.

NOTES ON THE AUXILIARY EXPERIMENTS IN CALIFORNIA.

Besides the experimental work conducted by the writer in the Sacramento Valley in the years 1894 and 1895, a considerable number of growers assisted in carrying on experiments in different portions of

California. Reports have been received from several of these growers, and while in some instances they are not as complete as desired, the results shown are amply sufficient to determine the practical value of the work undertaken.

Among the more complete and carefully prepared reports is one from Mr. A. D. Cutts, of Live Oak, Sutter County. The work was carried out in the winter of 1892–93, and was one of the experiments which led to the writer's detailed series of experiments outlined in the present bulletin. In this orchard the spray was not used in 1893 for the control of leaf curl, but was applied for the purpose of destroying the San José scale, which was gaining a foothold in the orchard. The trees infested by scale were scattered through a 40-acre block of the Crawfords Late variety. These trees had been marked, and in February, 1893, were thoroughly sprayed with the sulphur spray, consisting of 15 pounds sulphur, 30 pounds lime, 10 pounds salt, and 60 gallons water. Only a few of the trees were entirely sprayed. As curl developed seriously in that region in the spring of 1893, the contrast between the scattered sprayed trees and the remainder of the block was very striking, and Mr. Cutts kindly consented to preserve the records of yield of a few of the sprayed and unsprayed trees for use in this connection. In the table which follows is shown the amount of fruit produced by each of the 9 sprayed trees included in Mr. Cutts's records, as well as the weight and number of first, second, and third quality peaches. The same facts are given for an equal number of neighboring unsprayed trees for comparison.

Table 40.—*Experimental work conducted by Mr. A. D. Cutts, of Live Oak, Cal., in the spring and summer of 1893.*

[Crawfords Late, 4 years old.]

No. of tree.	Sprayed trees.							Unsprayed trees.						
	Total pounds of—				Number of—			Total pounds of—				Number of—		
	Fruit.	First-quality fruit.	Second-quality fruit.	Third-quality fruit.	First-quality peaches.	Second-quality peaches.	Third-quality peaches.	Fruit.	First-quality fruit.	Second-quality fruit.	Third-quality fruit.	First-quality peaches.	Second-quality peaches.	Third-quality peaches.
1	156	115	32	9	276	96	29	41	23	12	6	102	56	56
2	226	189	20	17	735	126	130	2	......	2	......	......	4	......
3	180	145	28	7	615	110	45	1	......	1	......	......	3	......
4	119	100	13	6	385	70	54	......	......	......	......	......	......	......
5	180	146	25	9	605	138	60	2	......	2	......	......	5	......
6	176	154	17	5	568	86	32	......	......	......	......	......	......	......
7	279	225	34	20	815	151	139	1	......	1	......	......	3	......
8	55	38	12	5	148	60	30	3	......	3	......	......	8	......
9	126	106	15	5	367	65	27	8	8	......	......	18	......	......
Total.	1,497	1,218	196	83	4,514	902	546	58	31	21	6	120	79	56

The average yield of fruit of the sprayed trees given in the table was 166.22 pounds per tree, while the average yield of the unsprayed trees was but 6.44 pounds. This represents a gain in fruit by the sprayed trees above the yield of the unsprayed trees of 24.8 times the yield of the latter. In other words, there was a gain in yield of 2,481 per cent from spraying. Much valuable information was also supplied by Mr. Cutts in relation to the preparation and application of sprays, and the writer has considered these subjects in other portions of the bulletin. Some of the more striking photographs of sprayed and unsprayed trees have also been obtained from Mr. Cutts's orchard, as well as the records of fruit buds elsewhere discussed (Pls. VII and XX).

The report of a test of the Bordeaux mixture (5 pounds copper sulphate, 10 pounds lime, and 45 gallons water) was furnished by Mr. H. B. Gaylord, of Auburn, Placer County. This experiment was made in the spring of 1895. Mr. Gaylord sprayed 10 Heaths Cling peach trees and 4 nectarine trees, the variety of which was not stated. The spraying was done February 15. Mr. Gaylord states that the unsprayed nectarines curled so badly that they bore no fruit at all, while the 4 sprayed trees yielded 320 pounds. He says that every alternate tree was sprayed in a row of nectarines, and that the sprayed peach trees were in the worst places in the orchard. Respecting the result of the work Mr. Gaylord writes, in part:

I herewith send you a partial report on the experiment for leaf curl. I used only one formula. The result is perfectly satisfactory. I sprayed some peach and some nectarine trees, both with good results. One nectarine tree sprayed has not a curled leaf, while one of the same kind, about 15 feet from it, which was not sprayed, has lost nearly all its leaves. The contrast is so great that it would be worth while to have them photographed. A neighbor, Mr. G. P. Dixon, used formula 3 (2 pounds copper sulphate, 3 pints ammonia, and 45 gallons water) with the same results, so that I am satisfied that the copper sulphate is what does the work.

Mr. Gaylord also states that no leaves were lost from the peach trees sprayed, while all of the leaves curled on the unsprayed trees of the remainder of the orchard.

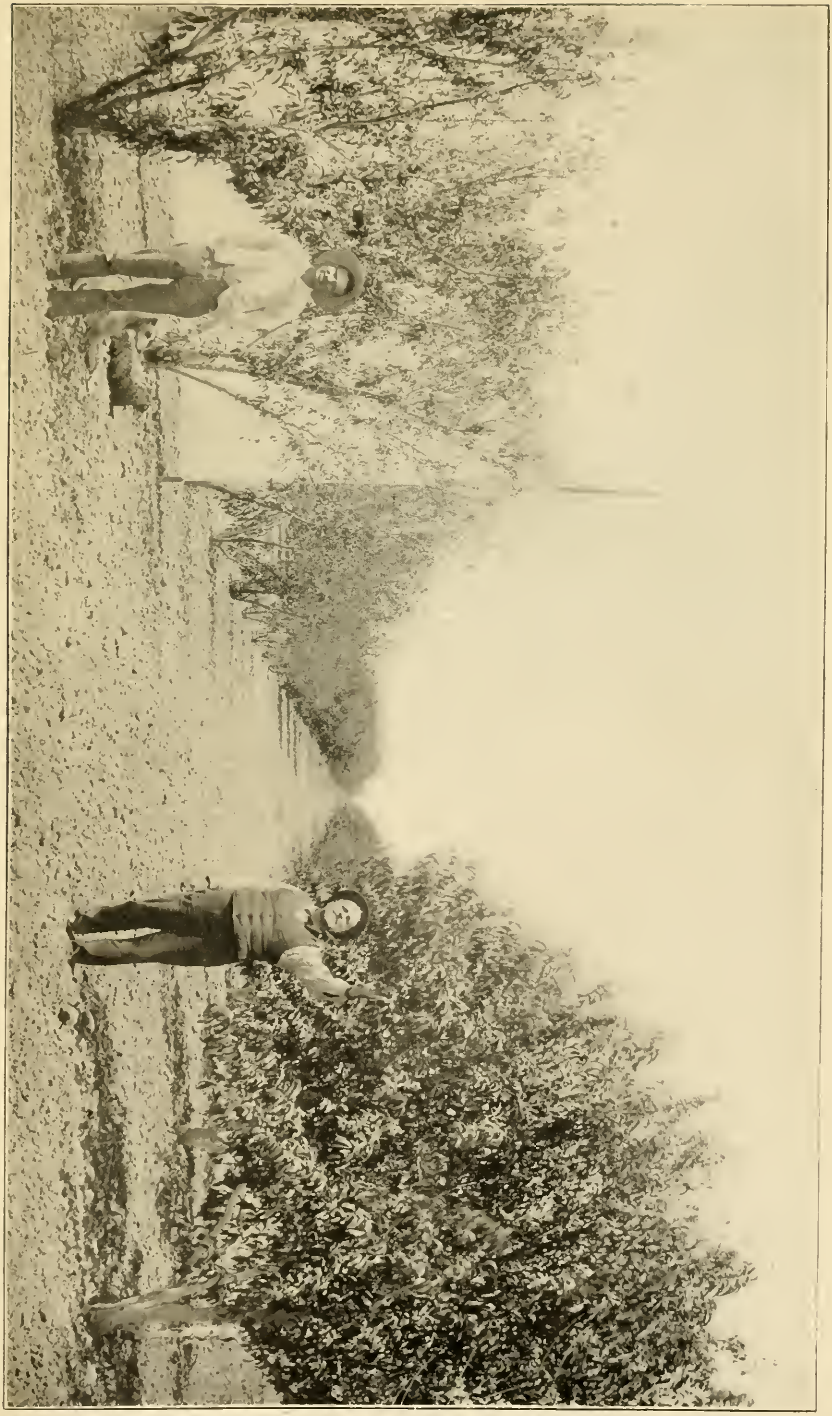
In Amador County an extensive experiment was made in the spring of 1895, by Mr. George Woolsey, of Ione. Mr. Woolsey sprayed some 2,500 trees of various varieties of peach and nectarine with 5 pounds of copper sulphate, 10 pounds of lime, and 45 gallons of water, and left 720 trees unsprayed for comparison. The spraying was done from February 20 to March 10. Most of the sprayed trees lost no foliage, but a few in a wet situation lost not to exceed 25 per cent, while the unsprayed trees lost not less than 50 per cent of the leaves and a large amount of fruit.

Mr. Woolsey gives some notes respecting the work in the spring of 1895, as follows:

A block of about 200 trees, Salways 12 to 15 years old, on well-drained soil, and 500 Salways 4 years old, adjoining, I did not spray, thinking they were curl proof. I regret I did not spray them. * * * The leaves are dropping, as well as a large percentage of the fruit. I shall certainly spray them in the future. * * * The

DESCRIPTION OF PLATE XX.

Sprayed and unsprayed Crawfords Late trees in the orchard of Mr. A. D. Cutts, Live Oak. The tree at the right was sprayed in February, 1893, with lime, sulphur, and salt; the trees at the left were untreated. See "Notes on anxiliary experiments in California," for a full account of the work at Liveoak. (Photographed in May, 1893, after most of the diseased leaves had fallen from the unsprayed trees. Compare with Pl. VII.)



TREATED AND UNTREATED CRAWFORDS LATE TREES, LIVE OAK, CAL.

apparent result of spraying, one application, is as follows: Four control trees of Early Rivers, adjoining trees sprayed March 2, are badly curled, leaves dropping, and also the greater portion of the fruit. The adjoining sprayed trees of this tender variety are all right (no curl) and make quite a marked contrast. Besides these, 4 white nectarines and 4 Bilyeau peaches, left at the same time, show curl and loss of fruit, although not as badly as the Early Rivers. The surrounding sprayed trees look vigorous and healthy, with no curl.

Mr. Woolsey was among the first peach growers to adopt the copper sprays for the control of curl. His first experiments were made in 1892, and they proved so satisfactory that he sprayed quite extensively in 1893 and again in 1894. The work in 1893 was of special interest, as the following extract from a communication received from him will show:

I sprayed nearly all my peach and apricot trees. I say nearly all; for, time pressing, I found I would not get over all the peaches, so to save what I considered the most valuable portion, viz, the young lower growth, I had that sprayed and left the tops unsprayed. The season was a damp one and leaf curl was very prevalent with my neighbors. On my place all trees sprayed were exempt, all others badly affected and crops on them almost a failure. On the ones partly sprayed there was a healthy growth on the lower part of the trees, while they were denuded of foliage above.

Mr. Woolsey's work in 1894 was negative, owing to the nondevelopment of the disease that season.

Two peach growers of Eldorado County, Mr. John M. Day, of Placerville, and Mr. A. L. Kramp, of Diamond Spring, furnished the writer with reports of their experiments conducted in the spring and summer of 1895. Mr. Day tried 4 formulæ, each showing a decided saving of foliage, but the fruit was lost from frost. The spray used by Mr. Kramp was composed of 10 pounds sulphur, 20 pounds lime, 5 pounds salt, and 45 gallons of water. He sprayed 600 trees, 3 years old, of the Hales Early, Briggs Early, and Wilcox Cling varieties, and 3,000 unsprayed trees were left for comparison. The sprayed trees lost no foliage and yielded 48,000 pounds of peaches, while the unsprayed trees lost not less than 50 per cent of their leaves and yielded 60,000 pounds. The average yield of the sprayed trees was thus 80 pounds per tree, while the average yield of the unsprayed trees was but 20 pounds, a net gain of 300 per cent.

Gen. N. P. Chipman, of Red Bluff, has been using for at least two years a formula for Bordeaux mixture which gave the writer exceedingly good results at Biggs (see row 21 of the writer's experiments, p. 117). Mr. Chipman writes that his experiments were upon several varieties of peach trees and that excellent results were obtained. He further says: "I used equal parts, or 5 pounds bluestone, 5 pounds quicklime, and 45 gallons water. I believe you have found an infallible remedy. I have used this spray two years with good effect." Mr. Chipman first observed the effects of this spray in the experiment block at the Rio Bonito orchard, in the summer of 1895.

NOTES ON THE AUXILIARY EXPERIMENTS IN NEW YORK, INDIANA, AND OTHER PEACH-GROWING STATES.

Much experimental work for the control of leaf curl has been undertaken at the suggestion of the Department by the peach growers of New York, Indiana, Illinois, Ohio, Kentucky, Maryland, Pennsylvania, Georgia, Tennessee, North Carolina, Arkansas, Missouri, Kansas, and other peach-growing States not already considered in this bulletin. For instance, 80 prominent peach growers of various peach-growing centers of New York were given full instructions for the control of curl in the winters of 1893–94 and 1894–95, and requested to report their work, which in a number of instances was carefully done. The same is true of 54 growers in Ohio, 135 in Pennsylvania, etc., and in each case where the work was properly conducted the results were in harmony with those already discussed in this chapter. For this reason, as well as from the fact that the work already considered has been selected from those sections of the country which are fully representative of the different climatic conditions, it is not thought necessary or desirable to enter much further into the details of the work. One or two experiments may be mentioned, however, before closing the consideration of this phase of the subject.

Mr. Joseph M. Cravens, of Madison, Ind., reported almost absolute success in the control of curl in his orchard. The sprayed trees of the 4 experiments made in no case showed more than 3 per cent of curled leaves, while the amount of curl on the foliage of the unsprayed trees ranged from 25 to 45 per cent. Mr. Cravens states in a letter accompanying his report that he sprayed separate rows through his orchard which were sufficiently far apart not to have the spray affect the intervening rows even if the wind blew at the time of application, and further that he is satisfied that two of the sprays used would have given absolute results had they been applied to every portion of every twig.

Mr. W. T. Mann, of Barkers, N. Y., sprayed 25 trees with the lime, sulphur, and salt spray April 9, 1894, and left 25 trees at their side without spraying for comparsion. On May 28 only 42 diseased leaves were found on the 25 sprayed trees, while as high as 40 per cent of curled foliage was present on some of the unsprayed trees. On the same date as the other spraying was done 25 trees were sprayed with Bordeaux mixture, while 21 were left for comparison. By May 28 only 59 curled leaves had developed on the entire 25 sprayed trees, while of the 21 unsprayed trees several had as high as 30 to 35 per cent of curled leaves. Mr. Mann says that from the fact that among the 50 trees treated not one showed an appreciable amount of disease, while all through the orchard trees were badly affected, was to him very satisfactory evidence of the value of the treatment, especially as he did not undertake the work with any great degree of confidence as to successful results.

Mr. James A. Staples, of Marlboro, N. Y., states that in the seasons of 1894, 1895, and 1896 he made the spray tests on peach trees for leaf curl which had been suggested by the writer, and says he is well satisfied that the disease can be controlled by proper spraying. He states that the winter treatment gave him the best results.

Mr. A. D. Tripp, of North Ridgeway, N. Y., states in his report of spray work for curl that he treated 208 trees and left 320 trees unsprayed. From the sprayed trees he gathered "360 baskets of as fine fruit as ever went to market." The baskets were one-third of a bushel, and the peaches averaged 56 to the basket. From the untreated trees only 15 baskets were gathered, and a portion of this fruit was imperfect. The variety was the Elberta.

19093—No. 20——10

CHAPTER VIII.

PREPARATION, COMPOSITION, AND GENERAL CHARACTERS OF THE SPRAYS USED.

PREPARATION OF THE COPPER SPRAYS.

It is not the intention to consider in this place the many forms of copper sprays which have been used at one time or another in the treatment of fungous diseases, but to confine the discussion to those forms tested in the present work.

Most of the formulæ for those copper sprays which have been tested in the treatment of peach leaf curl have been personally prepared at one time or another and the results they gave have been carefully studied. Several other formulæ have been recommended by the writer, but these were prepared and applied by the growers themselves, so that for the results of this work their reports have been consulted. There are still a few other formulæ for copper sprays which have been reported upon, but these are the suggestions of others or were chosen by the growers themselves.

The different copper sprays which have been tested in separate form (not in union with other fungicides) are shown in the following list. This list includes 22 distinct formulæ. Each formula is that used with 45 gallons of water, except the first for Bordeaux mixture, which was with 48 gallons.

TABLE 41.—*Copper sprays applied for the control of peach leaf curl.*

Copper sulphate solution:
- *4 pounds copper sulphate, 45 gallons water.
- *2 pounds copper sulphate, 45 gallons water.

Bordeaux mixture:
- †24 pounds copper sulphate, 45 pounds lime.
- *6 pounds copper sulphate, 15 pounds lime.
- ‡5 pounds copper sulphate, 15 pounds lime.
- *3 pounds copper sulphate, 15 pounds lime.
- ‡6 pounds copper sulphate, 10 pounds lime.
- *5 pounds copper sulphate, 10 pounds lime.
- *3 pounds copper sulphate, 10 pounds lime.
- *5 pounds copper sulphate, 5 pounds lime.
- *4 pounds copper sulphate, 5 pounds lime.
- *3 pounds copper sulphate, 5 pounds lime.

---

*Prepared and tested by the writer, and in many cases also tested by growers.

†Chosen and tested by grower.

‡Recommended by the writer, but tested by the growers.

Bordeaux mixture—Continued

*2 pounds copper sulphate, 5 pounds lime.

*6 pounds copper sulphate, 4 pounds lime.

*6 pounds copper sulphate, 3 pounds lime.

*3 pounds copper sulphate, 2 pounds lime.

Eau celeste:

*4 pounds copper sulphate, 3 pints ammonia (26°).

*2 pounds copper sulphate, 3 pints ammonia (26°).

Modified eau celeste:

*4 pounds copper sulphate, 5 pounds sal soda, 3 pints ammonia (26°).

*2 pounds copper sulphate, 3 pounds sal soda, 2 pints ammonia (26°).

Ammoniacal copper carbonate:

*5 ounces copper carbonate, 3 pints ammonia (26°).

*3 ounces copper carbonate, 2 pints ammonia (26°).

* Prepared and tested by the writer, and in many cases also tested by growers.

The preparation of the copper sprays containing different chemical constituents will be considered in the order in which they appear in the preceding list.

COPPER SULPHATE SOLUTION.

Copper sulphate ($CuSO_4.5H_2O$), commonly called blue vitriol or bluestone, forms, when dissolved in water, one of the most active fungicides known. This chemical, the composition, manufacture, and sources of supply of which will be more fully considered in a following chapter, dissolves in cold water, but somewhat more readily in hot water. As usually sold, the crystals are large, but a fine form may also be had in the market. If the large crystals are purchased and it is desired to dissolve them rapidly, they may be ground in a bone or shell mill before placing in the water. This has frequently been done by the writer when quick work was necessary.

Copper sulphate may be manufactured by dissolving the black oxide of copper in sulphuric acid, or by the various modifications of this process hereinafter discussed. A watery solution of this chemical is strongly acid, and for this reason a simple solution of copper sulphate is very corrosive and injurious to tender plant tissues, as foliage and opening buds. To avoid this injurious action, efforts have been made to obtain from the copper sulphate solution a spray retaining the fungicidal action of the copper, but by the addition of other chemicals to neutralize or largely remove its acid reaction and consequent corrosive effects upon plants. As a result there are a very considerable number of copper sprays, representing various modifications of the simple solution of copper sulphate.

Owing to the acidity of a solution of copper sulphate, the sulphate should not be dissolved or handled in metal dishes of any kind, especially those of iron. The copper will often go to the metal, thus injuring the effectiveness of the spray, and the acid may also injure or destroy the dishes. The most suitable vessels for dissolving copper sulphate for work such as here discussed are those composed wholly of wood, preferably of oak, and may be in the form of barrels, casks, vats, or tanks, of a capacity corresponding to the respective needs of the growers. For small orchards a few good oak barrels of 45 or 60 gallons capacity are very suitable. As concentrated solutions of copper sulphate can be made, enough of the sulphate can be easily dissolved in a 60-gallon barrel to serve for 300 or even 1,200 gallons of spray when properly reduced. It is well, when possible, to use 2 gallons of water to each pound of sulphate when dissolving the latter, but stock solutions may be of two to four times this strength. A solution of copper sulphate is heavier than water, so that it is an advantage in hastening the dissolving process to retain the chemical near the top of the water. If this can be done, the heavier copper solution will settle to the bottom of the barrel, leaving the purer water to continue the dissolving action upon the sulphate. The placing of the copper in a gunny sack and suspending the latter in the water has been recommended, but it is thought that other means more suitable may be found. The use of sacks or other cloths about the spray tanks is hardly advisable, as the freer the tanks are kept from lint, strings, fibers, etc., arising from straining cloths, sacks, frayed staves, and stirring sticks, the less trouble the sprayer will have with his nozzles in the orchard, and the better, quicker, and cheaper can the spray work be done.

Instead of a sack, a clean willow or hard-wood splint basket may be used for suspending the chemicals. A box may also be easily made for the purpose. It should have a diameter, when about 1 foot deep, sufficient to hold the copper sulphate to be dissolved, and it should be open at the top, with strong 1-inch slats across the bottom, the latter to be set one-fourth inch apart. If the box be fitted with a strong hoop bail it may be suspended in the barrel by placing a stick through the bail and across the top of the barrel. As a rule, however, the writer has found it sufficient to place the copper sulphate directly in the bottom of a good oak barrel, filling the latter one-third to one-half full of water, and stirring and crushing the crystals with a clean hard-wood pounder. A half hour's work is sufficient to dissolve many pounds of copper sulphate in this manner. With three or four good barrels one man can thus keep a large spraying gang supplied with material, if the water be convenient. It is always an advantage to place the copper in water in the barrels over night, when possible, as sufficient material is thus easily made ready in the morning for a half day's spraying. It is an advantage to strain all water before the copper sulphate is added, as afterwards ordinary strainers are liable to be injured by the acid, and, as before stated, the use of cloth strainers is not advisable.

The eyes and hands should be protected as much as possible from injury by this spray (p. 171). The unaltered solution of the copper sulphate is not only unpleasant to handle and apply, and injurious to tender vegetable tissues, but it is quite injurious to all metallic parts of pumps, hose, extension rods, and nozzles, nozzles being eaten out very rapidly by it. For these various reasons the solution of copper sulphate is rarely used as a spray in an unmodified form. In most cases its corrosive action is more or less altered or neutralized through the addition of some modifying agent. In other words, the copper sulphate solution is used as a base or stock solution for the preparation of several more or less noninjurious and equally effective sprays, as the Bordeaux mixture, the eau celeste, the modified eau celeste, the ammoniacal copper carbonate, etc. For this purpose it may be prepared in a concentrated solution, to be used as a stock solution for the preparation of any of the modified sprays mentioned, as already pointed out.

A convenient strength for stock solutions is 1 pound of copper sulphate to 1 or 2 gallons of water. In using stock solutions, two matters should always be considered: (1) The pails, barrels, or tanks used should be carefully gauged and marked, so that the number of gallons of water or of the solution they contain may be known and not guessed at.[1] (2) Before dipping from a stock solution any required number of gallons, the solution should be thoroughly stirred, otherwise the last dipped out will be very much stronger than that coming from the top, and consequently the work will be inaccurate and often very unsatisfactory; moreover, neglect of this precaution might, in many cases, lead to the injury or even to the destruction of the plants treated. It may also be said that the copper sulphate solution should be cold when used in the preparation of Bordeaux mixture, eau celeste, modified eau celeste, or ammoniacal copper carbonate.

BORDEAUX MIXTURE.

Bordeaux mixture is prepared by uniting the milk of lime with a solution of copper sulphate. The reaction which takes place when the two solutions are united as well as the other chemical phases

---

[1] The following rules for measuring square and round tanks and casks may prove of value in this connection:

Circular cisterns.—Multiply the square of the diameter in feet by the depth in feet and the product by $5\frac{7}{8}$ for the contents in gallons.

Circular casks or barrels.—Multiply the square of the average diameter in inches by 34, and that by the height in inches, and point off four figures. The result will be the contents in gallons and decimals of a gallon. The average diameter of a barrel may usually be obtained by adding the greatest diameter to the least diameter and dividing by 2.

Square tanks.—Multiply the width in feet by the length in feet, and that by the depth in feet, and that again by $7\frac{48}{100}$, which will give the contents in gallons. Another and simple method is to multiply the length, width, and depth in inches, and divide by 231, which will also give the contents in gallons.

of the subject, have formed the base for much discussion and investigation, which it is not necessary to consider here, especially as these chemical changes are variously interpreted by different writers. Those interested in the history and chemistry of Bordeaux mixture may learn of the extensive literature upon these subjects by referring to the writings of Lodeman,[1] Fairchild,[2] and others.

In the union of the milk of lime with a solution of copper sulphate there is produced a mixture having great value as a general fungicide, and, as already shown, of especial value for the treatment of peach leaf curl. The mixture possesses several advantages for orchard work over a simple solution of copper sulphate: (1) The addition of sufficient milk of lime to a simple solution of copper sulphate neutralizes the acids of the latter to such an extent that the resulting mixture is practically noninjurious to foliage and buds, while still retaining the fungicidal qualities of the simple sulphate solution. (2) The corrosive action of Bordeaux mixture upon pumps, pipes, nozzles, etc., is comparatively slight. This is of great advantage in doing uniform and thorough work. (3) The lime of Bordeaux mixture causes the spray to become visible upon the trees sprayed, and while this is not desirable in the spraying of maturing fruits, and is avoided by adopting other sprays, it is of very great value in the treatment of bare dormant trees, as it enables the workman to distinguish the sprayed from the unsprayed portions of the tree, and thus to complete his work more thoroughly than could otherwise be done. In case of the employment of hired help for applying sprays, as is usually done, the superintendent or owner of the orchard may know beyond question by the appearance of the trees whether or not his men are doing satisfactory work. As thoroughness is a matter of prime importance in the treatment of peach leaf curl, too much stress can hardly be placed upon this advantage of Bordeaux mixture over several other sprays. (4) The adhesive qualities of Bordeaux mixture are very great, and therefore it is even more desirable for a winter than for a summer spray. This is especially so in portions of the country where the summers are dry, as on the Pacific coast. (5) The whitening of the trees by the use of Bordeaux mixture, provided the spraying is done somewhat early in the winter, is claimed to retard the development of the buds. The unsprayed trees absorb more heat, which causes the buds to swell during warm days in winter, thus making them liable to injury from subsequent cold.[3]

The methods of preparing Bordeaux mixture for large and small orchards may vary according to the requirements and facilities of the

[1] Lodeman, E. G., The Spraying of Plants, Macmillan & Co., 1896.

[2] Fairchild, D. G., Bordeaux Mixture as a Fungicide, Bull. No. 6, Division of Vegetable Pathology, U. S. Dept. of Agr.

[3] Whitten, J. C., Winter Protection of the Peach, Mo. Agr. Exp. Sta. Bull. No. 38. Some of the conclusions from the work of Mr. Whitten are: Whitening the twigs and buds by spraying them with whitewash is the most promising method of winter protection tried at the Missouri Station; whitened buds remained practically dormant

growers, but the general principles involved remain the same. As a common example, the manner of preparing the 5-pound formula will be described: In a 45 or 60 gallon barrel place 5 pounds of copper sulphate and add 10 or 12 gallons of water. Pound and stir the copper sulphate until wholly dissolved. In a half barrel slake 5 pounds of quicklime and reduce with 10 or 12 gallons of water. Strain the milk of lime into the copper solution, stir thoroughly, and add sufficient water to make 45 gallons in all. The copper and lime solutions should both be cold when united. When the water is added and the whole is well stirred the spray is ready to be applied.

For the manner of preparing the stock solution of copper sulphate to be used for Bordeaux mixture the reader is referred to pages 148 and 149, where full instructions will be found. In respect to the addition of lime to the copper solution, it may be said that the milk of lime resulting from the slaking of 2 pounds of good quicklime in 6 or 8 gallons of water is sufficient to neutralize a solution of 3 pounds of copper sulphate. Larger amounts of copper should receive larger amounts of lime in proportion. In case foliage is to be treated, however, it is well before using the mixture to test it according to one of the methods given,[1] or to bring the weight of quicklime used to three-fourths,

---

until April, when unprotected buds swelled perceptibly during warm days late in February and early in March; whitened buds blossomed three to six days later than unprotected buds; 80 per cent of whitened buds passed the winter safely, and only 20 per cent of unwhitened buds passed the winter unharmed. These facts point to those sprays having large amounts of lime as most valuable in protecting buds, and they should be considered in those sections of the country where the buds are liable to winter injury. A fall spraying may also be a decided advantage in such situations in addition to the early spring spraying for curl.

See also on this subject the January number of the Canadian Horticulturist, 1899, pp. 18–20.

[1] There are at present several convenient methods practiced in making Bordeaux mixture to determine if enough lime has been added to the copper sulphate solution to prevent injury when the mixture is applied to foliage. We adapt the following two tests from Farmers' Bulletin No. 38 of this Department, p. 7: (*a*) After the milk of lime and copper sulphate solutions have been united and thoroughly stirred, hold the blade of a penknife in the mixture for at least a minute. If metallic copper forms on the blade or the polished steel surface assumes the color of copper plate, the mixture is still corrosive and should receive more milk of lime. If the blade remains unchanged, the mixture may be safely applied to most foliage under favorable weather conditions. (*b*) Pour some of the mixture into a saucer, hold between the eyes and the light, and breathe gently upon it for at least half a minute. If the mixture is properly made, a thin pellicle, looking like oil on water, will begin to form on the surface. If no pellicle forms, more milk of lime should be added. A third test (*c*) may be made with a 20 per cent solution of ferrocyanide of potassium: After the milk of lime is added to the copper sulphate solution, and the whole is thoroughly stirred, dip up a coffee cup full and add to this a few drops of the ferrocyanide of potassium solution. Allow the cup to stand a few minutes and then pour off the mixture carefully. If a red precipitate is found at the bottom of the cup, the mixture requires more milk of lime, which should be added until no such red precipitate is formed when the test is repeated.

four-fifths, or five-sixths of the weight of the copper sulphate used. With the present experiments it has been unnecessary to take this matter into consideration, for the spray was applied to dormant trees, not likely to be injured by any moderate spray. In nearly all the formulæ tested for curl the pounds of lime employed were equal or greater than the number of pounds of copper sulphate used.

The lime used in preparing Bordeaux mixture should be unslaked lime or quicklime of the best quality. There is no economy in using poor lime, and air-slaked lime should never be used. The use of poor or air-slaked lime is apt to result in an imperfectly neutralized, and very granular, unsatisfactory spray. While the slaking of lime and the preparation of a milk of lime is a very simple matter, it is one which few people not accustomed to the process will do well the first time. If not properly slaked, there are apt to be hard particles in the spray, causing trouble with the nozzles. In slaking lime, water should be added to the lime only fast enough to keep it from overheating, adding a little more each time as the heat increases. With some lime the use of a little hot water to start the slaking will hasten the process. With a little practice this work can be done so as to result in a perfect putty or cream of lime. When the thick, creamy consistency is obtained, it is well to allow the mixture to stand for half an hour, if possible, while hot, being sure that enough water is present to prevent drying out. If the Bordeaux mixture is then to be made, cold water should be added to the lime putty, or cream, and the whole stirred until it becomes a milk of lime and is cool. About 3 gallons of water should be added for each pound of lime. This cool or cold milk of lime should now be strained through a wire sieve or strainer into the copper sulphate solution, previously prepared, and the whole thoroughly stirred.

The solution of copper sulphate should also be cold when the milk of lime is added. After the two solutions are thoroughly united the mixture may be reduced to the required amount with cold water, when the spray is ready for use. The lime and copper solutions should never be united more than a few hours before the spray is to be applied. When making Bordeaux mixture wooden vessels should be used, as barrels, half barrels, tanks, etc.

For peach leaf curl the amount of copper sulphate and lime to be used to 45 gallons of water will vary according to the views of the grower, after making a study of the results obtained from the different formulæ tested in the present series of experiments.

EAU CELESTE.

The preparation of eau celeste is very simple. To each 2 pounds of copper sulphate dissolved in 6 or 8 gallons of water add 3 pints of strong ammonia, stir thoroughly, and dilute to 45 gallons. The stock solution of copper sulphate may be used in preparing this spray. Four pounds of copper to 3 pints of ammonia for 45 gallons of water has also proved an effective winter spray.

For dormant trees this spray is safe, but for the treatment of foliage it is too corrosive and burning. It is also quite corroding to nozzles and other metallic portions of the spraying outfit.

MODIFIED EAU CELESTE.

The modified eau celeste is less injurious to foliage than the eau celeste, but is more liable to injure tender leaves and buds than is well-made Bordeaux mixture. Its preparation is nearly as simple as that of the eau celeste. To 4 pounds of copper sulphate dissolved in 10 or 12 gallons of water add 3 pints of strong ammonia, dilute with water to 45 gallons, and stir in this mixture 5 pounds of sal soda (common washing soda) until dissolved. In preparing this spray of different strengths the same proportions of the chemicals may be maintained.

AMMONIACAL COPPER CARBONATE.

The ammoniacal copper carbonate spray is one of great usefulness in the treatment of fruits for fungous diseases, especially where the spotting of fruits by the use of lime is to be avoided. The fungicidal value of this spray is, however, far inferior to the ordinary Bordeaux mixture. In the treatment of peach leaf curl it has proved less satisfactory than several of the other copper sprays.

The manner of preparing this spray is simple. Place 5 ounces of copper carbonate in the bottom of a 3-gallon crock. From a 2-gallon vessel full of water pour about one-half pint of water upon the copper carbonate and stir the latter until it becomes like paste. Now add the remainder of the 2 gallons of water, stir again, and then pour into the mixture 3 pints of 26° ammonia. After this has been thoroughly stirred, it should be covered and allowed to stand for half an hour, when the whole should be added to a barrel containing 43 gallons of water. When well mixed this spray is ready to be applied.

A concentrated solution of copper carbonate in strong ammonia may be made as above described, using but one-half of the amount of water. If such a solution is very tightly stoppered in a large demijohn or jug it may be kept as a stock solution, ready for use at any time. By knowing the amount of copper carbonate in each quart of such a stock solution enough may be measured out at any time to prepare a given number of gallons of spray of any desired strength.

The copper carbonate used in the preparation of the present spray is frequently not obtainable in quantity at the drug stores in smaller towns. It is also frequently the case that druggists in such places charge two or three and sometimes four or five times as much as it is worth, making the ultimate cost of the spray beyond the reach of the grower. For this reason the writer gives, on page 183 of this bulletin, a simple way of preparing the copper carbonate on the farm at a minimum figure.[1]

PREPARATION OF THE SULPHUR SPRAYS.

While the use of copper sulphate as a base for sprays intended for the control of fungous diseases is very general, there are special diseases or combinations of diseases which may be more cheaply, and often more successfully, treated with sulphur in the form of powder or spray. The world-wide use of sulphur for the control of powdery mildew of the grape is a well-known example. It is also known that sulphur possesses valuable insecticidal qualities, and many of the scale insects and mite diseases of our fruit trees may be readily controlled by the use of sulphur so combined and prepared as to be applicable as a spray. For many years the most successful and almost the only treatment of the San José scale on the Pacific coast has been by sulphur sprays. This scale is very injurious to peach trees, and the time for the application of sulphur for its treatment is during the winter, at the time of treatment for peach leaf curl, when the tree is dormant. It has already been shown in this bulletin that such a winter treatment of the peach tree with sulphur sprays will also control peach leaf curl. For this reason, and the fact that the San José scale is constantly spreading throughout the East, much attention is here given to the presentation of this form of spray, one application of which may control two serious diseases. Experiments conducted by the writer have shown that the pear leaf mite may be controlled by the winter use of sulphur sprays, and it is thought probable that their use will also control the oyster-shell bark louse of the apple, which has become almost a scourge over much of the East and in the Pacific Northwest.

As in the case of copper sulphate sprays, it has also been found that the sulphur sprays may be most satisfactorily prepared by com-

[1] In view of the work of Mr. C. L. Penny, published in Bulletin 22 of the Delaware Agr. Exp. Sta., 1893, the amount of water recommended to be added before the strong ammonia water is poured upon the carbonate of copper is much greater than formerly used by the Department. Mr. Penny conducted a somewhat extended series of experiments to ascertain the solubility of copper carbonate in ammonia gas as it is contained in ammonia water of different strengths. He found that a given amount of ammonia gas in a weak solution of ammonia water dissolves more copper than the same amount of gas in a strong solution. A given weight of ammonia gas in a 2 to 4 per cent solution of ammonia water dissolves more copper carbonate than an equal weight of gas in either a weaker or stronger solution. The gas in a 2 to 4 per cent ammonia water will dissolve its own weight or more of copper carbonate. On the other hand, the ammonia gas in a 10 per cent solution of ammonia water will dissolve but 60 per cent of its weight of copper carbonate, and ammonia gas in a 20 per cent solution dissolves only about 35 per cent of its weight of copper. Furthermore, the ammonia gas contained in ammonia water of less than 2 per cent strength rapidly loses its power to dissolve copper carbonate as the solution is weakened.

bining sulphur with lime. Salt has also been used in connection with these sprays in several formulæ.

In the following table are shown the various formulæ for sulphur sprays which have been tested for the control of peach leaf curl. All formulæ are for 45 gallons of water, except where otherwise stated.

TABLE 42.—*Sulphur sprays applied for the control of peach leaf curl.*

*15 pounds sulphur, 30 pounds lime, 10 pounds salt, 60 gallons water.
*10 pounds sulphur, 20 pounds lime, 10 pounds salt, 60 gallons water.
†15 pounds sulphur, 30 pounds lime, 10 pounds salt.
*10 pounds sulphur, 20 pounds lime, 10 pounds salt.
†10 pounds sulphur, 20 pounds lime, 5 pounds salt.
*5 pounds sulphur, 10 pounds lime, 5 pounds salt.
†5 pounds sulphur, 10 pounds lime, 3 pounds salt.
†15 pounds sulphur, 30 pounds lime.
†10 pounds sulphur, 20 pounds lime.
†10 pounds sulphur, 8 pounds lime.
†6 pounds sulphur, 4 pounds lime.
†5 pounds sulphur, 15 pounds lime.
†5 pounds sulphur, 10 pounds lime.
†5 pounds sulphur, 5 pounds lime.

* Recommended by the writer, but tested by the growers.
† Prepared and tested by the writer, and in numerous cases also tested by growers.

It takes longer and is more difficult to prepare the sulphur than the copper sprays; but where the sulphur may be obtained at liberal wholesale rates the expense of the two classes does not vary greatly. For facts respecting the sources of sulphur, etc., the reader is referred to page 190.

The sulphur sprays are prepared by boiling the ingredients (sulphur, lime, and salt, or sulphur and lime) in water for not less than two hours. So far as the writer's experiments are concerned, there has resulted no apparent advantage in the treatment of curl by the addition of salt to these sprays. The usual method which growers having small orchards follow in preparing sulphur sprays is to slake one-third to one-half of the lime required, in the vessel in which the boiling is to be done. When slaked to a thin cream the sulphur is stirred in, all lumps of sulphur having been first pulverized. Boiling water is now added to make one-half to two-thirds the amount required by the formula. This mixture is boiled for not less than one and one-half hours, only boiling water being added if it becomes necessary to reduce the mixture. If the boiling is done in a kettle or iron pan, great care is necessary to prevent the caking and burning of the materials. When the mixture has boiled for the time stated or longer, the remainder of the lime is slaked and the salt is added to it and well stirred in. This lime and salt mixture is now added to that which has been boiled and the boiling is continued for at least one-half hour longer. The boiled spray should now be strained through a fine wire strainer into the spray tank or barrel, and enough boiling water added to make up the full amount of spray required by the formula. The spray may be boiled to advantage longer than two hours, but should never be boiled for a less time if the best results would be obtained. The sprays should be applied to the trees as hot as possible. The spray is more effective and easier to apply when hot, and contact with the air cools it sufficiently so that twigs of dormant trees are not injured by the heat.

The method of preparing the sulphur sprays here outlined is practically that which has been followed in California for many years. In the series of experiments here described, however, an effort has been made to ascertain if salt is necessary in this spray, and also whether there is any disadvantage in uniting all of the lime and sulphur at first. After a comparison of the results obtained from sprays with and without salt and of those in which the lime was added in two portions and at different times with those prepared by adding all of the lime and sulphur at first, it has not been possible to detect any advantage from the salt nor from the more complex method of preparing. This relates, of course, to the use of these sprays for the control of curl, but it is believed that the same will hold true in their use for the control of insect pests. The writer has personally prepared and tested a very large number of these sprays, and recommends the omission of salt, and further, that all of the lime and sulphur be united and reduced with boiling water before the cooking begins in all cases where the spray is to be applied either as a fungicide or insecticide, and where the method of boiling below described is followed. This will both cheapen and simplify the process.

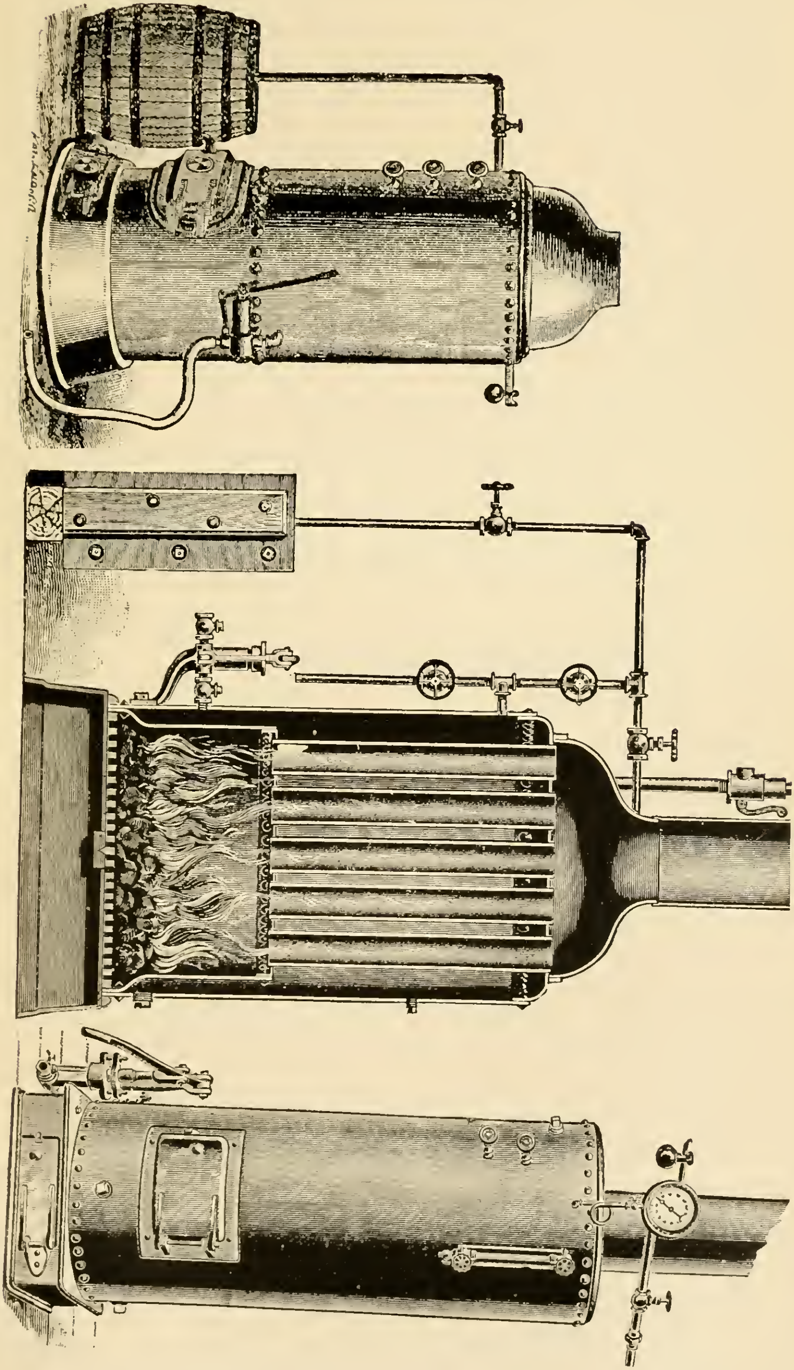
While many growers may feel obliged to prepare the sulphur sprays in kettles or iron pans, experience has shown that they may be boiled much more uniformly, more easily, and oftentimes better in barrels or wooden tanks by using live steam as the source of heat. These facts are widely recognized on the Pacific coast, and the knowledge is put into practice by some of the leading fruit growers, many of whom have established special steam cooking plants for preparing and handling the sulphur sprays. Some of these spray-cooking appliances are on quite an extensive scale and others more limited, being adapted to the needs or facilities of the growers. As the sulphur sprays have been widely used in California and Oregon, and are likely to become much more generally used throughout the East, especially as they are particularly intended for winter application to all deciduous trees and are known to be of marked value both as insecticides and fungicides, the more improved methods of preparing them will be of general interest to orchardists, and several are here given. Three types of cooking plants are described: (1) One adapted to the needs of an orchard of 10 acres, (2) one suited to the needs of an orchard of 100 acres, and (3) one of sufficient capacity to prepare sprays for the treatment of 500 to 1,000 acres of trees.

For small orchards sulphur sprays may be prepared in barrels by the use of steam. Upon a solid plank platform 3 feet wide, 12 feet long, and raised 18 inches above the ground, place three oak barrels holding 60 gallons each. Each barrel should have a bunghole through one side about 1 inch above the bottom, which is stopped with a long wooden plug while the spray is boiling in the barrel. The upper heads of the barrels should be removed, and each may be nailed in two parts to serve as a cover for the barrel while the spray is being boiled. Near one end of the row of barrels is set the boiler in which steam is to be generated. From the dome of this boiler a steam pipe should extend horizontally over the row of barrels, and not less than 2 feet above them. The farther end extends downward at a right angle, by means of an elbow, to within 6 inches of the bottom of the last barrel. Where the pipe passes over the first and second barrels, downward-extending pipes are connected by means of proper couplings, and extend to within 6 inches of the bottoms of the respective barrels into which they reach. In each of the downward-extending pipes is fitted a valve about 18 inches above the barrels, by means of which the inflow of steam may be controlled for each barrel separately. The lower end of each of the pipes leading into the barrels is left open for the escape of steam. With a sufficient head of steam a barrel of water may be brought to the boiling point with such an appliance in about five minutes. By having three barrels, as here suggested, two may be kept almost constantly filled with boiling sprays, while the third is filled with boiling water for use in slaking lime, filling the barrels after the sulphur is added, and reducing the spray to the required amount in the spray tank. With such an appliance for boiling, provided the two barrels for spray are charged alternately one hour apart, 60 gallons of well-made spray may be sent to the orchard about once an hour, after allowing each lot two hours of constant boiling. In preparing the spray for boiling, the lime is first slaked to a cream of lime in the bottom of the barrel, the pulverized sulphur is stirred in, the barrel is filled two-thirds full of boiling water, a top is placed over the barrel, and the steam is turned on by opening the valve above the barrel. Within a very few minutes the steam will bring the contents to a seething boil, and this can be maintained for the two hours required without danger of overheating and with little care, except of course that required to maintain and regulate the steam supply. The steam stirs the spray sufficiently when boiling. When thoroughly boiled the bunghole near the bottom of the barrel is opened by removing the long plug, and the spray is drawn off into pails and strained into the spray tank through a fine wire strainer. When the barrel is nearly empty enough boiling water is added to make up the amount of spray required by the formula, and this is then drawn off. Before a new charge of spray materials is placed in the barrel, the latter should be removed from beneath the steam pipe and cleaned. Convenient boilers suited to boiling one or more barrels of spray are shown in the illustrations given. (Pl. XXI.)

For orchards of 100 acres the boiling of sprays in barrels is too slow. The plan adopted by Mr. A. D. Cutts, at the Riviera Orchard, will here be given as admirably answering the purpose for such orchards. In this spray-boiling plant the live steam is obtained from the dome of the boiler of a 20-horsepower thrashing engine, and while cooking sprays from 60 to 80 pounds steam pressure is maintained. The spray is boiled in two rectangular vats or tanks, built of 2-inch dressed sugar pine. The inside measure of these tanks is, length 5 feet, breadth 3 feet, depth 30 inches. These tanks have the ends mortised into the side and bottom planks from one-fourth to three-eighths of an inch. Two long bolts run diagonally across at each end to hold the head in place, and in addition the planks are nailed together with 40^d cut nails. Each of these tanks will hold approximately 280 gallons of spray. They are raised 4 feet above the ground upon a strong and well-braced framework. They stand side by side with a platform between about 4 feet wide, on which a man may stand to attend to the spray while boiling. One end of each tank is toward the boiler, and the other, which is supplied with a faucet or sirup gate for drawing off the spray, extends to the side of a driveway. The steam is supplied to each of the tanks directly from the dome of the boiler. From the steam dome a 1½-inch pipe leads to near the ends of the tanks. This is connected with a transverse 1-inch horizontal pipe extending laterally to a point opposite the center of each tank and level with the tops of the tanks. The ends of this 1-inch pipe now turn at a right angle and extend to the center of the top of the ends of the tanks, turn down on the inside of the tanks to the bottom of the same, and then extend along the center of the bottom to near the farther end, where they are closed by having an iron cap screwed over the end. Through each side of that portion of the 1-inch pipe which extends along the inside of the bottom of each tank are drilled 6 small holes for the escape of the steam into the tanks. In the pipe leading to each tank is placed a globe valve for separately controlling or preventing the flow of steam to each of the tanks. When a tank of spray is ready to go to the orchard, the spray is run into another tank situated on a low truck wagon, the truck being first driven under the end of the boiling tank which is to be emptied. The low truck with the spray is then driven to the spray tanks in the orchard, and the spray is pumped from the truck tank to the spray tank, without delaying the work of the sprayers. The spray is strained twice, first when drawn off from the boiling vats through the faucet, and second when it is

DESCRIPTION OF PLATE XXI.

Steam spray-cooking appliances for small orchards. Figs. 1 and 3 show boilers suited to cooking sprays in 1 to 3 barrel lots; fig. 2 shows a boiler connected with a tank in which larger quantities of spray may be boiled at one time. These cooking appliances are well adapted to use in ten-acre orchards (p. 157). (Compare with Pl. XXII.)



STEAM SPRAY-COOKING APPLIANCES FOR SMALL ORCHARDS.

pumped from the truck tank into the spray tank in the orchard. The brass strainer cloth employed by tinners in making strainer pails is used for this purpose. It is very necessary to strain well, as in the unstrained spray there are always dregs that fill the nozzle and delay work. Mr. Cutts says that in tanks of this kind it is necessary to stir the spray frequently while boiling to thoroughly mix the different ingredients. Three hours' boiling is better than two. He also says that one man, at $2 per day, will tend the boiler and prepare from 1,500 to 2,000 gallons of spray per day, and that it will require about one-half cord of 4-foot wood to generate the steam in such a boiler as he uses.

In preparing the sulphur sprays for orchards containing 500 to 1,000 acres of trees it is desirable to have tanks of larger size than those used by Mr. Cutts and to avoid as much pumping and transferring of the sprays as possible. One of the most convenient and complete spray-cooking plants for orchards of large size which has thus far been seen by the writer will here be described. This plant is at the Rio Bonito orchard. The water for preparing sprays at this orchard is obtained from a well and is forced by means of a rotary force pump run by steam power into a large storage tank elevated upon a heavy framework some 30 feet above the ground. About 10 feet above the ground and at one corner of the open framework of the tank house is placed a circular tank holding about 300 gallons. This is a storage tank to receive the spray when prepared for the orchard. The bottom of this circular tank is supplied with steam pipes, so that the contents may be kept hot and ready for use. From the outer side of this storage tank, near the bottom, is a discharge pipe with valve and hose attached, through which the spray may be run by gravity into the tops of the 300-gallon spray tanks on wagons which are used in the orchard. These wagons are driven to the side of the storage tank and filled with boiling spray in a few minutes, much as street-sprinkling tanks are driven under the elevated hydrants and filled. The boiling tank proper is built of 2-inch surfaced pine plank within a firm framework, properly bolted, and rests firmly upon the ground. It is situated within the heavy framework of the water tank house. This boiling tank is approximately 18 feet long, 3 feet wide, and 3 feet deep, and its full capacity is 1,200 gallons. In the center of the tank house is a water pipe connected with the large water tank above. Near the bottom of this standpipe are hydrants for the attachment of hose, thus allowing of water being drawn directly from the water supply above into the boiling tank by opening a hydrant. An unlimited supply of cold water is thus always at hand without the necessity of lifting a pailful by hand. The steam pipe for heating the sprays in the boiling tank extends from end to end along the bottom within the wooden tank, and every 2 or 3 feet along this pipe are cross pipes leading toward each side of the tank. The ends of the central pipe and its branches are closed. Along both sides of this main pipe and its lateral branches are drilled small holes for the escape of steam into the tank. The flow of steam to the tank is controlled by means of a globe valve in the steam supply pipe, the valve being conveniently placed for the workman at the tank. Broad board covers are made for covering the whole tank when the boiling is in progress. As in the case of the spray-boiling plant of Mr. Cutts, the main steam pipe leads from the tank directly to the steam dome of the boiler. The spray is prepared in the boiling tank of double strength, and when sufficiently boiled is elevated to the storage tank above by means of an appliance planned like an injector of a boiler. An iron pipe about 2 inches in diameter leads from the boiling tank upward and over the top of the storage tank described. In this pipe is placed the injector, which is supplied with two lateral connections. One of these connections is with the cold-water supply pipe, and the other is with the main steam supply pipe. In each of the pipes connected with the injector are placed globe valves for the control of the inflow of water, steam, and hot spray. When it is desired to fill the storage tank above with hot spray from the boiling tank below, the valve opening into the steam pipe leading from the injector to the steam dome is opened. The live steam at once escapes through the injector into the pipe leading to the storage tank and then out of the end of the pipe. The valves leading to the boiling tank and the cold-water supply are now opened in such a manner that about equal parts of cold water and hot spray are admitted to the injector, and the escaping steam, by means of its tendency to form a vacuum, soon causes a combined stream of hot spray and cold water to follow up the pipe and escape into the storage tank above. There is thus established a kind of steam siphon, which soon carries up 150 gallons of boiled spray and an equal amount of cold water, filling the 300-gallon storage tank with spray of the required strength, the strength of the spray in the boiling tank being double that required. This work is accomplished by a careful adjustment of the inflow of steam, spray, and water to the injector, the storage tank being filled without the necessity of lifting a pound of spray by hand. The combining of the cold water with the hot spray in the injector is found to be necessary to the proper working of the latter as the temperature of the injector would otherwise become too high for efficient work. When the storage tank is full, steam is turned into the pipes situated at its bottom, and the spray is again heated to the boiling point and kept very hot until drawn off into a spray tank and taken to the orchard. The facility with which a plant of this description may be operated will depend to quite an extent upon the nature and capacity of the boiler used for generating steam. The more easily steam can be generated and the greater capacity for steam which the boiler possesses the better for the work.

STEAM SPRAY-COOKING APPLIANCES FOR LARGE ORCHARDS.

DESCRIPTION OF PLATE XXII.

Fig. 1 shows sulphur, lime, and salt spray-cooking appliances used on the Rio Bonito Rancho. The heavy framework at the left supports a large water tank not shown in the photograph. This tank is filled from a well by means of a steam rotary force pump, and supplies all water required in cooking and reducing sprays. On the ground, at the farther side of the framework of the tank, is shown a long wooden vat from which steam is issuing. This rectangular vat, described on page 159, is capable of cooking about 900 gallons of sulphur spray of double strength, and is seen in full operation in the illustration, the heat being applied by means of steam pipes at the bottom. The steam pipe is shown leading from the dome of the boiler in the shed at the right and in the background of the photograph. The round tank shown above the right end of the cooking vat holds 300 gallons of spray, ready for application to the trees. This tank is filled from the cooking vat by means of a steam injector, described on page 160, and the spray is maintained at a high temperature by means of steam pipes in the bottom, as in case of the cooking vat proper.

Fig. 2 should be considered in connection with fig. 1. The large, round tank, standing above the barrels, is the storage tank for sulphur spray after it has been prepared in the long vat below. This tank holds 300 gallons—sufficient spray to fill the tank seen on the wagon. The wagon tank is filled by gravity, the spray flowing into it through hose running directly from a spout at the bottom of the storage tank. A valve in this spout regulates or stops this flow of spray as desired. One of the spray wagons used in this large orchard is shown. The pump stands crosswise behind the corner stakes at the back of the wagon. These stakes serve to prevent the hose from falling beneath the wheels, as all lines of hose extend from the rear of the wagon when in use in the orchard.

By referring to Pl. XXII and the descriptions of figures the reader may obtain a good idea of the arrangement of this extensive spray cooking plant, as well as of the boiler supplying steam.

PREPARATION OF COMBINED COPPER AND SULPHUR SPRAYS AND NOTES ON OTHER SPRAYS TESTED.

For many years the use of combined copper and sulphur sprays has been practiced by peach growers in Oregon, and as they have reported good results the writer prepared the following four formulæ of this character for the control of curl.

BORDEAUX MIXTURE AND SULPHUR SPRAYS COMBINED.

The formulæ of the combined Bordeaux mixture and sulphur sprays tested are given in the following list:

List of sulphur sprays combined with Bordeaux mixture.

3 pounds copper sulphate, 10 pounds sulphur, 20 pounds lime.
3 pounds copper sulphate, 10 pounds sulphur, 10 pounds lime.
3 pounds copper sulphate, 5 pounds sulphur, 10 pounds lime.
2 pounds copper sulphate, 5 pounds sulphur, 10 pounds lime.

In preparing these combined sprays, which were found somewhat more effective in the control of peach leaf curl than the sulphur sprays alone, the Bordeaux mixture was added to the fully prepared sulphur spray. A portion of the lime given in the formula was reserved for making the Bordeaux mixture, while the remainder of the lime was combined and boiled with the sulphur in the manner already described. When the sulphur spray had been placed in the spray tank, the Bordeaux mixture, which had been freshly prepared from the copper sulphate and the remainder of the lime, was added, and after thorough mixing was at once applied to the trees. The union of the yellow sulphur spray with the blue Bordeaux mixture forms a spray of a distinct green color. The application of this spray is similar to that of the sulphur spray, requiring the same class of nozzles.

MISCELLANEOUS SPRAYS.

A large number of sprays not included in the preceding descriptions have been prepared and tested for peach leaf curl, and some of them have been discussed in other portions of this bulletin. Several of them were tested for the purpose of learning the value of the separate ingredients of the leading sprays, as salt, lime, etc. Among these were lime, applied as a simple milk of lime; salt, applied in solutions of different strengths; and lime and salt combined, applied as a whitewash. Sulphur was tested in the form of sulphide of potassium, applied in various strengths in liquid form, and the union of this sulphide of potassium with milk of lime was also tested. Iron sulphate, sulphur, and lime were tested in combination by adding to the sulphur spray a mixture prepared by uniting the milk of lime with a solution of iron sulphate. The union of the milk of lime with the iron sulphate solution produced a lead-colored mixture resembling Bordeaux mixture in consistency, and when united with the sulphur solution the color was dark green or approaching black. Iron sulphate and lime were also tested separately.

While some of these sprays gave evidence of considerable fungicidal action, none of them gave results which would warrant their substitution for the sprays already considered in previous chapters, and hence it is unnecessary to enter further into details respecting their preparation. The results of their use may be learned in the chapters of this bulletin which relate to the action of the sprays on the foliage and the fruit.

GENERAL CHARACTERS OF THE SPRAYS TESTED.

There are certain general characters of sprays adapting them or making them unsuitable for various classes of work, and to these it may be well to allude.

THE ENDURING QUALITIES OF THE SPRAYS.

In the work here described careful notes were made on the enduring or weathering qualities of the sprays tested.

During the last week in April and first week in March, 1895, 35 sprays, of different formulæ, were applied in the experimental block in the Rio Bonito orchard, most of them to 10 large trees, as has heretofore been shown. On August 10, or five months after the spraying was completed, the trees of each experiment row were examined to ascertain as far as possible the enduring or weathering qualities of the sprays, and according to the notes made at that time the appearance of the sprays upon the trees, after five months' weathering, may be grouped under the following four heads or classes:

(1) Sprays showing quite distinctly upon the trees on August 10.
(2) Sprays moderately evident on August 10.
(3) Sprays little evident on August 10.
(4) Sprays not observable on August 10.

The sprays classed under the first head, were those applied to rows 1, 3, 7, 9, 13, 15, 18, 19, 21, 22, 25, 33, 36, 41, 44, 45, 50, 54, 56, and 57; under the second head, those applied to rows 6, 10, 12, 16, 28, 42, 48, and 51; under the third head, those applied to rows 27 and 35; and under the fourth head, those applied to rows 30, 32, 38, 39, and 47. By referring to page 73 the reader will find a table giving the formulæ for sprays applied to each of the rows named, and an examination of these formulæ will bring out the following facts: All the sprays included under the first two headings contain lime, while those under headings 3 and 4 contain none; all formulæ containing 15, 20, or 30 pounds of lime to 45 gallons of water fall under the first head. Of the 18 sprays containing 4, 5, 8, and 10 pounds of lime, 10 fall under the first heading and 8 under the second; copper sulphate enters into the composition of 8 of the 10 sprays falling under the first head, while the remaining 2 contain iron sulphate; of the 8 sprays which fall under the second heading, only 1 contains copper sulphate, and that but 2 pounds, while 5 are sulphur sprays.

These facts seem to show that the union of copper sulphate and lime produces a spray possessing decidedly greater weathering qualities than the union of sulphur and lime.

In the following list are shown the pounds of lime contained in the various sprays tested; the numbers of the rows of trees to which each amount of lime was applied; the position of each spray as grouped according to its apparent weathering qualities into classes 1, 2, 3, or 4; and references showing the nature of all the sprays containing lime:

Weather-resisting qualities of sprays.

30 pounds lime in formula, class 1, rows 1 † and 7†.
20 pounds lime in formula, class 1, rows 3†, 9†, 13†, 36†*, and 44°.
15 pounds lime in formula, class 1, rows 15*, 33*, and 57†.
10 pounds lime in formula, class 1, rows 18†*, 19†*, 41*, 45*, 50††, 54*, and 56†††; class 2, rows 6†, 12†, and 48†°.
8 pounds lime in formula, class 2, row 10†.
5 pounds lime in formula, class 1, rows 21*, 22*, 25*; class 2, rows 28*, 42†°, and 51†.
4 pounds lime in formula, class 2, row 16†.
No lime in formula, class 3, rows 27 and 35; class 4, rows 30, 32, 38, 39 and 47.

† Sulphur and lime, or sulphur, lime, and salt.
†* Copper sulphate, sulphur, and lime.
° Lime.
* Copper sulphate and lime.
†† Iron sulphate and lime.
††† Iron sulphate, sulphur, and lime.
†° Potassium sulphide and lime.

It may be well to state in connection with the above list that while all the sprays not containing lime are classed under the third and fourth heads, this arrangement may not correctly represent their respective enduring qualities. As they are without lime, the eye can not detect their presence in many cases where it is possible the chemicals may really be present in effective quantity, and it is therefore apparent that the value of such a list is largely of a comparative nature among those sprays containing more or less lime in various combinations.

The general facts appear to be, as already indicated, that the copper sprays are more enduring than the sulphur sprays, considering pound for pound of lime in their composition, and also that the amount of lime may be much less in the copper than in the sulphur sprays and still maintain the enduring qualities. It is likewise the opinion of the writer that where a winter spray of copper and lime has proved of poorer weathering quality than is desirable in a given climate, the copper should be increased as well as the lime when greater resistance to weathering is sought. In other words, while the increase of lime enhances the weathering qualities of the spray, it also has a tendency to retard or obscure the action of the copper it contains, unless the latter is increased somewhat in proportion to the increase of lime.

THE CORROSIVE ACTION OF THE SPRAYS.

As the present use of sprays has been limited to their winter application, the notes on their corrosive action relate largely to the action upon dormant trees or upon the vegetation immediately following the commencement of spring growth. In each case these remarks relate to the use of sprays upon peach trees, which are known to be among the most tender deciduous fruit trees commonly grown in the temperate zone.

The sulphur sprays of the greater strengths used in these experiments caused in many cases the loss of some of the finer and weaker inner growth of the trees. This is more apt to be the case, it is believed, when the spray is applied shortly before growth begins in the spring. Where very strong sprays of this class are to be used, it is well to apply them comparatively early in the dormant period, say four weeks earlier than the copper sprays. Sprays having not more than 10 pounds of sulphur to 45 gallons of spray may be used with little danger up to within four weeks of the swelling of the buds.

There is no danger of injuring twigs or buds with the copper sprays if properly prepared and applied before the buds have opened. Well-made Bordeaux mixture may be used even as late as the opening of the first blossom buds. The ammoniacal copper carbonate may also be safely used to a late date, and both may be again applied, if desired, after the trees have passed out of bloom. The simple solution of copper sulphate and the eau celeste may be safely used to within a week of the opening of peach buds, but they should never be used upon the foliage of the tree. Modified eau celeste is less corrosive than the eau celeste, and may be used until the first buds begin to open, but from observation in other classes of spray work it is believed to be unsafe to apply this spray to the leaves of the peach.

The injurious action of the sulphur sprays when combined with Bordeaux mixture is fairly to be compared with the action of the sulphur sprays alone when containing equal amounts of sulphur.

The spray composed of iron sulphate and lime is more apt to injure tender shoots and buds than the Bordeaux mixture, and such a spray can not be recommended for use upon foliage.

Milk of lime appears to be practically harmless when applied to dormant trees or to trees in leaf; hence any injurious action resulting from the use of sprays containing lime should be charged to the other ingredients or to the lime as altered or modified through combination with such other constituents.

ADVANTAGES OF DISCERNIBLE AND INDISCERNIBLE SPRAYS.

Reference has been made in a brief way to the advantages possessed by certain sprays in forming a visible deposit upon the surfaces sprayed. While sprays forming such a visible deposit are decidedly advantageous for all winter work, those leaving no such distinct deposit are most desirable for the treatment of fruit, especially when approaching maturity. The advantages of white sprays in the winter treatment of deciduous trees are obvious, it being possible with such sprays to clearly see what portions of the plant have been thoroughly and properly covered. This advantage may even make the difference between success and failure in the work.

Some recent experiments in applying whitewash or sprays containing large amounts of lime have tended to show that the opening of the buds may be somewhat retarded by such winter treatment. The theory is that whitening the trees prevents, to some extent, their absorption of heat from the sun's rays, and that this aids in keeping the trees in a dormant condition somewhat later than would otherwise be the case. Whether this will prove of enough importance to warrant the outlay for spraying remains to be shown. An illustrated article on this subject appeared in the Canadian Horticulturist for January, 1899.[1]

All sprays, both copper and sulphur, which contain lime are adapted to the purposes here considered. The Bordeaux mixtures and sulphur sprays used in the work described are distinctly observable upon the trees when applied, and after drying for a very short time the treated trees become decidedly white. The greater the amount of lime the whiter the trees. (Pl. XXIII.)

In the summer treatment of trees and plants having fruit approaching maturity, the use of clear sprays is often most to be recommended. The spray now best adapted for this purpose is the ammoniacal copper carbonate. A stronger spray, though making less showing than Bordeaux mixture, is the modified eau celeste. As this is apt to cause injury in some cases, it is desirable to use Bordeaux mixture for summer work up to a date when the fruit is approaching maturity, and then to adopt the ammoniacal copper carbonate. The time at which the summer use of Bordeaux mixture should be discarded for the ammoniacal copper carbonate will depend largely upon the amount of summer rains in the locality where used. In New York State, for instance, where summer showers are frequent, the lime-containing

[1] Orr, W. M., l. c., pp. 18–20. See further remarks on this subject on p. 150.

Bordeaux mixture could be used upon fruit until a later date in the summer than it could in California, where almost no summer showers occur, and where the lime would remain upon the fruit until the latter was mature. This matter leads us naturally to the consideration of sprays adapted for wet and for dry localities.

SPRAYS ADAPTED TO USE IN WET AND IN DRY LOCALITIES.

Little can be said on this subject that has not been previously touched upon in this bulletin. A few general remarks, however, may be of advantage to the grower. The enduring qualities of sprays containing lime increase where the ratio of the other ingredients is maintained, very largely in proportion to the increase of the lime which the formulæ contain. For instance, the relative proportions of copper sulphate and lime being maintained, a Bordeaux mixture which contains 10 pounds of lime to 45 gallons of spray will obviously endure much longer upon the trees in a wet climate than a Bordeaux mixture containing but 5 pounds of lime to the same amount of spray. To avoid the loss in activity and effectiveness of a spray containing a large amount of lime, the fungicide, be it copper or sulphur, should be increased so as to maintain the same or nearly the same ratio between the copper and lime which exists in the spray containing less lime. It is advised, therefore, that sprays to be used in a wet climate, especially those intended for winter application, should be made stronger, both in lime and in the essential fungicide they contain, than is found necessary in a dry climate. If two sprayings are necessary, both should be given the dormant trees.

In wet climates the conditions favorable to the development of curl and other fungous diseases are increased. This supplies a further reason for using sprays containing increased amounts of fungicide and having greater enduring qualities than sprays used in dry localities. The soil conditions in wet situations are apt to delay spray work till the last moment compatible with effective work. In such cases the amount of copper should be sufficient, if this class of sprays be used, to act promptly. If the Bordeaux mixture be applied under such circumstances, it will not be found desirable to reduce the copper below the equivalent of 1 pound of copper for each pound of lime, and a higher proportion may often be used to advantange on dormant trees.

CHAPTER IX.

THE APPLICATION OF SPRAYS.

GENERAL ACCESSORIES FOR WINTER SPRAYING.

To those who have sprayed for years and have learned by experience the most suitable appliances for such work the present remarks may not prove of direct value. They are especially intended, however, for those undertaking such work for the first time.

NOZZLES SUITED TO WINTER WORK.

The past few years have seen in the United States a very great increase in the styles and places of manufacture of nozzles and other spraying appliances. At the present time the number of styles and makes of nozzles often leads to confusion in the mind of the prospective sprayer. In fact, however, there are but few essential features to a good nozzle. The form of greatest importance for most classes of work is that which gives to the discharged spray a rotary or cyclone motion. This movement is given in a very simple manner by admitting the stream at an angle into a circular chamber in the nozzle, so that it first strikes the curving side of the chamber, and is thus forced to assume a circular or rotary motion. The revolving stream then passes through the small central opening of the discharge plate and widens into a cone-shaped spray, which gives to this nozzle certain advantages not enjoyed by several other types now on the market. Spray from such a nozzle covers a greater area without moving the nozzle than is covered with most other types. There are nozzles, however, capable of throwing spray to greater heights. The rotary motion assumed by the spray in the cyclone or Vermorel nozzles is a dissipation of force, at least in most forms of these nozzles, so far as concerns the throwing of sprays to a great distance. A type of nozzle first used near San José, Cal., and now bearing the name of that town, is perhaps better adapted to long-distance spraying, and has been extensively used on the Pacific coast. The spray is formed by the fluid passing, under high pressure, through a narrow slit in a rubber or metallic plate. Where the rubber plate is used the escape of small particles may take place through the temporary expansion of the opening in the plate.

The cyclone nozzles are now made by many manufacturers in different portions of the country, and may be obtained through any first-class hardware dealer in the United States. The San José nozzle is also obtainable through hardware dealers generally.

There are many types and styles of cyclone nozzles. Some are planned to throw the spray away from the workman, with direct or forward discharge (fig. 1). Others are so constructed that the spray is discharged laterally or at a more or less acute angle (figs. 2 and 3). In using these nozzles for winter work on deciduous trees it has been found that most thorough and most satisfactory work can be done with less waste of spray when nozzles having a lateral discharge are employed. The reasons for this are evident. Dormant deciduous trees are but a skeleton or framework, presenting to the sprayer but a limited surface for stopping a direct spray. For this reason, where a nozzle having a direct discharge is employed, a large portion of the spray will of necessity pass through the limbs of the tree and fall upon the ground, while at best it will pass through the tree but once. By using the cyclone nozzle with lateral discharge, however, the cone of spray may be directed upward through the whole top, and in falling back it passes through the tree a second time. Here is a decided gain in the limb surface which will be reached by the use of a given amount of spray. The nozzle having lateral discharge can also be handled to much greater advantage than the nozzle with direct discharge. By turning the extension pipe which bears the nozzle, the cone of spray may be directed upward, downward, or laterally upon the limbs as desired. This has proven of great advantage in doing thorough work.

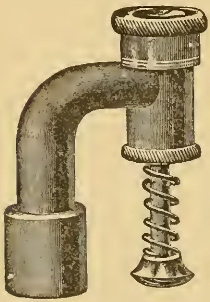


FIG. 1.—Cyclone nozzle, with direct discharge and degorger, for thin sprays.

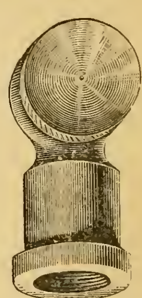


FIG. 2.—Cyclone nozzle, with lateral discharge, for thin sprays.

The ordinary lateral discharge cyclone nozzles are suitable for use with most of the copper sprays. For use with the sulphur sprays or Bordeaux mixture containing a large amount of lime, the common Vermorel or cyclone nozzle is rather too light and the opening too small. In California a special form of nozzle is in use for the application of such sprays (fig. 3). This nozzle is manufactured in San Francisco, and may be obtained from the leading hardware firms of that city. The nozzle is of the cyclone pattern, but is much larger, heavier, and stronger than the ordinary type of cyclone or Vermorel. The discharge opening is of sufficient size to allow of the use of thick sprays, and the discharge plate is heavy enough to withstand much wear from corrosive fluids. A fact of prime importance, however, for the work

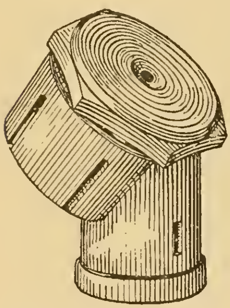


FIG. 3.—Heavy cyclone nozzle, with oblique discharge, for thick sprays.

being considered, is that the nozzle discharges the spray at an angle of about 45° with a line leading directly from the sprayer. This gives the nozzle the advantages of both the lateral and direct discharge. The work of either of these types (figs. 1, 2, and 3) may be accomplished with this angular discharge.

Makers of cyclone nozzles of all kinds are usually able to supply the discharge plates of the nozzles separately, and this is convenient for the grower, where the original discharge plates have been worn out. The separate discharge plates usually sell at 25 cents each.

HOSE AND EXTENSION PIPES.

Rubber hose of good quality is most satisfactory for all kinds of spray work. The strongest and best hose will usually prove cheapest if properly cared for. All hose should be thoroughly washed, both inside and outside, at the close of each day's work, and it should be well scrubbed, washed, and dried when the spray work is completed, and stored in a uniformly cool, dark, and medium dry place.

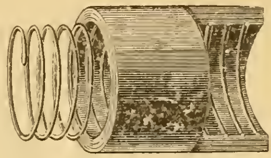


Fig. 4.—Wire-extended suction hose.

Fig. 5.—Bamboo extension pipe, with valve and hose coupling.

Practice varies somewhat as to the internal diameter of hose used. One-half inch is perhaps the most common size. The external diameter of the hose should not be so small nor its flexibility so great that it will easily kink and twist upon itself. Hose which does this is a constant source of annoyance, causing loss of time and often endangering itself. Where possible, it is best to have all lines of discharge hose leading from the pump pass from the back end of the wagon, between two short stakes, one at each corner. With such an arrangement there is little danger of its being caught in the wheels or run over by them. Many lines of hose are injured or destroyed in this way. The stakes at the back corners of the wagon also serve as a means of winding up the hose preparatory to going to or from the orchard.

Couplings for connecting 1, 2, 3, or 4 lines of hose with the pump may usually be obtained from responsible hardware firms, or through them from the manufacturers of the pumps used. The more common hose couplings are nearly always in stock at such hardware houses.

For most pumps it is well to supply wire-extended suction hose (fig. 4). Some styles have the spiral wire coil within the interior; others have it embedded in the rubber. When the metallic spiral is exposed to the spray in the interior of the hose it should be of brass, if possible, to enable it to withstand the corrosive action of the sprays.

Brass suction pipe strainers for attachment to the end of the pipe may be had of different forms. They are necessary when the end of the suction pipe is simply lowered into the spray tank or when it rests upon the bottom of the tank.

The extension pipes used by different growers vary. Some adopt common three-eighths or one-fourth inch iron tubing, while others obtain the bamboo-covered extensions, which latter contain one-fourth inch pipe. The essentials of an extension pipe are a brass coupling for connecting the hose, a good brass stopcock for controlling the flow of spray, a metallic pipe of sufficient length (which should be determined by the height of the trees to be sprayed), and upon the end of the pipe a thread and shoulder for the attachment of the nozzle and the reception of a washer. The ordinary length of extension pipes is 8 or 10 feet, but where trees are large a 12-foot pipe may be needed. Either of these lengths are now obtainable from dealers in spraying supplies in the form of bamboo extensions (fig. 5). There are advantages in the bamboo extension pipes over uncovered iron tubing. Where hot sulphur sprays are used the bamboo cover prevents the hands from feeling the heat, and where cold sprays are applied in very cold weather the bare, wet pipe is liable to chill or even freeze to the hand. The greater size of the extension pipe which is covered by bamboo also adds to the ease with which the pipe may be held and turned in the hands.

PROTECTION OF THE SPRAYER.

The nature of spray work makes it unpleasant for the workman, but much of this inconvenience arises from an incomplete or improper preparation for the work. Men who would not care to work in a rain storm without suitable covering are often improperly protected against the similar or worse conditions prevailing when they are spraying. In the spraying of large orchards it has been learned that one of the most suitable coverings for men who are applying sprays is a sailor's oilskin suit and sou'wester. This covering is light, impervious to wind and water, and is not as liable to crack as rubber clothing. Whatever form of head covering may be chosen it should be soft, so as not to be interfered with by limbs, and it should extend in front to protect the eyes and behind to protect the neck. It is always desirable to protect the hands with long rubber gloves, and these can usually be obtained from or through druggists. In selecting such goods, however, it is well to learn how long they have been held in stock by the dealer, and if they have been kept for more than a year it is best to order new ones from the manufacturer, as such goods soon rot when held in stock. Besides, new stock is no more expensive than old, and it will frequently endure twice as much use. Numbers 11 or 12 are usually about the right sizes for ordinary hands. Most wear can be obtained from gloves which are large for the hands, and in such the hands are not as apt to perspire. Where rubber gloves are not obtainable the hands may be greatly protected and kept soft by rubbing them thoroughly, as often as necessary, with a piece of beef suet.

If corrosive sprays are to be applied, such as the simple solution of copper sulphate, eau celeste, etc., it may be found necessary to protect the eyes. For this purpose ordinary clear glass goggles may be used, or the sprayer may provide himself with mica goggles of large size, such as are worn in some portions of the country by men employed about thrashing machines. Both the glass and the mica goggles may be usually purchased through druggists.

PUMPS FOR VARIOUS SIZED ORCHARDS.

The selection of a good spray pump is advisable. The difference between the first cost of a poor pump and that of a good one is little, while the difference in the expense of spraying an orchard with a poor and a good pump is apt to be considerable.

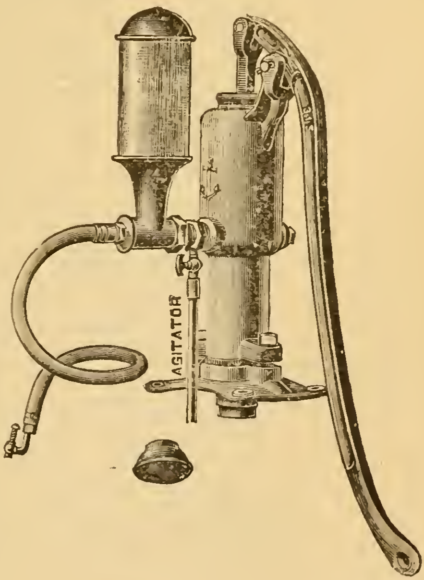


FIG. 6.—Spray pump for use on barrel or tank.

There are some features which every spray pump should possess. It should be furnished with an air chamber for the regulation of the flow, and the wearing parts should be of brass or brass lined. It should be strong and work easily, be supplied with means for firm attachment, and have capacity sufficient to maintain the required pressure without undue rapidity of stroke.

Pumps for small orchards should be capable of throwing two good sprays. Such pumps, suited for attachment to the top or side of barrels, or to other raised tanks or foundations, are shown in figs. 6 and 7. These pumps are supplied with air chambers and are of sufficient capacity for ordinary orchard spraying. Each has a connection for a small pipe leading down from the discharge pipe to the bottom of the barrel or tank. By opening a stopcock in the pipe a stream may be forced back into the tank close to the end of the suction pipe, thus serving to free the suction from deposit and to agitate the spray. These pumps can be obtained with brass-lined cylinders. The stroke is upward and downward. (See also Pl. XXVI.)

For orchards of medium to large size it is better to obtain more powerful pumps—those capable of throwing four strong sprays. The pumps shown in figs. 8, 9, and 10 are admirably suited for this class of work. Pumps of the type shown in fig. 8 are used in the 1,600-acre Rio Bonito orchard. In this orchard one man pumps for four men spraying (Pls. XXVII and XXVIII). In many portions of California the pneumatic pump, shown in fig. 10, is a favorite. It has been used extensively in the spraying of orange groves where the trees are large and where high pressure is necessary to throw the spray to their tops. The pumps shown in figs. 8 and 9 have perpen-

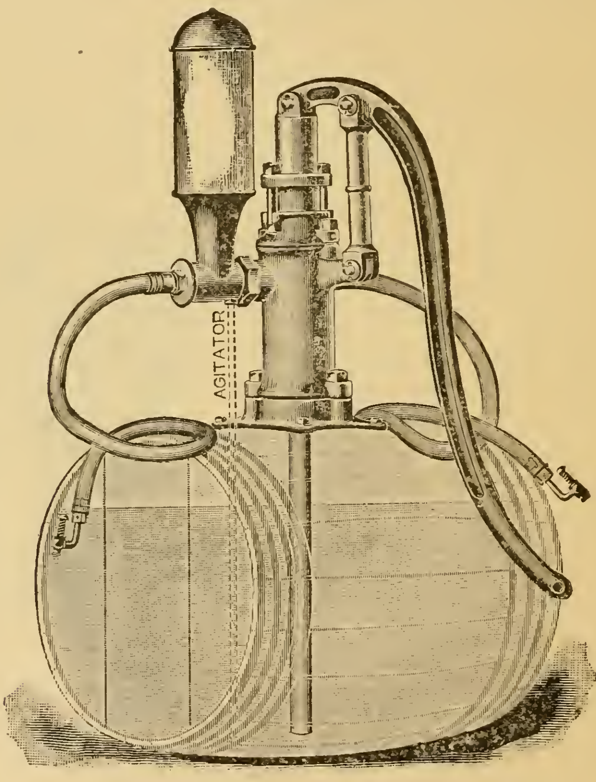


FIG. 7.—Spray pump for use on barrel or tank.

dicular levers, thus avoiding the bending or stooping motion of the operator. The levers of each of the three styles shown are long, and both the strength and capacity of the pump is sufficient. The style of pumps, both for small and large orchards, to which attention is here called, will be found figured and listed in catalogues usually to be found in the hands of leading hardware dealers.

Within the past few years leading orchardists and others have tested, with varying success, the application of different motive powers to the operation of spray pumps. Steam and gasoline engines have received most attention for this purpose. Many of the power sprayers as now constructed are heavy, cumbersome affairs, which could never be of practical value in everyday orchard work. Of the machines or descriptions of the same which have come to the writer's attention, none have thus far appeared better adapted to practical and continuous orchard work than one in use at San Diego. This machine was planned and constructed for Mr. H. R. Gunnis, of San Diego, and has seen practical service for several years. It has been more or less changed and perfected from time to time, such improvements being made as have seemed best from experience gained in actual and extensive orchard work. This machine, as first called to the attention of the writer by Mr. Gunnis in the early part of July, 1895, is illustrated in Pl. XXIX. The photograph from which this plate was made was taken while the machine was being used in spraying a young orchard near Santa Barbara. In reference to the changes made since this photograph was taken, Mr. Gunnis writes: "The changes made in the machine since I corresponded with you regarding it in 1895 consist in the addition of a rotary supply pump and the use of a tender cart for hauling the material to the machine instead of having to shut down and go to the material every time the tank is emptied." Mr. Gunnis further says, under date of March 10, 1899: "The machine is still in constant use, and I can still say, as I wrote you over three years ago, that it has developed no defects whatever. Some of the parts wore out from actual service and have been replaced, but no changes have been made in its construction. * * * The use of the supply pump and tender increases the capacity of the outfit 25 or 30 per cent, especially in large orchards. In very small places it can also be used economically by two men, both spraying, as a good, steady team can soon be taught to move and stop at the word. In this case it is not necessary to use the tender."

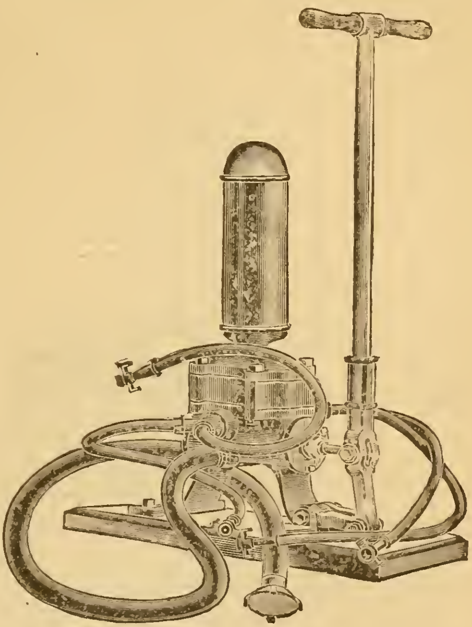


FIG. 8.—Spray pump for general orchard work, upright lever.

While it is believed that the machine which Mr. Gunnis has built and operated is superior to any other of its class, I am informed that the gentleman contemplates still further improvements. In regard to these changes Mr. Gunnis says that he is now building from nis own designs, and has almost completed, a small gasoline engine of 3 to 4 horsepower, weighing less than 200 pounds. This engine is intended for use with a spraying machine embodying all the features of his old apparatus, but lighter and more compact. He also has plans under way for a self-propelling machine, in which the extra power required will not cost half of what it does to feed a team, and which can be much more easily controlled.

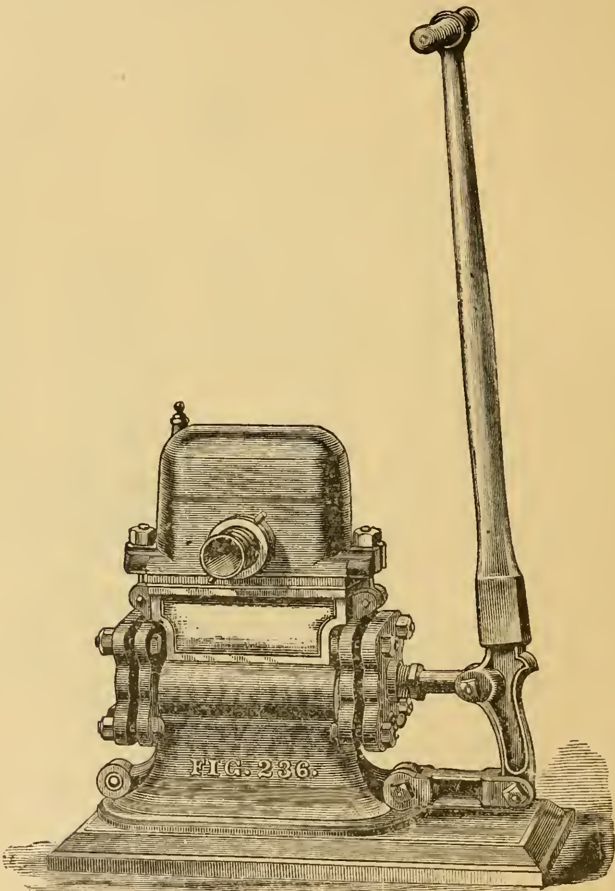


FIG. 9.—Spray pump for general orchard work, upright lever.

Pl. XXX shows the right and left sides of Mr. Gunnis's sprayer as it appeared after the addition of the rotary pump for filling the spray tank. A detailed description of this machine was prepared by Mr. Gunnis and published in the Yearbook of the Department for 1896 (pages 73 and 74), in an article by L. O. Howard, on the use of steam apparatus for spraying. Those wishing more complete details may refer to Mr. Gunnis direct, to whom the writer is indebted for the illustrations and facts here given.

SPRAYING TANKS.

A great variety of forms and sizes of spray tanks are in use. For small orchards, scarcely anything better could be desired than large oak barrels holding 60 to 80 gallons. These may be swung upon wheels separately if desired, but the most convenient way is to place them firmly in a one or two horse wagon. Large tanks, well hooped, are also very suitable for large orchards. Casks of this kind, holding 300 gallons, may easily be placed in the bottom of a two-horse wagon, leaving abundant room for placing and operating the heavy hand pump. Such casks are shown in Pls. XXVII and XXVIII. The manner of securing the tank by placing side timbers inside of the wagon bolsters is shown in Pl. XXII, as is also the stirring stick which projects from a square hole in the top of the cask.

Rectangular plank tanks are used by some, but it is generally found more difficult to keep them from leaking than in the case of casks, where the hoops may be tightened at will. Numerous spray carts, barrel attachments, etc., are illustrated in E. G. Lodeman's work on The Spraying of Plants.

The use of iron tanks is rare, and is hardly to be advised for general spray work, owing to the corrosive action of many sprays. For special sprays, as the kerosene emulsion, such tanks may, however, be safely employed.

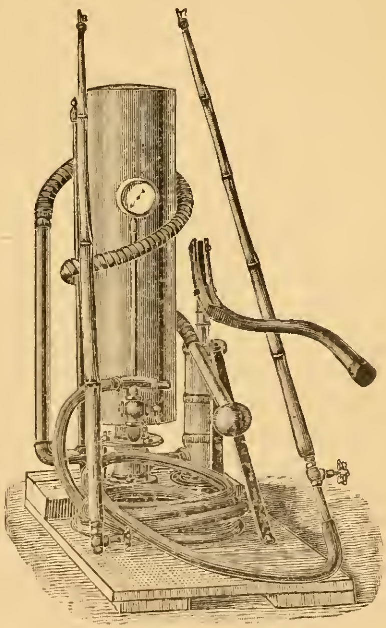


FIG 10.—Pneumatic pump for general spraying.

All spray tanks should be arranged in such a manner as to be easily cleaned, especially where Bordeaux mixture or the sulphur sprays are to be used, and they should be provided with some means for stirring or agitating the spray. The entrance to all suction pipes should be guarded with fine brass wire screen. It is well to wash the tanks out thoroughly at least once a day.

APPLYING WINTER SPRAYS FOR CURL.

A study of the many experiments conducted by the growers and described in this bulletin will give much information relative to the proper time for applying sprays for the control of curl. A presentation of a few general principles involved may, however, be properly made in this place.

THE TIME FOR WINTER SPRAYING.

The proper time for the application of winter sprays for the control of peach leaf curl depends very largely upon the conditions of climate, season, and situation of the orchard. The object to be attained is to prevent the fungus from infecting the first growth of spring. It has become apparent from the many and widely separated experiments which are here described that nearly if not all this infection results from the spores of the fungus, which are present upon the tree and not, as formerly supposed, from a perennial mycelium, and it naturally follows that these spores are to be destroyed or their germination prevented if the new growth is to be kept exempt from curl. When a spore is about to germinate or has just begun to germinate, its membranes are most tender and susceptible to fungicides. That most of the spores of *Exoascus deformans* enter upon the stage of germination at or about the time of the pushing of the first leaf buds in the spring admits of little doubt. That is the time when the tissues of the peach leaf are most tender, and when their infection by curl is actually known to take place.

The preceding facts indicate that the time when the fungicide is apt to do the greatest good is just before or at the time of the earliest pushing of the peach leaf buds. The spray should be everywhere present upon the trees just prior to the beginning of growth. To obtain this object it should be applied from one to three weeks before growth begins. This time may usually be determined by carefully watching the fruit buds, which show signs of swelling some time before they open. When they first begin to swell, the spray may be at once applied (Pls. XXIII, XXIV, and XXV).

This plan relates to regions of moderate rainfall, where a single thorough spraying, with sprays sufficiently strong and active, will prove sufficient. In regions of heavy precipitation more spray should be applied to the trees. It should be stronger and have greater adhering qualities, or else more than one spraying during the winter will be required to give the best results. If two sprayings are given, it is better to apply both to the dormant tree than to delay the second treatment till the leaf buds have opened The first spraying may be given in the fall or a few weeks before the second.

THE MANNER OF APPLYING WINTER SPRAYS.

The source of infection of the spring foliag of the peach by the fungus of leaf curl is local—i. e., it is to be found upon every portion of the tree. This fact is sufficient to show that any portions of the tree not reached by the spray will be as subjec to the disease as if no spraying had been done. It thus becomes apparent that very thorough work is essential to the general control of the disease upon the tree.

DESCRIPTION OF PLATE XXIII.

This plate shows the condition of the trees in the experiment block of the Rio Bonito orchard at the close of the spray work in the spring of 1895. The row of trees at the left has been sprayed; that at the right has been left unsprayed for comparison. The first 10 trees on the left have been treated with a spray containing a moderate amount of lime; the second 10 in the same row were treated with a spray containing more lime, and they are much whiter than those in the foreground. Each row of 10 sprayed trees on the left and the corresponding row of 10 unsprayed trees on the right constituted an experiment. The uniformity in the size of the trees in these experiments is here shown to advantage. It should be noted that the buds are still closed, while the spraying is completed.

APPEARANCE OF TREES AFTER TREATMENT, EXPERIMENT BLOCK, BIGGS, CAL.

DESCRIPTION OF PLATE XXIV.

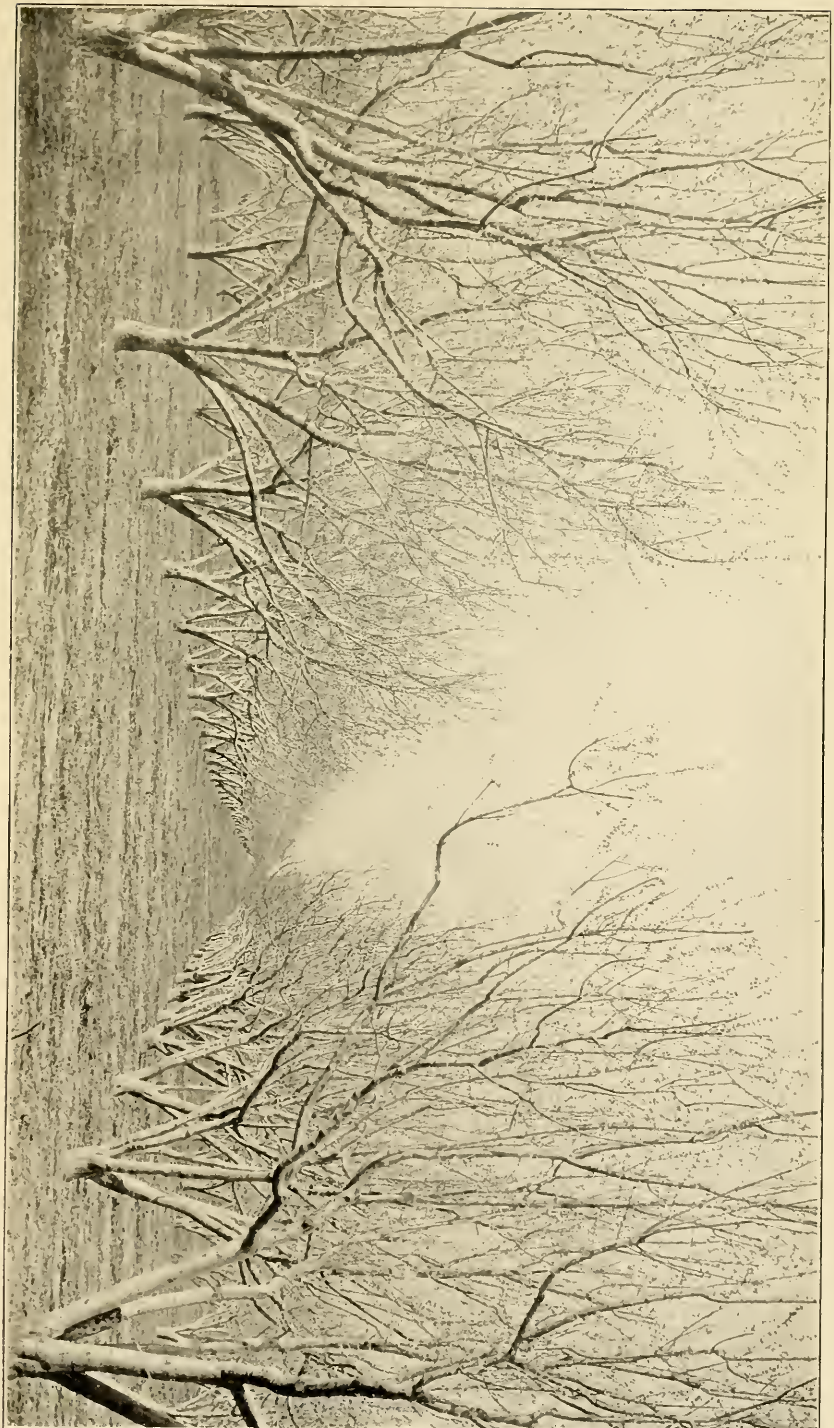
A portion of the Lovell trees in the Rio Bonito orchard left unpruned until too late to spray, many of the flowers being already open. This plate should be compared with Pl. XXV, which shows how the orchard should be pruned before spraying, and also with Pl. XXIII, which shows how far bud development may ordinarily be allowed to advance in the spring up to the time the spray work is completed.

UNPRUNED TREES; TOO LATE FOR TREATMENT.

Blossoms are opening.

DESCRIPTION OF PLATE XXV.

A properly pruned portion of the Rio Bonito orchard, which has developed too far for the best results of spraying. Spraying should be completed by the time the buds have developed as far as those shown in Pl. XXIII.



TREES PROPERLY PRUNED; TOO LATE FOR TREATMENT.

Blossoms are opening.

Thorough spray work requires that the sprays be applied in as calm weather as possible. Wind greatly retards and lowers the class of work done. Sprays should likewise not be applied when the twigs or limbs of the trees are covered by frost, snow, or sleet, or by the water of rains, dew, or heavy fogs. To avoid the presence of hanging drops of dew upon the limbs, it is frequently necessary to delay spraying until late in the morning. Such delay is preferable to the application of spray to the dripping trees. When the twigs are dry the spray dries where it strikes, and succeeding dews or showers, if the latter are not too heavy, will not wash off the spray to a very injurious extent.

If the sprayer is provided with suitable extension pipe and nozzle with lateral discharge, the work of spraying peach trees of ordinary size may be rapidly and easily done. The cone of spray is first turned upward under the base of one of the main limbs of the tree and the pipe moved so that the spray passes outward toward the end of the limb, spraying the entire under surface of the limb from base to tip. The sides and top of the limb are now sprayed, together with all of its terminal branches and twigs. Each main limb of the tree is treated in like manner, the sprayer passing about the tree as the work is completed. The habit of actively moving the nozzle back and forth while at work will soon be acquired by the workman desirous of doing good work, and by this means the most uniform spraying is accomplished.

SPRAYING WHERE OTHER DISEASES ARE PRESENT WITH CURL.

There are many peach diseases which may coexist upon the tree with curl. Many of these are amenable, in whole or in part, to treatment adapted to the control of curl, but in some cases where two or more are present it may be advisable to make slight alterations in the treatment. The following notes on some of the more common diseases may prove of value.

PRUNE RUST ON THE PEACH (*Puccinia pruni* Pers.).

It is a fact which does not appear to be generally known that prune rust infests the tender branches of the peach as well as its leaves. This has been found especially true in young trees. Spore clusters are found upon the young shoots before growth begins in the spring, showing that the disease winters over by means of spores produced upon and remaining attached to the branches, as well as by the spores produced upon the leaves and scattered over the tree. Where the trees are suffering from rust it is therefore apparent that a thorough winter treatment is required to clean the tree and prevent the spring infection, hence such spraying is recommended for the control of both curl and rust, though the full control of the latter disease is very difficult and will, at best, be necessarily followed by several summer treatments. There can be little doubt, however, that a thorough winter spraying will prevent a greater portion of the injury from rust than any single spraying applied at a later date, as it gives a practically clean tree at the opening of the season of growth. Winter sprays for the control of rust must be strong; but summer sprays if strong should be positively neutral and noncorrosive, as peach foliage is exceedingly tender.

MILDEW OF THE PEACH (*Podosphæra oxyacanthæ* De B.).

Peach mildew is widely distributed in the United States and in Europe. The fungus causing it attacks the leaves, fruit, and tender branches in the early part of the summer. The branches serve for the wintering over of the spores, thus aiding in supplying the source of spring infection. Winter treatment of the trees, with either the copper or sulphur sprays, will largely limit this spring infection, but later treatment with weak sprays will often be necessary for full control.

BROWN ROT OF THE PEACH (*Monilia fructigena* Pers.).

Brown rot of the peach has become one of the worst fungous diseases of the peach over large portions of the United States. It is quite general throughout most peach-growing sections of the East, and has become well established in the Pacific Northwest. It has been shown by Erwin F. Smith that the fungus winters over in the diseased branches and in the dried fruit adhering to the tree. These facts point to a thorough winter spraying with active fungicides as one of the first steps required in its treatment. Summer sprayings will also be required, and even when thoroughly followed up, the disease will prove hard to control. Too much stress can not be laid, however, upon the necessity of disinfecting the dormant tree as perfectly as possible by thorough winter treatment.

BLACK SPOT OF THE PEACH (*Cladosporium carpophilum* Thüm.).

This disease, which produces black spots upon the peach, is well known in many portions of the United States and in Europe, and in the East and South, especially in Texas, it has become quite troublesome. In some parts of Europe it has been known as a true epiphytotic. Whether this Cladosporium infests the branches the writer can not say, but it appears not improbable that such is true, or in any case that the spores probably find winter lodgment upon the tree itself. Black spot has been controlled in Texas by the use of the copper sprays, and there seems no reason to doubt that the winter treatment of the infected trees would largely tend to disinfect them and materially reduce the summer development of the disease.

WINTER BLIGHT OF THE PEACH AND OTHER SPOT AND SHOT-HOLE DISEASES, SUCH AS *Phyllosticta circumscissa* BERK., *Cercospora circumscissa* SACC., ETC.

In the Northwest, on the Pacific coast, there are several diseases of the peach not generally known throughout the East, and also several other diseases common to both sections of the country. These troubles are generally known as leaf spot or shot-hole diseases. One very widely distributed disease is that produced by *Cercospora circumscissa* Sacc., but one of the most troublesome diseases of this class that occurs in California and Oregon, is induced by a fungus not yet fully studied, which infests the tender and bearing branches and appears to begin its vegetative activity some time prior to the blooming of the tree in the spring. On account of the habit of the fungus to grow in the dormant or semidormant branches of the tree, the disease is termed by the writer the *winter blight* of the peach. It is one of those diseases which destroys the most valuable young growth of the tree, i. e., the shoots which are low and suited to the production of the finest fruit. This disease, in common with another quite prevalent on the Pacific coast and which is probably induced by a *Coryneum*, does most damage in the more humid localities. Both do their more serious work so early, as is also true of peach leaf curl, that summer spraying would have but little effect toward their control. Both induce gummosis of the affected branches, as is true of the action of many fungi, and is a well-marked result of the presence of *Coryneum byerinckii* Ond. Winter blight has already been successfully treated with the winter sprays, and it is believed that such spraying is sufficient for its control, provided the work be done thoroughly and repeated each year.

There is no doubt that the winter treatment of the peach for curl is properly and essentially the first step for the control of any of the above-mentioned diseases. Too much can not be said in favor of this treatment, which disinfects the trees before vegetative growth begins. The striking thoroughness of such disinfection work may be seen from the records given below.

SOOTY MOLD OF THE PEACH.

When the Department spraying experiments began in the Rio Bonito orchard, there was everywhere present on the trunks, inner limbs, and older bark of the experiment trees a fungous "smut," or "sooty mold," giving the bark a black appearance when closely examined. Of the 58 rows included in this block, 35 were sprayed, as before stated, prior to March 10, and 23 left unsprayed for comparison. On August 10, 5 months after the spraying was completed, all but 4 rows were examined for the presence of sooty mold, with the following result:

Sprayed rows showing no sooty mold August 10: Nos. 1, 3, 6, 7, 10, 12, 13, 15, 16, 18, 19, 21, 22, 25, 27, 28, 33, 35, 36, 38, 39, 41, 45, 47, 48, 50, 51, 54, 56, and 57—total, 30 rows.

Sprayed rows showing a trace of sooty mold: Nos. 42 and 44 (sulphide of potassium was applied to row 42 and simple milk of lime to row 44)—total, 2 rows.

Unsprayed rows showing the presence of sooty mold upon the trees August 10: Nos. 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 34, 37, 40, 43, 46, 49, 52, 55, and 58—total, 19 rows.

Unsprayed trees showing no sooty mold, none.

Rows sprayed in 1894, but not sprayed in 1895: No. 4, no mold apparent; No. 24, some mold present; No. 53, a little mold present—total, 3 rows.

Rows for which no notes on sooty mold were obtained: Nos. 9, 30, 31, and 32—total, 4 rows.

The above notes show that records of the sooty mold were obtained from 32 rows of sprayed trees 5 months after treatment. Of these, 30 rows showed no sooty mold, while 2 showed a very little. Neither of these exceptional rows was sprayed with a generally recognized fungicide. On the other hand, of the 19 unsprayed rows examined, all showed sooty mold. The record for rows sprayed in 1894 but left unsprayed in 1895, shows that the trees had but little mold upon them 17 months after spraying.

The preceding facts show the disinfecting value of a single winter spraying, even where the whole tree surface is covered with fungous mycelium and spores.

ANIMAL PARASITES OF THE PEACH TREE.

Among the insect pests of the peach tree now prevalent in many parts of the United States, the San José scale (*Aspidiotus perniciosus* Com.) is probably the most injurious. This pest, as is already well known on the Pacific coast, can be controlled by winter spraying with the sulphur sprays considered in this bulletin. Where the insect is known to be present, the strongest of these sprays described should be used, and it would be well to apply it somewhat earlier in the spring than where weaker sprays are used.

All leaf-eating insects depositing winter eggs upon the tree may be largely controlled by the winter use of sulphur sprays. There is also a mite (*Phytoptus* sp.?) infesting the peach leaves in California, which the writer believes may be destroyed in this manner, from the fact that experiments conducted in 1895 in the Sacramento Valley showed that the same line of treatment is effective in the destruction of a related mite (*Phytoptus pyri* Sor.) upon the pear.

Mr. William N. Runyon, of Courtland, Cal., makes the following statement respecting the peach moth, which may also prove of value to growers suffering from this pest: "Incidentally I would state that experience shows that peach trees sprayed with lime, sulphur, and salt are not subject to the attacks of the larva of the peach moth. Some growers claim a saving of 90 per cent of affected fruit."

CHAPTER X.

NATURE AND SOURCE OF THE SPRAYING MATERIALS USED.

The following notes on the chemicals for sprays are presented for the general information of the fruit grower. The facts given are those which every sprayer should understand.

Spraying is frequently retarded or prevented owing to a want of information relative to the nature, sources of supply, or true value of the chemicals required. A grower uninformed upon the last-named point is often at the mercy of local druggists or other dealers. For example, copper carbonate can be made by the grower himself at from 13 to 14 cents per pound, and ammonia of 26° strength may be purchased at about 60 cents per gallon, while local prices have been known to range as high as $1 per pound for copper carbonate and $1.50 per gallon for ammonia, which makes it impossible to undertake spray work. The writer has found the same conditions prevailing in respect to prices for sulphur, which is used very largely in the sulphur sprays and for the treatment of mildew. In some cases the prices asked by dealers in the East have been 400 or 500 per cent higher than growers have for years been paying in California. It can not be expected that the sulphur sprays will be generally used in the East under such conditions.

COPPER SULPHATE (formula $CuSO_4 5H_2O$).

Of all fungicides thus far known, copper sulphate is the most important. It is commonly known as blue vitriol or bluestone in the United States. Its foreign names are largely equivalents of these terms, although the Germans also apply the name of copper vitriol (*Kupfervitriol*).

When pure, copper sulphate crystallizes in large, blue, triclinic prisms. It contains about 25.3 per cent of copper, and dissolves in four parts of cold water and two parts of boiling water.

The presence of iron is indicated by a greenish color of the crystals or at the surface of a watery solution when exposed to the air. A solution of pure copper sulphate should be blue. The presence of a small amount of iron, which commonly occurs when copper sulphate is manufactured as a by-product in modern smelting works, does not necessarily detract from its value as a fungicide, while this by-product may often be purchased at a somewhat lower figure than a purer article. Spraying tests have been made by the writer for the comparison of pure commercial bluestone with that obtained as a by-product of smelting works, and which contained a considerable amount of iron, and the results showed that the latter article contained fully as great fungicidal value as the former.

The manufacture of copper sulphate is carried on at a considerable number of establishments in the United States, and various processes are followed. A large amount of this chemical is also imported, chiefly from England.

Bluestone is prepared by dissolving cupric oxide in sulphuric acid, or by oxidizing the sulphide of copper, the latter being the cheaper process. Mr. Alfred Rapp, a gentleman who has enjoyed a wide experience, has kindly supplied the following facts respecting the manufacture of copper sulphate by a leading smelting firm of the Pacific coast. He states that the copper is mainly derived from mattes produced in the blast furnaces, and, secondly, from an acid solution of sulphate of copper resulting from the precipitation of silver by metallic copper out of a sulphate solution. To bring the copper in the different mattes in solution they are first crushed and pulverized to about one-thirty-second of an inch or finer, and subjected to a roasting process by which the sulphur is nearly all oxidized. The roasted matte contains the copper as oxide and partly as sulphate, with a small amount still as sulphide. This material is pulverized once more and fed into lead-lined leaching tanks, where the acid copper sulphate solution is added, and, if necessary, sulphuric acid. The whole mass is heated by steam running through lead pipes. The copper oxide and the copper sulphate in the roast is thus brought in solution as a sulphate. About 80 per cent of the copper contained in the mattes is thus leached out. The resulting solution, of course, is not a neutral one, but still contains an excess of free sulphuric acid. This solution is transferred to other lead-lined tanks, containing, suspended from wooden sticks, strips of lead about 3 inches wide, the central portion of which is bent downward between the sticks so as to form a loop, which is held by the ends of the lead strips being bent over the sticks. The copper sulphate when run down to these crystallizing tanks is about 36° to 44° B. During the cooling process, which takes about four to seven days, the copper sulphate, or rather part of it, separates out of the solution as blue crystals, which are deposited upon the strips of lead. These crystals are dried and packed in barrels ready for the market. This, Mr. Rapp adds, is the general way in which bluestone is made the world over, except that they have at the works considered, in addition to the copper in the mattes, the acid copper sulphate solution from a silver refinery.

Water draining from copper mines sometimes carries copper sulphate in solution, in which case the crystals are procured by evaporating the excess of water. Barrels of copper sulphate weigh from 300 to 600 pounds.

The manufacturer's price of copper sulphate will depend largely upon the price of copper and sulphuric acid—two leading constituents, as they are sold in the market—and upon supply and demand. The cost to the manufacturer will not, however, necessarily depend upon the market value of copper and acid, for one or both may be obtained by him as by-products in other regular and profitable lines of manufacture, such as the smelting of gold and silver ores, etc.[1]

COPPER CARBONATE.

Copper carbonate as usually prepared shows the following formula: $CuCO_3 . CuH_2O_2$. It is widely used in the preparation of ammoniacal copper carbonate sprays, and is especially well adapted to the treatment of maturing fruit where subject to fungous diseases. As commonly sold on the market, the carbonate of copper is green and finely granular or powdery. It contains about 57.4 per cent of copper. Native minerals of similar composition occur, such as malachite and azurite.

Copper carbonate is manufactured by a number of firms in the United States, but much less extensively than the sulphate. In most cases it is prepared by adding to a solution of copper sulphate an excess of sodium carbonate (sal soda) in solution. This gives a flocculent mixture of pale blue color, afterwards changing to green. Heating makes the precipitate more granular.

Owing to the difficulty of obtaining carbonate of copper in smaller towns, as well as the high price usually charged for it, the Department has usually recommended that the fruit growers prepare it. The following instructions for this work were published by the writer in a circular sent to the peach growers of the country in 1894–95: In a barrel dissolve 6 pounds of copper sulphate in 4 gallons of hot

[1] Owing to the somewhat enhanced value of copper at this time (March, 1899), the wholesale price of copper sulphate has advanced. San Francisco producers quote copper sulphate in barrels, f. o. b., at $5\frac{1}{4}$ cents, and carload lots at 5 cents per pound; Omaha quotations are, by the ton or carload, $5\frac{1}{2}$ cents; one New York firm quotes $5\frac{3}{4}$ cents by the barrel or ton and $5\frac{1}{2}$ cents by the carload, and a second firm quotes 6 cents by the barrel, $5\frac{9}{10}$ cents by the ton, and $5\frac{3}{4}$ cents by the carload; Denver quotations are 6 cents by the barrel, $5\frac{3}{4}$ cents by the ton, and $5\frac{1}{4}$ cents by the carload; Cleveland quotes 6 cents per pound in any quantity; one Philadelphia firm quotes 6 cents by the barrel, $5\frac{7}{8}$ cents by the ton, and $5\frac{3}{4}$ cents by the carload, and a second firm quotes $5\frac{3}{4}$ cents by the barrel, $5\frac{1}{2}$ cents by the ton, and $5\frac{1}{4}$ cents by the carload; Baltimore quotes $5\frac{3}{4}$ cents by the barrel, $5\frac{1}{2}$ cents by the ton, and $5\frac{1}{4}$ cents by the carload; Great Falls, Mont., quotes $4\frac{3}{4}$ cents per pound in carload lots and 5 cents per pound for less than carload lots, etc.

water. In another wooden vessel dissolve 7 pounds of washing or sal soda, in 2 gallons of hot water. The soda should be clear (translucent), and not white and powdery, as it appears when air slaked. When cool, pour the soda solution slowly into the copper solution. As soon as bubbles cease to rise fill the barrel with water, stir thoroughly, and allow the mixture to stand over night to settle. The next day siphon off all the clear liquid from the top with a piece of hose, fill the barrel with water, stir thoroughly, and allow it to stand a second night. Siphon off the clear liquid the second day, fill the barrel with water, stir, and siphon off the clear liquid once more the third day. Now pour the wet sediment from the barrel into a crock or other earthen dish, strain out the excess of water through a cloth, and dry slowly in an open oven, stirring occasionally, if necessary, to prevent overheating. Prepared in this manner there should be obtained, if none of the sediment in the barrel be lost, about 2.65 pounds of carbonate of copper.

Owing most probably to the comparatively limited sale of carbonate of copper, the market price has been and still remains too high. It can rarely be obtained for less than 30 to 40 cents per pound, which is from two to three times the cost to the grower when it is prepared at home. This condition reacts upon the manufacturer by causing the grower to make his own carbonate, the market never feeling his demand. With fungicides which the grower is unable to prepare the conditions are different. His needs increase the demand in the market, and increased demand tends ultimately to lower prices.

The cost of copper carbonate when prepared by the grower will depend upon the cost of copper sulphate and sal soda. Quotations of March and April, 1899, placed copper sulphate at 5 cents per pound by the barrel and sal soda at $\frac{4}{10}$ of a cent per pound in like quantity. At these rates the grower should be able to prepare the carbonate of copper at about 12.3 cents per pound. Quotations on larger lots of sal soda and copper sulphate placed the price at $\frac{4}{10}$ of a cent and $4\frac{3}{4}$ cents per pound, respectively. At these prices the raw materials for a pound of copper carbonate would cost about 11.8 cents. These facts show that wholesale druggists and manufacturing chemists could place the carbonate upon the market at 15 or 20 cents per pound and still make a good profit, even when buying their sodium carbonate and copper sulphate in the open market. If we go a step farther back, however, we may see that the first cost of copper carbonate can be greatly reduced below any figures here given. Ten-elevenths of the cost is seen to depend upon the price of copper sulphate, and the first cost of this latter depends upon the cost to the manufacturer of sulphuric acid and copper. Both of these articles may be produced as by-products of modern smelting processes. A firm at Blacksburg, S. C., informs the writer that they employ gold-bearing pyrites for the manufacture of sulphuric acid, the sulphur fumes being driven off with heat and condensed in lead chambers in the usual way. The acid, the firm states, pays the expenses, hence the gold collected is a by-product with them. For the same purpose sulphur may be obtained by heat from several kinds of pyrites—that is, from the sulphides of copper and iron. As already shown in the notes on copper sulphate, copper for the production of this chemical may be derived largely from the mattes of silver smelting works. In view of the fact that both the copper and sulphur of copper sulphate may be obtained as by-products in the extensive gold and silver smelting works, the first cost of this chemical can certainly be placed at a figure admitting of the manufacture of copper carbonate at a very low cost. It could probably be placed on the market to-day by the leading smelting companies at 15 cents per pound and still leave a liberal profit on first cost. It is to be hoped that this matter will be looked into by some of the larger smelting firms, and that the carbonate of copper may soon be had on the market at prices which are not prohibitive to its purchase by the horticulturists of the country.[1]

AMMONIA (*formula* NH_3).

Ammonia is of gaseous nature and strongly alkaline in reaction. It is readily taken up or dissolved in water, in which form it is used in preparing the ammoniacal copper carbonate, eau celeste, and modified eau celeste—three of the more important copper sprays. A strong solution of ammonia may be commonly had on the market or from the manufacturers. Such a solution contains, by weight, about 28 per cent of ammonia gas, and is sold as 26° ammonia, as shown by Baumé's hydrometer test. A weaker solution is often prepared by druggists and is sold as ammonia water, or aqua ammonia. This often contains no more than 10 per cent of ammonia gas, and is obtained by reducing the stronger article with water. It is scarcely necessary to add that there is no economy in buying this dilute liquid. The price is apt to be out of proportion to the strength, and if quantities are to be shipped long distances there is a needless increase of freight, owing to the

[1] The following quotations on copper carbonate were received March, 1899: St. Louis quotes 10-pound lots at 27½ cents per pound, 100-pound lots at 25 cents per pound, and 1,000-pound lots at 23 cents per pound, f. o. b.; one Philadelphia firm quotes 10-pound lots at 23 cents per pound, 100-pound lots at 22 cents per pound, 1,000-pound lots at 21 cents per pound, f. o. b., and a second house quotes 28 cents per pound for ordinary quantities and 21 cents per pound by the barrel; New York quotes 10-pound lots at 35 cents per pound, 100-pound lots at 28 cents per pound, and 1,000-pound lots at 22 cents per pound f. o. b.; Boston quotes 10-pound lots at 20 cents per pound, 100-pound lots at 18 cents per pound, and 1,000-pound lots at 16 cents per pound.

The writer invites attention to the great variation in quotations from different centers of trade. It is satisfactory to note that quotations just received from Boston indorse the view already expressed, that carbonate of copper can be placed upon the market at about 15 cents per pound and leave a sufficient profit to the manufacturer.

added percentage of water. It is always desirable to specify the strength of the ammonia solution when obtaining quotations.

Plants and animals furnish the main sources of commercial ammonia. In each case the ammonia is obtained through the decomposition or destructive distillation of the organic matter. Mr. Mallinckrodt, of the Mallinckrodt Chemical Works, of St. Louis, and president of the Pacific Ammonia and Chemical Company, states that there are, as already indicated, but two prime sources from which aqua ammonia is obtained, viz, "bone liquor," obtained as a by-product in the manufacture of bone coal, and "gas liquor," obtained from the scrubbing of gas in works for the manufacture of coal gas. A similar source is also found in the making of coke. It is further stated that ammonia is obtained from bone liquor almost exclusively in the form of sulphate of ammonia, often of crude quality, which is used in the manufacture of fertilizers. Gas liquor is partly worked into a sulphate of superior quality, but mostly into aqua ammonia, by what is called the direct process. It is redistilled and aqua ammonia made therefrom. Aqua ammonia obtained from this source is largely used in the manufacture of ice and for other technical purposes. Obtained in this way, it is said to be the cheapest article of good quality that can be supplied.

A crude concentrated ammoniacal liquor is also largely made by concentrating gas liquor without purification. This concentration is carried on mainly at smaller works for the purpose of transporting the liquors in a more concentrated form, to save the expense of freight, to works where crude liquor is redistilled and manufactured into pure aqua ammonia. The concentrated liquor is, however, also largely used in the preparation of nitrate of ammonia, which is used in the manufacture of powder, but most largely in the manufacture of soda ash. This crude liquor contains, besides a small amount of free ammonia (NH_3), a considerable amount of carbonate, sulphide, cyanides, and other ammonia salts, together with tarry and empyreumatic matter resulting from the destructive distillation of coal. The strength of this liquor can not be made greater than 15 to 20 per cent, and it is doubtful if it could be advantageously used as a substitute for aqua ammonia in the preparation of sprays. The ammoniacal liquors obtained in the manufacture of coal gas are entirely a by-product.

As the gas works of the United States have been largely supplanting coal gas with water gas, in the manufacture of which ammonia is not obtained, the quantity of ammonia produced in the country has been steadily decreasing, and the demand is being supplied principally from England. Both aqua ammonia and anhydrous ammonia are made largely from imported sulphate of ammonia, and very large quantities of the imported article are also consumed in the manufacture of fertilizers.[1]

---

[1]San Francisco's quotation on ammonia water of 26° hydrometer test, in drums of about 750 pounds, f. o. b., is 7½ cents per pound.

SODIUM CARBONATE (*formula* $Na_2CO_3.10H_2O$).

Sodium carbonate, sal soda, or washing soda is used in making carbonate of copper from the sulphate of copper and in preparing the modified eau celeste. As obtained in the market it is in colorless, monoclinic crystals, showing a strongly alkaline reaction to litmus paper. When exposed to the air much of the water of crystallization is lost from the crystals, which rapidly effloresce or slake to a white powder. When perfect, nearly two-thirds of the crystals, by weight, is water.

Carbonate of soda dissolves in 1.6 parts of water at 59° F. and in 0.2 part of boiling water. When a solution of sal soda is added to the solution of copper sulphate in making copper carbonate, or to any other acid solution, a decided effervescence takes place, so that in making the copper carbonate the two solutions used should be united slowly or they may overflow the containing vessels. The more common impurities found in sodium carbonate are sodium chloride (common salt) and sodium sulphate (Glauber's salt). These impurities are due to the source and manner of manufacture of the sal soda, but are not usually present in the latter in sufficient amount to require attention in the spray work being considered.

The sources of sodium carbonate are somewhat numerous, but the commercial supply of to-day is derived mainly from common salt or from natural deposits of the carbonate. In nearly all arid countries carbonate of soda is frequently found in the soil in such quantities as to be injurious to vegetation. West of the Missouri River large accumulations of the different soluble salts of the soil are frequently met with. In the East such accumulations are prevented by the greater rainfall, the salts being eventually washed from the soil and carried to the sea, but in the West they often coat the ground, appearing white or black, and are known as "alkali beds," owing to the frequent presence of strongly alkaline salts, such as sal soda. The most abundant constituents of these deposits are sodium sulphate, sodium chloride, and sodium carbonate. The sodium chloride and sodium carbonate are, when in excess, so injurious to vegetation as to constitute a leading bane of the horticulturist of the western half of the United States. In the great plateau region between the Rocky Mountains and the Sierra Nevada and Cascade ranges are vast stretches of alkaline soils, the soluble salts of which accumulate in lakes and along water courses through the drainage of the winter rains. During the long, dry summer these waters evaporate to a considerable extent, leaving the salts deposited along the margins of the lakes and rivers.[1] In some cases these deposits of alkali are composed largely of sodium carbonate, and in several instances, after passing through a simple purifying process,

[1]These deposits are very well shown in the illustrations of Bull. No. 14, Division of Soils, U. S. Dept. of Agr.

this salt is obtained in a quite pure state, the original deposits containing as high as 90 per cent of sal soda. This latter is obtained from the soda lakes of South America, Egypt, etc., as well as from those of the United States. There are several such soda lakes in Wyoming, Nevada, and California. Large amounts of sal soda are crystallized from crude carbonate of soda obtained from Soda Lake, near Ragtown, Nev. This lake is known as Big Soda Lake, to distinguish it from a smaller soda lake near by. The lake is a beautiful sheet of water, lying in a depression of the desert, the water being about 150 feet in depth at the deepest point. It is very close to the old emigrant road running from the sink of the Humboldt River to Carson River. The separation of carbonate of soda from the waters of this lake is largely by solar evaporation. In the fall the salts deposited are taken up, washed, passed through a furnace, and shipped in sacks to San Francisco, where the soda is refined and bleached for various uses. The principal uses on the Pacific coast are in glass-making and borax-making. It is stated that sal soda obtained as here described is practically a pure article, though the natural color is somewhat yellow or brownish. It is generally useful, except as a fancy article for the retail trade. For such purposes it must be bleached with chloride of lime, after which it presents beautiful crystals.

There is also a large plant in operation at Owens Lake, Cal., getting out carbonate of soda from the waters for the Pacific market. This product, with that above described, is nearly equal in strength and purity to the eastern and the imported product, so much so that consumers are safe in using the western product, if desired. All or most sodas (carbonates) found on the Pacific coast proper are in the form of sesquicarbonates, and are often so much contaminated with sulphates and chlorides that much expense is entailed in their separation, and they are therefore of little value as sources of supply.

The second great commercial source of sal soda is common salt. The salt deposits of the country are vast and inexhaustible in quantity. The Onondaga Salt Group of the Upper Silurian alone underlies much of the large extent of country, as well as the Great Lakes, situated between Salina, N. Y., and Green Bay, Wis. At certain points the salt deposits of this group are known to exceed 100 feet in thickness. The deposit is tapped by wells at Warsaw, N. Y., in western Ontario, in eastern and in western Michigan, and elsewhere. The rock salt of western Michigan is 20 to 30 feet in thickness, and is reached at a depth of 1,800 to 2,200 feet. Other large salt deposits are found in Kansas and in numerous other portions of the country.

Sal soda is manufactured from salt on a commercial scale according to two leading processes. The older of these is known as the Leblanc process, and has been extensively employed in England and throughout Europe. It involves two steps in the manufacture, (1) the conversion of salt into sodium sulphate, and (2) the decomposition of sodium sulphate and its conversion into sodium carbonate. The first operation is known as the "salt-cake" process, and the second as the "soda-ash" process. The first step is carried out by the application of sulphuric acid to the salt and the decomposition of both in a furnace, the double decomposition resulting in the formation of hydrochloric acid and sodium sulphate. The hydrochloric acid is condensed and preserved, while the salt is converted by heat into a hard cake of acid sodium sulphate. There is usually in this cake, however, more or less unaltered sodium chloride. In the second step the salt cake is pulverized and mixed with an equal weight of pulverized limestone or chalk and half its weight of fine coal. This mixture is heated to fusion in a furnace, being constantly stirred or revolved. The combustion of the coal under the heat which is maintained seems to convert the sodium sulphate into sodium sulphide, and the decomposition of the sodium sulphide and limestone, with the interchange of elements, produces calcium sulphide and sodium carbonate. The resulting mass is cooled in iron receivers, broken up finely, and digested in tepid water. The alkali dissolves and leaves the insoluble impurities. The sodium solution is evaporated, and when dry the mass is calcined with one-fourth its weight of sawdust, to more fully convert the alkali into carbonate. This product—the soda ash of commerce—is again dissolved in hot water, and the solution filtered and allowed to cool. As the solution cools the carbonate of soda is deposited in large, transparent crystals, such as are supplied to the trade. Soda ash was formerly largely imported from England, but in the last few years has been made in the United States to a very large extent. The dissolving of the soda ash and the crystallizing of the sal soda is carried on extensively by firms not manufacturers of the ash. A St. Louis firm states that they crystallize the solution of soda ash in tanks holding about 8,000 pounds each. After the crystallization has progressed sufficiently, which takes from ten to fourteen days, according to the temperature of the weather, the mother lye, which contains all the impurities, is drawn off and the sal soda is then broken, dried, and packed in barrels. It is stated that a newer process is to crystallize the solution in small tanks, holding perhaps 200 pounds. In this small quantity the liquid crystallizes in a very short time, say over night, but does not give any mother lye, and consequently no impurities are removed.

A system entirely different from the Leblanc process is in use in the United States in some of the leading salt regions and has come very largely into use in Europe. It is known as the ammonia soda process, or the Solvay process. It consists in decomposing a solution of common salt with ammonium bicarbonate, whereby the greater part of the sodium is precipitated as bicarbonate, while the ammonia remains in solution as ammonium chloride. This latter salt is heated with lime to liberate ammonia, which is then reconverted into bicarbonate by the carbonic acid evolved in the conversion of the sodium bicarbonate into monocarbonate by heat. The ammonium bicarbonate thus reproduced is employed to decompose fresh portions of sodium chloride, so that the process is made continuous.[1]

SULPHUR (*symbol* S).

The value of sulphur as a fungicide, insecticide, and germicide has been known for many years. Its use in a powdered state has been long followed in hothouses and vineyards, and its application in the treatment of parasitic skin diseases of man and the lower animals, and in the control of fermentation in fruits and wines is equally well known. In connection with potash and soda it has been applied to the treatment of fungous diseases in the form of sulphides of these bases.

The recent marked use of sulphur in preparing sulphide of lime for the spraying of trees is believed to have been first suggested in California, the idea coming, it is thought, from the use of sulphur in a similar form as a dip to kill scab mites on sheep. The spraying of trees infested by scale insects was a natural application of its known insecticidal qualities to the needs of the orchard. In combination with lime and salt it is now very widely used on the Pacific coast. These chemicals are boiled together for a considerable time, and result in the formation of one or more of the sulphides of calcium in liquid form. While the value of this spray is well established in regions west of the Rocky Mountains, its introduction in the East has been slow, though it is almost certain to have a wide application in that section in coming years, when the full importance of winter spraying for the control of insect pests and fungous diseases is more fully appreciated. This is more especially true where both of these classes of diseases occur at one time on the same host plant.

Sulphur is obtainable in the market in several forms and degrees of purity. The forms most common are known as brimstone, the flour of sulphur, and flowers of sulphur. Brimstone is sulphur in the solid form, flour of sulphur is ground brimstone, and flowers of sulphur is sulphur which has been sublimed. Common brimstone is the cheapest form on the market, flour of sulphur stands next in price, while flowers of sulphur comes still higher. The purity of any of these

---

[1] Quotations on sal soda were received as follows during March and April, 1899: San Francisco quotes 50-sack lots at 60 cents per 100 pounds, 10-barrel lots at 70 cents per 100 pounds, and smaller quantities at 75 cents per 100 pounds; Los Angeles quotes by the barrel $1.25 per 100 pounds, and by the car in sacks $1 per 100 pounds; St. Louis quotes by the car load in barrels 55 cents per 100 pounds; New York quotes, f. o. b. Syracuse, in jobbing lots, barrels of 375 pounds, 40 cents per 100 pounds; Fairport, N. Y., quotes 50 cents per 100 pounds, f. o. b.

forms is usually sufficiently high for the use of the horticulturist. Brimstone and flour of sulphur are usually about 98 per cent pure, while flowers of sulphur is almost entirely pure. Brimstone weighs most, flour of sulphur less, and flowers of sulphur least for a like bulk.

The horticulturist uses sulphur in all the above-named forms, brimstone being employed for bleaching fruit, nuts, etc., while flour and flowers of sulphur are used in field work for the control of insect and fungous pests. A simple mode by which one may test the purity of sulphur is to weigh out any desired amount and then dry and burn it; the weight of the remaining incombustible portion, added to the amount of weight lost in drying, determines the amount of impurities.

The sources of the sulphur supply of the United States are numerous and varied. A large amount of crude sulphur is imported, although much of the sulphur now used in the production of copper sulphate, sulphuric acid, and various other chemicals is obtained in the United States through the decomposition of several native metallic sulphides, such as the sulphides of iron and copper, which are known as iron and copper pyrites. It has been estimated that the amount of sulphur consumed in the United States in 1892 was 243,154 tons. The sources of this sulphur were as follows:

From 100,721 tons of imported brimstone (98 per cent) ....98,707 tons.
From 1,825 tons of domestic brimstone (98 per cent) .... 1,787 tons.
From 210,000 tons of imported pyrites (43 per cent) .....90,300 tons.
From 119,000 tons of domestic pyrites (44 per cent) ......52,360 tons.

At the present time the amount used is probably much greater than in 1892.

Great deposits of native sulphur are found in many foreign countries and in various portions of the United States. Most of the natural deposits occur in past or present mountain regions, and are of volcanic origin. "The exhalations of volcanoes include, as a rule, sulphurous acid (SO_2) and sulphureted hydrogen (H_2S), which two gases, if moist, readily decompose each other into water and sulphur, a circumstance which accounts for the constant occurrence of sulphur in all volcanic districts." It is estimated that 5,000,000 tons of sulphur exist in one deposit in Japan. The deposits of Sicily are famed the world over, and 400 distinct workings are said to exist in that island. In central Sicily, at Assoro, Imera, Villarosa, and elsewhere, large amounts of brimstone, in the form of short truncated pyramids, are commonly seen piled near the railroad stations, as wood is piled in the United States. These large blocks, probably weighing 100 pounds each, are brought to the railroad on the backs of donkeys driven down from the mines in the mountains in long trains. Large refineries, devoted to the refining of such brimstone, are located at Catania. The annual output of sulphur in Sicily is said to exceed 300,000 tons, and the present importation of the United States from Sicily is about 120,000 tons. The richer sulphur ores of Sicily run from 30 to 40 per cent of sulphur. A considerable quantity is also imported from Japan.

The leading native sulphur deposits of the United States are located in Nevada, Utah, California, Wyoming, and Louisiana. While the amount of sulphur ore in the country is inexhaustible, the writer is informed by a New York dealer that not to exceed 3,000 tons are mined here annually, which, of course, does not include the amount extracted from pyrites. Respecting the Utah sulphur mines, which are located in the foothills of the Wasatch Mountains and in Beaver County, about 200 miles from Salt Lake City, the writer has received the following interesting data from Mr. C. F. G. Meyer, of St. Louis: The sulphur supply at these Utah mines is practically unlimited, and the price of the product is governed entirely by foreign markets. The sulphur is found in an immense bed, the ore beginning at the surface of the earth and extending down to unknown depths. This ore is of a very soft character, containing sand, gypsum, and gravel, and has from 15 to 95 per cent sulphur. The profitable ore is mined through open cuts and hauled on a tramway to smelters. The smelters are cast-iron retorts and hold a ton of ore. Each charge is hermetically sealed and the retort is subjected to 40 atmospheres of steam pressure. Under this heat the sulphur percolates, in the shape of liquid sulphur, through the foreign matter into a pot below, from which it is drawn off and passes into a distilling vat for the purpose of permitting all foreign substance to settle to the bottom of the tank; thence it is drawn off into wooden molds, holding about 200 pounds, and allowed to cool, after which it is passed through a grinding process in an attrition mill. The product obtained by the above process is about 99 per cent pure, and forms the flour of sulphur, which is extensively used, as already indicated. For obtaining what is commonly known as flowers of sulphur, which is chemically pure, the ground sulphur is passed through a resubliming vapor process.

Respecting any possible advantage to the horticulturist by purchasing sulphur refined in Europe in preference to that refined in the United States, a prominent sulphur refiner of San Francisco has kindly supplied the following facts:

The sulphur refined is mostly from imported Sicilian and Japanese products. While there exists the remnant of a former prejudice against California sulphur, it should be of interest and value to know that there is absolutely no difference between that manufactured here and that manufactured in France, Italy, Denmark, and other European countries. Both start with the same raw material coming from Sicily, the same apparatus is employed, and even experienced foreigners are hired to refine the brimstone in the identical manner in which it is treated in the above places. There comes to the horticulturist no advantage, therefore, to offset the present duty of $8 per ton levied on the refined imported sulphur, and our agricultural population, it is claimed, is duped when demanding French, Italian, or other European refined sulphur. The same manufacturer further states that Sicily sulphur of 98 per cent purity is at present admitted to the United States duty free, and that it can be ground or sublimed in this country and sold at a price below the cost of the imported foreign-refined sulphur. It is also said, as to the comparative value to the horticulturist of ground (flour) and of sublimed sulphur (flowers), that for ordinary purposes domestic ground or powdered sulphur, which averages less than 1 per cent of impurities, will answer all requirements in a wash, being finer than the imported, the only impurity being a neutral, inert volcanic ash. The sublimed sulphur, as before stated, is identical with the imported and contains little, if any, trace of anything but elementary sulphur. It is lighter in bulk and more stringy than ground sulphur (if examined under the microscope), but is not usually enough better for agricultural purposes to offset the difference in price. In other words, the difference in purity percentage between ground sulphur and sublimed sulphur is not in any way commensurate with the difference in price, and a great saving could be effected by substituting the former for the latter in ninety-nine cases out of a hundred.

To these views the writer would add that the flour of sulphur is certainly what should be used in the preparation of sprays. As to the relative value of flour of sulphur and flowers of sulphur for powdering vines for mildew, there is a difference of opinion among vine growers, the ease with which the fumes are given off being considered of prime importance in the treatment of this disease.[1]

---

[1] Quotations on sulphur in March, 1899, were as follows: New York quotes flour of sulphur in 250 pound barrel lots at $2.20 per 100 pounds, 100 pound sacks at $2.15 per 100 pounds, and car loads in barrels at $1.80 per 100 pounds, and in sacks at $1.75 per 100 pounds, all f. o. b. A second New York firm quotes roll brimstone at $2 per 100 pounds; flour of sulphur, heavy, at $2.20, and light at $2.25 per 100 pounds by the barrel; sublimed flowers of sulphur at $2.37½ per 100 pounds, in carload lots, f. o. b.; roll brimstone, $1.70 per 100 pounds; flour of sulphur, heavy, 100 pound bags, $1.75; 250 pound barrels, $1.80 per 100 pounds; light, 175 pound barrels, $1.85 per 100 pounds; flowers of sulphur, sublimed, $2 per 100 pounds. San Francisco quotes powdered sulphur, sacks or barrels, by the car load at $1.50 per 100 pounds, less quantity at $1.60 per 100 pounds; sublimed (flowers of sulphur), sacks or barrels, car load lots, $1.75 per 100 pounds, less quantity, $1.85 per 100 pounds; roll, barrels only, $1.85 per 100 pounds; refined, barrels only (quality same as roll), $1.75 per 100 pounds; crude, sacks, $1.40 per 100 pounds.

CHAPTER XI.

PEACH VARIETIES AND NURSERY STOCK IN RELATION TO CURL.

COMPARISON OF PEACH VARIETIES.

It is a well-known fact that certain peach varieties are less susceptible to curl than others. When planting, many growers strive to select varieties which are known to be comparatively resistant. This has led nurserymen to select and grow as hardy varieties as possible, and such selection has resulted in cultivated varieties becoming to some extent more hardy than the majority of seedlings. Of 97 peach growers who have stated whether, in their opinion, seedling or budded trees are most affected by curl, 50 say that seedlings are most affected, 19 think budded trees are affected most, and 28 growers have observed no difference between budded and seedling trees in this respect.

In spite of the fact that some varieties of budded peaches are quite hardy, many of the finest peaches grown are much subject to curl. There are also varieties which are hardy in one locality and become very subject to the disease when grown under different conditions. There are, in fact, so many influences, such as season, soil, situation, etc., that it has been difficult to decide, except in a few cases, whether a variety may be fairly classed as hardy or susceptible. It is found by wide inquiry that a peach which is considered hardy in one portion of the country is not resistant to curl in another. The views of peach growers vary so widely respecting the hardiness of varieties that it has been thought best to give the results as obtained, rather than strive to draw from them any final conclusions. Of a large number of growers who have been asked whether early or late-blooming varieties are most affected, 70 have expressed their views. A majority, or 42 of these growers, think there is no difference between early and late blooming varieties, 23 believe early blooming varieties most subject to the disease, and only 5 believe the late bloomers most affected. It would seem that the late blooming varieties may be less liable to injury, owing to the increased warmth when they push in the spring, but the difference is certainly not well marked. Respecting the hardiness of early or late maturing varieties, there appears to be little difference from the replies to the circular letter. Among 79 peach growers who have expressed their views, 22 think early varieties most subject to the disease, 16 believe the late varieties most subject to it, and 41 think there is no difference.

Besides the facts respecting the hardiness of varieties gathered by a circular letter addressed to the peach growers of the country in 1893, the following list contains such information on this subject as it has been possible to glean from the publications accessible to the writer. In this list are tabulated 191 peach varieties and a few nectarines in relation to their resistance to curl. So far as possible the form of the glands, the season of ripening, and the adhesion of pit is shown.[1] The susceptibility to curl is shown in three columns—little susceptible, medium susceptible, and very susceptible. Every record for or against a variety has been obtained from a distinct source from all other records for that variety, and the list includes over 1,000 records. As a record under medium susceptible or very susceptible is against the variety, showing that it is subject to the disease, these two columns are added and the sum carried to a final column. This final column may thus be fairly contrasted with the first column, which gives the records of varieties little susceptible to curl. The entire list goes far to show that few varieties are practically free from curl in all localities, and that some of the finest varieties are very susceptible to it. (See for example the records under Crawfords Late, Crawfords Early, Elberta, Heath Cling, Lovell, etc.)

TABLE 43.—*Relations of peach varieties to peach leaf curl, with records of glands, time of ripening, and adhesion of pit.*

No.	Peach varieties.	Character of glands.	Season of ripening.	Adhesion.	Little susceptible.	Medium susceptible.	Very susceptible.	Total medium and very susceptible.
1	Aigle de mer, *Sea Eagle*	r	e	f	......	1	......	1
2	Albright	g	l	f	1	......	......	......
3	Alexander	g	e	f	18	11	6	17
4	Alpha	r	e	c	2	......	......	......
5	Amelia	r	e	f	......	2	......	2
6	Amsden	g	e	f	8	5	2	7
7	Austin	r	l	c	......	1	......	1
8	Beatrice	r	e	f	......	......	2	2
9	Beers (smock)	r	l	f	4	2	3	5
10	Bilyeaus Late	g	l	c	......	2	4	6
11	Bishops Early	g	e	f	1	......	......	......
12	Bonanza	r	l	f	1	......	3	3
13	Boston	......	......	......	1	......	......	......
14	Brandywine	g	l	f	2	2	1	3
15	Brett (Mrs.)	r	l	c	......	1	......	1
16	Brices Early	......	e	......	......	1	......	1
17	Briggs May	g	e	f	4	4	3	7
18	Bronson (seedling)	r	l	f	1	......	1	1
19	California (cling)	......	......	c	......	......	2	2
20	Canada	g	e	c	4	......	......	......
21	Cape Clingstone	......	......	c	......	1	......	1
22	Cape Freestone	......	......	f	......	1	......	1
23	Cape Pavie	......	......	......	1	......	......	......
24	Chairs (choice)	r	l	f	......	......	2	2

[1] In some instances it is known that the form of the glands of a variety is reported differently by different writers, and on this account a few errors may have crept into the table here given, but where it has been possible to determine such questions by referring to several authors it has been done. Unfortunately the writer has not been able to study this matter in the orchard except for a portion of the varieties given.

TABLE 43.—*Relations of peach varieties to peach leaf curl, with records of glands, time of ripening, and adhesion of pit*—Continued.

No.	Peach varieties.	Character of glands.	Season of ripening.	Adhesion.	Little susceptible.	Medium susceptible.	Very susceptible.	Total medium and very susceptible.
25	Charlotte				4		3	3
26	Chinese (cling)	r	l	c		2	10	12
27	Clemence	r	l	f	1			
28	Columbia	r	l	f	1		1	1
29	Comet	r	l	f	1	1		1
30	Cooledge (favorite)	g	e	f	1	2	3	5
31	Cots (cling)			c			1	1
32	Cranes Early Yellow		e		1			
33	Crawfords Early	g	e	f	29	25	26	51
34	Crawfords Late	g	l	f	10	18	27	45
35	Crimson Beauty	r	e	c	1			
36	Crocketts White	r	l	f		1		1
37	Crosby	r	l	f		1		1
38	Doctor Hogg	r	e	f		1		1
39	Downing						1	1
40	Dumont	r	e	f	1			
41	Early Albert	g	e	f			1	1
42	Early June		e			1	1	2
43	Early May		e				1	1
44	Early (red) Rareripe	s	e	f	1			
45	Early Rivers	r	e	f	1	3	7	10
46	Early Rose		e				1	1
47	Early Slocumb		e				1	1
48	Elberta	r	e	f	1	5	30	35
49	Ellison	r	l	f		2	1	3
50	Florin		e	f	2			
51	Fords Late White	g	l	f		1	1	2
52	Foster	g	e	f	12	7	3	10
53	Fox (seedling)	g	l	f			1	1
54	General Bidwell		l	f		1	5	6
55	George the Fourth	g	e	f	2	2		2
56	Georges Late		l		2	3	1	4
57	Globe	g	e	f	1	3	3	6
58	Gold Dust					1		1
59	Golden Cling			c			2	2
60	Golden Drop	r	l	f	4			
61	Governor Briggs	g	e	f	1			
62	Governor Garland		e	f	1			
63	Governor Wood					1		1
64	Grave Cling			c	1			
65	Grosse Mignonne	g	e	f	1	2	3	5
66	Grover Cleveland		l	c			2	2
67	Hales Early	g	e	f	11	4	13	17
68	Hales Late		l		1	1		1
69	Hardy White Tuscany						2	2
70	Hardy Yellow Tuscany				4			
71	Heath Cling	r	l	c	4	3	24	27
72	Heath Free			f	5	1	1	2
73	Henrietta, *Levys Late*	r	l	c	2			
74	Hills Chile	r	l	f	2	5	7	12
75	Honest Abe		e		7	1		1
76	Honey Cling			c			2	2
77	Hood Cling			c		1		1
78	Imperial (early)	g	e	f		1		1
79	Indian Blood (cling)	r	l	c			9	9
80	Ingles (seedling)				1			
81	Ironclad				1			
82	Jacques Rareripe	r	l	f	1		3	3
83	Japan Blood				1		1	1
84	Jenny Worrell				1			
85	Jenny Worthen	r	e	f	1			
86	Jones (seedling)	g	l	f	2			
87	Kalamazoo	r	e	f	1			
88	Kennedy (cling)			c	1			
89	Keyport White				1			
90	Kites Honey						2	2
91	Lady Palmerston	r	l	f		2		2
92	La Fleur	r	l	f		1	1	2
93	La Grange			f			5	5
94	Large Early York, *Honest John*	s	e	f	6	4	2	6
95	Large White Cling	g	l	c	1	2	3	5
96	Large Yellow						1	1
97	Late Admirable	g	l	f			2	2
98	Late Barnard	r	l	f	1	2	8	10
99	Late October		l				1	1

TABLE 43.—*Relations of peach varieties to peach leaf curl, with records of glands, time of ripening, and adhesion of pit*—Continued.

No.	Peach varieties.	Character of glands.	Season of ripening.	Adhesion.	Little susceptible.	Medium susceptible.	Very susceptible.	Total medium and very susceptible.
100	Late Rareripe	g	l	f			1	1
101	Lemon Cling	r	l	c	5	2	1	3
102	Lemon Free	r	l	f	1			
103	Lewis Seedling	r	e	f	2		1	1
104	Lewis Stanley					1		1
105	Lola (Miss)	r	e	f			1	1
106	Lord Palmerston	g	l	f	1	1	1	2
107	Lovell	g	l	f	1	2	13	15
108	Lovetts White	r	l	f			2	2
109	Lovetts Wonder					1		1
110	Lyons		l	c			1	1
111	Marys Choice				4	2		2
112	McClish					1		1
113	McCollister				1			
114	McCowan (cling)			c			1	1
115	McDevitts (cling)			c	2	1	1	2
116	McKevitts (cling)			c	1	2	1	3
117	Millers (seedling)						1	1
118	Moore	g	e	f		1		1
119	Morris White	r	e	f	1	5	2	7
120	Mother Porter		l	c	1			
121	Mountain Rose	g	e	f	10	5	4	9
122	Muir	r	l	f	9	11	4	15
123	Newhall		e	f	4			
124	Nichols Orange			c	3			
125	Noblesse	s	e	f		1		1
126	Oldmixon Cling	g	l	c	6	3	1	4
127	Oldmixon Free	g	l	f	1	4	10	14
128	Onderdonk	r	e	f	2		1	2
129	Orange Cling	r (?)	l	c	7	2		2
130	Oregon				2			
131	Pallas	g	e	f			1	1
132	Peen-To, *South China Saucer*	r	e	f			2	2
133	Perkins					1		1
134	Piequets Late	r	l	f	3	3	2	5
135	Plummer						1	1
136	Pratt	r	e	f	1			
137	President	g	l	f	1			
138	Red Ceylon						1	1
139	Red Cheek	g	l	f	1		1	1
140	Red Madeline				1			
141	Reeds Crawford	g	e	f			1	1
142	Reeds Early Golden						1	1
143	Reeves Favorite	g	l	f	2	4		4
144	Reeves Golden Yellow				1			
145	Reine de vergers, *Orchard Queen*	r	l	f			1	1
146	Richmond	r	e	f	2			
147	Roseville (cling)	g	l	c		1		1
148	Royal George	s	e	f	2		1	1
149	Runyons Orange	g	l	c	1	2	1	3
150	Sallie Worrell	s	e	f			1	1
151	Salway	r	l	f	11	12	13	25
152	Schumacher						1	1
153	Sellers Cling			c	5	1		1
154	Sellers Free			f	1	1	2	3
155	Sener	r	e	f	1			
156	Shinns Rareripe				1			
157	Shipleys (late red)	g	l	f			2	2
158	Silver Twig						1	1
159	Smocks Free, *St. George*	r	l	f	2	1		1
160	Smocks Late	r	l	f	7	8	3	11
161	Snow	r	l	f	3			
162	Snows Orange	r	e	f	2	4		4
163	St. John	g	e	f	5	4	3	7
164	Steadly	r	l	f			2	2
165	Stevens Rareripe	r	l	f	2			
166	Stilsons		l	f		1		1
167	Strawberry Cling			c		2	4	4
168	Stump the World, *Jersey Stump*	g	l	f	7	10	6	16
169	Sturtevant	g	e	f		1		1
170	Summer Snow	g	l	c	1			
171	Susquehanna	r	l	f			6	6
172	Susquehanna No. 2				5	4	1	5
173	Switzerland	g	l	f			1	1
174	Tillotson (early)	g	e	f	3	2		2

TABLE 43.—*Relations of peach varieties to peach leaf curl, with records of glands, time of ripening, and adhesion of pit*—Continued.

No.	Peach varieties.	Character of glands.	Season of ripening.	Adhesion.	Little susceptible.	Medium susceptible.	Very susceptible.	Total medium and very susceptible.
175	Thissells White	......	......	......	......	......	4	4
176	Troths (early)	g	e	f	1	1	4	5
177	Tuskena, *Tuscan Cling*	......	......	c	2	2	......	2
178	Ulatis	r	c	f	......	2	......	2
179	Wager	r	l	f	2	2	1	3
180	Wards Late Free	r	l	f	2	1	2	3
181	Waterloo	r	e	f	2	2	1	3
182	Wheatland (early)	g	c	c	1	2	2	4
183	White English	......	......	......	1			......
184	White Melocoton	......	......	......	1	1	2	3
185	Wilcox Cling	......	......	c	......	......	1	1
186	Wiley	......	......	......	2	......	......	......
187	Wilkins Cling	......	......	c	1	4	7	11
188	Willow (peach)	......	......	......	1	......	......	......
189	Winters	......	......	......	......	......	1	1
190	Wonderful	r	l	f	1	2	3	5
191	Yellow Rareripe	g	e	f	......	......	1	1
	NECTARINES.							
192	Boston	g	l	f	2	......	......	......
193	Early Newington	s	e	c	1	1	......	1
194	Hardwicks Seedling	g	e	f	3	......	......	......
195	Lord Napier	r	e	f	2	2	......	2
196	Rivers Orange	r	l	f	......	......	1	1
197	Victoria	r	c	f	......	......	1	1

A digest of 98 reports on peach varieties in respect to the form of glands, earliness or lateness of ripening, and adhesion or nonadhesion of the pits, as these characters may or may not be related to susceptibility to curl, is given in the following table.

TABLE 44.—*Comparative susceptibility of 98 peach varieties in relation to form of glands, earliness or lateness of ripening, and adhesion or nonadhesion of pit.*

Character of glands.	Period of ripening and adhesion of pit.	Number of varieties— Very susceptible.	Number of varieties— Little susceptible.	Total varieties— Very susceptible.	Total varieties— Little susceptible.
Reniform, 50 varieties	Early	8	12	24	26
	Late	16	14		
	Free	20	23		
	Cling	4	3		
Globose, 42 varieties	Early	9	12	21	21
	Late	12	9		
	Free	19	18		
	Cling	2	3		
Serrate, 6 varieties	Early	....	5	....	6
	Late	....	1		
	Free	....	4		
	Cling	....	2		

In the above table a most striking correlation appears between peach varieties with serrate leaves and susceptibility to curl. All the six varieties for which full information could be obtained are little susceptible, which is all the more interesting from the fact that the varieties with serrate leaves have long been known to be very subject to mildew. A list of seven such varieties for which the characters of the leaves have been obtainable is here given in contrast to the above.

TABLE 45.—*List of peaches subject to mildew.*

Name.	Characteristics.		
	Glands or leaves.	Ripens.	Adhesion.
Briggs May	Serrate	Early	Free.
Downing	do	do	Do.
Early Anne	do	do	
Early York	do	do	Free.
Red Rareripe	do	do	Do.
Royal George	do	do	Do.
Tillotson	do	do	Do.

Some correlations of the shape and absence of leaf glands with the time of maturity of the fruit and the adhesiveness of the pit have been compiled from over 400 varieties, and these correlations are shown in the table which follows.

TABLE 46.—*Correlation of shape or absence of the leaf glands of the peach with the period of maturity of the fruit and the adhesiveness or nonadhesiveness of the pit.*

	Reniform glands.	Globose glands.	Serrate leaves, or without glands.
Early	46	130	32
Late	140	50	4
Free	124	166	32
Cling	62	14	4
Early free	35	120	28
Late free	89	46	3
Early cling	14	10	4
Late cling	48	4	1

This table shows that of 208 early-fruiting varieties, 46 have reniform glands, 130 globose glands, and 32 serrate leaves; while of 194 late varieties, 140 have reniform glands, 50 globose glands, and 4 serrate leaves. In other words, of the early varieties given there are nearly three times as many with globose glands as with reniform glands. On the other hand, of the late varieties, there are nearly three times as many with reniform glands as with globose glands. The table also shows that there are 120 early free globose to 35 early free reniform varieties, while there are 89 late free reniform to 46 late free globose varieties. This table is given as a step in the direction of future investigations along this line, which appear warranted by the correlations found to exist between the form of glands, the date of maturity, the date of bloom, etc., and the little or great susceptibility of varieties to curl and mildew. Such facts may prove of much importance when taken in connection with future work in originating hardy or otherwise desirable varieties by cross breeding.

The preceding records, showing the comparative susceptibility to curl of nearly 200 varieties of peaches, will enable the grower who contemplates setting an orchard to make his choice of varieties advisedly. As already said, however, many superior varieties are very subject to curl, hence the practical methods of preventing it as detailed in this bulletin make it possible to successfully grow the most susceptible varieties in the most unfavorable situations, so far as this disease is concerned. Such varieties are in fact saved to the peach industry of large sections of the country by means of this preventive treatment. The Elberta, a favorite in both the East and the West, and the Lovell, a favorite in California, may now be cultivated to any desired extent in regions from which they have heretofore been practically excluded by curl—advantages that are certainly not the least of those arising from the recent work in the treatment of that disease.

As a striking illustration of what has just been said, the following, contained in a letter recently received by the writer from a gentleman in northern California, is given: He states that the Lovell variety will curl in his locality so as to be of little use, if not sprayed. One of his neighbors, who had a small orchard of that variety, stated that he intended grafting the trees to some other peach, as they did so badly on account of curl, but our correspondent advised the winter use of Bordeaux mixture, cautioning the grower to spray his trees thoroughly. This was done, and the trees bore a fine crop of fruit. The work was so satisfactory that instead of grafting over the Lovell variety a block of Fosters was grafted to the Lovell, the variety with which the detailed experiments of the writer were conducted in the Sacramento Valley in 1894 and 1895.

TREATMENT OF NURSERY STOCK.

The nursery is not only the source of the orchard, but also very largely the source of orchard diseases, and its health is therefore of common interest to the orchardist and nurseryman. Could a nursery be freed from curl, many orchards planted from it would not suffer from the disease for years, especially if isolated. There is little doubt that curl has been largely disseminated throughout the world by means of nursery trees.

It has been supposed that the main source of spring infection of trees was from the perennial mycelium already in the buds, and were this hypothesis true nurserymen could scarcely hope to procure buds for their seedlings which were free from this disease. The spray work upon curl has shown, however, that the single external application of a fungicide is sufficient to prevent 95 to 98 per cent of curl when the treatment has been thoroughly made. This appears to indorse the view that at least 98 per cent of the spring infections are, as elsewhere claimed in this bulletin, from spores upon the tree, probably largely resting upon or within the bud scales themselves.

The facts given are sufficient to warrant some general considerations and recommendations:

(1) The trees from which buds are to be selected should be thoroughly sprayed with strong copper sprays before the buds are removed. (2) Where the last year's branches are removed as a whole, the buds to be cut out while budding is in progress in the nursery, the bud-bearing shoots should be thoroughly dipped once or twice in a well-made Bordeaux mixture before being taken to the nursery.[1] (3) After the nursery trees are budded they should be sprayed with Bordeaux mixture, no portion of the tree or newly inserted bud being omitted. This treatment should be repeated as often as found advisable, and the more thorough the better, especially after the removal of the seedling top.

The writer feels that these recommendations are for the best interests of the nurseryman, as well as the prospective purchaser. The Bordeaux mixture will not only prevent the injurious action of the disease, but will increase the diameter and height of the trees more than sufficient to warrant the outlay, and will make them in every way more valuable to the nurseryman and orchardist.[2]

Messrs. Dressel Bros., proprietors of the Hart Nurseries, Hart, Mich., sprayed their peach nursery in the spring of 1894 with Bordeaux mixture. They reported good success from this work in the control of curl. In the spring of 1895 they undertook an experiment with the use of 5 pounds of copper sulphate, 10 pounds of lime, and 45 gallons of water, this experiment including 110,000 nursery peach trees one year old and of several varieties. The sprayed trees were treated twice, the first spraying being done April 1 and the second April 16. On July 21 the foliage of sprayed and unsprayed trees was estimated, and it was found that while none of the leaves had fallen from the sprayed trees, 15 per cent had fallen from those unsprayed. There were 100,000 sprayed trees and 10,000 unsprayed trees in this experiment.

Dressel Bros. state respecting this experiment that they considered the work very successful, that their nursery stock showed good results, and that the work would be continued. The sprayed stock showed an increase in height. In 1897 they again treated their trees,

---

[1] This is a matter calling for careful and detailed experiments. It should be comparatively easy to dip such shoots one, two, three, or four times, and to have the buds from such shoots inserted in seedling trees of separate nursery rows. By such method a record could be kept of the number of trees showing curl upon the pushing of the first leaves. In this manner much could be learned about the disease, and a standard could be determined for the treatment of the shoots to be used as the source of buds.

[2] In relation to the added size and weight of sprayed over unsprayed nursery trees, the reader is referred to Bull. No. 7, Division of Vegetable Pathology, U. S. Dept. of Agr., 1894. This bulletin relates to the effect of spraying with fungicides on the growth of nursery stock.

leaving unsprayed trees for comparison. The trees of the sprayed block, it is stated, were very nice and straight and made a good growth, and there was no curl, it being hard to find a leaf affected, while growth started well and continued thrifty throughout the season. The unsprayed trees on the other hand curled so badly that many were crooked and stunted, not attaining the height of the sprayed trees within a foot, and a good many were worthless. The treated trees were sprayed twice in the month of March, 1897. They note that Bordeaux mixture, to do its work properly, should be on the trees for seven or eight days without rain.

SUMMARY.

(1) Peach leaf curl has a world-wide distribution, occurring in every region in which the peach is grown. In humid localities it is a leading hindrance to peach culture, and in portions of the Pacific coast States it has greatly limited the extent of the industry.

(2) The orchard losses from peach leaf curl vary from a small amount of fruit to the entire crop, while in many instances young trees are killed. The national losses from this disease will amount to $3,000,000 annually.

(3) Curl is caused by a parasitic fungus known as *Exoascus deformans*, the ravages of which are largely dependent upon the atmospheric conditions prevailing while the trees are leafing out. Rains and cold weather at that time tend to increase the severity of the trouble by favoring the growth of the parasite and interfering with the proper functions of the host. For these reasons orchards near large bodies of water and in low or damp situations are more subject to curl than those in dry regions or in elevated situations.

(4) Most of the spring infections of peach leaves are due to the spores of the fungus and not to a perennial mycelium, as formerly held, hence the efficacy of sprays.

(5) Curl was first successfully treated in California during the period from 1880 to 1885, the success depending upon the application of fungicides to the dormant trees. The disease was not successfully treated in Europe for ten years after its prevention in the United States.

(6) The copper sprays are now found to be more effective than the sulphur or other sprays first used. Of the various sprays experimented with, Bordeaux mixture, in the proportion of 5 pounds copper sulphate, 5 pounds lime, and 45 gallons of water, gave the best results, the equal weights of the copper sulphate and lime being most effective when the mixture is applied shortly before the opening of the blossom buds. When it is desired to increase the durability of a spray by increasing the proportion of lime, the application should be made earlier or equal proportions of copper and lime should be maintained.

The total saving of foliage increases with the increase of copper sulphate when the amount of lime remains constant, but the average saving per pound of copper sulphate decreases with the increase of copper used.

(7) In the treatment of peach leaf curl, from 95 to 98 per cent of the spring foliage was saved by spraying. A net gain of 600 per cent in foliage over that retained by adjoining unsprayed trees resulted in the case of several different sprays. Bordeaux mixture when applied to the dormant tree increased the weight and starch-producing power of the leaves, and the sprayed trees showed a great gain over the unsprayed in the number and quality of the fruit buds they produced for the following year, the gain in the number of spur buds being over 100 per cent in some cases. The lower limbs of sprayed trees showed a marked gain over those of unsprayed trees as compared with the upper limbs in both the number of fruit buds and lateral shoots they produced.

(8) The average value of the fruit per tree in rows treated with the most effective Bordeaux mixture ranged as high as $6.20 above that per tree in adjoining untreated rows, or the equivalent of a net gain of $427.80 per acre where trees are planted 25 by 25 feet. Over 1,000 per cent net gain in the fruit set has resulted in the use of some of the more effective sprays.

(9) The trees should be sprayed each season, as the experiments proved that treatment one season will not prevent the disease the following year. Spraying should also be done even though the trees may not be expected to bear, as the loss of the crop of leaves is shown to result in as great a drain upon the trees as does the maturing of one-half to two-thirds of a crop of fruit.

(10) The work demonstrates that peach leaf curl may be cheaply and easily prevented in California, in western Oregon and Washington, and along the east shore of Lake Michigan, where curl causes great loss, as well as in all other peach-growing sections of the United States.

(11) The copper and lime sprays are less injurious to the trees than those composed of sulphur and lime. The use of lime in winter sprays has proven an advantage in enabling the workmen to see their work and complete it with greater thoroughness than would otherwise be possible. A proportional increase of both lime and copper sulphate is recommended for wet regions, and for very wet localities a second winter spraying is advised.

(12) Cyclone nozzles with lateral or diagonal discharge are best adapted to the work.

(13) The proper time for winter spraying and the number of applications depend to some extent on the locality, season, etc., but active sprays are likely to do most good if applied from one to three weeks before the opening of the blossoms in spring. The proper time to

apply sprays for the prevention of curl is in dry, calm weather, and during the middle of the day, in order to avoid dew or frost upon the limbs as much as possible.

(14) Of nearly 200 peach and nectarine varieties considered with a view of determining their comparative susceptibility to curl, it was found that very few were wholly free from the disease and that some were very subject to it. Some of the choicest varieties, as the Elberta and Lovell, are seriously affected, but it has been demonstrated that a single winter treatment will prevent the disease upon even these varieties. It may be thus fairly claimed that the spraying methods recommended will save to the peach industry some of its finest varieties, as well as result in the saving of foliage and crops already indicated.

O

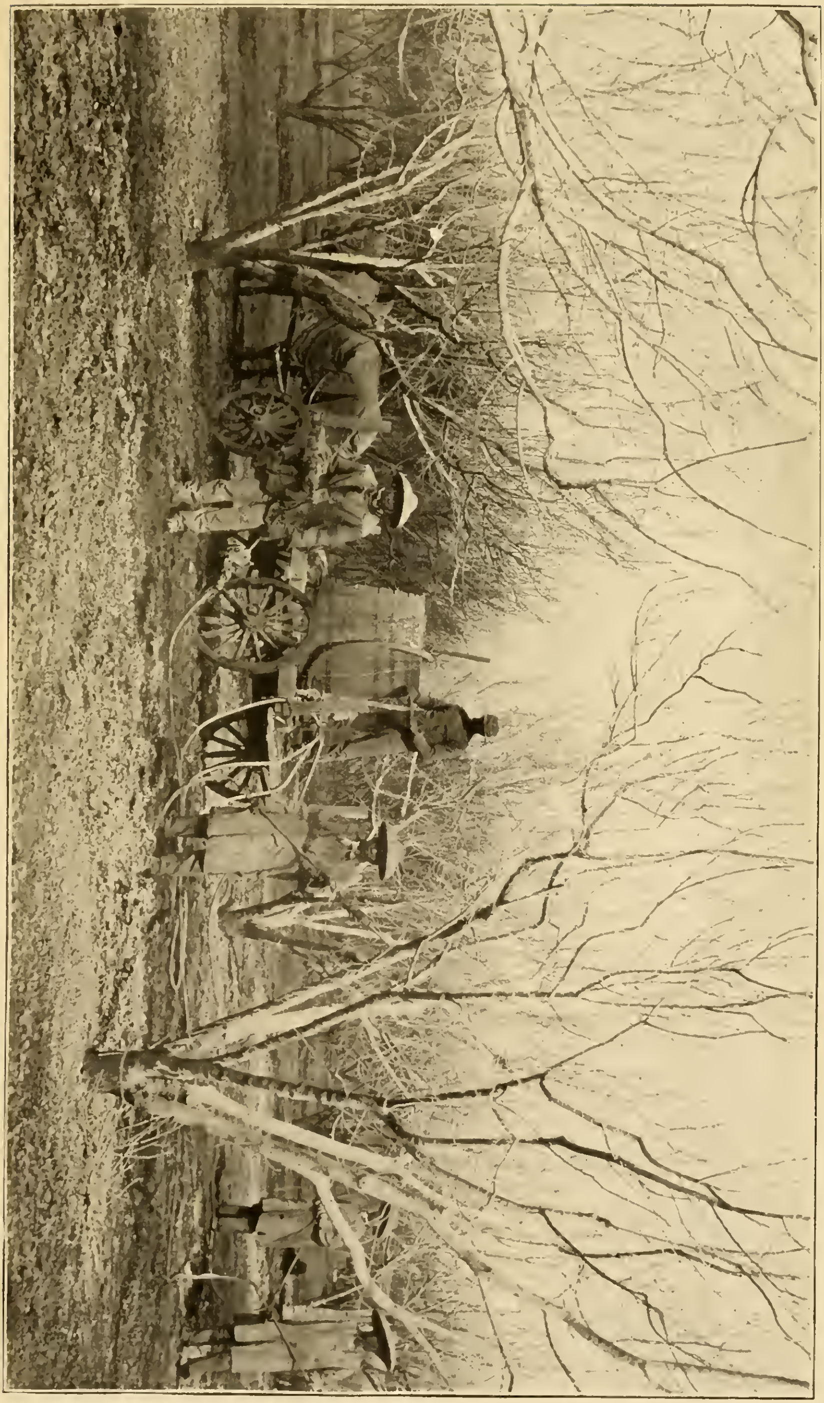
DESCRIPTION OF PLATE XXVI.

A suitable outfit for spraying small orchards. One horse, two men, and a boy spray two trees at a time. This scene represents the experimental spraying outfit used by the writer in the Rio Bonito orchard.

OUTFIT FOR SPRAYING SMALL ORCHARDS.

DESCRIPTION OF PLATE XXVII.

Spraying 4 trees at a time, with 5 men and 2 horses. There is here used a 300-gallon spray tank and long-lever (Gould), brass-lined piston pump, which has sufficient capacity to supply 4 nozzles, 1 man pumping. The horses are protected by means of gunny sack covers. The Chinese hats in use furnish good protection to the eyes and neck, but are too stiff for the most convenient work under limbs.

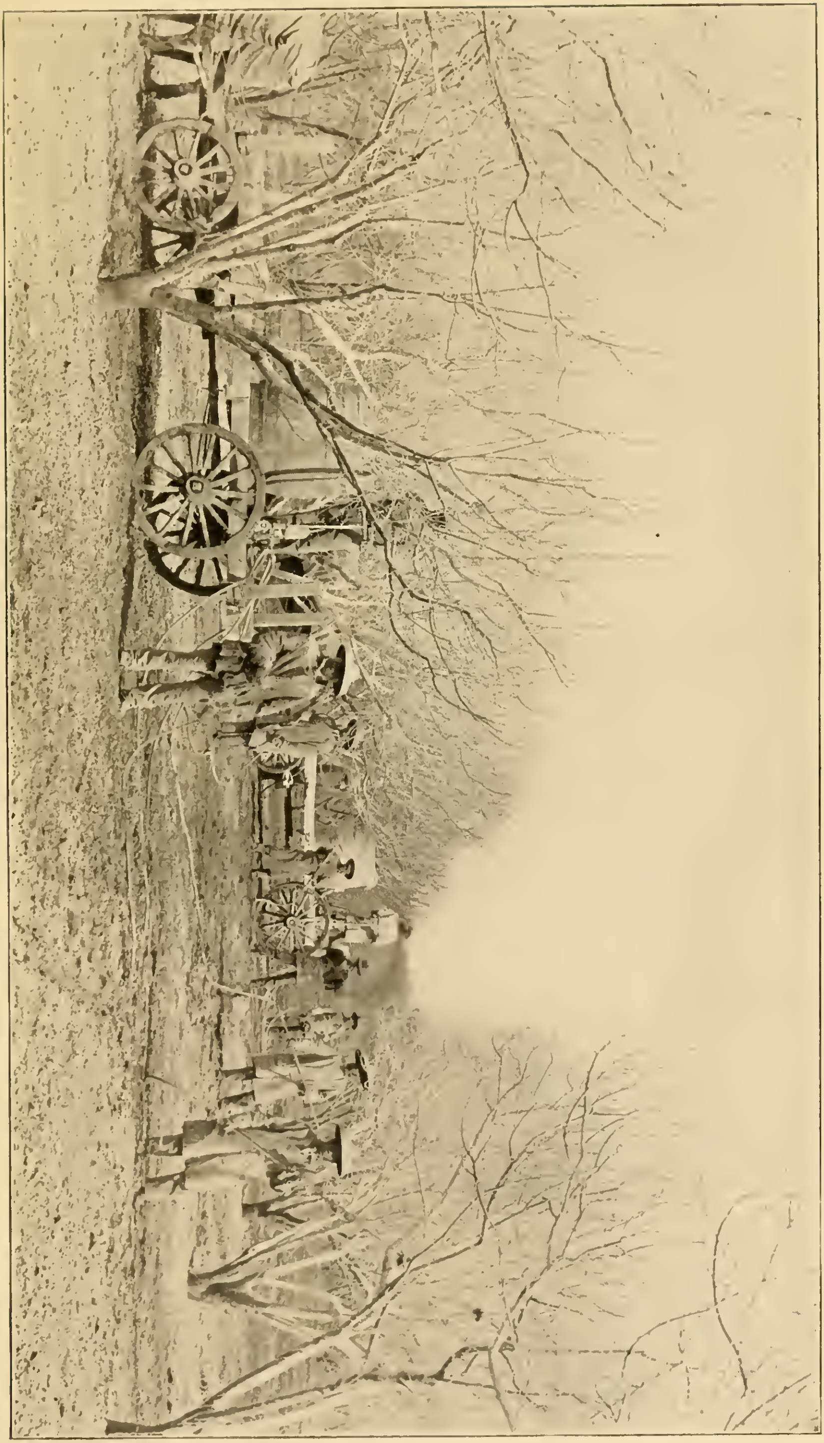


OUTFIT FOR SPRAYING MEDIUM-SIZED ORCHARDS.

Treating four trees at a time.

DESCRIPTION OF PLATE XXVIII.

Regular winter spray work in the Rio Bonito orchard. Eight trees are here being sprayed at one time, with 10 men and 4 horses. The trees being treated are well advanced, the buds being much swollen, although not yet open. If work is thoroughly done at this stage of bud development the results will commonly prove satisfactory; but an active spray should be used, such as the eau celeste, or Bordeaux mixture with a low percentage of lime and high percentage of copper sulphate. Such sprays should not be applied, however, after the opening of the blossoms. Earlier spraying is better, the chemicals in such cases doing less harm to the tree and having a longer time to reach all spores that endanger the new growth.



SPRAYING IN LARGE ORCHARDS.

Treating eight trees at a time.

DESCRIPTION OF PLATE XXIX.

A power sprayer in use in a young orchard at Santa Barbara, Cal. This sprayer was built by the Union Gas Engine Company, San Francisco.