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KALE YELLOWS IN CALIFORNIA, CAUSED BY FUSARIUM CONGLUTINANS WOLLENW.

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INTRODUCTION

Attention was called to the yellows disease of kale (*Brassica oleracea* var. *acephala* DC.) in the Petaluma district, Sonoma County, California, in 1927. A survey of the ranches in this district showed the disease to be widespread. The wide distribution and the severity of the disease showed conclusively that it had been present in the district for some time.

Petaluma is widely known as one of the largest poultry centers in the United States. The poultrymen depend almost entirely upon kale for green food for their chickens, using a large, smooth-leafed variety known as Jersey or Thousand Headed kale. The importance of kale as a crop in Sonoma County may be well understood from the fact that there are in the county approximately 4,000 chicken ranchers, of which 80 per cent depend upon kale for green food for their chickens. The average size of the kale plot on each ranch is approximately one acre; thus between 3,000 and 4,000 acres in the county are annually devoted to this crop. The majority of the ranchers have only a limited amount of land and must necessarily grow kale on the same land year after year. Once the disease is introduced into the soil, growing kale on the same land year after year only serves to increase the severity of the disease. Continuous cropping to kale has made the yellows disease so severe on many ranches that the growers have been forced into trying substitute crops for poultry greens. Through the practice

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of securing seedling plants that have been grown on infested soil from neighbors or others in the district, the disease is gradually being spread throughout the entire poultry-producing area. The increasing seriousness of the disease and the economic importance of kale in the district led to a study of the causal agent concerned.

HISTORY AND OCCURRENCE

Apparently the first report of kale yellows was that of Gardner[1] from Indiana in 1919. The same author again reported kale yellows, caused by *Fusarium conglutinans,* in 1921[2] as being very destructive in the Indianapolis market gardens, but did not state what variety of kale was affected. According to Jones, *et al.*,[7] Monteith observed the yellows disease on kale at Santa Rosa, California, in 1922. *Fusarium* yellows of kale, cabbage, and flowering stock was reported from California in 1924 by Smith,[11] but no information other than that of its occurrence was given. Walker[13] reported the yellows disease as being destructive to kale, collard, and kohl-rabi, but stated that cauliflower, broccoli, and brussels sprouts were, in the main, highly resistant. In a recent abstract the writer[8] reported on the seriousness of kale yellows in the Petaluma district, California, and considered the causal agent to be the same as that causing cabbage yellows, *Fusarium conglutinans.* Wollenw.

A similar disease on cabbage (*Brassica oleracea* var. *capitata* L.) was first reported by Smith[10] as occurring in New York state in 1895. He correctly considered the causal agent of the disease to be a soil *Fusarium* but did not conduct inoculation experiments nor name the organism involved. In 1913 Wollenweber[16] described and named the organism causing cabbage yellows as *Fusarium conglutinans.* Since the early report of cabbage yellows in New York state, many subsequent reports have shown the disease to be widely distributed over the United States. The yellows disease of cabbage is particularly severe in the cabbage-growing sections of Iowa and Wisconsin, where resistant types have been developed.[6, 7, 9]

In 1922, Gregory[4] reported the yellows disease caused by *Fusarium conglutinans* as being destructive to cabbage, cauliflower, kale, turnip, kohl-rabi, brussels sprouts, broccoli, and collard in Indiana. Gardner,[2] from the same state, reported the occurrence in 1921 of a yellows disease on turnips, caused by *F. conglutinans,* on land where cabbage yellows had previously occurred.

The yellows disease has not been observed by the writer in California except on kale in Sonoma County. No intensive survey has been made to determine the occurrence of the disease in other sections of the state, but many observations have failed to reveal the presence of the disease outside of the Petaluma district on any species of *Brassica*. Since the organism that causes the yellows disease is a relatively high-temperature parasite, its absence on *Brassica* in other sections of California probably results from the fact that these crops are grown mainly during the winter months, when the soil temperature is below that at which the disease will develop.

SYMPTOMS

Kale yellows, like cabbage yellows, is characterized by the progressive yellowing and dropping of the leaves, beginning with the lowest and continuing upward as the disease advances. Plants may be attacked in the seedling stage when grown in infested soil. If favorable temperature prevails, the disease manifests itself on seedling plants from two to four weeks after the seeds are sown. The first visible symptom of the disease on a young plant is a slight yellowing along the veins on one side of a leaf (fig. 1). The yellowing progresses rapidly until the entire side is yellow and a lateral or downward curling of the leaf results (fig. 1). Sometimes the yellowing involves the entire leaf, but it is more often confined to one side.

Not all plants are equally affected. In the seedling stage, some plants may show severe symptoms, as evidenced by a rapid yellowing and dropping of the leaves and a rather sudden dying of the entire plant. In other cases, severely diseased plants may lose all their leaves except the small leaves in the terminal bud (fig. 3). As these leaves unfold and start growing, they in turn become yellow and drop, while the plant continues to make a feeble growth. With the advent of higher temperatures, such plants usually die. Plants in a field may show all gradations of symptoms, from the very severe mentioned above to a very slight yellowing of the lower leaves on one side and a slight stunting of the plant.

More often the disease is confined to one side of the plant. As new leaves are formed on the diseased side, they turn yellow and drop off, while the leaves on the other side maintain their normal green color and make a moderate growth. When the disease is confined to one side of a young plant, there is often a dark brown sunken streak on the

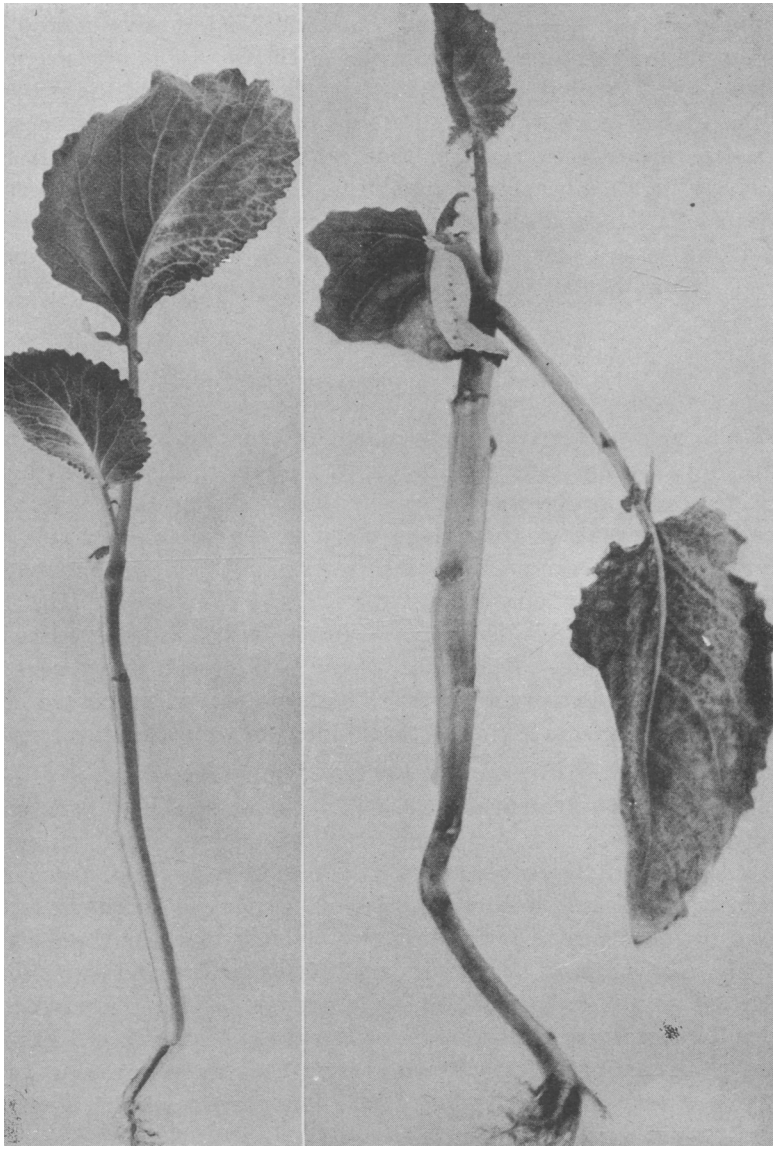

Fig. 1. Symptoms of kale yellows on young plants. The slight yellowing along the veins on one side of the upper leaf of the plant on the left and the lateral curling of the leaf are characteristic of the first symptom of the disease. The plant on the right shows the result of the dropping of the leaves in a more advanced stage of the disease; the yellowing and stunting of one side of the middle leaf and the normal green color on the other caused a downward curling of the leaf.

side of the main stem. The brown discoloration may extend into the leaves, which soon die and drop from the plant (fig. 2).

If the main stem of a diseased plant is cut across the base, a dark brown discoloration is plainly visible in the invaded vessels of the vascular system. Often one may diagnose the disease in the field by breaking off yellow leaves at the main stem and observing the dark brown diseased vascular bundles. A plant may, however, be diseased and show yellow leaves without showing vascular discoloration in the leaf petiole.

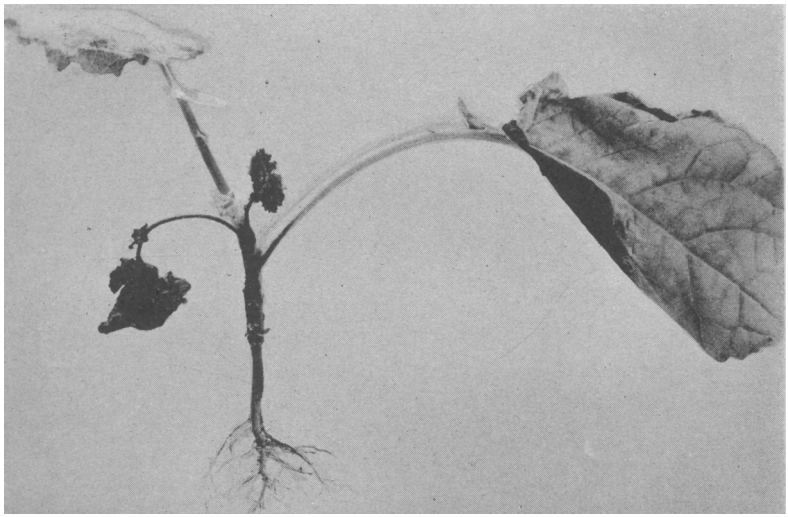

Fig. 2. Young Jersey kale plant one month after inoculation, showing the dark brown discoloration on one side of the stem, extending into the leaves.

The symptoms and development of kale yellows are dependent upon temperature. In Sonoma County the kale plants are started rather early, while the weather is still cool. The disease is not noticeably evident in the field until the advent of higher temperatures, usually in the latter part of June or the first of July. Until this time the diseased plants make fair growth because the causal organism is unable to thrive at relatively low temperatures. As soon as warmer weather occurs, the diseased plants show the characteristic yellowing and dropping of the leaves. In a few weeks, the more severely diseased plants die, and in many cases only one-third to one-half of the original plants remain. Many of the remaining plants continue to make a feeble growth until mid-summer or even later, but eventually succumb to the disease. Some of the less severely diseased plants continue

growth throughout the summer, but have a yellow, stunted appearance, and yield very little green feed for the rancher's chickens.

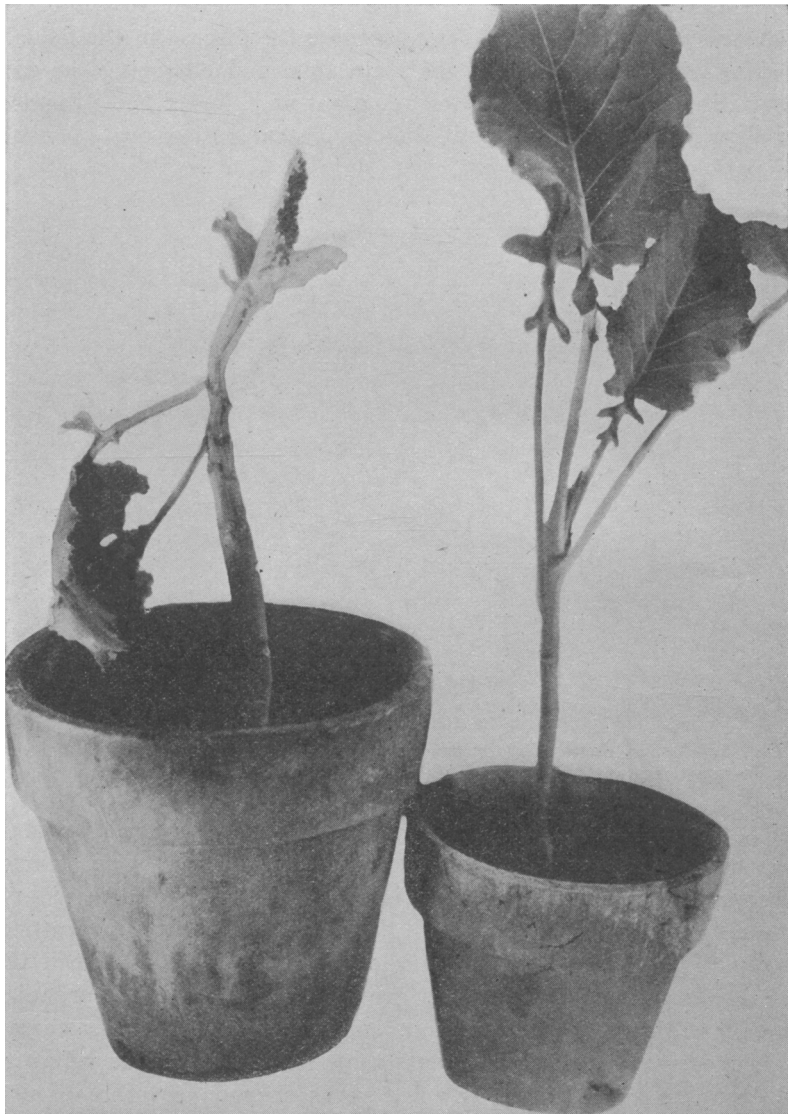

Fig. 3. Left, diseased Jersey kale plant resulting from artificial inoculation. The dropping leaves, leaf scars, light color of terminal leaves, and slight curvature of the stem are characteristic of the yellows disease, as compared with the normal growth and color of the control plant on the right.

CAUSAL ORGANISM

Kale yellows in California is caused by a soil fungus, *Fusarium conglutinans* Wollenw. Repeated isolations from the vascular tissues of diseased material have consistently given the same fungus. Although little doubt was entertained that the causal agent was the same as that causing cabbage yellows, cultural studies and inoculation tests were made to prove the identity of the organism.

Single-spore cultures of the fungus isolated from diseased kale plants were made and used in all cultural studies as well as inoculation trials. Two single-spore cultures of the kale organism and a culture of *Fusarium conglutinans* isolated from cabbage and furnished by Dr. J. C. Walker were carried in parallel series on the following culture media: potato hard agar (3 per cent agar agar) with 5 and 2 per cent dextrose respectively, potato agar (1½ per cent agar agar) with 5 and 2 per cent dextrose respectively, synthetic agar, oat agar, cornmeal agar, steamed rice, steamed potato plugs, string beans, and abutilon stems. Both poured-plate and tube-slant cultures of the various agar media were made.

All cultures were held for one month at room temperature (22°–25° C) and then examined for character of growth, color, and spore production. There was no appreciable difference in the macroscopic appearance of the different cultures on the same medium. Where color was present, as on steamed rice, it was pale salmon to pale ochraceous (Ridgway). In no case was an intense color produced.

Spore production was typical for the species on all media used. Sporodochia and pinnotes were absent. Non-septate hyaline conidia were produced in abundance on short conidiophores throughout the mycelial growth. Observations throughout the studies of this organism have shown that the non-septate conidia usually appear in abundance on cultures three to five days old on all media. One-septate and three-septate cylindrical hyaline conidia were sparingly produced. Terminal and intercallary, spherical to ovoid one-celled, sometimes two-celled, chlamydospores were produced in older cultures.

The comparative cultural studies of the *Fusarium* isolated from diseased kale in California and the *Fusarium* causing cabbage yellows in Wisconsin showed no appreciable differences in character of growth, color, spore production, and spore measurements. Pathogenicity

studies, which are given elsewhere in this paper, have also shown the kale organism to be similar to the cabbage yellows organism *Fusarium conglutinans* Wollenw. Since this organism has been previously described by Wollenweber[16] and later revised by Gilman,[3] a repetition of the published description will not be made here.

PATHOGENICITY STUDIES

Single-spore cultures of the *Fusarium* isolated from kale as well as from the culture of the cabbage yellows *Fusarium* sent by Dr. J. C. Walker were used for all inoculation tests. Inoculum was prepared by growing the fungus from six to ten days on poured plates of potato agar, then cutting agar and fungus growth into small shreds with a flamed scalpel and adding the shreds to flasks of sterile water. Plants were produced for inoculation trials by sowing seed in 4 to 6-inch pots of steam-sterilized soil. When the plants were 1 to 2 inches high, they were thinned to from 6 to 10 per pot. As soon as the plants started to produce true leaves, the soil around the plants was loosened with a scalpel, care being taken not to wound the plants, and the inoculum prepared in the way described above was poured around the base of the plants. The soil was then leveled around the plants again.

On December 12, 1927, 48 young Jersey kale plants in 4-inch pots were inoculated with four strains of the organism isolated from kale, 12 plants being used for each strain. The plants were held in a small greenhouse in which no heat was available. No signs of infection had become evident by February 1, 1928. During this period, the maximum temperature ranged from 48° to 55° F with the exception of two days when the maximum was slightly above 60° F. The mean temperature at Davis for the duration of the experiment was 44.2° F, which according to Gilman,[3] Tisdale,[12] and Melhus *et al.*[9] is below that at which the organism will cause infection.

Another series of inoculation experiments was started on February 23, 1928, three of the four cultures mentioned above being used. Fifteen young Jersey kale plants were inoculated with each strain, and 16 were held as controls. In twenty-one days from date of inoculation, typical symptoms of kale yellows were evident with each strain of the organism used. Eighteen of the 45 plants inoculated showed unmistakable evidence of yellows, and 15 subsequently died from the effects of the disease. During this period the mean temperature at Davis was 55° F. The highest temperature during the period of these

trials was 81° F, and the lowest was 32 °F. The average mean temperature during the period of the second series of inoculation experiments was approximately 10° F higher than during the time of the first inoculation experiment. The failure to secure infection in the first trials undoubtedly resulted from the low temperature prevailing at the time, as the second inoculations were an exact duplication of the first. In each of the series mentioned above, the organism was reisolated. The 16 control plants remained healthy until April 13, when they were destroyed.

In order to test the susceptibility of several different species of *Brassica* and to compare the organism isolated from kale with the organism isolated from cabbage (furnished by Dr. J. C. Walker), a series of inoculation trials was started December 21, 1928. Young plants growing in 4 and 6-inch pots of steam-sterilized soil were inoculated according to the method outlined above. The pots were held in a greenhouse in which the temperature fluctuated from 58° to 90° F. The extreme high temperature occurred only for short periods each day between the hours of 11 A.M. and 4 P.M. After 4 P.M. there was a sharp decline in the temperature curve until about 8 P.M., after which a fairly constant temperature of 62° to 65° F was maintained until about 8 A.M. The reason for the extreme fluctuation in temperature was the outside heat from the bright sunlight during the day.

Twenty days from date of inoculation, the first symptoms of the yellows disease were visible. The disease progressed rapidly in the infected plants, and by January 28 many were dead. The experiment was discontinued February 12. The results are presented in conjunction with a duplicate inoculation series in table 1.

The above experiment was duplicated in the greenhouse beginning February 12, 1929. The plants were grown in 4-inch pots of steam-sterilized soil, and the inoculum was prepared and applied as in the previous trials. The time of the appearance of yellows symptoms and the results did not differ appreciably from the first experiment. A recording thermometer in the greenhouse showed a temperature range approximately the same as that during the period of the experiment conducted December 21, 1928, to February 12, 1929. The second experiment was terminated March 28, and final records taken. Since the two trials did not show material differences, the results are combined and presented in table 1.

The results of inoculation trials presented in table 1 show that there is no significant difference in pathogenicity between the *Fusarium* causing kale yellows in California and the one causing cabbage yellows

in Wisconsin. The kale-yellows organism proved to be somewhat more virulent to Jersey kale, Danish Ballhead cabbage, brussels sprouts, and California Wonder cauliflower. There was, however, no difference in the symptoms (figs. 1 and 4) produced by the two organisms. It will be noted that Chinese cabbage proved to be resistant to the disease under the conditions of the trials reported herein. California Wonder cauliflower showed only slight susceptibility to the kale organism and resistance to the cabbage organism, while Early Snowball cauliflower

TABLE 1

SUSCEPTIBILITY OF SOME *Brassica oleracea* SUBSPECIES TO THE YELLOWS DISEASE AND COMPARATIVE INOCULATION TRIALS WITH STRAINS OF FUSARIUM ISOLATED FROM KALE YELLOWS IN CALIFORNIA AND CABBAGE YELLOWS IN WISCONSIN

Variety and subspecies	Fusarium from kale yellows		Fusarium from cabbage yellows		Controls	
	Number of plants inoculated	Percentage of plants diseased	Number of plants inoculated	Percentage of plants diseased	Number of plants	Percentage of plants diseased
Jersey or Thousand Headed kale	93	40.9	82	28.0	57	0
Dwarf Scotch Curled kale	66	27.3	56	26.8	52	0
Danish Ballhead cabbage	66	37.8	54	25.9	52	0
Early Winnigstadt cabbage	12	33.0	13	30.7	13	0
Mammoth Red Rock cabbage	60	20.0	52	23.0	48	0
Wong Bok Chinese cabbage	56	0	38	0	39	0
California Wonder cauliflower	30	6.6	30	0	22	0
Early Snowball cauliflower	25	0	10	0	17	0
Dwarf Perfection Brussels sprouts	59	8.5	45	4.4	43	0

was not attacked by either organism. Brussels sprouts showed only slight susceptibility to each organism. The results obtained with cauliflower and brussels sprouts are in accord with the findings of Walker and Wellman[15] in that these two subspecies of *Brassica* are distinctly more resistant than most varieties of cabbage. There was only slight manifestation of yellows symptoms in all cases of successful inoculations with cauliflower and Brussels sprouts, while many cabbage and kale plants died soon after showing the disease. Controls in all cases remained healthy throughout the experiments.

The comparatively low percentage of disease even in kale and cabbage no doubt resulted from the relatively low temperature prevailing throughout most of the day. The failure to produce infection in some cases with cauliflower and with Chinese cabbage might possibly have been the result of the low temperature prevailing during the trials.

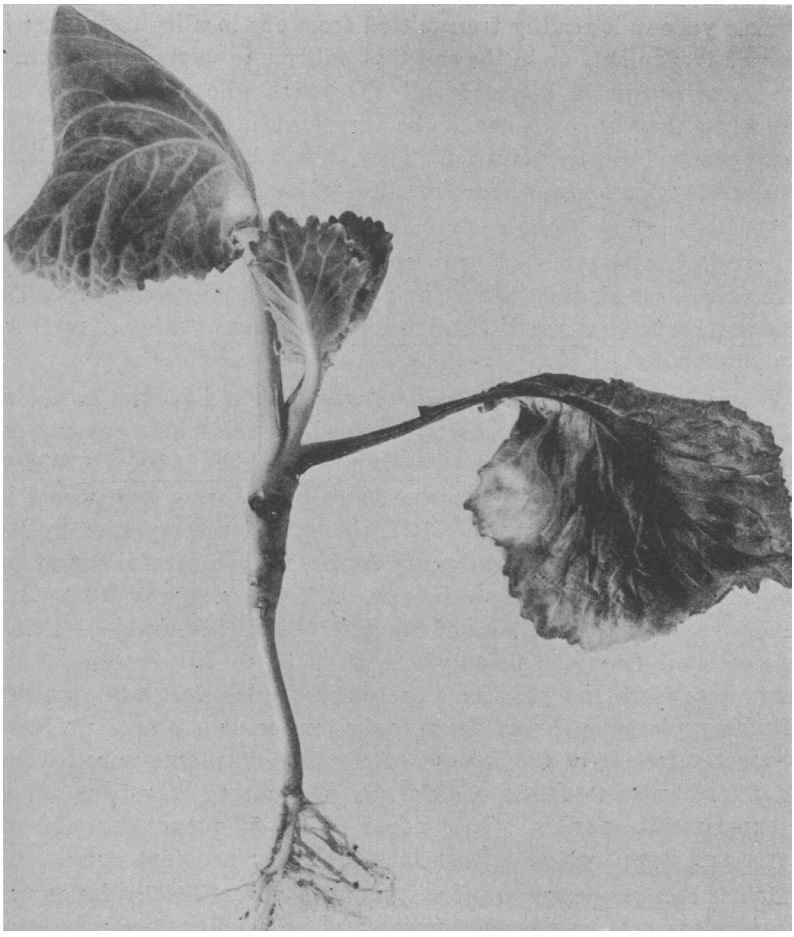

Fig. 4. Young Danish Ballhead cabbage plant showing the yellows disease resulting from artificial inoculation with *Fusarium* isolated from kale yellows. The one-sided effect of the disease is evident from the darkened leaf scars and the wilted leaf on the right, which is partially abscised from the stem.

CONTROL

Kale yellows is readily transmitted from one locality to another in diseased transplants or in the soil that adheres to young plants which have been grown in diseased soil. Growers who do not have the disease on their ranches should be very careful about the source of young plants for transplanting. They should be sure that the plants have been grown on land free from the yellows disease.

Earlier work by Jones and Gilman,[5] and Melhus, Erwin, and Van Haltern[9] has shown that crop rotation and soil treatment are of little value as control measures for a similar disease on cabbage. The same authors have succeeded in developing strains of cabbage resistant to a similar disease.

Since the kale growers in the Petaluma district have not succeeded in finding a suitable substitute green food for their chickens and are reluctant to give up their attempts at growing kale, it became evident that the development of a resistant strain of Jersey kale would be very desirable. In the fall of 1927, the writer, accompanied by Mr. Herbert von Lehe, Assistant County Agent, made a careful survey for kale yellows in the Petaluma district. After this survey, 10 healthy plants were selected from each of five different chicken ranches. Plants were selected from the fields where from 50 to 75 per cent of the plants were dead from yellows. Care was taken to select large, healthy-appearing plants in areas where only one or two plants remained apparently free from the disease. A total of 50 plants were selected and transported to Davis, California, where they were put out in an experimental garden. Thirty-four of the 50 plants survived the winter and were used as a basis for developing resistant strains.

It has been necessary to infest land at Davis artificially for experimental plots. A considerable number of selfed lines are now being grown on diseased soil, some of which show evidence of resistance. Although progress has been made in eliminating susceptible strains, the work has not progressed to the point where it is deemed advisable to distribute seed of those strains that show evidence of resistance. This phase of the work will be reported in detail in a later publication.

SUMMARY

The extensive plantings of Jersey or Thousand Headed kale in the Petaluma district, Sonoma County, California, are seriously affected each year by a disease known as yellows. About 80 per cent of the approximately 4,000 chicken ranchers in the county use kale for poultry greens. The disease is widespread in the district, and many poultrymen are being forced to find a substitute crop for green feed for their chickens.

A similar disease of cabbage is widely distributed over the United States. The disease has not been observed elsewhere in California, either on kale or on other species of *Brassica.*

The disease usually attacks the plants in the seedling stage, causing characteristic yellowing and dropping of the leaves from the ground upward. Often the disease is confined to one side of the plant. Many of the affected plants soon die if high temperatures prevail. If relatively low temperatures prevail, the diseased plants may continue to make a weak growth but they will show a sickly yellow, stunted appearance.

Not all plants are equally affected. Some plants are only slightly or moderately diseased and may make a feeble or stunted growth throughout the summer.

Kale yellows is caused by a parasitic fungus. Morphological and pathogenicity studies have shown that kale yellows in California is caused by the same fungus, *Fusarium conglutinans* Wollenw., that causes a similar disease on cabbage in other parts of the United States.

The causal fungus is a soil-borne parasite. The disease is largely spread to new localities by infected transplants. Care should be exercised against bringing the disease into uninfested soil on seedling plants.

The development of resistant strains is the most promising method of control where the soil has once become infested. At present, no resistant strains are available, but the development of such strains is now under way at this experiment station.

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The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

1. The Removal of Sodium Carbonate from Soils, by Walter P. Kelley and Edward E. Thomas. January, 1923.

4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.

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

6. A Study of Deciduous Fruit Tree Rootstocks with Special Reference to Their Identification, by Myer J. Heppner. June, 1923.

7. A Study of the Darkening of Apple Tissue, by E. L. Overholser and W. V. Cruess. June, 1923.

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9. Experiments on the Reclamation of Alkali Soils by Leaching with Water and Gypsum, by P. L. Hibbard. August, 1923.

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11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.

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14. The Respiration of Potato Tubers in Relation to the Occurrence of Blackheart, by J. P. Bennett and E. T. Bartholomew. January, 1924.

15. Replaceable Bases in Soils, by Walter P. Kelley and S. Melvin Brown. February, 1924.

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17. Nutrient and Toxic Effects of Certain Ions on Citrus and Walnut Trees with Especial Reference to the Concentration and Ph of the Medium, by H. S. Reed and A. R. C. Haas. October, 1924.

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