BOTRYTIS ROT OF THE GLOBE ARTICHOKE [1]

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INTRODUCTION

Gray mold rot causes heavy losses in practically all truck-crop shipments made during the cooler months of the year, especially from California. Cross-inoculation experiments have indicated that the strains of *Botrytis* sp. affecting the Globe artichoke (*Cynara scolymus* L.) are pathogenic to those vegetables subject to decay from the Botrytis usually called *B. cinerea* Pers.

In their survey of plant diseases as they occur on the market, Link and Gardner [2] reported gray mold rot (*Botrytis* spp.) as the only disease affecting the buds of the Globe artichoke in transit and on the market.

The disease has been observed in the United States wherever artichokes have been examined. Practically all the artichokes marketed in this country are grown in Contra Costa and San Mateo Counties, Calif., mostly on the rich loams and clay loams of the narrow strip along the seashore from Montara to Pescadero; some are grown also in the canyons extending from the seashore into the mountains. The buds are shipped in refrigerator, freight, and express cars to eastern markets, 50 per cent of the total shipments going in 1922 to New York.

The economic importance of the Botrytis rot of the artichoke is suggested by abstracts which the plant disease survey made of inspection certificates issued by the food products inspection service of the Bureau of Agricultural Economics. Although the inspection service does not examine all cars arriving terminal in markets, the abstracts of inspections made show the artichoke to be affected by only one rot, which is practically the only cause of loss in transit. Ninety-six per cent of the car-lot inspections made during 1918 to 1923 report losses of 2 to 100 per cent due to Botrytis, the remainder being due to freezing. About 10 per cent of the inspections show losses of 50 per cent and over; 20 per cent show loses of 20 per cent and over; 70 per cent show losses of less than 20 per cent. These losses are considerable since the market price of a car (470 to 480 boxes) is $1,800 to $2,500, depending upon market conditions, with a freight and icing charge of about $375 from California to Chicago. The presence of even slight decay necessitates expensive resorting and considerable loss to wholesalers and retailers. Severely affected buds are a total loss, although slightly affected ones can be sold at a reduced price.

Inquiries from receivers, carriers, and food products inspectors of the Bureau of Agricultural Economics in 1919 to 1922 have shown a prevalent supposition that the serious losses on artichoke shipments were mainly attributable to freezing injury and chilling. There were consequent mutual recriminations among growers, shippers, carriers, and receivers, each believing some other responsible for the occurrence of such injury. None had realized that the great losses in transit might be connected with the presence in the field of a certain fungus.

Reduction of such wastage and loss in transit, with fixing of the responsibility for these, calls for definite knowledge concerning the source and mode of contamination, the time, place, and manner of infection, and the development and spread of the disease. As there were no experimental data adequate for formulating control measures and placing responsibility for losses in vegetables from this source, the artichoke was chosen for investigation of the disease, on account of certain advantages which it affords for type

[1] Received for publication Feb. 28, 1924—issued January, 1925. Paper from the Cooperative Laboratory for the Investigation of Market and Transit Diseases of Vegetables and Fruits, the U. S. Department of Agriculture and the University of Chicago cooperating.

[2] Link, G. K. K., and Gardner, M. W. market pathology and market diseases of vegetables. Phytopathology 9: 497-520. 1919.

Link, G. K. K., Ramsey, G. B., and Bailey, A. A. botrytis rot of the globe artichoke (cynara scolymus l.). (Abstract.) Phytopathology 13: 58. 1923.

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study, even though this product is less important than the majority of crops affected by the fungus.

The work discussed in the present paper leads to the conclusion that, without previous or attendant freezing injury, a species of Botrytis, to be placed in the *cinerea* group, can produce the condition responsible for the deterioration and consequent losses in transit.

DESCRIPTION OF THE DISEASE

The lesions which indicate the disease are so small and inconspicuous that they are often overlooked in harvesting and packing, the more so since they vary with external conditions.

In the field the lesions are usually but 1 to 2 mm. in diameter on actively growing buds of vigorous plants, and are generally restricted to the tips of the scales. They are sunken and brown to black. Sometimes buds severely affected by Botrytis are found on aging plants, or on vigorous plants after the close of the active period of bud production (October to May). These usually shrivel and wither, and are covered with sporulating mycelium.

Extensive lesions of the moist type can be seen on vigorous plants in the field. They usually start in the wounds made when the buds are cut, whence they progress down the flower stalks and spread to the lateral branches and even to the main stems of the plants.

The lesions may occur anywhere on the bud. Spore infection seems most frequent on the cut stem and at the tips of the scales which are generally somewhat split by growth tensions. Contact with the mycelium leads to infection of any part; under moist conditions the spider weblike growth of the mycelium starting from one original center of infection frequently involves the entire bud, the rot progressing from scale tip to scale tip and down into the scale so that finally the entire bud is destroyed (pl. 1, A, B). Infection at the base of the scales or in the stem may destroy the entire stem and receptacle so that the bud readily falls apart (pl. 1, B). Under dry conditions, an affected bud then becomes a shriveled mummy.

Under moist conditions the lesions on the buds have definite slightly water-soaked borders, semimoist to wet, odorless, reddish-brown to brown, and generally with abundant growth of sporulating mycelium on their older portions. Under drier conditions the advancing edge is not water-soaked, the affected tissues are dry and firm, brown to black, and show no aerial development.

THE CAUSAL ORGANISM

ITS ISOLATION AND IDENTITY

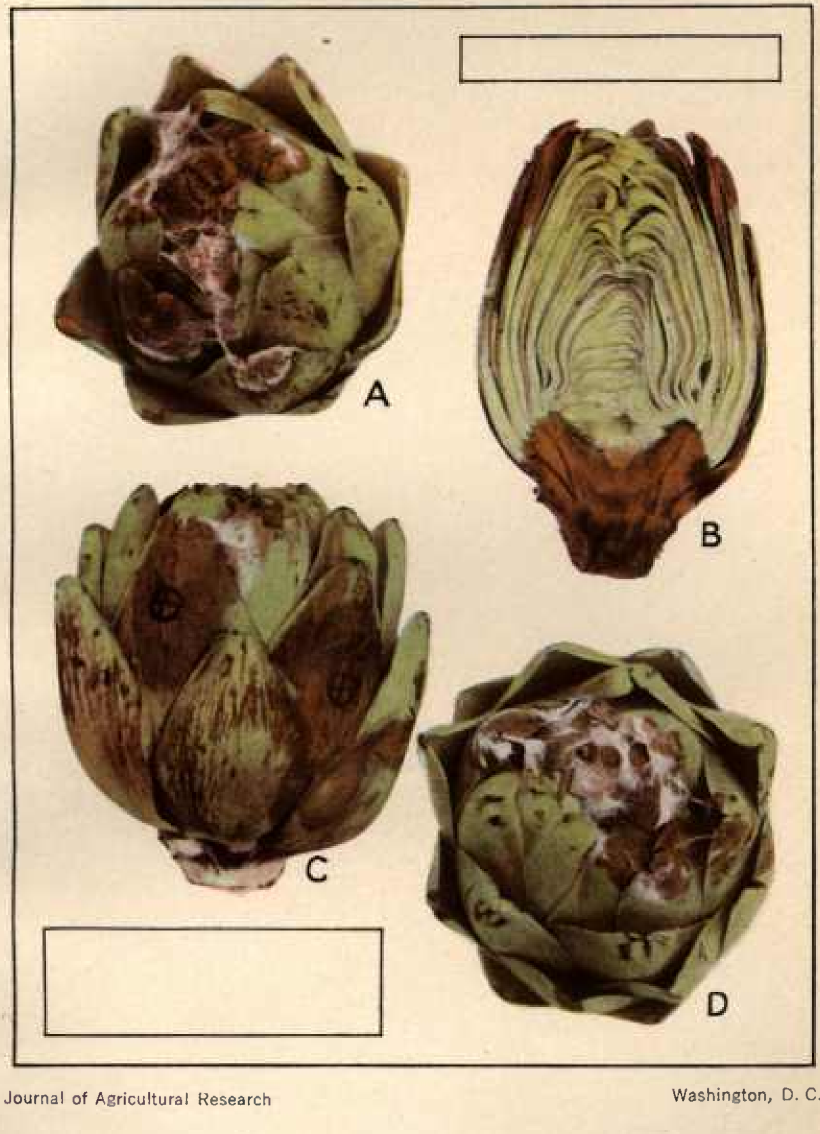
Isolations of *Botrytis* sp. made from the flower buds of artichokes collected on the Chicago market, and from the stalks, stems and buds collected in the fields near Half Moon Bay, Calif., furnished the cultures used in the present study. A lot shipped from the fields was of particular interest because the entire plants including flower buds were frozen solid during transit. Viable cultures apparently identical with strains collected on the market were isolated from this material. One strain isolated from the interior of a frozen stem showing a brown surface lesion has maintained characteristics seeming to indicate a difference from all other cultures. On first isolation plates this culture, No. 255, grew more like a Fusarium than a Botrytis; but after one week's growth sclerotia began to develop and conidia were observed around the edges of the plate. The cultures of this strain always produce a honey-yellow[3] color in the substratum and fine ivory-yellow mycelium on potato-dextrose agar plates, as contrasted with the smoke-gray to light grayish-olive mycelium and grayish-olive substratum of the other strains. The gray strains also make greater vegetative growth and sporulate much more freely and abundantly than the yellowish strain.

Morphologically, there do not seem to be great differences among the cultures under observation. The mycelium is pale smoke-colored at first,

[3] RIDGWAY, R. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., illus. Washington, D. C. 1912.

EXPLANATORY LEGEND FOR PLATE 1

A. Artichoke held in a humid atmosphere, showing lesions and spider weblike growth of Botrytis mycelium over the surface.
B.—Longitudinal section through bud showing stem and receptacle infection.
C.—Artichoke showing points of inoculation and lesions resulting therefrom. Mycelium was inoculated into wounds whose position is indicated by circles. Dark discolored areas show limits of fungus advance. The blotched discoloration on lower two scales is due to bruising.
D.—Lesions and mycelium on split and wounded tips of scales resulting from inoculation with a spore suspension.


A
B
C
D

becoming gray to grayish-brown with age. Conidia are produced in rather loose clusters on the rounded to slightly inflated ends of the tips and lateral branches of the upright sporophores. In old cultures sclerotia are present, which on germination give rise either to vegetative mycelium or to short, rather compact tufts of conidiophores with grayish-brown conidia.

With the possible exception of culture No. 255, whose spores are usually slightly smaller than those of the others, there is very little variation in size of the conidia of the various cultures. In the seven cultures used in most of the studies, the spores ranged from 8.2 to 10.5μ in width and from 11.3 to 14.4μ in length, averaging 9.4 by 13.1μ.

The growth characteristics and spore measurements of these fungi are well within the range and description of the fungus usually designated *B. cinerea* Pers. In view of the existing confusion regarding species within the genus Botrytis, it has been thought best to refer to the organism or organisms under consideration as the *B. cinerea* type, since, as stated in the beginning of this article, practically all Botrytis strains occurring on vegetables are identical and can be grouped as the *B. cinerea* type (with the possible exception of culture No. 255).

TEMPERATURE RELATIONS

In temperature experiments on plates and tubes of potato-dextrose agar, it was found that one culture, No. 1610, just isolated from an artichoke bud, was able to make radial growth ranging from 1 to 7 mm. within seven days at −2° C. None of the other strains which had been cultured on artificial media for some time were able to grow under the above conditions, although in other respects the strains appear very similar. This suggests that a difference in pathogenicity may be expected in cultures, due to loss of vigor in growing on artificial media. All other strains grew from 0.5 to 2 mm. in radius at −1.5° to −1° in seven days. During the seven-day period at 0° these strains grew 7 to 14 mm. in radius while the newly isolated strain No. 1610 under parallel conditions grew but slightly faster. At higher temperatures growth becomes more rapid until at 20° to 22° an average daily radial growth of 5 to 7 mm. is made. From experiments conducted at still higher temperatures it appears that the optimum for growth on potato-dextrose agar lies between 22° and 25°. These observations agree well with the results of Brooks and Cooley [4] for *B. cinerea.*

The reactions to temperatures above 31° are approximately alike for the various strains in plate cultures. Usually very little growth is made. An increase of 1 to 2 mm. observed in some cases was mostly a very fine aerial mycelium arising from the inoculum. A few sporophores bearing conidia were also noted developing from the inoculum of one strain. But their vitality is so reduced at the above temperature that the organisms are not likely to produce appreciable decay.

SPORE GERMINATION

The spores of all strains germinate readily in hanging drops of sterile water and on the surface of nutrient agar plates. The majority germinate within 24 hours at room temperature and above, while a smaller percentage form germ tubes at temperatures around 0° C. The extreme range is wide, as successful germination has been obtained at temperatures as low as −2° and as high as 32° C.

An experiment in which the temperatures ranged between −2° C. and −1.5° with a mean of −1.75° showed good germination in the three strains tested. In a similar experiment in which spore dilutions of four different strains were poured upon plates of potato dextrose agar and placed where the temperature varied between −1° and −3°, good germination was obtained within 48 hours. From 50 to 75 per cent of these spores germinated, and their germ tubes ranged from 20 to 90μ in length. It appears from these and other tests that mature conidia falling upon a suitable nutrient medium can germinate and make slow growth at temperatures below 0°. In sterile water at the above temperatures, however, germination seldom occurs, or is at most rather feeble compared with growth on a nutrient medium.

Spore dilutions on potato-dextrose agar plates held at 31° to 32° C. give 50 to 90 per cent germination within 24 hours. Growth of the germ tubes continues 4 or 5 days, then usually stops when they reach 100 to 200μ in length. This would seem to indicate a temperature of 32° as the maximum for growth from conidia in the strains under observation.

[4] BROOKS, C., AND COOLEY, J. S. TEMPERATURE RELATIONS OF APPLE ROT FUNGI. Jour. Agr. Research 8: 139-163, illus. 1917.

PROOF OF PATHOGENICITY

The pathogenicity of the organism was established by its constant association with and isolation from lesions and by numerous inoculation tests made with artichoke and other vegetables.

Vigorous fresh-appearing buds, free from blemishes, were used. They were prepared for the test by making a fresh cut of the stem; by thorough washing; by dipping into 1:1,000 mercuric chloride solution for about a minute followed by thorough rinsing in sterile water. Longer immersion in corrosive sublimate solution was found to cause discoloration of the tender scales. Preliminary experiments and the controls proved the method adequate to remove or kill any spores on the buds.

To duplicate the method of inoculation which seems to occur naturally, both spores and mixtures of spores and mycelium were used as inocula. The spores were suspended in water and the suspension either poured or sprayed on the buds. These methods, especially the latter, approached as nearly as possible to the manner of inoculation in the field. Mycelium inoculation was made by inserting agar inoculum, or infected scales which generally had some mycelium on their surfaces, between the scales of sound buds. This duplicated the mode of inoculation involved when the disease spreads in transit. After inoculation the buds were kept in moist chambers or covered battery jars.

Inoculation experiments with infected scales demonstrated that the fungus can produce decay throughout its temperature range. As the buds freeze at −2° C., no tests were made below this temperature. None of the cultures which had been grown on agar for some time produced appreciable decay at −2°, whereas strain No. 1610, recently isolated from artichokes, produced decay. Four scales of a bud inoculated with this strain became infected to the extent of 6 sq. cm. after a week. The presence of the fungus in the advancing edge of the lesions was proved by microscopic examination and plate cultures. At −1° all strains produced decay. The percentage of successful inoculations increases steadily up to the optimum temperature of 22° to 25° C. Failures were infrequent at this temperature but increased rapidly above 24°; occurred in about 85 per cent of the attempts at 26°; and lesions were obtained but rarely between 26° and 32°.

Although infection was more consistently and rapidly obtained through wounds when mycelium was used as inoculum, the experimental evidence shows that wounds are not a necessity. The inoculum was applied at the tips, the middle, and the bases of the scales, as well as at the cut surface of the stem, and consisted of mycelium taken from agar plates (Pl. 1, C). Similar results were obtained by using infected scales as inoculum. Seventeen tests at 0° C. gave 12 lesions on wounded buds and 2 on unwounded buds. Fifty-one tests at 7° gave 46 lesions on wounded buds and 43 on unwounded buds. Fifty-one tests at 22° gave 48 lesions on wounded buds, also 48 on unwounded buds. Eight tests at 30° gave five lesions on wounded buds, none on unwounded buds. It was difficult to keep the humidity high enough to produce infection at the higher temperatures. Unfortunately, no apparatus was available for making controlled humidity tests.

Except at very low temperatures, inoculation and infection by contact seem limited much more by moisture than by temperature or by the presence of wounds. With adequate moisture, infection took place and was quite independent of wounds, except at very low temperatures. A saturated or nearly saturated atmosphere induces very rank development of mycelium, which, however, as in plate cultures, seldom sporulates unless subjected to a change in humidity. It was necessary to wrap each bud in waxed paper for keeping in moist chambers in the laboratory, in high-temperature incubators, or in incubators cooled by mechanical means which freeze out the air moisture. In low-temperature incubators, cooled by melting ice, wrapping was not necessary.

Experiments with spore suspensions gave negative results except on wounded tissue. Moisture was again a limiting factor, but even more decisively. In early experiments no infection was obtained at any temperature with spore suspensions sprayed or poured on wounded or unwounded scales. Wrapping was entirely inadequate when spore suspensions were used, but the difficulty was finally solved by fogging the chambers containing the buds once every 24 hours during the first three or four days. This was done by spraying water into the chambers with an atomizer. It was a very unsatisfactory method because there was no way of determining just what degree of humidity is essential for spore inoculation; but it duplicated field conditions in that the air was saturated and water was condensed on the buds at least once a day.

In inoculation tests with spore suspensions made with wounded and unwounded buds at temperatures ranging from −1° C. to 26°, negative results were obtained at −1°, 0°, 0.5°, and 1.5°. Infection resulted occasionally at 5.5°, but only in wounds. The number of infections obtained was greater at 7° than at 5.5°, and still greater at 10°, with a maximum between 15° and 21°. Between 26° and 32° infection was obtained only occasionally. All infection obtained started in artificial or natural wounds (Pl. 1 D). Scales which had been wounded and dipped in spore suspensions developed lesions of 2 to 5 sq. cm. with sporulating mycelium on the surface in nine days at 26°.

The presence or absence of wounds seems, therefore, the most important limiting factor so far as infection by spores is concerned, with moisture, and then temperature next in importance. For infection by mycelium, however, moisture is the main limiting factor, temperature and wounds ranking in the order named.

Infection with spores was not obtainable when the tissues were not wounded. Wounds are abundant and inevitable, however, on both the growing and the harvested buds. There is more or less tearing of the scale tips during growth, for they are curved inward and indented (Pl. 1, A, D) so that tensions arise at the spine and lead to tearing as the scales enlarge. A large wound is made when the bud is cut from the plant in harvesting (Pl. 1, B), and later when buds are crowded into crates for a tight pack there is more tearing of the scales and considerable bruising of the sides as well.

Holding tests made at 7° C. show that the buds of a lot which appear sound at the beginning of a test develop Botrytis decay progressively, and eventually almost all show decay. Possibly this is due to a weakening of the tissues. It is a general observation in the field that *Botrytis* readily attacks aging or weakened parts of plants, such as the outer dying leaves of lettuce or celery. Field observations indicate that the age or vigor of artichoke buds is a factor, inasmuch as the small buds produced at the close of the seasonal productive period or by old plants show greater decay than buds from more vigorous plants, some inspection certificates reporting 4 to 10 per cent decay in large buds and 20 to 30 per cent in small ones. It has also been observed that tissues killed or weakened by overheating or freezing are more readily attacked than healthy ones.

THE DISEASE

PLACE OF ORIGIN, SPREAD, AND DEVELOPMENT

Observations in packing houses indicate that even though some buds with small lesions are packed, by far the greatest number of boxes contain few buds showing any signs of lesions or of the fungus. Field observations indicate that spore contamination in the field is probably the original and chief source of the disease in transit. Here can be found buds and other parts of the plants covered with sporulating mycelium. A much more serious source of infection, however, is the immense amount of plant trash allowed to lie in or adjacent to the fields, which is often covered with an extensive sporulating growth of Botrytis that liberates clouds of spores whenever disturbed. The great quantities of plant trash exist because the bearing plants, which resemble huge thistles, are cut down annually in May and their roots allowed to sprout or sucker. The new tops come into bearing during September and October, and in the fourth or fifth year, when buds begin to be small and hard, the plants are replaced by new shoots.

Examination upon arrival of buds taken out of boxes not previously opened shows that the lesions usually start at the tips of the scales or at the cut stem surface. This indicates that the original infections come from spores that lodge in these places and that secondary infections in transit are primarily by contact. Secondary infection by spores also may take place, since infected scales frequently are covered with sporulating mycelium.

That the bud surfaces carry either spores or mycelium of Botrytis is easily demonstrated by taking buds from packing boxes and exposing them to favorable temperature and moisture conditions. Botrytis rot develops almost invariably. In fact, if the buds were not washed and sterilized, it seemed impossible to have control material come through the experiments, which lasted from several days to several weeks, without developing Botrytis rot. That the contaminations were mostly on the surface is proved by the fact that a few minutes' dipping in corrosive sublimate solution sufficed for sterilization. Thorough washing was also frequently sufficient. Yet occasional development of decay in buds so treated proved that incipient but invisible infections were also present.

It was found that spores or incipient infections may lie dormant for considerable periods if conditions are unfavorable, and then begin or resume growth when conditions become favorable. That transit gives ample time for the development of lesions already present and the starting of new ones is indicated by the following data: At 7° C. lesions with a radius of 0.5 to 2 mm. developed in 7 days when wounds were inoculated. Scales inoculated with spore suspensions at 25° developed lesions which had an area of 2 to 5 sq. mm. on the ninth day and were covered with sporulating mycelium. Lesions increased in radius at 10° at the rate of 1.5 mm. every 24 hours; at 15 to 20°, at the rate of 4 to 5 mm.; at 27°, at the rate of only 2 mm.; and at 30° there was no increase. The maintenance of an average temperature of 7° is very good for a refrigerator car. Thus temperature conditions in transit are not unfavorable for the development and spread of the decay.

RELATION TO TEMPERATURE IN THE FIELD AND IN TRANSIT

The optimum temperature for growth of Botrytis lies between 22° and 25° C. The range from this to the maximum of 32° is only 7°, whereas the range to the minimum extends beyond −2°, or more than 27°. Unlike many other fungi, this fungus can make a very appreciable growth and sporulate between 5° and 10°.

The temperatures of the leading artichoke-producing section in California are not unfavorable for the growth of the fungus. The nearest weather reporting station where weather is comparable to that of the Half Moon Bay section is San Francisco, Calif. Here the temperature rarely exceeds the maximum for *Botrytis cinerea* Pers.; the lowest temperature is above its minimum and the mean is below rather than above its optimum.[5] At the annual mean temperature of the region (54.9 °F.), the fungus can enlarge lesions on inoculated buds at the rate of about 4 to 5 mm. per day under favorable moisture conditions.

Abstracts of food products inspection certificates show that the amount and severity of the decay of artichoke buds in transit vary with the temperature. Almost always the decay is heaviest in the two upper layers of car-lot shipments, and in these it is most severe at or near the doors. The following are typical reports: "Ten per cent decay in fourth and fifth layers; none in lower three"; or "Decay in two top layers, 40 to 60 per cent; in lower two, 2 per cent," or "Practically no decay in boxes near bunkers; 30 to 50 per cent in boxes at doors" and "Two top layers, all buds decayed; two bottom layers, slight decay." The direct temperature relation is shown by the temperature report for the last abovementioned car, in which the temperature of the artichokes was 21° C. at the top of the load in the door, 11° at the bunker, and 4.5° at the bottom of the load at the bunkers.

RELATION TO MOISTURE IN THE FIELD AND IN TRANSIT

The experiments show that while moisture ranks second to wounds as a limiting factor for infection by Botrytis spores, it ranks first as a limiting factor for mycelial growth and infection by mycelium. For sporulation, however, changes in humidity are more important than continuous humidity.

Botrytis rot is generally reported as serious in sections having abundance of foggy weather or in other sections during foggy seasons. Since few regions offer such consistently favorable conditions as the Pacific coast, this probably accounts for the prevalence of Botrytis rot in vegetable shipments from California. The artichoke sections of California lie within the coastal belt of California where fogs are a daily occurrence, so characteristic that the cooperative growers association markets its best brand of artichokes under the trade name "Fog-Kist." During the growing season fogs drift in from the sea every afternoon and are not dissipated until late the next morning, so that vegetation is thoroughly wetted at least once daily.[6]

The artichoke buds are packed in paper-lined boxes which are generally loaded into iced cars. In the early part of the season buds are packed in iced drums. It was found that condensation of water frequently takes place in the buds when the boxes are first placed in the iced cars and that often the buds are moist when they are unloaded in receiving markets. Therefore moisture conditions in transit are also favorable for mycelium development, sporulation, infection, and development of lesions.

[5] U. S. Dept. of Agriculture, Weather Bureau. SUMMARY OF THE CLIMATOLOGICAL DATA FOR THE UNITED STATES, BY SECTIONS. REPRINT OF SECTION 14, CENTRAL AND SOUTHERN CALIFORNIA. 25 p., ILLUS. 1912.

[6] PALMER, A. H. FOG ALONG THE CALIFORNIA COAST. Mo. Weather Rev. 45: 496–499, illus. 1917.

CONTROL OF THE DISEASE

Two lines of control suggest themselves. The first and most effective, if it were possible, is prevention of contamination and, to a lesser extent, of primary infection in the field; the second is prevention of primary spore infection and of secondary contamination and infection in transit.

There was no opportunity for trial of protective sprays or dusts. In general, these have not been very successful in combating diseases caused by *Botrytis* sp. The greatest promise of control in the field lies in sanitary measures, such as the destruction of plant trash. Yet, even though scrupulous sanitation in the artichoke fields would very much lessen the amount of contamination, it would not necessarily eliminate Botrytis entirely, since coastal California weather conditions allow the fungus to grow saprophytically and parasitically on a great range of wild and cultivated plants. Maintenance of the low temperatures which can be obtained in the best refrigerator cars can not completely control the disease because even though low temperatures above the freezing point of the buds retard infection, development, and spread of the disease, they do not control it completely, since the fungus can grow at temperatures low enough to injure and freeze the buds. Moreover, low humidity controls primary spore infection as well as secondary contamination and infection much more than do low temperatures. Infection by spores or by mycelium was not obtainable at any temperatures unless the buds were kept in a humid atmosphere. Unfortunately, equipment was not at hand to determine just what humidity is necessary for spore germination and for infection by spores and mycelium. Control of humidity in refrigerator cars at present is difficult, because the present method of cooling cars by melting ice inevitably leads to a humid atmosphere.

Since these experiments show that even though spore germination and growth can take place at temperatures between −2° C. and 5°, and since infection by spores (the primary method of infection) does not take place at temperatures below 5°, much infection might be prevented if it were possible to get the buds cooled to this temperature immediately after cutting. Once infection has taken place, growth of the fungus and the infection by mycelium, for which wounds are not essential, can take place at temperatures ranging from −2° to 32°. Commercially significant lesions can develop in infected buds at 0° during the 10 to 15 days necessary to get the buds to eastern markets. Nevertheless, maintenance of a temperature of about 5° C. is desirable, as preventing secondary infection by spores, retarding growth of the fungus, and lessening secondary infection by mycelium.

Though some tearing of the tips of scales takes place during growth and a large wound must be made when the buds are cut from the plants, more careful handling of the buds during harvesting and packing could eliminate a great deal of wounding.

Control of the disease is therefore a complex problem, and responsibility for losses in transit or storage is divided among all those who handle the crop. Growers should keep fields and their environs free from plant trash. The packer should avoid packing buds which show discolorations and lesions, since there are indications that buds cut in badly infested fields are more heavily contaminated than those from clean fields. He should not mix badly contaminated and clean buds, should handle them with the greatest care to avoid wounding, and should pack without delay and cool them at once to about 5°. The carrier should provide the most rapid car movement possible, because each additional hour increases the chances of infection with the consequent danger of larger and more numerous lesions. He should also provide a temperature of about 5° while the buds are in transit, and try to prevent saturation of the atmosphere in the car. It is of advantage to the dealer to receive this stock quickly. He should then keep it in fairly dry, refrigerated places if it must be held any length of time.

SUMMARY

1. A rot induced by a Botrytis of the cinerea type causes serious transit losses of shipments of Globe artichoke buds from California. Morphologically, the Botrytis strains isolated from the artichoke (except culture No. 255 from the interior of a frozen stem) seem to be identical with those generally obtained from other vegetables. Cross inoculation tests lend additional weight to the view that a Botrytis of the cinerea type is responsible for practically all Botrytis rot of vegetables.

2. Although disease is of practically no importance in the artichoke fields so far as quality and quantity of marketable buds are concerned, the fields are the original source of con-

tamination, where the fungus attacks vigorous growing plants to some extent, occurring much more frequently on aging plants and on plant trash.

3. The fungus has a wide temperature range, its minimum lying below —2° C., its optimum between 22° and 25° C, and its maximum at about 30° to 33° C. Infection was obtained experimentally throughout the temperature range of the fungus. It is obtained more readily below the optimum than above it. The rate of development of lesions is greater below the optimum than above it.

4. The temperature reactions of the fungus are essentially the same on both agar and bud scales. Mycelium can cause infection without wounds at all temperatures within its temperature range, whereas wounds are necessary for infection by spores.

5. Moisture is the principal limiting factor for both spore and mycelium infection. High humidity followed by a decrease in humidity leads to sporulation. Temperature and especially moisture conditions in the artichoke-producing section of California are favorable for the growth of Botrytis with consequent contamination of the buds.

6. Control involves field sanitation and possibly protective spraying or dusting of the buds; also careful handling to avoid unnecessary wounds in harvesting and packing.

7. Control also involves the maintenance of low humidity and of temperatures of about 5° C. in transit, although even at this temperature complete control is not possible after infection has occurred, because the decay, when once started, progresses at —2°, the freezing temperature of the buds.

8. Responsibility for losses in transit or in storage is not single, but generally rests severally upon growers, packers, shippers, carriers, and storage men, each of whom could contribute some measure of prevention.