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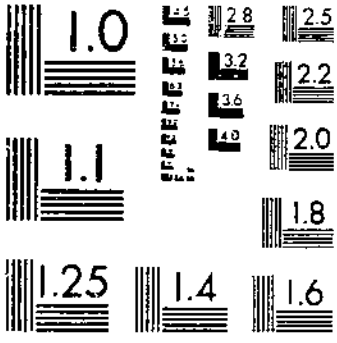

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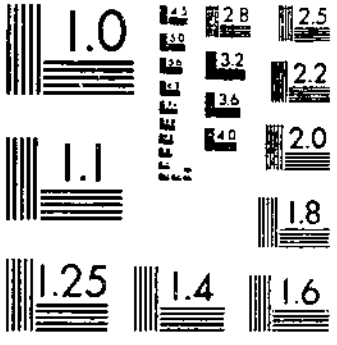

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Prevention of Damage by the Seed-corn Maggot to Potato Seed Pieces[1]

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INTRODUCTION

The seed-corn maggot (*Hylemya cilicrura* (Rond.))[3] is an insect inhabiting all arable portions of North America and many other parts of the world. Among its wide range of foods are newly planted potato seed pieces, injury to which is particularly serious late in the winter and early in the spring in the sections of the South Atlantic Coastal Plain where early potatoes are grown.

The investigations reported herein were conducted during the period from 1925 through 1933 in the eastern parts of North Carolina and South Carolina, most of the studies having been carried on in the vicinities of Bayboro, N. C., and Charleston, S. C. These investigations on control were conducted in connection with studies on the biology of the insect in those areas, the results of which are being published separately.

INFESTATIONS ON POTATO SEED PIECES

Since injury by the seed-corn maggot to potato seed pieces is of such a nature that it is quite often overlooked by growers, occurrences of the damage have not been mentioned in the literature of economic

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[2] Acknowledgments are due W. A. Thomas for his supervision of the entomological phases of the project; D. C. McCotter and W. H. Holton of Cash Corner, N. C., M. W. Hooker of Alliance, N. C., and J. M. Harrison, James W. Geraty, E. W. King, and H. A. Felder of Charleston, S. C., who, without compensation, greatly facilitated the investigations by placing at the disposal of the writers for this work their laborers, farm buildings, equipment, land, fertilizer, and seed potatoes; and B. L. Wade of the Bureau of Plant Industry for his advice concerning the statistical study of the data.
[3] Order Diptera, family Anthomyiidae. Specimens of the insect involved were determined by H. C. Huckett in 1925 and by J. M. Aldrich in 1929.

entomology as often as they might have been had the injury been more apparent. According to Chittenden (*6*)[4] the first record of injury by the seed-corn maggot to potato seed pieces in the United States was made by Lintner in New York, just prior to 1894. Sellards (*26*) stated that heavy loss to seed potatoes resulted in Florida in 1905 from decay and maggot injury. The maggots seemed to prefer decaying potatoes, and Sellards says: "It is doubtful if the injury to the tubers would be particularly serious were it not for the accompanying rot of the potatoes." Chittenden [5] reported that during the spring of 1909 very extensive injury to seed potatoes was incurred in tidewater Virginia and Maryland. According to Tucker (*28*), seed potatoes were infested by the seed-corn maggot at Valverda, La., in March 1913 and at Ventress, La., in March and April 1915. Probably the most notable outbreak on record occurred in the spring of 1921. This infestation is described by Hyslop (*11*). Other instances of injury are recorded by Hawley (*9, p. 952*) as occurring in western New York in 1922; by W. A. Thomas [6] as occurring in Pamlico County, N. C., in 1924; by Leach (*16*) in Minnesota in 1926; by Ogilvie (*20, Rept. 1927*) in Bermuda in 1926; by the Insect Pest Survey [7] in the Carolinas, Virginia, and other points in the East Central, West Central, and North Central States in 1930; by Hutson [8] in Michigan in 1931; by Robinson [9] in Alabama in 1932; by Smith (*27*) in Kansas in 1931; by Cockerham [10] in Alabama in 1933; and by Hinds [11] in Louisiana in 1934.

During the course of these investigations the senior author observed severe infestations on potato seed pieces in commercial plantings at Beaufort, S. C., in March 1925; at Pollocksville, N. C., in April 1926; at Charleston, S. C., in April 1929; at Chadbourn, N. C., in April 1931; and in home-garden plantings in Chester County, S. C., in April 1926. The commercial plantings were being grown in the sandy loam soils of the Coastal Plain sections of the Carolinas and the home-garden plantings in both clay and sandy soils of the Piedmont of South Carolina.

NATURE OF INJURY TO POTATO SEED PIECES

Injury to potatoes by the seed-corn maggot results from the feeding of the larvae, or maggots, on the seed pieces after they have been planted. Although feeding usually ends before or shortly after the plant reaches the surface of the soil, the plant is often affected adversely for a longer time, either as a result of lack of nutrition from the affected seed piece during the early part of its growth or by associated disease organisms that may have entered during or after the period of feeding (pp. 6 and 7).

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[4] Italic numbers in parentheses refer to Literature Cited, p. 35.

[5] In unpublished notes of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

[6] Unpublished notes, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

[7] UNITED STATES BUREAU OF ENTOMOLOGY. SEED CORN MAGGOT. U. S. Bur. Ent. Insect Pest Survey Bul. 10: 456. 1930. [Mimeographed.]

[8] HUTSON, R. SEED CORN MAGGOT (HYLEMYIA CILICRURA ROND.). U. S. Bur. Ent. Insect Pest Survey Bul. 11: 286. 1931. [Mimeographed.]

[9] ROBINSON, J. M. SEED CORN MAGGOT (HYLEMYIA CILICRURA ROND.). U. S. Bur. Ent. Insect Pest Survey Bul. 12: 60. 1932. [Mimeographed.]

[10] COCKERHAM, K. L. SEED CORN MAGGOT (HYLEMYIA CILICRURA ROND.). U. S. Bur. Ent. Insect Pest Survey Bul. 13: 124. 1933. [Mimeographed.]

[11] HINDS, W. E. SEED CORN MAGGOT (HYLEMYIA CILICRURA ROND.). U. S. Bur. Ent. Insect Pest Survey Bul. 14: 83. 1934. [Mimeographed.]

Apparently the larvae always begin feeding on the cut surface or other exposed areas of the seed piece. They have not been observed to enter through the skin of the tuber. After feeding on the surface the larvae usually bore into and often throughout the seed piece, which may be honeycombed by the feeding tunnels. In cases of heavy infestation the seed piece may be almost entirely devoured. As many as 75 maggots have been found feeding on one seed piece.

The degree of infestation of potato seed pieces is apparently largely dependent on the larval populations in the soil at the time of, or following, planting, and on the suitability of the seed pieces as food for the maggots. The number of larvae in the soil depends chiefly on the

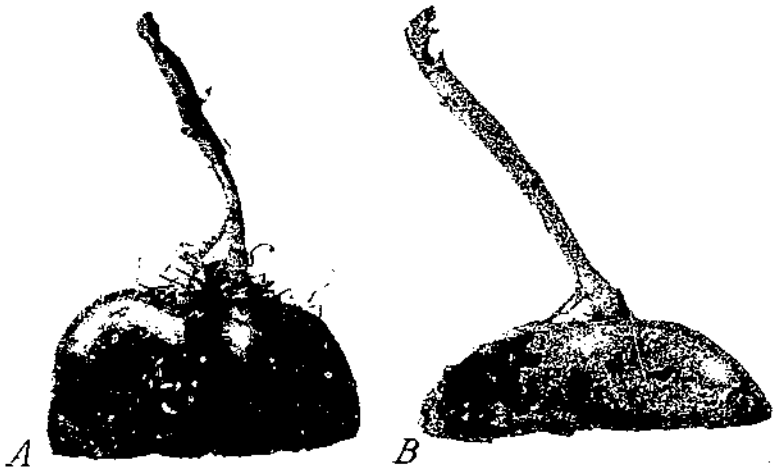

FIGURE 1.—Injury to potato seed pieces caused by the seed-corn maggot: *A*, Larvae feeding; *B*, typical feeding tunnels.

adult population of the area and the quantity of oviposition attractants present in the soil, especially those near the surface.

The degree of damage caused by the seed-corn maggot depends on a number of factors, chief of which seem to be the number of insects that attack the seed piece, the stage of larval development at the time of the attack, the size and condition of the seed piece, the stage of sprout development during the feeding, and on disease, soil, and weather conditions. When the attack is accompanied by organisms of decay the damage to the crop is increased. Heavy infestations of the seed-corn maggot may necessitate the replanting or abandonment of the crop. Such damage is particularly costly to the grower because of the relatively high cost of seed potatoes and the need of producing the crop as early in the season as possible for greatest financial returns. Less severe infestations result in weakened or poor stands of plants, with consequent reduction in yields.

Examples of typical injury to potato seed pieces by the seed-corn maggot are illustrated in figure 1.

INSECTS LIKELY TO BE MISTAKEN FOR THE SEED-CORN MAGGOT

During the biological investigations flies resembling adults of *Hylemya ciliicrura* were frequently taken in traps along with that species. This associated insect was determined by J. M. Aldrich as "*Fucellia maritima* Hal., a kelp fly of the family Anthomyiidae."

In May 1925 an infestation resembling that of the seed-corn maggot was found in newly planted potato seed pieces near Asheville, N. C. The infested pieces were decaying. Adults reared from the material were determined by H. C. Huckett in June 1925 as belonging to a species of the dipterous family Sepsidae.

The little housefly (*Fannia canicularis* (L.)), determined by H. C. Huckett in June 25, was reared from decaying potato seed pieces in Pamlico County, N. C., during the spring of 1925.

Johannsen (*12*), in reporting an outbreak in Maine in 1910 of what was apparently then considered to be the seed-corn maggot, said:

> Some complaints were also received from farmers in Aroostook County claiming injury to seed potatoes. Specimens submitted were badly decayed and infested with the larvae of the fly. It is quite possible that the infestation by the fly occurred after decay set in, as some decayed tubers were found free from larvae. The flies emerged the latter part of June.

Johannsen (*13*) reported in 1921 that he reared male specimens of the anthomyiid fly *Hylemya* (*Phorbia*) *trichodactyla* Rondani from maggots infesting a lot of seed potatoes sent from Aroostook County, Maine. The adults were obtained on June 27, 1910. He stated that the species has a wide distribution and is fairly common and that it is not unlikely that it is of economic importance in the United States, but that because of their similarity the species is probably often mistaken for the seed-corn fly, *H. ciliicrura*, the males of the two species resembling each other in having the hind tibiae ciliated on the inner (flexor) side, but differing in that *H. trichodactyla* has a few long, bristly hairs on the upper (extensor) side of the basal segment of the middle tarsus.

REVIEW OF LITERATURE AND RECORDS

At the time the present investigations were begun in 1925 very little had been published concerning the seed-corn maggot as a pest of potato seed pieces, and no satisfactory means of preventing its injury to that crop had been recorded. Berger (*3*), in 1909, had advocated immediate covering of the seed and clean cultivation before planting. In 1926 Leach (*16*) stated that "preliminary experiments indicate that a thin coating of mercuric bichloride over the surface of cut seed pieces may be effective in preventing injury."

Several methods of control of the insect on other crops have been recommended, among which are the use of carbolic-acid wash, calomel, and other mercury compounds, sand and kerosene, kainit, and soda fertilizers (as deterrents) and of cultural practices such as shallow planting, clean cultivation, planting when germination will occur quickly, avoiding use of animal manure, use of only mineral fertilizers (*23*), use of excess seed, thorough preparation of the soil, and regulation of the time of planting. Peterson (*21*), in 1924, suggested the use of poisoned baits for the adults. Rekatch (*25, pp. 284–285*), in

1931, suggested the use in Transcaucasia of trap pits around the borders of the host-plant fields, and the use of poisoned cotton meal (presumably cottonseed meal). Harukawa and others (*8*) reported, in 1933, the results of tests in Japan on the control of the insect as a general plant pest.

The possible relation of certain factors to maggot injury to potato seed pieces was suggested in the writings of several authors prior to and during the course of the investigations reported herein. Chief of these possible factors are seed-piece decay and the presence of fertilizers.

Tucker (*28*), in describing an infestation of seed potatoes by the seed-corn maggot in Louisiana in 1913 and 1915, stated that in every case the seed pieces were decaying at the time the infestation was found. Hyslop (*11*), in a report on the unusually severe outbreak of the seed-corn maggot on seed potatoes along the Atlantic seaboard in the spring of 1921, states that—

> conditions were possibly advantageous for the development of certain fungous diseases which, undoubtedly, were associated with the depredations of, if not responsible for the damage attributed to the seed-corn maggot.

In 1925 Leach (*14*) published an article on the relation of the seed-corn maggot to potato blackleg. He said:

> The writer has obtained evidence recently which shows that the seed-corn maggot, *Phorbia fusciceps* Zett., is a common agent of dissemination as well as inoculation of potato blackleg in Minnesota. Preliminary experiments indicate also that the pathogene may be biologically transmitted by the insect, thus providing another important means of hibernation.

Further discussions by Leach of the relations of the seed-corn maggot to potato blackleg appeared in 1926 (*15*), (*16*), 1930 (*17*), and 1931 (*18*). He found that the insect is "an agent of dissemination, inoculation, and hibernation of plant-pathogenic bacteria" (*16*); that "the bacteria are constantly associated with the insect, passing through the pupal stage, and emerging with the adult fly in a virulent state" (*16*); and that "nutritional studies with the larvae of the seed-corn maggot indicate that bacteria aid its development by transforming the plant tissues into a form more readily assimilated" (*18*), and it was concluded that "the kinds of bacteria associated with the insect are determined largely by the nature of the material on which it feeds" (*18*).

In the meanwhile Huff (*10*) reported the results of his nutritional studies on the seed-corn maggot at Chadbourn, N. C. This work had for its chief object the question as to the exact role of bacteria in the nutrition of the fly larvae. As stated by Huff:

> from the economic point of view it was desired to learn whether or not the action of bacteria must precede the attack of the larvae upon potato seed pieces, sprouting corn, and other plants susceptible to attack by the insect.

Huff concludes:

> From the results obtained in these experiments it seems necessary to conclude that the presence of bacteria, per se, is not essential to the development and pupation of the larvae of *Hylemyia cilicrura*. It seems permissible to conclude also that in the nutrition of the larvae of this species, the bacteria by their action on the medium sometimes play the role of preparing a suitable substratum for growth of the larva.

It seems permissible to conclude also that the substances essential to the growth of these larvae are present in bacteria-free, growing seedlings of beans and some other seeds.

For the spring seasons of 1929 and 1930 Reiner Bonde, of the Maine Agricultural Experiment Station, was temporarily appointed by the Bureau of Plant Industry, United States Department of Agriculture, for a cooperative study of the relation of the seed-corn maggot to potato seed-piece decay. A complete account of the results of his studies has not been published. In a preliminary discussion, however, Bonde (*4*), says:

> In laboratory tests, adult flies of the seed-corn maggot (*H. cilicrura*), caught in the open, did not infect potato seed pieces by direct contact. From eggs of such flies deposited in sterilized soil, maggots emerged which induced decay in potato slices in damp chambers. In seed pieces in soil, rapid decay was dependent upon shallow lesions caused by various fungi and bacteria on unhealed surfaces and upon the entrance of the maggots through such lesions. Thus, with maggots present, decay occurred in freshly cut seed pieces planted in nonsterilized soil (and attacked by fungi or bacteria), but not in suberized seed pieces planted in nonsterilized soil or in freshly cut seed pieces planted and becoming healed in sterilized soil.
>
> In commercial potato-growing conditions in Maine, the maggots showed a similar relation to seed-piece decay, except that entrance lesions due to fungi and bacteria developed largely in storage and not in soil, even on freshly cut seed. From the inside of the puparia, *Bacillus phytophthorus* and some other potato-pathogenic bacteria have been isolated.

The results of Bonde's studies which have been quoted are quite pertinent from entomological as well as pathological standpoints to the role played by the seed-corn maggot as a pest of potato seed pieces. His findings are entirely in accord with the observations and experiments upon which the writers' control recommendations are based. Unless soil conditions are optimum for the immediate formation of wound periderm over the cut surfaces of seed potatoes planted while freshly cut, shallow lesions in the cut surface are quite likely to be caused by various soil fungi and bacteria. Such lesions attract and provide suitable food for the larvae of *Hylemya cilicrura*, as was confirmed by the work of Huff (*10*). From the lesions the larvae tunnel into all parts of the seed pieces. The larvae have not been observed under field conditions to attack potato seed pieces free of such lesions. At the time of planting the commercial early potato crop along the South Atlantic seaboard, and possibly elsewhere, soil conditions are usually not favorable (because of low temperature and often excessive precipitation) for rapid healing of freshly cut seed. Thus seed potatoes planted immediately after being cut, which is the usual commercial practice, are subject to injury by the seed-corn maggot.

The potato disease known as blackleg does not appear to be very prevalent on the early commercial crop of the Carolinas. Other organisms, however, have been found associated with the seed-corn maggot in the area.

Fusarium oxysporum, or a closely related variety, was isolated by Freeman Weiss of the Bureau of Plant Industry in March 1924 from decaying seed pieces collected by W. A. Thomas in Pamlico County, N. C., in February. This organism is described as a "vascular parasite of the potato, causing both a field wilt and a rot of tubers."

Fusarium discolor var. *sulfureum*,[12] with associated bacteria, also was isolated by Dr. Weiss from material obtained by Mr. Thomas at the same time.

An apparently pathogenic organism similar in tests to *Bacillus carotovorus* was isolated by Dr. Weiss from potato seed pieces infested with seed-corn maggots collected by the senior author at Beaufort, S. C., in March 1926. Fungi that were probably *Actinomyces* (=*Oospora*) *scabies*, *Rhizopus nigricans*, and *Fusarium martii minus*, all nonpathogenic, also were found in these specimens.

Fusarium sp., *Penicillium*, *Mucor*, *Alternaria*, and a nonpathogenic bacterium resembling *Bacillus phytophthorus* [13] were isolated by Lillian C. Cash of the Bureau of Plant Industry from seed pieces collected by the senior author at Chadbourn, N. C., in March 1931.

The possibilities of a relationship of plant fertilizers to the injury by *Hylemya cilicrura* to seed potatoes appears in the account of Tucker (*28*), who found the maggots in large numbers feeding in cottonseed meal used as a fertilizer for potatoes, and in that of Hyslop (*11*), who, in describing the severe outbreaks of the seed-corn maggot on seed potatoes along the Atlantic seaboard during the spring of 1921, said:

> One of the most interesting features of the survey reports on this insect were the independent reports from Maryland, Massachusetts, and New Jersey, that infestations were far worse on fields where meat scrap or fish scrap fertilizers were used.

Further instances of the effects of fertilizers or their ingredients upon the insect's activity are cited by Bourne [14] as regards tankage, by Ogilvie (*20, Rpt. 1926*) concerning castor pomace, by Rekatch (*25*) in regard to "cotton-meal," and by Brown (*5*), who found that poorly distributed fertilizer adversely affected the germination, stand, and yield of potatoes. James W. Geraty, an experienced potato grower of Charleston, S. C., stated to the senior author in 1924 that seed-corn maggot damage to seed potatoes often occurred when it was a practice to broadcast about 1,000 pounds of cottonseed meal over land to be planted to potatoes, and especially when the material was not thoroughly incorporated with the soil.

CONTROL STUDIES

Nature and Scope of Control Studies

Control studies were begun in February 1925 in Pamlico County, N. C., following the severe outbreak of the seed-corn maggot on potato seed pieces along the Atlantic seaboard in the spring of 1921 and its known recurrence as a potato pest in eastern North Carolina in 1924. These investigations were made in conjunction with studies of the insect's biology. Control studies were also conducted in several of the potato-producing districts of eastern North Carolina and eastern South Carolina in 1926 and 1927; in Charleston County, S. C., from 1928 to 1930; in both eastern North Carolina and eastern South Carolina in 1931; and in Charleston County in 1932 and 1933.

[12] Letter of J. E. Graf to W. A. Thomas under date of March 13, 1924.
[13] Letter of Lillian C. Cash to W. J. Reid, Jr., dated January 26, 1932.
[14] BOURNE, A. I. SEED CORN MAGGOT (HYLEMYIA CILICRURA ROND.). U. S. Bur. Ent. Insect Pest Survey Bul. 6:162. 1926. [Mimeographed.]

All the experiments were confined to what is termed the early commercial crop and were conducted on privately owned farms, with the exception of the tests of 1933, which were located at the South Carolina Truck Experiment Station near Charleston. All tests were in soils of the Norfolk fine sandy loam type. The Irish Cobbler variety of potato was used in all experiments.

The studies of 1925 to 1927 are classed as preliminary, as they consisted of a variety of field tests and observations made to find some promising method, or methods, of preventing seed-corn maggot damage to potato seed pieces that might be studied in detail later. The control investigations of 1928 to 1931, conducted in cooperation with the Bureau of Plant Industry, consisted of intensive field experiments designed to test the value as a control measure of seed suberization in advance of planting. The work of the 1932 season was chiefly devoted to observing the value of suberization when practiced by several growers of the Charleston district. In the spring of 1933 a suberization test was conducted on grounds of the South Carolina Truck Experiment Station, on an area which was under entire control and showed indications of a heavy insect infestation.

With the results of the studies of 1928 to 1931 as a basis, an account of the value of suberization of potato seed pieces before planting as a means of avoiding seed-corn maggot injury was published in 1932 (*24*).

Preliminary Control Studies

EXPERIMENTS OF 1925

The control experiment conducted in Pamlico County, N. C., late in the winter and in the spring of 1925 consisted of the testing in field plots of a rather large number of possible methods of preventing injury to potato seed pieces by the seed-corn maggot. A list of the various treatments is as follows:

A, Fertilizer treatments:

1. Fertilizer applied and covered 2 weeks before seed pieces were planted.
2. Same as (1), except not covered until the planting.
3. Fertilizer applied and covered 1 week before the planting.
4. Same as (3), except not covered until the planting.
5. No fertilizer.
6. Use of all-mineral and of 50 percent organic ammoniate fertilizer mixtures.
7. Fertilizer mixtures composed of 10 percent and 25 percent of tobacco dust.
8. Fertilizer treated with sodium arsenite.

B, seed pieces treated, before and after cutting, with each of the following: Sulfur, sand and kerosene, hydrated lime, carbon disulfide emulsion, mercuric chloride, bordeaux-oil emulsion, and formaldehyde.

C, row treatments, the following materials being poured into the drill just ahead of the planting: Sulfur, carbon disulfide emulsion, mercuric chloride, bordeaux-oil emulsion, hydrated lime, and a mixture of sand and kerosene.

The control measures were tested in a single treatment on plots of approximately one-sixtieth of an acre. Results were based on comparative infestations of 10 seed pieces of each plot dug at weekly intervals during the period of insect activity, and upon comparative yields.

The infestation of the 1925 experimental planting proved light, which in view of later findings may have been due to the absence of suitable oviposition attractants in the soil. There were no significant

differences in yield. The majority of the seed treatments were found to have injured the seed pieces to some extent, especially when they were treated after being cut. Those seed pieces which showed injury to the cut surfaces had the heaviest insect infestations.

During the latter part of March 1925 a report of insect injury to potato seed pieces in the vicinity of Beaufort, S. C., was investigated by the senior author. It was found that the seed-corn maggot had injured the seed pieces seriously in several potato plantings of that district. The greatest damage occurred in fields that had been planted to cabbage in the fall and early in the winter, particularly when large quantities of the unmarketed parts of the plants were mixed into the soil. At the time the section was visited the majority of the maggots had pupated, and the infested seed pieces were so badly decayed that it was impossible to determine what might have been their condition at the beginning of the insect's feeding and to get a true picture of the actual damage caused by it.

EXPERIMENTS OF 1926

Because such a light infestation occurred in the Pamlico section of North Carolina, to which the seed-corn maggot investigations in the field had been confined in 1925, it was thought advisable to make as many observations as possible in the Beaufort, S. C., district during the 1926 season. Consequently no field-plot tests were made that year as had been done in 1925, but a number of different farms, representative of the most important types of soil and of grower's practices, were selected in each of the North Carolina and South Carolina sections. These farms were visited and the fields examined as carefully and frequently as possible throughout the spring months. Particular attention was devoted to the methods of fertilizing and planting each field, the type of soil, previous crop and disposition of same, the condition of seed and soil, and the maggot activity in each field at the time of each observation.

The infestation of the seed was again heavier during the 1926 season at Beaufort than in the Pamlico district. Consequently, much of the information concerning the habits of the insect obtained during that season from the control standpoint came from the Beaufort part of the observations.

A light infestation of the seed-corn maggot in seed potatoes was observed during the 1926 spring season in the immediate vicinity of Chadbourn, N. C.

During January 1926 cage tests were begun at Chadbourn to determine the preferences of larvae of *Hylemya cilicrura* for potato seed pieces with the various conditions of cut surfaces normally found under field conditions. Results of these tests clearly indicated that freshly cut seed pieces were not suitable as food for first-instar larvae of the seed-corn maggot, and that these were fed upon to only a very limited extent by second-instar and third-instar larvae. Seed pieces with the cut surfaces well healed and suberized were not attacked by larvae of any stage of development. Those seed pieces, however, that bore lesions on their cut surfaces or which were decaying proved suitable as larval food.

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EXPERIMENTS OF 1927

The control investigations of 1927 consisted in the continuation of the observation of growers' plantings in both eastern North Carolina and eastern South Carolina, including the Charleston district, and of additional cage experiments at the Chadbourn laboratory. During 1927 assistance was given to Clay G. Huff in his cooperative nutritional studies of the seed-corn maggot, the results of which (*10*) are discussed on page 5.

SUMMARY OF RESULTS OF PRELIMINARY CONTROL INVESTIGATIONS

Results of the preliminary control experiments and observations might be summarized as follows:

No chemical treatment of seed potatoes was found to be effective in the control of the seed-corn maggot. Because of the nature of the attack, such treatments, to be effective, would have to be made after the seed was cut. The chemicals that were tested served only to increase the insect infestation. This increase was apparently due to a burning or breaking down of the tissues of the cut surface of the seed by the chemicals. Any formation of lesions on the cut surface of a potato seed piece was found to induce seed-corn maggot attack.

The treatment of potato seed pieces with ground sulfur before planting was found to be a practice of growers in certain districts of eastern North Carolina and eastern South Carolina. The intended purpose is the protection of the seed from insects and diseases. In one instance during the preliminary control studies such a treatment was observed to have apparently aided in the prevention of seed-corn maggot injury. In this planting, near Chadbourn in 1927, the sufur-treated seed was definitely less damaged by the insect, and gave a 96-percent stand of plants as compared to an 87-percent stand from adjoining untreated seed. In most cases, however, no benefit in the way of preventing seed-corn maggot attack was derived from sulfur treatments. In several instances the sulfur was noted to have seemingly interfered with normal healing of the cut surfaces of the seed pieces, lesions being present on the cut surfaces and maggots being found feeding thereon. These unfavorable results of sulfur treatments often followed the use of finely ground sulfur on freshly cut seed that evidently had not dried before the treatment. Treatment of the seed with a coarsely ground sulfur after drying did not seem to injure the surfaces so noticeably. In general, sulfur treatment of the seed was considered of sufficient promise to warrant more extensive tests.

Although it was found that the organic constituents of plant fertilizers attracted the adults of *Hylemya cilicrura*, stimulated their egg laying, and served as larval food, this factor did not seem to play a very important part in actual infestations of potato seed pieces unless there was failure to cover the fertilizer promptly, especially when applied during periods of adult activity. Potato fertilizers are usually covered with soil to a depth that is apparently sufficient to prevent their being an attractant to the insect. The cage tests and field observations, however, indicated clearly that fertilizers often increase the degree of seed-corn maggot damage to seed pieces by causing lesions on, and preventing normal healing of, the cut surfaces of those pieces with which it had come in contact in the soil. This injury to the seed potatoes by fertilizer was most prevalent when the fertilizer

was applied just before the planting and was not thoroughly mixed into the soil. As this burning of the cut surfaces of the seed was probably caused by the mineral constituents of the fertilizer, it seemed evident that both the mineral and the organic components of a fertilizer are capable of aggravating seed-corn maggot damage to potato seed pieces. Consequently, further studies of the fertilizer factor were deemed advisable.

Adults of the seed-corn maggot were found to be strongly attracted to partly decayed plant tissue, to sprouting seed, and to the commonly used organic fertilizing materials, namely, cottonseed meal and fish meal or scrap, dried blood, and other animal products. The female fly is attracted to these materials when present in the soil and lays her eggs in the soil near the substances. The remains of a crop of cabbage, spinach, beans, or peas serve as ideal oviposition attractants. Other things being equal, the seed-corn maggot population of a given soil, and consequently the possibility of a seed-potato infestation, depends to a large extent on the quantity of these attractive materials in the soil during the egg-laying period of the insect. Potatoes when planted after a crop of cabbage, spinach, or beans, especially where large quantities of these crops were left in the field, are quite liable to attack by the seed-corn maggot. On the other hand, observations throughout the period of the studies indicated that potatoes planted in a soil comparatively free of these attractive organic materials are not usually subjected to maggot injury. This is evidently due to the small maggot population of such soils. No evidence was noted that planted seed potatoes served as attractants to the fly for egg laying, or that the eggs were laid on the seed potatoes before they were planted.

The most significant outcome of the control studies of the first three seasons was the observation that, regardless of the type of soil, previous crop, or nature and method of applying the fertilizer, those potato seed pieces which became thoroughly healed soon after being planted were not attacked by the seed-corn maggot. It is the customary practice for growers of the commercial early potato crop to plant their seed potatoes shortly after cutting them. Under favorable conditions potato seed pieces will heal normally in the soil. These favorable conditions, however, are not always present, or not even commonly found to exist at the time the early crop is planted in the Carolinas. The soil at that time is likely to be cold and wet. Instead of a firm periderm layer being formed, the cut surface of seed planted late in January and in February in the Carolinas is likely to become covered by brown lesions. These lesions, which are disintegrated tuber tissue and in themselves apparently not harmful, were found to attract seed-corn maggots to the seed piece and to serve as food for the young larvae. After feeding a short while on the lesions the insects usually tunnel into the firm portion of the seed piece, as illustrated in figure 2. The larvae appear unable to obtain suitable food from freshly cut surfaces of potato tubers or from seed pieces with the cut surfaces well healed. As a result of these findings, attention was turned to the possibility of planting previously healed, or suberized, seed potatoes as a means of preventing seed-corn maggot attack.

Seed-Suberization Experiments

During the period from 1926 through 1930 the Bureau of Plant Industry conducted at the Arlington Experiment Farm in Virginia,

near Washington, D. C., an investigation of the effect on subsequent yields of storing cut seed potatoes at different temperatures and humidities. The results of that series of studies were published later by Wright, Peacock, and Whitcomb.[3] In order that some of these investigations of the Bureau of Plant Industry might be con-

ducted under field conditions existing in the early-potato-producing area of the South Atlantic States and that tests might be made of the value, in the control of the seed-corn maggot, of planting previously healed seed potatoes, a series of cooperative experiments between the Bureaus of Plant Industry and Entomology were begun in the early part of 1928 in the immediate vicinity of Charleston, S. C.

Under certain conditions the cut surfaces of potato tubers become healed. The nature of this process and the conditions under which it takes place had been described in 1906 by Appel (*1*), by Priestly and Woffenden (*22*) in 1923, and by Artschwager (*2*) in 1927. The healing of cut or otherwise wounded surfaces of potato tubers is essentially the formation of a protective layer of cells with thickened walls, which is known as wound periderm, and the process as suberization.

That a wound-periderm layer is effective to some extent in preventing the infection of wounded potato tubers by several species of fusarium rot was reported in 1928 by Weiss, Lauritzen, and Brierley (*29*). This fact is significant from the standpoint of control of the seed-corn maggot, since partly decayed seed pieces are particularly susceptible to injury by the insect.

NATURE AND SCOPE OF THE SUBERIZATION EXPERIMENTS

The information furnished by previous investigators and the experience gained from completed parts of the studies being conducted by the Bureau of Plant Industry at Arlington farm served as a basis for the cooperative suberization experiments begun at Charleston in 1928 and continued through the spring of 1931. These experiments were essentially comparisons in field experimental plots of the results from planting seed potatoes shortly after they were cut to those from the use of seed potatoes that had been cut and suberized in advance of the planting. The tests included seed that was suberized in storage houses of the growers, both with and without artificial heat, and seed suberized in a specially constructed room where the temperature and humidity could be better controlled.

The specially constructed suberization room was in a farm building and was lined on its top and sides with a commercially prepared cane-pulp insulating board. It was heated by a small poultry-brooder stove, with the aid of which a fairly uniform temperature of approximately 50° to 60° F. was maintained. The relative humidity of the room was raised to approximately 80 to 90 percent by having a moist layer of sand over the concrete floor and supplementing this by hanging moistened, previously disinfected potato bags on the walls, and around the stove when necessary.

In the storage houses of the various growers the seed was covered with moist bags held at a distance from the seed by the edges of the seed containers or by a wooden frame. In most cases no artificial heat was used in the growers' places of storage.

All seed potatoes used in the tests were taken at random from the growers' stocks. The seed that was to be cut just before planting was always of the same lot as the suberized seed. Both lots of seed were disinfected to destroy surface-borne disease organisms and were stored under the same conditions during the suberizing process of the one lot. The technique of disinfecting, cutting, storing during the suberization process, and other handling was essentially that recom-

mended by Wright and others (*30, p. 20*). The conditions of temperature and humidity in the storage room during the healing process were recorded. The length of the suberization period ranged in the different experiments from 6 to 28 days. All seed was planted by hand at a uniform spacing of approximately 12 inches in the rows of the field plots. The suberized and the freshly cut lots of seed were planted in systematically paired groups of plots consisting of from two to four rows each, each treatment being replicated from one to five times, usually four, in each experiment. Several experiments were conducted each season, and these were on at least three different farms during the seasons of 1929, 1930, and 1931.

Results of all control experiments were judged on the basis of comparative seed-corn maggot infestations, plant stand, and tuber yield. The insect infestation was determined by an examination of a definite number of seed pieces, usually 25, taken at random from and replaced in each experiment at approximately weekly intervals throughout the period of possible insect activity. The examined seed pieces were taken from a different treatment replication each week, unless there were more weekly examinations than replications. The various experiments received from 2 to 6 such examinations, the usual number being 3. Thus 75 seed pieces representing each type of seed were examined in the case of most experiments. The seed-piece examination consisted of the determination of the number of infested seed pieces, the number of larvae feeding on each, the progress of germination, and the condition of each piece. Plant-stand counts were made on the entire experimental area when approximately half the plants had appeared above ground, and again when germination was apparently complete. Yield records were obtained by carefully harvesting, grading, and weighing all tubers produced by each plot.

Seed for the suberization experiments of 1928 was disinfected with an organic mercury compound and allowed to dry thoroughly before being cut. It was noted that the cut surfaces of seed pieces that had been treated with either organic or inorganic mercury compounds before being cut often became discolored and failed to heal properly where they came in contact, during the suberization period, with the skin surface of neighboring seed pieces on which there evidently were mercurous residues. These "burned" areas were found to serve as entrance points for the seed-corn maggots. Therefore the standard hot-formaldehyde method of disinfection of the uncut seed was used in all suberization tests of subsequent seasons, as formaldehyde was not observed to affect the healing process.

After the tests of the 1928 season, which consisted of two experiments on one farm, the experimental plantings were made under more varied soil, seasonal, and locality conditions.

As the studies of the seed-corn maggot had been begun in Pamlico County, N. C., where field conditions were somewhat different from those at Charleston, S. C., suberization tests were conducted in that locality and also at Chadbourn, N. C. (an intermediate point), as well as at Charleston in the 1931 season.

The suberization studies of 1932 and 1933 were conducted by the Bureau of Entomology alone, the cooperation of the Bureau of Plant Industry on that project having ended after the close of the 1931 season.

STATISTICAL TREATMENT OF THE DATA

The significance of the data pertaining to insect infestation and to the yield of U. S. No. 1 tubers, in the comparisons of freshly cut and suberized seed during the 1928 and subsequent seasons, and for all seasons combined, was determined statistically by the procedure known as Student's pairing method, as given by Goulden (7). Data concerning the yield of No. 1 tubers from each experiment consisting of more than two replications of the treatments were studied separately and then in combination with data of all experiments of the year. Afterwards the yield data of all years were combined for statistical treatment.

In the statistical studies maggot-infestation data were grouped by years and then as a single unit. As the differences in the infestation of freshly cut and suberized seed were so apparent in most cases and proved so highly significant, it was not considered advisable to analyze these data by single experiments.

Results of the statistical studies of the data are indicated in the tables giving the results of experiments of individual years, and in the final summary (table 7). Figures listed under the table heading "mean difference" indicate the calculated mean differences in the yields of U. S. No. 1 tubers produced by the various replications of the treatments, no preceding symbol being used when the difference was in favor of suberized seed but the minus sign being used when the difference was in favor of freshly cut seed. In the case of differences between maggot infestations the minus sign is used to denote that the suberized seed had the lesser infestation.

Odds listed in the tables under that heading are based on the calculated values of t, with known values of n, and were taken from Livermore (*19*), the table used having to do with odds in one direction only. Odds as great as 39 : 1 are considered as indicating significant differences, and odds above 199 : 1 as indicating highly significant differences.

EXPERIMENTS OF 1928

The control experiments of 1928 consisted of tests of seed-piece suberization in advance of planting and of treatments of the cut seed with sulfur and with each of two commercially prepared organic mercury compounds used as seed disinfectants, of tests of the effect of depth of planting, and of tests of various fertilization practices as means of preventing injury by the seed-corn maggot. The experimental plantings were made on a private farm near Charleston, Maine-grown tubers being used for seed.

In experiment No. 1, seed suberized for 20 days in the grower's storage house was compared in 12-plot replications of each treatment with seed planted freshly cut. Each plot consisted of 3 rows of plants, each row containing approximately 200 seed pieces, set 12 inches apart. Within this suberization test was included an experiment for comparison of fertilizers. The 12 replications of suberized and freshly cut seed, consisting of a total of 24 plots, were divided into 4 consecutive groups of 6 plots each. Each of these groups of plots thus contained 3 replications of suberized versus freshly cut seed. One of these replications was fertilized with the commercial mixture being used by the grower, another with an all-mineral mixture, and the third with a

50-percent organic mixture (all the nitrogen of which was derived from organic materials). Thus each fertilizer treatment was replicated 4 times. The fertilizer mixtures were of an approximate 7–5–5, phosphorus-nitrogen-potassium, analysis and were applied at a rate of 3,000 pounds per acre. There was an unfertilized barrier row between each fertilizer replication. The soil of the area devoted to this experiment contained only small quantities of decaying vegetation.

At the time of planting of experiment 1, on February 29, the seed pieces that had been cut and held for 20 days were apparently well healed and were firm. The cut surfaces were light colored and had a definite corklike covering. There were no evidences of excessive drying or any decay of the seed.

An additional small-scale suberization experiment, No. 2, consisted of a comparison of suberized with freshly cut seed in soil containing decaying cabbage plants of the winter crop. Previously conducted biological studies of the insect had indicated that soils containing partly decayed vegetation are most likely to have greater populations of the seed-corn maggot. The grower had planted part of the field with freshly cut seed, the supply of which became exhausted before the field was entirely planted. Suberized seed of the same general lot was planted in 5 rows adjoining the freshly cut seed. Thus the test was composed of a single comparison of the treatments in plots consisting of 5 rows 60 yards long, or approximately 900 seed pieces per plot.

As the seed-corn maggot attacks a seed piece only through a cut surface it was considered that, to be effective in reducing injury by the insect, any chemical treatment tested should be applied to the cut surfaces. The preliminary control tests had indicated that such treatments are likely to injure the cut surfaces of the tuber, resulting in a breaking down of the tissues which only serves to increase seed-corn maggot damage. To get more information on this subject, however, the studies of 1928 included two seed-treatment experiments, Nos. 3 and 4. Experiment 3 was a small-scale test of the value of sulfur as a seed treatment and experiment 4 was composed of 3 replications of two-row plots planted with freshly cut seed treated with ground sulfur, with 2 commercial organic mercury compounds, and with untreated seed. In order to offset as far as possible the effect on disease organisms and on consequent yields of disinfection of the seed, and thus to separate that factor from the effects of insect injury, the tests included seed that was disinfected with the standard mercuric chloride treatment before being cut. Each plot of this experiment contained approximately 200 seed pieces.

There were 3 replications of the depth-of-planting experiment (No. 5), each plot consisting of 2 plant rows containing about 200 seed pieces each. Freshly cut seed was planted at depths of 2½, 3½ to 4, and 5 to 6 inches, these depths being classed respectively as shallow, average, and deep.

Seed of the suberization and depth-of-planting tests was disinfected with the standard cold-formaldehyde treatment before being cut.

Seed of the suberization parts of the experiment was planted by hand, and that of the other experiments by machine.

TABLE 1.—*Summary of data of experiments 1 and 2 in seed-corn maggot control, in which potato seed pieces planted while freshly cut were compared with those suberized before being planted, Charleston, S. C., 1928*

Experiment No.	Fertilizer	Seed treatment	Replications	Storage conditions				Plant stand	Maggot infestation	U. S. No. 1 tubers			Yield per acre of other grades
				Location [1]	Duration	Mean temperature	Mean humidity			Yield per acre	Mean difference	Odds	
			Number		*Days*	*° F.*		*Percent*	*Percent*	*Bushels*	*Bushels*		*Bushels*
1	Commercial	Freshly cut	4	G	20	52.2	High	97.7	4.0	288.1			38.2
	do	Suberized	4	G	20	52.2	do	95.5	2.7	312.0	23.9	10:1	32.3
	All-mineral	Freshly-cut	[2] 3	G	20	52.2	do	98.5	6.7	271.4			35.4
	do	Suberized	3	G	20	52.2	do	96.5	4.0	284.3	12.9	3:1	40.6
	50-percent organic	Freshly cut	[2] 3	G	20	52.2	do	98.5	6.7	294.2			36.9
	do	Suberized	3	G	20	52.2	do	94.7	5.3	313.6	19.4	5:1	33.0
	All three types	Freshly cut	10	G	20	52.2	do	98.2	5.8	284.9			36.8
	do	Suberized	10	G	20	52.2	do	95.6	4.0	304.2	[3] 19.3	58:1	35.3
2	Grower's	Freshly cut	1	G	11	48.2		96.5	42.0	139.9			54.6
	do	Suberized	1	G	11	48.2		98.3	1.0	183.6	43.7	1:1	36.2

[1] G signifies in grower's storage house, at existing temperatures.
[2] 1 replication eliminated because of error during harvest.
[3] Weighted according to number of replications.

Experiments 1 and 2: Difference in maggot infestation between freshly cut and suberized seed=[3]−11.25 percent, $n=15$, $t=7.818$, odds=9,999:1.
Experiments 1 and 2: Difference in yields (U. S. No. 1) between freshly cut and suberized seed=[3]21.5 bushels per acre, $n=10$, $t=3.130$, odds=178:1.

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Data obtained from the combined suberization and fertilizer experiment, No. 1, and from the strictly suberization experiment, No. 2, are given in table 1. Summaries of the results of the other control experiments of the 1928 season appear in table 2. Figures given under the headings of table 1, and of subsequent tables, headed "Mean temperature" and "Mean humidity" refer to the condition of the air in the places of storage during the suberization process, as calculated from 2-hour readings of instrument recordings. Maggot-infestation data represent the percentages of the examined seed pieces that contained seed-corn maggots, or that showed evidence of their feeding. The letters G or C occurring under the table heading "Location" indicate, respectively, whether the seed was suberized in buildings of the various growers, at existing temperatures, or under conditions of partly controlled temperature in the specially constructed and heated room.

TABLE 2.—*Summary of data of experiments 3, 4, and 5 in seed-corn maggot control in which comparisons were made of freshly cut seed treated with various chemicals, and in which different depths of planting were compared, Charleston, S. C., 1928*

Experiment No.	Seed treatment	Replications	Plant stand	Maggot infestations	Yield per acre of—	
					U. S. No. 1	Other grades
		Number	*Percent*	*Percent*	*Bushels*	*Bushels*
3	Sulfured	2	94.4	53.5	166.5	34.9
	Untreated	2	87.2	55.0	167.7	34.2
4	Organic mercury compound No. 1	3	78.6	32.0	282.3	21.9
	Mercuric chloride, whole seed	3	73.3	31.3	280.3	17.2
	Sulfured	3	79.6	15.3	269.5	20.1
	Organic mercury compound No. 2	3	78.6	36.0	257.5	16.4
	Untreated	3	89.4	20.0	251.2	15.1
5	Planted:					
	Shallowly (2½ inches)	3	94.2	45.7	291.4	28.4
	At average depth (3½ inches)	3	83.6	20.0	240.0	17.1
	Deeply (5–6 inches)	3	53.2	22.0	187.3	18.0

It will be noted (table 1) that the seed-corn maggot infestation of the main suberization experiment (No. 1) was light, evidently as a result of the small quantity of decaying vegetation in the soil. Nevertheless, areas planted with suberized seed produced a significantly greater quantity of U. S. No. 1 tubers than did areas planted with freshly cut seed. When data of the two suberization experiments (1 and 2) were combined it was found that highly significant differences existed between the maggot infestation of the two types of seed and that there were significant differences in yield. Suberized seed had the lesser infestation and gave the greater yield.

In the case of the fertilizer-comparison part of experiment 1 there were no significant differences in the infestations that followed the various fertilizer treatments. Yield differences, their significance not determined, are attributed to nutritional effects of the different fertilizers.

It is evident that there were no significant differences between the infestation and the yield of the sulfured and the untreated seed of experiment 3 (table 2) of the 1928 season.

A statistical study of the data of experiment 4 (table 2), in which each treatment was compared with every other treatment by the use of Student's method of pairing values, indicated that there were

no significant differences between the seed-corn maggot infestation or the yield of U. S. No. 1 tubers of the variously treated and the untreated seed potatoes. Differences between the maggot infestations and between the yields of the seed treated with organic mercury compound No. 1 and of that treated with sulfur approached the significant points most closely, the odds being slightly above 19 : 1 that the first-mentioned treatment resulted in the greater infestation, and the odds being between 36 : 1 and 37 : 1 that the first-mentioned treatment gave the greater yield. Evidently the fungicidal effect of the mercury compound was sufficient to offset the maggot injury.

There were no significant differences between the seed-corn maggot infestations of the seed potatoes planted at different depths (table 2, experiment 5). Differences in yield of U. S. No. 1 tubers were significant only in case of the shallow as compared to the deepest planting, the odds being above 74 : 1 that the shallow planting produced the greater yield. This difference was undoubtedly due to the greater degree of seed-piece decay occurring in the deeper plantings.

EXPERIMENTS OF 1929

As the control experiments of 1928 had indicated clearly that suberization of cut seed potatoes before planting offered the greatest possibilities as a means of preventing injury by seed-corn maggots, experimental work of the 1929 season, and of the years that followed, was centered around that control measure; and as it was demonstrated in 1928, as well as in previous seasons, that infestations are likely to occur only in soils containing decaying vegetation, the later experiments were conducted under a wider variety of soil conditions. The tests were conducted on several farms each season and included the greater part of the commercial planting season of the areas involved.

The control studies of 1929 consisted of five experiments on three farms in the vicinity of Charleston. Comparisons were made of seed planted freshly cut with that suberized in the previously described insulated and heated room and with seed suberized in the storage houses of the various growers before being planted.

During 1929 tests were made of the use of small-sized seed potatoes as a means of preventing or reducing seed-corn maggot injury. The smaller tubers were either planted whole or were cut into two or three pieces. It should be noted that these tests did not involve the planting of smaller sized seed pieces than those cut from larger tubers, but of pieces with less cut surface or not cut at all.

The experiments of 1929 were composed of from one to six, and in most cases four, replications of each type of treatment in field plots of two rows of plants each, the rows ranging in length in the different tests from 420 to 525 feet. The plots of most experiments were approximately one-fifteenth of an acre in area.

Maine-grown seed was used in all parts of experiments 1, 2, 3, 4A, 4B, and 5. New Jersey seed was used in experiments 4C and 4D.

Seed-corn maggot infestations developed in two of the five experiments conducted during the 1929 season. Those experiments having infestations were in soils containing large quantities of partly decayed spinach and cabbage plants of previous crops, whereas there were no infestations in the soils comparatively free of decaying vegetation. Data of the experiments of 1929 are given in table 3. It is evident

TABLE 3.—*Summary of data of experiments 1–5, inclusive, in seed-corn maggot control, in which potato seed pieces planted while freshly cut were compared with those suberized before being planted, Charleston, S. C., 1929*

Experiment No.	Replications	Storage conditions				Plant stand		Maggot infestation		Yield per acre of U. S. No. 1 tubers				Yield per acre of other grades	
		Location [1]	Duration	Mean temperature	Mean humidity	Freshly cut seed	Suberized seed	Freshly cut seed [3]	Suberized seed	Freshly cut seed	Suberized seed	Mean difference [2]	Odds	Freshly cut seed	Suberized seed
	Number		*Days*	*°F.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Bushels*	*Bushels*	*Bushels*		*Bushels*	*Bushels*
1	5	C	14	54.9	83.6	99.4	99.1	0	0	301.0	282.8	−18.2	6:1	37.5	36.9
2	5	C	19	55.7	82.8	99.4	98.4	0	0	276.7	265.7	−11.0	8:1	45.1	44.1
3	5	C	14	54.9	83.6	[3]									
4A	3	C	23	59.9	82.5	99.5	98.7	61.3	0	115.4	131.3	15.9	12:1	61.7	57.5
4B	1	C	23	53.4		91.0	97.5	73.0	12.0	121.7	134.7	10.0	[4]	58.0	38.9
4C	2	C	23	59.9	82.5	98.7	99.0	49.3	0	150.2	152.2	−7.0		37.2	20.3
4D [5]	1	C	23	59.9	82.5	98.4	99.0	42.7	1.3	188.0	231.4	43.4		32.3	24.0
5A	2	C	23	59.9	82.5	99.2	97.4	73.3	1.3	169.3	174.1	4.8		62.4	45.7
5B	1	C	23	53.7		99.7	97.5	60.0	2.0	172.6	183.6	11.0		46.5	43.7
4 and 5 [6]												7.2	11:1		

[1] C signifies stored under partly controlled temperature conditions in specially constructed and heated room; G, in growers' storage rooms.
[2] Minus (−) sign denotes less yield from suberized tubers.
[3] Experiment abandoned after most of seed decayed in wet soil.
[4] Odds not calculated in case of individual experiments composed of less than 3 replications.
[5] Seed listed in this experiment under "Suberized seed" were small-sized uncut seed, and the single infestation of such seed occurred in a bruised portion. Those listed under freshly cut seed were cut from smaller-sized tubers than used in parts A and B of experiment 4.
[6] Those parts having an infestation.

Experiments 4 and 5: Mean difference in maggot infestation between freshly cut and suberized seed = −58.0 percent, $n=11$, $t=14.78$, odds=9,999:1.
Experiments 1–5, inclusive: Mean difference in yields (U. S. No. 1) between freshly cut and suberized seed = −4.3 bushels per acre, $n=18$, $t=.805$, odds=4:1.

that seed suberization in advance of planting reduced the seed-corn maggot infestation to a highly significant degree, as had been true during the previous season, and that grower's storage afforded satisfactory conditions for the healing process. Differences in yield of U. S. No. 1 tubers produced by freshly cut and by suberized seed plantings in 1929 were not significant. Based on the single comparisons, provided in experiments 4A, 4B, 4C, and 4D and not allowing for analysis of data, seed pieces cut from smaller sized tubers did not show an appreciable decrease in infestation over that of pieces cut from larger tubers. The infestation of tubers planted uncut, however, was much less than that of cut tubers, and there was a marked increase in the yield from the uncut seed (experiment 4D).

Although the planting of small, uncut tubers instead of cut seed pieces proved an effective means of practically eliminating seed-corn maggot injury, and although the yield from such plantings was decidedly higher than that of cut seed in the one experiment in which the uncut seed was used, it is doubtful whether such a control measure would prove practical. The supply of small tubers is limited, and their use in the propagation of potatoes might react unfavorably from a genetical standpoint.

EXPERIMENTS OF 1930

As seed suberization before planting had continued to give such satisfactory results in the 1929 season, and appeared to be within the limits of practical use, the process was given further tests in 1930. The control work of that season consisted of comparisons of seed planted freshly cut with that suberized under partly controlled temperature and humidity conditions and that suberized in the growers' storage houses. The length of the suberization period was varied, ranging in the different tests from 7 to 20 days. There were nine experimental plantings, located on five different farms in the vicinity of Charleston. These plantings were made on the various types of soil used for potato production in the district, but the majority were on soils containing decaying vegetation, as past experience had shown that maggot infestations were most likely to occur in such soils. Each seed treatment was replicated at least four times in each of the nine experiments. The treatment plots consisted of from one to two rows, the rows being 2¾ feet wide and ranging in length in the different experiments from 100 to 300 feet. The planting period was from February 14 to March 4. All seed was cut from Maine-grown stock.

Seed-corn maggot infestations developed in all the nine experiments of the 1930 season. The infestations were generally much lighter than those of the previous season, evidently as a result of weather conditions that were more favorable for healing in the soil of those seed pieces that were planted immediately after being cut. Conditions during 1930 also were favorable for rapid sprouting of the seed pieces. The maggot infestations were most severe in those seven plantings made in soils containing decaying cabbage or spinach plants, and were lightest in experiments 1 and 6, which were located in soils comparatively free of decaying vegetation.

Seed-piece suberization in advance of the planting afforded excellent protection against seed-corn maggot injury in the 1930 experiments. Differences between the infestation of suberized seed and that of seed planted freshly cut were highly significant. Seed healed

TABLE 4.—*Summary of data of experiments 1–9, inclusive, in seed-corn maggot control, in which potato seed pieces planted while freshly cut were compared with those suberized before being planted, Charleston, S. C., 1930*

Experiment No.	Replications	Storage conditions				Plant stand		Maggot infestation		Yield per acre of U. S. No. 1 tubers				Yield per acre of other grades	
		Location [1]	Duration	Mean temperature	Mean humidity	Freshly cut seed	Suberized seed	Freshly cut seed	Suberized seed	Freshly cut seed	Suberized seed	Mean difference [2]	Odds	Freshly cut seed	Suberized seed
	Number		*Days*	*° F.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Bushels*	*Bushels*	*Bushels*		*Bushels*	*Bushels*
1	4	C	14	56.6	82.2	99.0	99.1	4.0	0	119.2	149.8	30.6	53:1	122.4	88.7
2A	4	C	12	55.4	85.9	98.8	99.1	20.0	1.3	121.8	121.4	−.4	1:1	57.2	59.4
2B	4	C	12	50.7		98.8	98.1	21.3	0	127.2	103.0	−24.2	22:1	50.2	47.9
3	4	C	18	56.2	83.1	99.1	99.0	8.0	0	114.8	128.4	13.6	28:1	68.2	52.8
4A	4	C	12	55.4	85.0	99.8	99.1	16.0	2.7	116.6	122.3	5.7	3:1	83.6	86.2
4B	4	C	12	50.7		99.6	99.3	4.0	1.3	118.1	102.9	−15.2	6:1	76.3	96.8
5	4	C	12	55.4	85.9	97.5	99.0	14.7	0	84.9	101.2	16.3	115:1	77.2	77.0
6A	4	C	7	56.4	86.1	99.5	99.3	2.7	0	103.2	115.9	12.7	8:1	50.6	52.4
6B	4	C	7	50.1		99.6	99.8	0	0	112.9	111.5	−1.4	1:1	52.9	48.8
6C	4	C	20	56.2	83.2	99.6	99.6	0	0	110.0	105.2	−4.8	1:1	51.0	52.1
6D	4	C	20	51.1		99.3	99.5	0	0	101.6	112.8	11.2	70:1	51.9	54.3
7A	4	C	7	56.4	86.1	98.7	99.6	4.0	2.6	192.8	196.1	3.3	1:1	40.4	41.2
7B	4	C	7	50.1		98.0	99.6	10.6	0	200.5	206.5	6.0	4:1	34.6	41.0
7C	4	C	20	56.2	83.2	99.6	99.1	6.7	0	194.7	199.9	5.2	4:1	44.5	34.9
7D	4	C	20	51.1		99.1	100.0	9.3	1.3	176.8	190.6	13.8	3:1	34.7	38.8
8	4	C	11	55.9	86.7	97.2	98.8	18.0	2.0	99.7	105.9	6.2	4:1	48.2	50.5
9	5	C	18	57.7	84.5	89.6	91.8	28.8	2.4	69.7	78.1	8.4	4:1	29.6	29.6

[1] See footnote 1, table 3.
[2] Minus (−) sign denotes less yield from suberized seed.

Experiments with infestation: Mean difference in maggot infestation between freshly cut and suberized seed = −12.0 percent, $n=43$, $t=6.429$, odds = 9,999:1.
Experiments 1–9, inclusive: Mean difference in yields (U. S. No. 1) between freshly cut and suberized seed = 5.2 bushels per acre, $n=68$, $t=2.101$, odds = 55:1.

in the specially constructed, insulated room and in the storage houses of the various growers was practically free of maggot feeding, as indicated in table 4. Only those suberized seed pieces that failed to heal properly or those that were decayed showed an infestation. The 7-day suberization period was apparently sufficient to protect the seed from maggot injury. The yield of U. S. No. 1 tubers produced by suberized seed was significantly greater than that from seed planted freshly cut. Plant stands during 1930 evidently were not affected by the relatively light maggot infestations. All yields were greatly reduced by the severe drought that extended over the greater part of the growing season.

EXPERIMENTS OF 1931

The experiments of the 1931 season involved the further testing of seed suberization before planting as a means of preventing injury by the seed-corn maggot. The experimental work was in Pamlico County, at Chadbourn, and near Charleston. The tests in the North Carolina districts consisted of the comparison of seed planted freshly cut with that suberized under a frame covered by moistened bags in a well constructed, insulated, sweetpotato-curing house of a local grower at Cash Corner, N. C. The work at Charleston involved the supervision of, and keeping records of, attempts of two local growers to suberize part of their seed potatoes before planting, and the comparison of these with adjoining plantings of freshly cut seed. Each treatment was replicated from two to five times in the eight North Carolina experiments, and one and four times, respectively, in the two South Carolina tests. The treatment plots in North Carolina were composed of from one to two rows each, the rows being 3½ feet wide and ranging in length from 120 to 263 feet in the various experiments; those of the South Carolina tests were composed of from one to six rows, 2¾ to 3 feet wide and 80 to 510 feet long. The seed of the Charleston experiments was cut and planted by the growers. The suberization period ranged from 6 to 41 days and the planting period from February 5 to April 2. Maine-grown seed was used in experiments 8 and 10, and in part of 5 and 9; Prince Edward Island-grown seed was used in all the other tests. Experiments 1 and 2 were conducted at Charleston, 3 to 9, inclusive, in Pamlico County, and No. 10 at Chadbourn.

Infestations of seed pieces by the seed-corn maggot occurred in both experiments in the vicinity of Charleston and in four of the North Carolina experiments. The soils of the four North Carolina tests that had no infestation were relatively free of decaying vegetation. Infestations were most severe at Chadbourn and were comparatively light in the other North Carolina experiments. Suberized seed was practically free of maggot injury in all tests, the differences in infestation of suberized and of freshly cut seed being highly significant. The yield of U. S. No. 1 tubers was highly significantly greater in the case of the suberized seed plantings. The growers at Charleston evidently were able to suberize their potato seed pieces sufficiently to prevent entirely seed-corn maggot injury. Data obtained from the various experiments of the 1931 season are given in table 5.

TABLE 5.—*Summary of data of experiments in seed-corn maggot control in which potato seed pieces planted while freshly cut were compared with those suberized before being planted, experiments 1–2, Charleston, S. C., experiments 3–9, Pamlico County, N. C., and experiment 10, Chadbourn, N. C., 1931*

Experiment No.	Replications	Storage conditions				Plant stand		Maggot infestation		Yield per acre of U. S. No. 1 tubers				Yield per acre of other grades	
		Location [1]	Duration	Mean temperature	Mean humidity	Freshly cut seed	Suberized seed	Freshly cut seed	Suberized seed	Freshly cut seed	Suberized seed	Mean difference [2]	Odds	Freshly cut seed	Suberized seed
	Number		*Days*	*°F.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Bushels*	*Bushels*	*Bushels*		*Bushels*	*Bushels*
1	1	G	9	[3] 53.1	[4] —	99.5	99.3	34.6	0	265.8	266.2	0.4		15.0	12.7
2	4	G	10	[3] 54.7	[4] —	99.2	99.6	4.0	0	305.8	354.6	48.8	287:1	24.1	26.4
3	4	G	10	52.6	88.2	92.1	87.7	0	0	154.5	157.8	3.3	3:1	30.9	30.2
4	4	G	15	52.4	89.6	98.3	93.3	0	0	165.7	161.5	−4.2	3:1	35.5	33.0
5	4	G	28	51.2	87.1	98.8	97.2	6.0	0	177.7	191.7	14.0	4:1	38.4	39.5
6	4	G	16	52.3	89.8	98.7	98.9	0	0	209.4	204.8	−4.6	2:1	20.4	22.0
7	3	G	15	52.4	89.6	99.5	99.2	6.0	0	371.3	370.1	−1.2	1:1	22.8	19.0
8	2	G	6	53.1	91.2	96.9	98.4	0	0	330.2	346.3	16.1	5:1	15.6	20.1
9	3	G	28	49.4	89.6	99.7	97.7	2.0	0	252.4	276.3	23.9	12:1	18.4	21.9
10	4	G	[5] 22	50.6	90.2	97.5	96.8	48.0	8.0	82.0	89.6	7.6	9,999:1	29.0	29.8

[1] See footnote 1, table 3.
[2] Minus (—) sign denotes less yield from suberized seed.
[3] Daily means of outside air, recorded by Weather Bureau of the U. S. Department of Agriculture.
[4] No records kept, but potatoes stored under high (80 to 90 percent) humidity conditions.
[5] Kept under normal storage conditions for 19 more days before being planted.

Experiments with an infestation: Mean difference in maggot infestation between freshly cut and suberized seed=−16.48 percent, $n=24$, $t=4.623$, odds=9,999:1.
Experiments 1–10, inclusive: Mean difference in yields (U. S. No. 1) between freshly cut and suberized seed=10.9 bushels per acre, $n=32$, $t=2.652$, odds=214:1.

EXPERIMENTS OF 1932

As the experimental work previous to 1932 had shown that injury to potato seed pieces could be prevented to a large extent by suberization of the seed before their planting, and as several growers of the Charleston district had expressed the desire to give the method an accurately weighted test on their farms, it appeared advisable to observe the efforts of these growers in order that the practicability of seed suberization as a control method might be further established. In connection with other studies then under way at the laboratory, observations were made of all stages of the seed-suberization attempts of two growers of Charleston County. These growers were given the necessary information, their operations were observed, and representative samples of the suberized seed of each farm were planted in a designated location by each grower and in such a manner as to allow a comparison with seed planted freshly cut. One planting of each treatment was made on each farm, the plots consisting of two rows, 150 yards long on one farm and 143 yards long on the other farm, the rows being 3 feet wide in each case. The suberized seed of each farm was held in storage about 10 days after being cut and before being planted.

On one of the farms no seed-corn maggot infestation developed, On the other farm a comparatively light infestation occurred, 16 percent of the freshly cut seed and none of the suberized seed showing injury. Evidently the damage was not sufficiently severe to affect the plant stand or the yield. The plot planted with freshly cut seed showed a plant stand of 97.2 percent and produced 102.5 bushels of U. S. No. 1 and 36.4 bushels of No. 2 tubers per acre; the plot planted with suberized seed had a 97.9-percent stand and produced 100.5 bushels of No. 1 and 35.8 bushels of No. 2 tubers per acre. The decrease in yield of the suberized seed may have been due to the fact that germination of this seed was slightly delayed as compared to that of the freshly cut seed and that the potatoes in the experiment were harvested before the plants were mature, in accordance with the usual commercial practice.

Observations of the 1932 season would indicate that potato-seed-piece suberization in advance of planting may be practiced with satisfactory results in the storage houses of the average grower of the South Atlantic States. Evidently there is sufficient formation of wound periderm over the cut surfaces of the seed pieces stored under high humidity at the temperatures of 50° to 55° F. normally existing late in January, February, and early in March to protect the seed pieces from the seed-corn maggot. It was demonstrated that adequate humidity could be maintained by keeping the cut seed under a canopy of moist bags and by wetting the floor of the storage room.

EXPERIMENTS OF 1933

The headquarters of the Charleston field laboratory of the Bureau of Entomology was moved during the summer of 1932 from a private farm to the newly established South Carolina Truck Experiment Station. As the facilities of the new location afforded an opportunity to conduct field tests under conditions wherein all farm operations could be controlled, it was thought advisable to extend the seed-suberization tests another season. Particularly was it desired to

determine whether the seed would heal under the existing temperatures of another season, and to give the treatment further tests under conditions that indicated probable development of a severe seed-corn maggot infestation.

The seed potatoes, Maine-grown certified Irish Cobblers, were all treated on February 6 with formaldehyde, 1 pint to 15 gallons of cold water, for a period of 2 hours. After the seed had dried thoroughly following the disinfection, one-half the quantity of potatoes was cut on February 6 into blocky seed pieces and stored along with the uncut seed in ventilated bushel baskets placed on the cement floor of a 6- by 10- by 8-foot room in the basement of the experiment station office and laboratory building. The cut seed was poured, at the end of 24 and 48 hours from the time of cutting, from one container to another to prevent the cut surfaces of the seed pieces from sticking together. A light wooden frame was constructed to fit over the entire lot of seed, whole and cut. This frame was covered with the bags in which the seed had been shipped, a 12-inch space being allowed between the frame and the seed. These bags were given the formaldehyde disinfection at the outset and kept moist during the storage period by being daily immersed in water and the excess of water wrung out by hand. No artificial heat was used in the storage room. After 2 weeks of this storage the seed was moved to the well ventilated portion of the basement and allowed to dry for 3 days until the date of planting. The remaining half of the lot of potatoes was cut into seed pieces on the day of planting.

Each of the two seed treatments was replicated four times in plots consisting of two rows of plants, each row being 480 feet long and 33 inches wide. Thus each seed treatment was tested on individual plots 2,640 square feet in size and on a total area of about one-fourth acre. The plants were spaced 12 inches apart.

The experimental plot was planted in a Norfolk fine sandy loam soil containing a large quantity of partly decayed cabbage plants of the winter crop. The potatoes were planted February 23 and harvested May 22-25, one replication being dug each day.

An examination of 25 seed pieces of each type of seed on March 15 indicated that 72 percent of the seed pieces that had been planted freshly cut were, or had been, infested with the seed-corn maggot. None of the suberized seed showed signs of injury by the insect. The examination was made shortly after the peak of larval abundance and when most of the larvae were pupating. The insect injury apparently was not serious enough to affect the stand of plants but did significantly affect the yield. The odds were 102:1 that areas planted with suberized seed produced 19.5 bushels of U. S. No. 1 tubers per acre, or 23.4 percent, more than did areas planted with freshly cut seed. Germination records showed that plants from the suberized seed were somewhat later reaching the soil surface than the sprouts of seed pieces planted freshly cut. As this delay evidently did not result in a reduced yield, under the conditions of the experiment, it might prove of advantage in instances of late frost, which often seriously injures the early potato crop of the South Atlantic States.

Data obtained from the 1933 experiment are summarized in table 6.

TABLE 6.—*Summary of data of experiment in seed-corn maggot control in which potato seed pieces planted while freshly cut were compared with those that were suberized before being planted, Charleston, S. C., 1933*

Seed treatment	Replications	Storage conditions				Plant stand	Maggot infestation	Yield per acre of U. S. No. 1 tubers				Yield per acre of No. 2 tubers
		Location [1]	Duration	Mean temperature	Mean humidity			Yield per acre	Mean difference	t	Odds	
	No.		*Days*	*°F.*	*Pct.*	*Pct.*	*Pct.*	*Bu.*	*Bu.*			*Bu.*
Freshly cut	4	C	14	56.1	93.9	98.5	72.0	83.3				39.8
Suberized	4	C	14	50.1	93.9	98.7	0	102.8	19.5	4.655	102:1	38.7

[1] See footnote 1, table 3.

GENERAL DISCUSSION OF RESULTS OF CONTROL STUDIES

A summary of the data of the suberization experiments which were presented in tables 1 and 3 to 6, inclusive, is given in table 7.

It will be noted that for the general summary the experiments of the various years were divided into the following groups: (1) Those having maggot infestations; (2) those that had no infestations; (3) a combination of (1) and (2); (4) those having an infestation and for which the seed was suberized under partly controlled temperatures; (5) those having an infestation and for which the seed was suberized in storage houses of the growers at existing temperatures; (6) those having no infestation and for which the seed was suberized under partly controlled temperatures; and (7) those having no infestation and for which the seed was suberized at existing temperatures in the storage houses of growers.

In all there were 136 comparisons (treatment replications) of potato seed pieces suberized in advance of planting and of seed pieces planted while freshly cut. Seed-corn maggot infestations developed in 100 of these comparisons. Of the 100 tests, 48 were of seed suberized under partly controlled temperatures and 52 were of seed suberized at existing temperatures.

The time during which the seed was held after being cut and before being planted ranged from 6 to 28 days, with the exception of one lot that was kept under high humidity for 22 days and under normal conditions for an additional 19 days before being planted.

Mean temperatures ranged from 48.2° to 59.9° F. during the periods of suberization of the various lots of seed, ranging from 48.2° to 56.1° when the seed was held under existing temperatures and from 54.9° to 59.9° when the seed was stored under partly controlled temperatures.

The mean relative humidity during the period of seed-piece suberization ranged from 82.2 to 93.9 percent. As it proved more difficult to maintain a high humidity when artificial heat was used in the place of storage, the mean relative humidity prevailing during the suberization of seed at partly controlled temperature fluctuated between 82.2 and 86.1 percent, whereas the mean humidity ranged from 87.1 to 93.9 percent when no artificial heat was used.

TABLE 7.—*Summary of data of all experiments in which freshly cut potato seed pieces were compared with those suberized to protect them from seed-corn maggot injury, 1928 to 1931, inclusive, and 1933, Charleston, S. C., Pamlico County, N. C., and Chadbourn, N. C.*

Grouping of experiments as to maggot infestation	Seed treatment	Replications [1]	Storage conditions				Maggot infestation			Plant [5] stand	Yield per acre [6]	
			Location [2]	Duration range	Mean temperature range	Mean humidity range	Observations [3]	Mean difference [4]	Approximate odds		Mean difference	Approximate odds
		Number		*Days*	*°F.*	*Percent*		*Percent*		*Percent*	*Bushels*	
(1) With	Freshly cut	100	C and G	7–28	48.2–59.9	82.2–93.9	98			98.3		
	Suberized	100	do	7–28	48.2–59.9	82.2–93.9	98	−19.3	9,999:1	98.0	10.7	9,999:1
(2) Without	Freshly cut	36	do	6–20	50.1–56.2	82.8–91.2	22			98.3		
	Suberized	36	do	6–20	50.1–56.2	82.8–91.2	22			97.2	−3.2	5:1
(3) Combination of 1 and 2	Freshly cut	136	do	6–28	48.2–59.9	82.2–93.9	120			98.3		
	Suberized	136	do	6–28	48.2–59.9	82.2–93.9	120	−15.7	9,999:1	97.8	7.0	6,284:1
(4) With	Freshly cut	48	C	7–23	55.4–59.9	82.2–86.7	41			97.9		
	Suberized	48	C	7–23	55.4–59.9	82.2–86.7	41	−21.3	9,999:1	98.1	9.6	6,284:1
(5) With	Freshly cut	52	G	7–28	48.2–56.1	87.1–93.9	57			98.6		
	Suberized	52	G	7–28	48.2–56.1	87.1–93.9	57	−17.9	9,999:1	98.0	11.7	1,454:1
(6) Without	Freshly cut	14	C	14–20	54.9–56.2	82.8–83.6	10			99.5		
	Suberized	14	C	14–20	54.9–56.2	82.8–83.6	10			99.0	−11.8	20:1
(7) Without	Freshly cut	22	G	6–20	50.1–53.1	88.2–91.2	12			97.5		
	Suberized	22	G	6–20	50.1–53.1	88.2–91.2	12			96.1	2.2	4:1

[1] Does not include the 2 replications of experiment 1 of the 1928 season eliminated because of errors during harvest, and the single replication composing experiment 4D of the 1929 season as this was not a true comparison of freshly cut and suberized seed.
[2] See footnote 1, table 3.
[3] Of 25 seed pieces each.
[4] In favor of suberized seed.
[5] Weighted in accordance with the number of replications.
[6] U. S. No. 1 tubers.

A total of 120 determinations of seed-corn maggot infestation were involved in the total of 136 field-plot replications of the 2 types of seed, and 98 such determinations in those 100 replications having an infestation. Thus there was approximately 1 such determination for each replication. As each infestation determination involved the examination of 50 potato seed pieces, 25 of each type of seed, a total of 6,800 seed pieces were examined during the course of the suberization experiments.

The statistical study of the infestation data indicated that during each of the five seasons, and during the entire period as a unit, the odds were above 9,999:1 that suberized potato seed pieces had a smaller degree of seed-corn maggot infestation than did seed pieces planted while freshly cut. These highly significant differences existed in the case of seed suberized under partly controlled temperatures and in the case of seed suberized at existing temperatures. Mean differences existing between the infestations of suberized and of freshly cut seed were 19.3 percent in all those experiments having infestations, 15.7 percent in all experiments combined, 21.3 percent in the experiments planted with seed suberized under partly controlled temperature, and 17.9 percent when the seed was suberized at existing temperatures. It should be noted that these figures do not represent differences between the peaks of infestation, but of the entire period of the seed-piece examinations, which in most cases were begun before the seed was attacked.

In none of the 136 field comparisons did suberized seed pieces show a significantly greater infestation than those planted while freshly cut. The infestations that occurred in the suberized seed plantings were in every case confined to decaying seed pieces, to those that failed to heal, or to those that had been bruised in such a manner as to approximate the conditions of sets planted while freshly cut.

When the data obtained from the several experiments of each year were grouped by years (tables 1 and 3 to 6) it was found that significant increases in the yield of U. S. No. 1 tubers resulted from the use of suberized seed as compared with freshly cut seed in four out of the five seasons of study. In the other year (1929) there was no significant difference between such yields of the two types of seed. Apparently the infestations or the accompanying conditions of that season were such as not to affect the yield. Significant increases in U. S. No. 1 tuber yield followed the use of suberized seed in six individual experiments during the five seasons. The greatest significant increase was a mean difference of 30.6 bushels per acre in experiment 1 of the 1930 season. In no single experiment or season did freshly cut seed give a significantly greater yield of U. S. No. 1 tubers.

When the yield data of all seasons were combined (table 7) and the experiments were grouped according to the presence or absence of seed-corn maggot infestations and according to where the seed was stored during the suberization process, it was found that in those 100 comparisons having an infestation there was a highly significant increase of 9.6 bushels of U. S. No. 1 tubers per acre following the use of seed suberized under partly controlled temperature, a highly significant increase of 11.7 bushels of such tubers per acre when the seed was suberized at existing temperatures in growers' storage houses, and a highly significant increase of 10.7 bushels per

acre when data of the two types of comparisons are combined. Suberized seed showed a highly significant increase of 7.0 bushels per acre of U. S. No. 1 tubers when data of all experiments of all seasons were combined, regardless of whether or not seed-corn maggot infestations were present. There were no significant differences between the U. S. No. 1 tuber yield of suberized and of freshly cut seed when data of those experiments having no infestation were combined. This was true regardless of whether the seed had been suberized under partly controlled temperature or under existing temperature conditions.

As it was demonstrated that suberized potato seed pieces had a significantly smaller seed-corn maggot infestation than did seed

FIGURE 3.—Potato seed pieces with suberized cut surfaces: *A*, Wound periderm layer broken to show its nature; *B*, layer intact; *C*, seed piece cut to show appearance of a freshly cut tuber surface.

planted freshly cut, and that the tuber yield of U. S. No. 1 from suberized seed was significantly greater than that from freshly cut seed in the presence of infestations and was not significantly different from that of freshly cut seed when no infestations were present, it might be considered that it was thereby established that the seed-corn maggot was directly associated with a reduction of 7.0 bushels of U. S. No. 1 tubers per acre under all conditions existing during the five seasons, and for a reduction of 10.7 bushels per acre of such tubers when only those comparisons having an infestation are considered.

As the comparisons of freshly cut seed with that suberized in the two types of storage were not always conducted under conditions that would result in fair storage comparisons, any differences in maggot infestation and in yield following the use of the two types of storage should not be considered as indicating superiority of either type of storage.

There was no appreciable difference in the maggot infestation of seed suberized for 6 or 7 days and that held as long as 41 days before being planted. Although it is realized that the suberization process

probably was not complete at the end of the shorter storage periods, it would appear that the healing had advanced sufficiently to protect the cut surfaces of the seed pieces from the soil organisms that cause such surface lesions as induce maggot injury.

Comparative stands of plants and the yield of tubers other than U. S. No. 1 apparently were not greatly affected in the experimental plantings by maggot injury or by suberization of the seed in advance of planting. It was not deemed advisable to make a statistical study of such data.

Infection of several lots of suberized seed with *Fusarium coeruleum*[15], and probably with other organisms, decreased the plant stand and probably the yield to some extent. The infection evi-

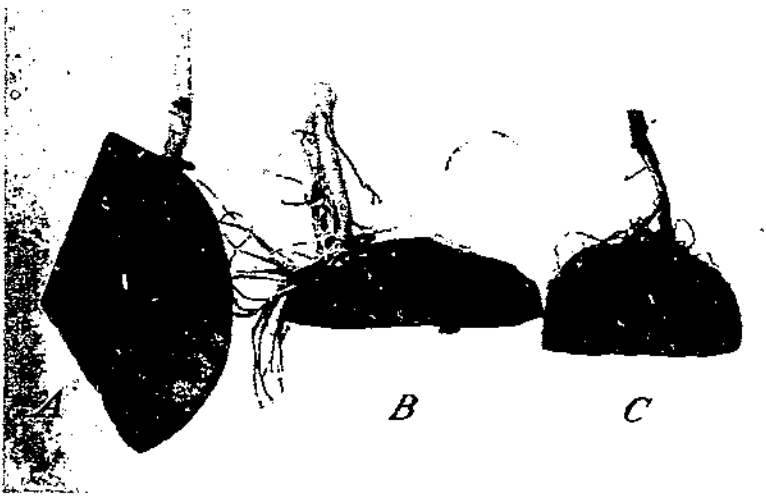

FIGURE 4.—Effectiveness of suberization in preventing seed-corn maggot injury to potato sets: *A*, Suberized before being planted; *B*, planted freshly cut, with the resulting surface lesions; *C*, same as *B*, but with maggot injury.

dently began in the storage room after the seed was cut and before the suberization process was well under way, and probably was a result of ineffective disinfection of the seed or the surroundings.

Specimens of seed pieces that were suberized before being planted for comparison in field plantings with seed planted freshly cut are shown in figure 3.

In figure 4 are shown three potato seed pieces which illustrate the effectiveness of suberization of the cut surfaces in preventing seed-corn maggot injury. All three sets were planted at the same time and in adjoining rows. Set *A* was suberized before being planted, and sets *B* and *C* were planted while freshly cut. On set *B* may be seen the lesions that often appear on the cut surfaces of seed pieces that are planted soon after being cut. These lesions were present on set *C*, which was cut to reveal the seed-corn maggots and their injury.

[15] Identified by Freeman Weiss of the Bureau of Plant Industry.

CONTROL RECOMMENDATIONS

The recommendations that are offered herein for the prevention of injury by the seed-corn maggot to planted potato seed pieces by cutting the seed pieces 10 days or more in advance of planting are based on experiments conducted during six seasons in the early-crop-producing districts of North Carolina and South Carolina and upon observations of practices of growers in those districts during an additional three seasons. It is possible that the control recommendations will be found applicable to potato-growing districts other than those of the South Atlantic Coastal Plain.

Details that should be followed in order to obtain satisfactory healing of the cut surfaces of potato seed pieces have been described by Wright and others (*30, p. 20*). The most pertinent parts of the suggestions of those writers are as follows:

Seed potatoes should be treated or disinfected to destroy surface-borne disease organisms, and should be dried before cutting.

Cutting should be done with sharp thin-bladed knives to insure smooth cut surfaces.

Cutting should not be done in full sunlight.

The seed should be handled only in clean containers, preferably disinfected with the solution used to treat the potatoes, and stored in a clean location where the walls and floors have been disinfected or fumigated.

Cut seed may be stored in baskets, crates, or barrels. The contents should be poured from one container to another after 24 hours and again after 48 hours, in order to break apart the pieces that stick together.

The cut seed should be stored in a fairly airtight room with a temperature of about 60° F. A humidity of 85 to 90 percent should be maintained. This may be accomplished by wetting the floor or hanging up clean wet sacks around the walls. An earth floor is desirable, as it is easily kept damp.

Cut seed handled and kept under the above conditions may safely be held as long as 10 days before planting. If it is necessary to hold them longer than this the temperature should be lowered to about 40° F., in order to retard sprouting.

It is well to remove the seed from the high humidity to an airy place 2 or 3 days before planting, in order to allow the cut surfaces to dry out and toughen before handling.

There are other important details that should be taken into consideration in the suberizing of potato seed pieces in advance of planting and in the use of such seed in seed-corn maggot control.

Even though seed potatoes are disinfected before being cut, the chemical used may cause injury to the cut surfaces later as a result of their coming in contact with the treated skin surfaces of adjacent seed pieces in a container. Compounds containing mercury were found to be capable of causing lesions which served to increase seed-corn maggot injury. Formaldehyde was the most satisfactory of the disinfectants used.

A canopy of moist, previously disinfected bags held on a frame over and around the seed potatoes during the suberization process is an effective aid in maintaining high humidity. The bags should be remoistened daily by being dipped in and wrung free of excess water, or by being sprinkled while in position on the frame.

Suberized seed should be handled with care and be planted by hand or with other than a picker type of planting machine in order to prevent breaking the newly formed protective covering of the cut surfaces.

Suberization of potato seed pieces in advance of planting should be most beneficial when the crop is to be planted in soils containing

quantities of decaying vegetation, particularly that of such crops as cabbage, spinach, or beans, or when organic fertilizers are to be used and not promptly and thoroughly covered with soil. The seed-corn maggot is usually more abundant under such conditions.

The cost of seed suberization should be only that of the labor of the extra handling during the healing period and that of the maintenance of a high humidity in the storage house. The actual expense would depend on the efficiency of and the prevailing costs of farm labor. As stated by Wright and others (*30, p. 20*),

> Many potato growers consider it of economic advantage to cut potatoes into seed pieces in advance of planting time because of the better distribution of labor that this practice affords.

SUMMARY

The seed-corn maggot (*Hylemya cilicrura* (Rond.)) is an insect that inhabits all arable portions of North America and many other parts of the world. If often causes severe damage to newly planted potato seed pieces, this damage occurring frequently to the early crop of sections of the South Atlantic Coastal Plain. The injury results from the feeding of the larvae of the insect. This feeding begins on the cut surfaces of seed pieces and may extend throughout the set. Weakened plants or missing hills, with a consequent reduction in plant stand and in tuber yield, are results of the insect injury.

Experiments designed to develop an effective and practical means of preventing damage by the insect to potato seed pieces were conducted by the Bureau of Entomology and Plant Quarantine, with the later cooperation of the Bureau of Plant Industry, during the period from 1925 to 1933 in the vicinities of Charleston, S. C., and Bayboro and Chadbourn, N. C. All tests were made on what is known as the early potato crop.

Seed-corn maggot injury to potato seed pieces was found to be most prevalent in soils containing quantities of decaying vegetation. Infestations occurred most frequently when potatoes were planted after the plowing under of the remains of such previous crops as cabbage, spinach, and beans.

Preliminary control studies indicated that no chemical treatment of the seed pieces or of the surrounding soil would prove effective in preventing damage by the insect. All such treatments showed tendencies toward increasing seed-corn maggot damage, either by interfering with normal healing of the cut surfaces of the seed pieces or by causing lesions on these surfaces. The presence, on the cut surfaces of potato seed pieces, of lesions caused by such agencies as bacteria, fungi, or fertilizers was also found to induce seed-corn maggot injury. Coating of the seed pieces with finely ground sulfur, a common practice of growers in certain sections, seemed to offer great possibilities during the early studies, but did not give a significant reduction of seed-corn maggot infestation in more intensive tests.

The most important outcome of the preliminary control studies were the observations that seed pieces with well-healed cut surfaces were notably free of seed-corn maggot injury.

Healing of the cut surface of a potato tuber consists in (1) a chemical transformation, known as suberization, in the cell walls of the cut surface whereby the cellulose is changed to, or infiltrated with, suberin, and (2) the formation, resulting from cell division, of a pro-

tective covering known as wound periderm, or "scar tissue," under the suberized layer. Under favorable conditions this process will take place in the soil, but favorable conditions are not often present when the early crop is planted.

Intensive tests were made during 5 seasons at 3 locations to determine the value as a control measure of suberization in advance of planting. Seed pieces that had been cut and held from 6 to 28 days under known temperature and humidity were compared in systematically paired field plots with seed planted while freshly cut—the usual practice. The seed planted freshly cut was always of the same lot as the suberized seed with which it was compared, and was stored under the same conditions at all times. The field plots usually were composed of 2 plant rows, and were planted with from 200 to 900 seed pieces, spaced approximately 12 inches apart. Each experiment contained from 1 to 12 replications of the 2 types of seed, the usual number of replications being 4. From 1 to 10 experiments on a number of different farms were conducted during each of 5 seasons. Results are based on comparative seed-corn maggot infestations of 25 seed pieces of each treatment taken at random from each experiment each week during the period of insect activity, and upon the yield of U. S. No. 1 tubers on the entire field plot.

There were 136 field-plot comparisons of suberized and of freshly cut potato seed pieces. Seed-corn maggot infestations developed in 100 of these comparisons, 48 of the comparisons where there were infestations being of freshly cut seed with that suberized under partly controlled temperature conditions and 52 being of freshly cut seed compared with that suberized in growers' storage houses at existing temperatures. There were 36 comparisons in which no infestation developed, evidently owing in most cases to the scarcity of decaying vegetation in the soils.

Statistical studies of the data of individual seasons indicated that the odds are above 9,999:1 that the seed pieces suberized in advance of planting had a smaller degree of seed-corn maggot infestation during each of the five seasons that the statistically analysed investigations were underway. These highly significant odds in favor of suberized seed also existed when infestation data of all five seasons were combined. Seed suberized under partly controlled temperature as well as that suberized at existing temperatures had significantly less infestation than that planted while freshly cut, the mean differences in infestation being 21.3 and 17.9 percent, respectively. Considering both types of storage together, the reduction in maggot infestation with suberized seed was 19.3 percent in the case of those tests that developed infestations and 15.7 percent when all experiments are considered, regardless of whether or not the insect was present. These infestation figures represent the percentage of the total number of examined seed pieces which either contained seed-corn maggots or showed evidence of their feeding. As the determinations of infestation were begun in many cases before the insect appeared, the figures represent the average and not the peak of the infestation.

As indicated by a statistical study of the data of individual seasons, significant increases (odds ranging from 55:1 to 214:1) in the yield of U. S. No. 1 tubers resulted from the use of suberized seed during four of the five seasons of study. Yield differences during the other season were not significant. When the data of all seasons were

grouped together it was found that a highly significant difference (odds above 9,999:1) existed between the yields from suberized seed and the yields from freshly cut seed in the grouping of those experiments in which a seed-corn maggot infestation developed. The mean difference was 10.7 bushels per acre of U. S. No. 1 tubers in favor of suberized seed. Differences between the yield of suberized and of freshly cut seed were not found to be significant when the data of all experiments not having infestations were grouped together. Considering all experiments of all seasons as a whole, a highly significant mean difference of 7.0 bushels per acre was found to exist in favor of suberized seed. In those experiments where there was a seed-corn maggot infestation the increase in yield of suberized seed over that of freshly cut seed was highly significant regardless of whether the suberization took place under partly controlled temperatures in a well insulated room at approximately 55° to 60° F. or in the fairly airtight storage houses of growers at existing mean temperatures of approximately 50° to 55°. In either case relative humidities above 80 percent were maintained.

The association of seed-corn maggot infestation with a reduction in the yield of U. S. No. 1 tubers was established. Plant stands and the yield of other than U. S. No. 1 tubers were apparently not greatly affected by the infestations that occurred during the course of the investigations.

Seed suberization before planting is recommended as a means of preventing maggot injury to potato seed pieces when the crop is to be planted under conditions that induce attacks by the insect.

A method of obtaining satisfactory suberization of potato-seed pieces in advance of planting is described. The studies indicated that seed-piece suberization sufficient to protect the sets against the seed-corn maggot can be satisfactorily accomplished by growers in the coastal area of the South Atlantic States by storing the cut-seed pieces for about 10 days in fairly airtight houses at normally existing temperatures, provided the seed and surroundings are thoroughly disinfected and a high humidity is maintained.

If existing mean temperatures are approximately 50° to 55° F., the cost of the process should only be that of the extra handling of the seed and the maintenance of a relatively high humidity. Actual expenses will depend upon efficiency and prevailing costs of labor. It might be considered an economic advantage to cut seed potatoes in advance of planting time because of the better distribution of labor resulting therefrom.

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