SEED TREATMENTS

FOR THE CONTROL OF CERTAIN DISEASES

of

WHEAT
OATS
BARLEY

By

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Seed Treatments for the Control of Certain Diseases of Wheat, Oats, and Barley

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ANNUAL LOSSES from easily preventable diseases in oats, wheat, and barley run into something like ten millions of bushels in Illinois. Tho much is being said at the present time about the need of crop reduction, all thinking people will agree that the economical way to reduce crops is thru reduction of acreages and not thru permitting the ravages of preventable diseases, pests, and other destructive forces. Every piece of research that enables the farmer to market superior quality products or to operate at a lower cost of production means just that much gain in meeting world competition in agriculture.

The smuts are major diseases in each of the common small-grain crops. Losses from these diseases may be of two kinds. Stinking smut of wheat causes a loss in yield of grain and also in quality. When this smut is prevalent, the threshed grain is discolored and has a foul odor. When sold, it is discounted, so that the farmer receives less per bushel than for smut-free grain. Some smuts cause principally a loss in yield. The loss in yield may be greater than the percentage of smutty heads would indicate, for, as will be shown later, where smut is prevalent, not all infected plants show smutty heads but they are often so reduced in vigor that they yield less than normal plants.

The aim in seed disinfection is to kill all disease infection and at the same time not injure the vitality of the seed. The perfect seed disinfectant has not yet been found, but important advances in that direction have been made in recent years.

Altho certain effective seed disinfectants have been recommended

[a]Acknowledgment for their cooperation in carrying out the experiments reported herein are due R. W. Leukel, Office of Cereal Crops and Diseases, U. S. Department of Agriculture; J. E. Johnson, manager of a group of farms, Champaign, Illinois; and the following present and former Illinois farm advisers: W. F. Purnell, Ford county; G. F. Hoover, Douglas county; C. E. Johnson, Iroquois county; S. G. Turner, Livingston county; Otis Kercher, Vermilion county; R. N. Rasmusen, DeKalb county; H. S. Wright, DuPage county; V. J. Banter, Stephenson county. Valuable help was rendered also by C. J. Simmons, Stockton, as well as by the farmers whose names are given in Tables 9 and 12, pages 539, 548, and 549.

for years, in some cases farmers have found them difficult to handle satisfactorily, and for that reason have not used them. The annual smut infection of oat heads is still 5 percent, causing a total loss in yield of at least 7 percent. Thru rapid strides in organic chemistry in recent years an array of new disinfectants has become available for study. In the present investigations comparisons were made with disinfectants already in general use. Some of the newer products are patented articles that are now being advertised widely, and it is important for the public to know how these compare with other materials available on the market.

Because many seed disinfectants will control certain diseases but, at the same time, will so depress the vigor of the plants that little or no increase in yield is obtained, tests of yield as well as disease control have been considered of prime importance in the experiments here reported. In order to check more closely on the possibility of treatments injuring the seed, tests were made with nearly disease-free seed as well as with seed known to be infected.

HISTORICAL RESUMÉ

As the literature on the effectiveness of seed treatments is very voluminous, only a few references on the history of such treatments and some of the more recent articles that have a close bearing on the experiments reported will be given.

The use of preventive seed treatments may have started in England.[4*] It is said that in about 1760 a shipload of wheat sank at Bristol and that the wheat was salvaged after having been in the sea water. As the germination still was satisfactory, the whole cargo was sold and much of it was sown by farmers thruout that area. At harvest time much of the wheat in England was smutty, but that grown from the seed which had been soaked in sea water apparently was free from smut. From this accidental discovery, the brining method was developed. This method, however, has not proved entirely satisfactory.

Copper sulfate was first recommended as a seed treatment for stinking smut of wheat by Schultess in 1761.[34*] This material did not get into practical use, however, until a century later, when Kühn[32*] carried out more extensive scientific experiments with copper sulfate and made his recommendations in 1858. When a sufficiently strong solution was used to kill the smut spores, germination was frequently weakened. Later it was found that this injury to the grain could be largely prevented by dipping the grain in a lime solution after it had

*These and similar numbers refer to literature citations on pages 571-575.

been dipped in bluestone. This method is used by some to this day. Its use is primarily for treating wheat against stinking smut.

A method for treating grain with hot water to kill smut infection was worked out by Jensen[64*] in Denmark in 1887. It is still the only effective treatment known for loose smut of wheat and one of the loose smuts of barley. It is effective also against the other smuts of small grains, but being exacting and, even at best, injuring the grain slightly, it is used only when no other methods can be used.

Formaldehyde was used as a seed disinfectant by Geuther in Germany in 1895 and by Bolley[3*] in North Dakota in 1896. It soon became a standard treatment for the smuts of oats and stinking smut of wheat and is widely used today. It is quicker and simpler than the hot-water method. A formaldehyde dust for the dry treatment of grain was later developed by Sayre and Thomas.[79*]

Copper carbonate was the first successful dry dust disinfectant. As early as 1902 this material was used successfully by Von Tubeuf[87*] for the control of bunt, but it did not get into commercial use until later. Successful experiments with copper carbonate were made by Darnell-Smith[14*] in 1915, and Mackie and Briggs[50*] introduced it into the United States for bunt control in 1920. It immediately attracted much attention, because here for the first time was a disinfectant that caused no seed injury and remained on the seed until after it was planted, so that some protection was offered against contamination from the soil. It is today a standard treatment for stinking smut, or bunt, of wheat.

Organic mercury disinfectants were first used in medicine. Wesenberg[5*] (Germany) introduced chlorophenol mercury for seed disinfection. The first official tests were made by Riehm. He made some laboratory tests in 1912[69*] and field tests with bunt of wheat and stripe of barley in 1913.[70*] During the next few years various organic mercury compounds were used, all of them wet treatments. Chief of these was a chlorophenol mercury compound marketed in 1915 under the trade name of "Uspulun." A similar material was introduced into this country in 1921 under the name of "Chlorophol." Soon other organic mercury disinfectants were made available to plant pathologists.

Organic mercury dry treatments were used experimentally in the United States for dusting grain as early as 1922.[8, 86*] A commercial dry treatment called "Uspulun Dry Dressing," which was a mercurized nitrophenol compound, appeared in Germany in 1924, and a somewhat similar seed disinfectant (Bayer Dust) was manufactured in the United States in 1925. Further new compounds kept on appearing from time to time, a few of them with superior merit. As a result ethyl mercury chlorid was put on the market in 1927 and ethyl mercury phosphate in 1931 under the trade names "Ceresan" and "New Improved Ceresan" respectively.

While copper carbonate has been fairly satisfactory as a dry treatment for wheat, the organic mercury dry treatments now available are of outstanding value for the treatment of oats and barley as well as being satisfactory for wheat. As a barley treatment they practically stand alone at the present time.

DISEASES INFLUENCED BY SEED TREATMENT: DESCRIPTION AND CONTROL

Only those diseases of wheat, oats, and barley which can be controlled, or of which certain phases can be controlled, by seed treatment will be discussed here. There are many other major and minor diseases of these cereals that cannot be controlled by seed disinfection.

SEEDLING DISEASES OF CEREALS

Seedling diseases occur commonly in all the cultivated cereals and at times cause considerable harm. These infections may kill the young plants before or after they emerge or they may only weaken them. Winter wheat plants so weakened do not survive the winter so well as normal plants; in spring-sown grains the weakened plants do not yield as well as the strong plants.

Some of the seedling diseases are caused by seed-borne fungi such as Gibberella (scab), Fusarium, Helminthosporium, and others. There is little doubt that soil fungi also play an important part in causing seedling diseases. Ethyl mercury chlorid (Ceresan) and ethyl mercury phosphate (New Ceresan) treatments have usually given increases in stands and yields of wheat, oats, and barley even in the absence of known seed infection. Examination of treated and untreated seedlings has clearly shown a difference in amount of seedling infection in some plantings. Good dry treatments, as well as certain wet treatments, help against both the seed-borne and soil-borne diseases, whereas formaldehyde helps only against the seed-borne diseases.

WHEAT DISEASES

Stinking Smut (Bunt)

Stinking smut is not very evident until the grain is threshed. Infected heads look very much like sound heads (Fig. 1) but instead of containing kernels of grain these heads contain small galls filled with

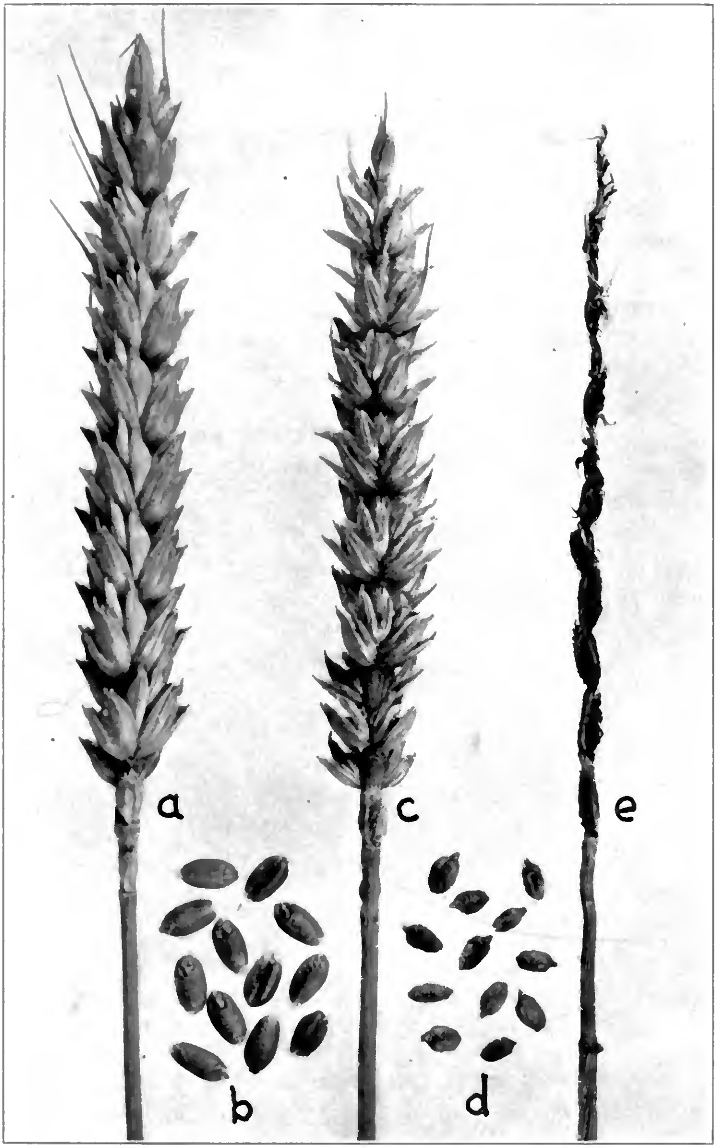

FIG. 1.—SMUT-INFECTED WHEAT (RIGHT) AND A HEALTHY HEAD (LEFT)

(a) Sound head of Fulhio wheat, (b) sound kernels, (c) heads infected with stinking smut, (d) stinking smut galls formed in place of kernels, (e) loose smut head with smut spores mostly blown away. Different methods of seed disinfection must be used to control these two smuts.

black smut spores (*Tilletia levis*) which have a foul odor. In threshing, many of these smut galls break, causing the grain to become discolored and giving it a bad odor. Buyers pay less for such grain than for clean grain, and thus there is a double loss—a loss in yield and a reduced price on the remaining grain. The estimated average annual percentage of wheat heads infected with stinking smut in Illinois wheat fields is about 1.5. This, however, very likely does not represent all the loss to yield, for it has been shown by a number of investigators that stinking smut often causes additional loss by reducing the yield from plants that have smut-free heads. In the experiments later reported in this bulletin (Table 13, page 552) it is shown also that the losses in yield from smut infection in the seed planted were greater than could be accounted for by the number of smutty heads in the resulting crop.

Taken as a whole, the loss from stinking smut may appear small and not worth much attention. The fact is, however, that its distribution is very irregular and on many farms the loss is great. Data on carload shipments of wheat grading smutty are given in Table 1. From these figures it is apparent that the disease varies considerably in importance from year to year and from place to place.

TABLE 1.—WHEAT: PERCENTAGE OF CARLOAD SHIPMENTS GRADING SMUTTY AT NINE ILLINOIS TERMINALS DURING TEN YEARS 1923 TO 1932[a]

Terminals	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Ten-year average
Alton	.3	5.5	0	0	8.4	.1	.9	0	0	0	
Bloomington	0	0	21.9	18.5	0	0	...	...	14.3	0	
Cairo	0	1.1	0	0	0	0	...	...	0	0	
Champaign	.7	0	12.1	0	....	...	...	...	...	...	
Chicago	1.7	0	.03	0	0	1.2	1.2	2.5	.8	.6	
Decatur	...	0	0	3.3	61.2	0	10.3	1.1	1.2	.6	
East St. Louis	3.3	3.0	1.2	3.7	17.1	6.6	1.0	2.6	1.7	.7	
Peoria and Pekin	3.3	4.6	4.9	3.6	13.9	5.1	4.4	4.1	1.1	1.0	
Springfield	...	...	...	...	....	...	2.2	12.9	2.9	.8	
Average	1.3	1.8	5.0	3.6	14.4	1.9	3.3	3.9	2.8	.5	3.85

[a]From U. S. Department of Agriculture reports on smutty wheat; Report No. 6 by Boerner, Leighty, Zehner, and Meier; Reports 16, 17, and 18 by Boerner and Haskell.

These variations are due, to a large extent, to moisture and temperature conditions at the time of planting. A smutty crop results only from infected seed,—the worse the infection, the worse the smut in the crop that follows,—but even if the seed is infected, there may be no smut if the environmental conditions are not suitable. Before the seed is planted, the fungus occurs only on the surface of the grain. After the seed is placed in moist soil, the fungus spores and the wheat kernels both sprout. Then the fungus must penetrate into the tissues of the young plant before the young plant comes thru the soil if it is to penetrate it at all. If, during this time, the soil is very dry or very wet,[28, 47*] or if the soil is warmer than 65° F., very little stinking smut may be expected regardless of the amount of infection carried on the seed.

Smut spores can be seen only in mass; single spores are too small to be seen with the naked eye. Wheat may therefore carry considerable infection which may not show by ordinary examination of the grain. Hence to be entirely safe against stinking smut, the grain should be treated.

Control.—Stinking-smut infection from the soil rarely occurs in Illinois because of the usual rains between threshing and seeding time, and because wheat is nearly always grown in a rotation with other crops. A proper seed treatment is therefore usually very effective in controlling this disease. Two treatments are recommended, copper carbonate and New Ceresan (pages 563 and 565). The cost of these is about the same on the bushel basis. Copper carbonate has the advantage of not causing deterioration of the grain when stored, while grain treated with Ceresan has the advantage of going thru the drill about like untreated grain.

Smut balls in the seed are a source of trouble, causing a certain amount of infection in spite of treatment. It is desirable, therefore, that the smut balls be removed by proper cleaning machinery. A combination of a disk cleaner and fanning mill has been found very satisfactory for this purpose[33, 51, 80*] (Fig. 16, page 565).

In areas where only a small amount of wheat is grown, and where farmers plan to seed as soon as possible after the Hessian fly danger is over, usually little trouble from stinking smut is experienced, and it may be advisable to plan to treat for it only when it does occur.

Stinking smut can be avoided also by growing varieties of wheat that are resistant to it. Resistant varieties that may be adapted to Illinois conditions but have not yet been tested at this Experiment Station are Hope spring wheat[7*] and certain Nebraska selections of Turkey wheat.[31*]

Loose Smut of Wheat

Loose smut (*Ustilago tritici*) is most conspicuous when the wheat is in bloom. At this time the infected heads are black with loose, dusty spores which are blown about by the wind (Fig. 1, e). At harvest time only the empty rachis remains. As the smut spores are blown about during blossoming time, some of the spores come in contact with embryonic kernels and cause infection. The fungus penetrates deep into the kernels and therefore cannot be reached by surface disinfectants. The fungus becomes dormant soon after entrance, and the infected kernels look just like healthy ones. The infected kernels germinate in the same way as healthy ones but if the surrounding conditions are suitable they will produce plants with smutty heads.

The estimated average annual loss from loose smut of wheat in Illinois is 1.6 percent. It can be found in nearly every field every year but only occasionally has it caused any considerable loss. There seem to be some differences in susceptibility of different varieties but the differences usually are not great.

Control.—Only the hot-water method of seed treatment is effective against loose smut. As the treatment is a little difficult to apply and causes some damage to germination,[81*] and as loose smut is not usually very serious, treatment is not ordinarily recommended. Often when a farmer does have trouble with this smut he can exchange grain with a neighbor whose wheat carries less infection. However, the hot-water treatment has been used with success by farmers here and there the world over, and any careful person can manage it. It is described on page 568.

Wheat Scab

Wheat scab (*Gibberella saubinetii*) infection takes place during or after flowering time.[63*] It is best seen while the heads are still green, just before they turn straw color. At this time the infected parts will be straw colored and a trifle shrunken, while the normal parts of the head will still be green. Often there will be a light pink growth at the base of the spikelet and along the edges of the glumes where they overlap. One, several, or all of the spikelets of a head may be infected (Fig. 2). Upon examination the infected kernels show a shriveled and bleached condition (Fig. 3), and some of the bleached kernels may show a little of the pink fungous growth. When kernels are shriveled from other causes such as drouth or rust, they do not show the bleached condition.

Infection takes place only when there is much rainy, muggy weather either during or shortly after the heading period. As moisture conditions during the heading period vary considerably from year to year, prevalence of the scab disease also varies considerably, only an occasional year ordinarily being favorable for a very destructive epidemic. An outstanding epidemic occurred in 1919, when great losses resulted, some fields being so completely ruined that they were not harvested. Scab was also of importance in Illinois in the years 1917, 1921-1924, and 1927-1929. In the intervening years there has been little or no loss from scab in the state.

FIG. 2.—SCAB-INFECTED WHEAT CONTRASTED WITH A HEALTHY HEAD (LEFT)

On these immature heads the healthy parts have remained a normal green color, whereas the infected parts have turned straw color: (a) healthy head, (b) central part of head infected, (c) upper half of head infected, (d) whole head infected. When mature, the kernels in the infected parts will look as they do in Fig. 3(B).

Head infection does not come from infected seed, as it does with the smuts, but comes from spores produced in old, infected crop refuse, especially cornstalks. Extensive surveys have shown that wheat grown after corn is likely to suffer much more from scab than wheat that follows some other crop.[16, 36*]

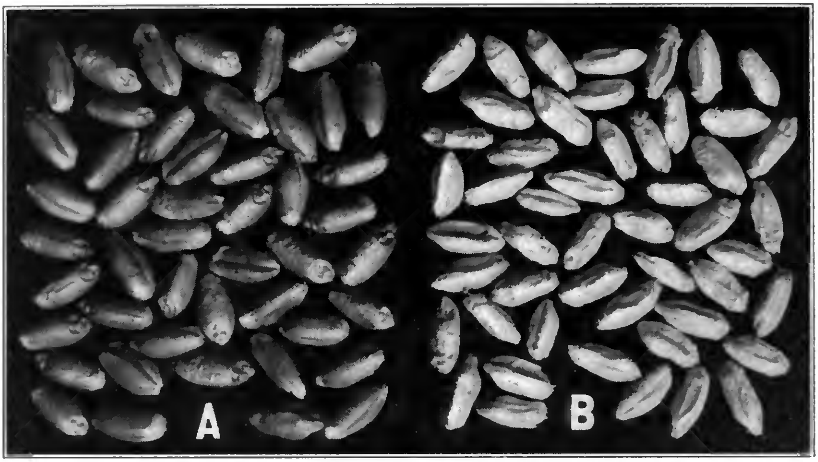

FIG. 3.—HEALTHY WHEAT KERNELS (A) AND SCAB-INFECTED KERNELS (B)

Scab-infected kernels are more or less shriveled, light in weight, bleached, and some kernels usually show some pink color. The infected kernels can be removed, to a large extent, by thoro fanning, but a certain percentage will always remain in the seed lot. Seed treatment with good organic mercury compounds causes a definite benefit to the resulting crop.

Infected seed, however, does cause damage by causing seedling blight and sickly plants (Fig. 4), many of which in winter wheat die during the winter. It is only the seedling disease resulting from scab infection that can be controlled by seed treatment.

Control.—Wheat scab can be controlled to a considerable extent by thoroly plowing under corn refuse or by not growing wheat or barley after corn. Barley is subject to the same disease, and the same recommendations hold for it as for wheat. It is impossible to tell in advance whether a season will or will not be favorable for scab, and it is always best, therefore, to follow such practices as will insure the most nearly disease-free crop.

Different varieties of wheat differ in susceptibility to wheat scab. According to their behavior at the Illinois Station farm at Urbana they may be classed as follows:

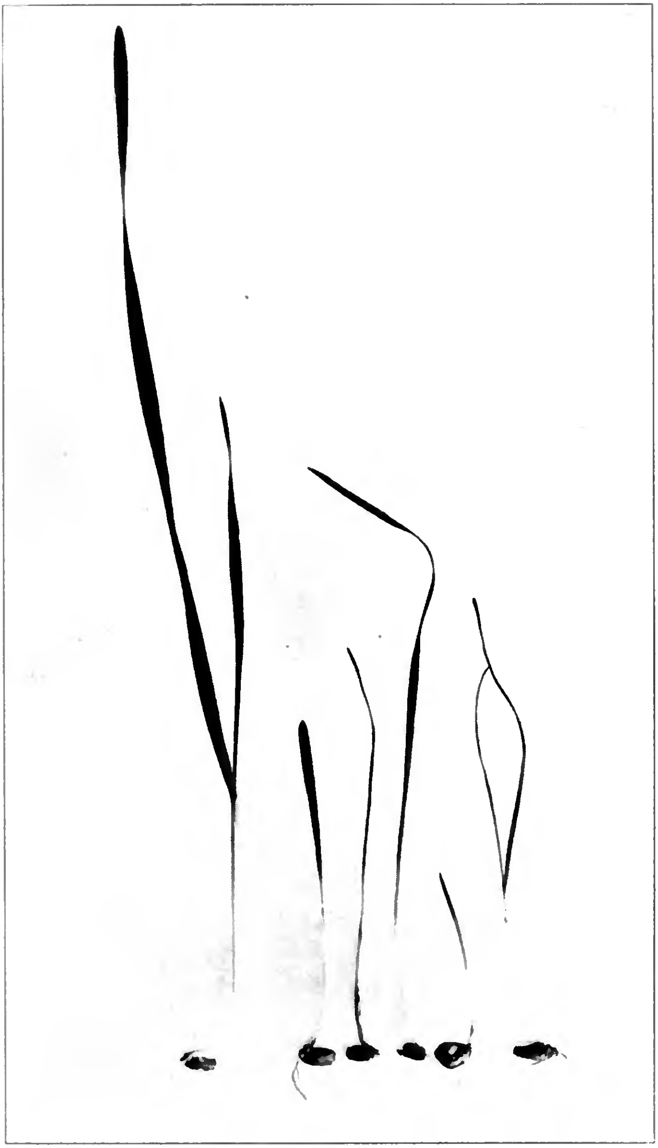

Fig. 4.—Seedling Disease of Wheat Caused by Scab Infection
(Gibberella saubinetii)

The plant at the left is healthy, the others are weak and have a rot at the base of the sprout as a result of scab infection. Often the sprout dies before it comes thru the soil. Seed disinfection with certain organic mercury compounds has helped very materially to reduce this kind of infection.

Winter Wheat

Resistant	*Intermediate*	*Susceptible*
Hardy Northern	Kanred	Blackhull
Minhardi	Winter Fife	Fulhio
Minturki	Forward	Ilred
	Michikof	Michigan Amber
	Purkof	Minnesota Reliable
	Turkey Red	Harvest Queen
	Indiana Swamp	Trumbull

Spring Wheat

Resistant	*Susceptible*	*Very Susceptible*
Illinois 1-B	Marquis	White Australian
	Progress	Garnet
	Kota	Thatcher
		Komar

The scab·seedling blight is controlled by first fanning the grain thoroly to remove the light grain, much of which would not grow or at least could not produce strong plants, and then treating the remaining seed with an organic mercury compound such as New Ceresan (see page 565).

OAT SMUTS

The oat smuts are caused by two closely related fungi, *Ustilago avenae,* loose smut, and *Ustilago levis,* covered smut (Fig. 5). It is not always possible to distinguish between these two smuts in the field and, as their treatment is the same, they are discussed here together. Both forms are very common in Illinois. Spores of the loose smut begin to scatter soon after heading, and the covered smut begins to scatter a little later. As millions of spores are in the air, many come into contact with sound heads and cause infection of the grain. Some of the spores sprout and the fungus enters the hull and penetrates the seed coat[19*] or simply forms layers of dormant mycelium between the kernel proper and the hull.[92*] Some spores simply cling to the grain and remain there dormant until the seed is planted.[37, 75*] Infection may take place from either source. Infected seed cannot be detected with the naked eye, but when planted it may produce smutty heads.

The actual number of smutty heads in oats during the last fifteen years has averaged about 4.9 percent but, as will be shown later in this bulletin, the damage to yield is greater than this, 7 percent being perhaps a conservative estimate. Smut of oats causes the greatest average bushel loss (12 million bushels) of any disease of small grains in Illinois.

Not all infected grains when planted produce smutty heads. In some cases the smut on the seed probably does not enter the seedling at all. Sometimes it kills the very young seedling so that the stand is

FIG. 5.—SMUT-INFECTED OATS (RIGHT) CONTRASTED WITH HEALTHY PLANT (LEFT)

(a) A healthy panicle, (b) loose smut, (c) covered smut. It is sometimes difficult to distinguish these two smuts by field observation. The same treatment controls both. These two smuts are altogether too prevalent in most Illinois oat fields.

reduced. Sometimes the smut fungus penetrates into the growing oat plant but stays in the lower parts and thereby causes a reduction in vegetative vigor and yield of grain even tho the heads show no signs of smut.[27, 88, 91*]

Soil temperature and moisture, from the time of planting until the oats come up, have considerable influence on the development of smutty heads. It was found in certain experiments[1,30,67*] that moderately low soil moisture was favorable for smut development, and a soil temperature of about 56 to 70 or 75° F. was most favorable. Plantings made at different times in the spring during four years at the Illinois Station have shown considerable differences in smut. In two years the early planting on March 10 evidenced the most smut; in the other two years the last planting on April 25 produced the most smut. In the two years when the March plantings showed much smut, 1927 and 1929, the weather records for the month showed abnormally warm temperatures. In 1928 and 1930 the March temperatures were practically normal compared with a 46-year average. It would appear, therefore, that on the average one would expect least smut in the early plantings, which fortunately also yield the best.

Control.—Some varieties of oats that are resistant to smut have been produced, such as Markton, Carlton, Black Mesdag, Nevarro, Bond, and Victoria, and others will probably soon be released by plant breeders. Of these only one, Markton, has been tested in yield experiments at the Illinois Station. During the five years it was grown it ranked twenty-second in yield among sixty-eight varieties tested. The seed was treated against smut each year. Had smut been allowed free play, Markton no doubt would have ranked much higher.

Seed treatments with New Ceresan (ethyl mercury phosphate) or formaldehyde control smut of ordinary hulled oats equally well (pages 565-568). The Ceresan is more expensive than formaldehyde applied by the spray or sprinkle methods but has given better yields. The grain should not be treated until about ready to sow, if the usual dosage is given. Copper carbonate, as used for wheat (page 563), and New Ceresan (page 565) are recommended as disinfectants for hull-less oats. Copper carbonate gives only partial smut control in hulled varieties.

BARLEY DISEASES

Loose Smuts of Barley

Loose smut is much more common than covered smut in Illinois barley fields. Both are illustrated in Fig. 6. The estimated annual loss is 2 percent. In reality there are at least two distinct kinds of loose smut, but both look very much the same to the naked eye. The one kind can be controlled by surface disinfection with such materials as formaldehyde or Ceresan, the other is not controlled by these disinfectants. Data gathered in northern Illinois in 1932 and 1933 indicate that these two forms were about equally prevalent, both often occurring in the same fields.

The one form, long known as *Ustilago nuda,* is carried as an infection deep within the kernel. Spores from smutty heads are carried by the wind to the blossoms of healthy heads. There the spore germinates and the mycelium enters the developing embryo of the kernel. But the fungus soon becomes dormant, and the kernel develops and looks healthy. Later, when the kernel is planted, if the environment is right, it will grow but the plant instead of producing heads of barley will produce heads of smut. The story is the same as for loose smut of wheat.

The other form of loose smut has been designated as a distinct species, *Ustilago nigra*[83*] (*Ustilago medians*[2*]). It has also been pointed out that there are not only one but several forms of barley smut that have the appearance of loose smut but behave more like covered smut.[74*] Infection with some of these may take place in the same way as in loose smut of oats. Some spores fall on healthy heads at flowering time, and infection becomes established as a dormant mycelium between the kernel and the hull. This in no wise interferes with the normal development of the kernel. The mycelium does not enter the embryo. Other kernels may simply carry ungerminated spores on the surface. Seedling infection appears to be produced by either method.[74*]

There are good indications that more loose smut develops when the soil is moderately dry from time of sowing until the plants come up than when there is considerable soil moisture.[43*]

Control.—Only the hot-water treatment (page 568) will control both types of loose smut on barley. One type is controlled by New Ceresan or formaldehyde. Because it controls other seed- and soil-borne diseases and causes no seed or plant injury, New Ceresan (page 565) is recommended as the most effective treatment available at present.

Covered Smut of Barley

When barley heads are infected with covered smut, the glumes, or hulls, remain more or less intact but at the same time the smut can be clearly seen without disturbing the heads (Fig. 6). The appearance is intermediate between loose smut, which destroys the glumes, and

FIG. 6.—TWO HEADS OF SMUT-INFECTED BARLEY (RIGHT) AND A HEALTHY HEAD (LEFT)

All common barley varieties are susceptible to smut. At *b* is shown covered smut; at *c*, one of the two loose smuts. Chemical seed treatment effectively controls the covered smut and one of the loose smuts.

FIG. 7.—STRIPE-INFECTED BARLEY PLANTS (LEFT) CONTRASTED WITH A HEALTHY PLANT (RIGHT)

Stripe-infected barley plants seldom produce heads, but are short and weak, as here shown. The leaves have dark stripes on them, as shown in Fig. 8, and many of them become split before the grain ripens.

normal healthy heads. In the early stages, covered smut may possibly be confused with loose smut because loose smut also has a pale-colored membrane corresponding to each kernel and covering the spore masses for a day or two after heading out. The appearance of smutty heads of both kinds of smut varies considerably with different varieties of barley.

Covered smut is reported to be more injurious than loose smut in some localities, but in Illinois during recent years covered smut has not been important. It was present on certain farms in three counties in northern Illinois to the extent of less than one-half of 1 percent in 1932 and 1933 (Table 12, pages 548-549).

Control.—Covered smut of barley is easily controlled with New Ceresan (page 565).

Stripe of Barley

Barley plants infected with stripe are stunted and usually do not produce heads (Fig. 7). One has to look closely among the plants to find the infected ones because they usually are shorter than normal. Practically all the leaves of an infected plant show varying numbers of dark-colored stripes (Fig. 8). In advanced stages the middle part of the dark stripes turns gray and often the leaves split apart at the stripes.

Spores of the causal fungus, *Helminthosporium gramineum,* are borne on the gray parts of the stripes. These spores are microscopic in size and are carried by the air to sound heads. There they cause no trouble at that time but, when infected seed is sown, diseased plants are again produced.

After a spore comes in contact with an embryonic kernel at flowering time, and possibly later, the spore germinates and forms a mycelium between the hull and the kernel, some of the mycelium penetrating the outer coat of the kernel. The mycelium then lies dormant until the kernel is planted, when it revives and infects the seedling. Infection in the dry seed may remain alive for years. The location of the fungus on the seed seems to be about the same with stripe as with oat smuts.

Stripe infection of the seedling, however, takes place differently from smut infection. In the smuts the fungus penetrates the young sprouts and becomes located within the culms. In stripe the infection is first established in the sheath which pierces thru the ground. Infection at this point is in turn carried to the outer surface of the first leaf that comes thru the sheath, and each additional leaf as it emerges becomes infected from the previous leaf.

Moderately dry soil and soil temperatures of 60° F. or lower during the time the grain sprouts favor stripe infection. Wet soil and soil temperatures of 70° F. or higher check infection with this disease.[45*]

Control.—Wisconsin Pedigree 38 is a variety that is highly resistant to stripe and is well adapted to central and northern Illinois conditions.

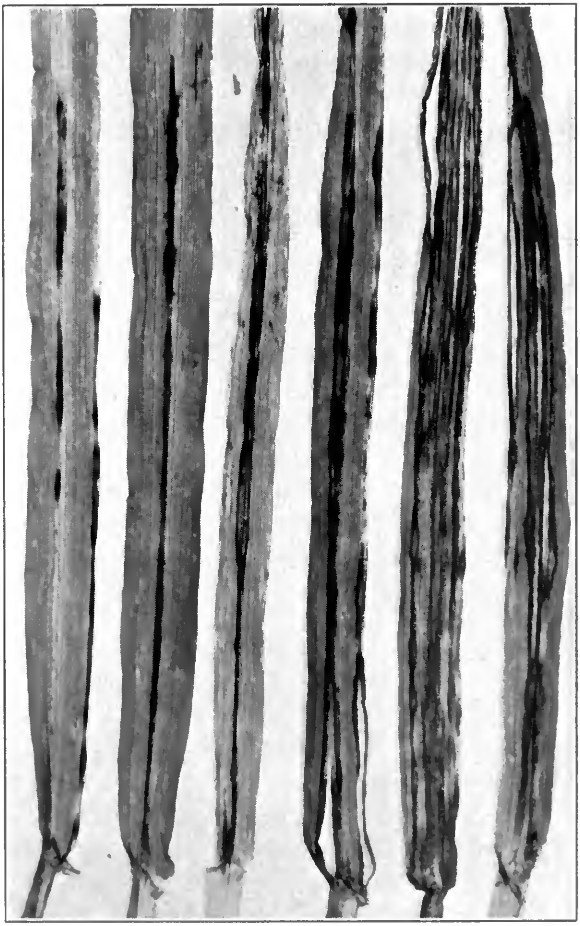

FIG. 8.—STRIPE-INFECTED BARLEY LEAVES

First the stripes are very dark brown, then gray streaks develop along the middle of the stripes, and finally the leaves split along the stripes and become tattered. Spores of the fungus are borne on the gray parts, and these are carried by the air to the young kernels of healthy plants, where they remain ready to reproduce the disease in the following year unless the seed is treated.

When this variety is grown, no trouble with stripe should be experienced. Stripe can be controlled on other varieties by seed treatment with New Ceresan (page 565). Formaldehyde dust has not given satisfactory control.

Barley Scab and Blight

Barley, like wheat, is subject to scab, and the development of the disease is the same. The appearance of scab in the heads of barley or in the kernels is not so distinctive as in wheat. In wheat the affected areas of the head are straw-colored in contrast with the bright green of the healthy parts. In barley the normal heads do not appear so uniformly green as wheat heads after the kernels are in the dough stage. Scab-infected parts show decided grayish and brownish discolorations. Infected threshed barley kernels show these same grayish, brownish discolorations and sometimes a little pink color (Fig. 9).

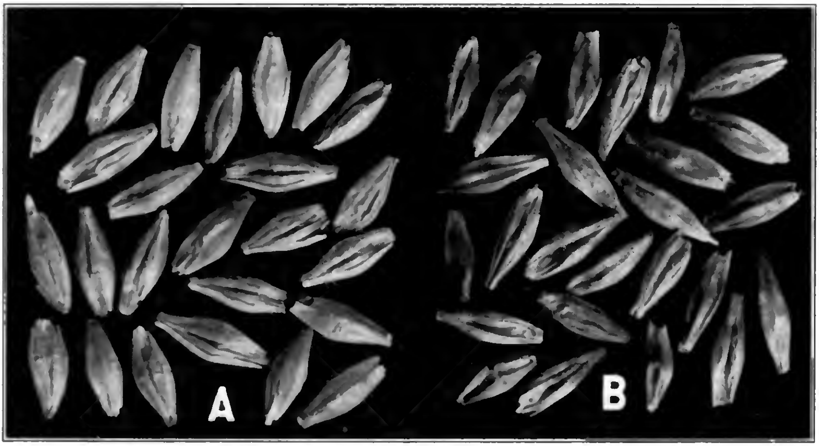

FIG. 9.—HEALTHY BARLEY KERNELS (A) AND SCAB-INFECTED KERNELS (B)

As barley kernels are covered with a hull, scab infection is not so easy to detect by mere observation as is scab in wheat. Infected kernels show brown to grayish brown discolorations, and sometimes some of the pink fungus growth can be seen.

An epidemic of barley scab occurred in Illinois and widely in the upper Mississippi valley in 1928. As infection depends on warm, rainy, muggy weather at and after heading, occurrence of scab from year to year is very variable. In feeding experiments it was found that severely infected barley given to pigs caused them to become very sick or they would refuse to eat it. Horses, dogs, and man were also adversely affected by it. On the other hand, cattle, sheep, and poultry experienced no ill effects.[71, 73*]

Scab infection in barley heads is sometimes called head blight, but there is also another important head blight which is caused by the fungus *Helminthosporium sativum*. This latter fungus causes spots and blotches on the leaves and sometimes infects the heads severely. Severe blight of this kind occurred in northern Illinois and in states to the north and west in 1933. Kernels infected with this blight are often indistinguishable, by general appearance, from kernels infected with scab. Helminthosporium, however, causes no pink colorations; in any event the two kinds of blight can be distinguished readily by a laboratory test. Both kinds of blight-infected seed grade the same under the grain standards. Tho both of these diseases can be controlled by seed treatment, there is this important difference—that seed infected with Helminthosporium blight when fed to pigs and some other animals does not cause sickness as scab does.

Control.—To control barley scab and blight, a rotation should not be used in which barley or wheat follows corn, or if such a sequence cannot be avoided, then the corn land should be plowed deeply and all corn refuse turned under completely. Several 12-foot lengths of No. 9 wire fastened to the plow and dragged in the furrow help to hold the stalks down so they will be covered.

If infected seed has to be sown it should first be fanned thoroly to remove light, dead, or badly diseased grain. Treatment should then be applied. New Ceresan (page 565) will help to control the seedling-disease stage of scab and blight and thus tend to insure a good stand of strong plants. Seed treatment will not, however, prevent a recurrence of head infection, because infection at that place comes from spores carried by the air.

ILLINOIS EXPERIMENTS

METHODS USED

Seed Used.—Many of the experiments with seed treatments for small grains conducted in the past were concerned only with smut control and germination of the treated seed. When no tests are made of the yields of grain from treated seed, the economic value of the treatment has not been completely tested, for while two seed disinfectants may control a disease equally well and the seed may germinate equally well in laboratory tests, yet the plants may differ in vigor and in the amount of grain they will produce. In the present experiments, yield tests have been considered of fundamental importance.

All diseased seed used in these tests was infected naturally; none was artifically inoculated. The loose smut and the covered smut of oats were classified together. Loose smut greatly predominated in the Sixty-Day oats, whereas covered smut usually predominated slightly in the Big Four variety. The nearly disease-free seed was grown from treated seed under conditions which resulted in very little infection of the seed produced. Some of the seed came from crops grown on the Experiment Station farm at Urbana; other seed lots were obtained from farmers in the state, and a few from other sources.[a]

In addition to the tests on the Experiment Station farm at Urbana, a number of farmers have cooperated by conducting tests on their own farms with their own seed (Tables 9 and 12).

Disinfectants Used.—Copper carbonate dust was already accepted as a standard treatment for stinking smut of wheat when these experiments were started in 1925, but there was at that time no dry treatment for the smuts of oats or smut and stripe diseases of barley that could be recommended. Some dry organic mercury disinfectants were being offered by certain companies for experimental purposes. The superiority of organic mercury compounds over other disinfectants available was already being demonstrated for corn, and good results were being reported by others when used on wheat, oats, and barley. Special attention, therefore, was given to these materials as a possibility for better disinfectants for small grains.

A number of materials were tried in addition to the ones mentioned below. Those materials that obviously were of no value are for the most part omitted from the tables in order to conserve space. Those mentioned are, or were, manufactured by the following companies:[b]

Uspulun......................	Formerly made by Bayer Company, Inc.,
Bayer P. M. A................	New York

[a]Acknowledgment for seed furnished is extended to the following: (*In Illinois*) Floyd Carter, Gridley; Guy Cunningham, Bismark; G. T. Swaim, formerly farm adviser in Ford county and now in Kankakee county; W. H. Stuckemeyer, Chenoa; Axel Palmberg, Ludlow; Clarence Goodrich, Gibson City; Gilster Milling Company, Chester; M. McConnell, Reynolds; Jacob Meyer, Tremont. (*Other states*) C. O. Johnston, Department of Botany and Plant Pathology, Kansas State College of Agriculture, Manhattan; J. G. Dickson and R. G. Shands, Department of Plant Pathology, College of Agriculture, University of Wisconsin, Madison; and James Godkin, Department of Botany and Plant Pathology, Virginia Polytechnic Institute, Blacksburg. R. W. Leukel, U. S. Department of Agriculture, not only furnished some of the seed but cooperated in conducting some of the experiments.

[b]The listing of these names is not to be construed as any recommendation for these companies or their products.

Semesan Jr. ... Ceresan ... New Ceresan ...	Bayer Semesan Company, Wilmington, Del.
Corona Oat Dust ... Copper Carbonate ...	Pittsburg Plate Glass Company, Corona Chemical Division, Milwaukee, Wis.
Ansul Formaldehyde Dust ...	Ansul Chemical Company, Marinette, Wis.
Smuttox ...	Stadler Products Company, Cleveland, Ohio, formerly made by the Grasselli Chemical Company of Cleveland
Abavit B ...	Schering Kahlbaum Akt. Ges., Mainz, Germany, formerly Chemiche Fabrik Ludwig Meyer
Wa-Wa Dust ...	Chicago Process Company (discontinued)
Sanoseed ...	American Cyanamid & Chemical Corp., 535 Fifth Avenue, New York

In the tables that follow, the chemical nature of a compound, in so far as it is known, is given first, followed by the trade name or names. Confusion has arisen several times in these investigations by the discontinuance of a certain compound by a manufacturer and the transfer of the trade name to a different compound. Unless, therefore, the chemical nature of the compound is given on the label, one can have no assurance that a product obtained under a given trade name from time to time is in reality the same kind of material. It is impossible, consequently to recommend such products by their trade names only; the chemical description must also be indicated.

Application of Disinfectants.—For dusting small samples of grain suitable for rod-row work, a small electrically driven machine was devised[35*] (Fig. 10). A very similar machine was developed independently at the Wisconsin College of Agriculture.[84*] Four Mason jars half-filled with grain were handled at one time. Each jar contained enough seed for 12 replications of rod rows for the yield test and kernels for spaced plantings for stand counts. The machine was run at a speed of 40 revolutions a minute for 10 minutes.

Larger quantities of seed for the larger experiments were made in a 10-gallon barrel churn. The barrel part was made of glazed crockery and could be wiped out clean between treatments.

Treatments applied on the farm by cooperating farmers were made by machines. Homemade apparatus built from steel oil drums (Fig. 15) was used in most instances. Some small-sized power-driven concrete mixers with a tight cover over the usual opening were also used.

The formaldehyde liquid treatments were made either with the spray or the sprinkle method described on pages 566 and 567.

Storage of Treated Grain.—In a number of tests treated seed was stored for some time before it was planted, in order to determine the effect of storage. It was placed in ordinary two-bushel canvas grain sacks tied shut. A sample for planting was taken from the center with a grain sampler. When only a small quantity of seed wanted for test purposes was available, a 300-gram treated sample was placed in a small light-weight muslin bag, and this in turn was buried in the center of a regular two-bushel grain sack full of other grain similarly treated.

Field Plot Technic.—All tests of yields were made in rod rows. Usually, and unless otherwise stated in the tables, there were 12 replications of each treatment in each test and 24 replications of the check.

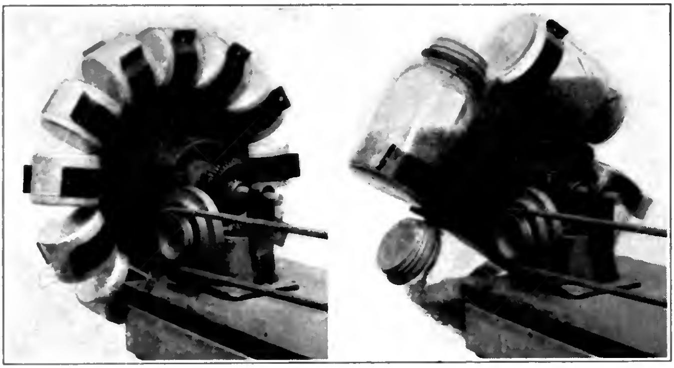

FIG. 10.—MACHINE FOR DUSTING SMALL AMOUNTS OF SEED

This contrivance consists of a small reducing gear fitted with detachable heads for holding seed containers of different sizes. It is driven with a small motor. A quart Mason jar one-third full treated enough seed to sow 12 replications of rod rows.

The row arrangement since the fall of 1929 has been according to the Hartley method,[21*] which insures even distribution of neighboring influences if there are any. Previous to that time another system for breaking up the row sequences was used.

The planting was done with a Columbia planter so adjusted as to sow 13 to 15 grams of seed per 16-foot row. Stand counts were made from separate plantings in which single seeds were spaced 2½ to 3 inches apart in the row so that the individual plants could be definitely distinguished. Usually 500 kernels were used for each treatment for this purpose. Spring sowings were made approximately March 10 to 25, fall sowings August 28 to September 10.

As soon as cut, the bundles were hung, heads down, in a screened drying shed and later they were threshed with a small nursery thresher equipped with a fanning mill. Odds of probability for evaluating the significance of differences in yield were calculated by Student's method.

EXPERIMENTS WITH TREATED WHEAT

Seed Infected With Stinking Smut (Bunt)

Control of stinking smut was satisfactory when the following materials were used; copper carbonate, either the 18 to 20 percent or the 50 percent grades at the rate of 2 or 3 ounces per bushel; ethyl mercury chlorid 2 percent, 2 ounces per bushel; ethyl mercury phosphate 5 percent, ½ ounce per bushel; and several other compounds which have not been placed on the market (Table 2). Formaldehyde dust gave satisfactory control when the dust was strictly fresh (Item 19, Table 2), but dust received nine months before using and stored on a laboratory shelf gave no control (Item 20).

Yields from smut-infected seed were increased consistently by treating the seed with copper carbonate or ethyl mercury chlorid (Ceresan). Ethyl mercury phosphate (New Ceresan) gave good increases in yield in the two tests that included yield determinations.

Scab-Infected Wheat Seed

Scab infection causes seedling blight and weak plants. The effectiveness of the seed disinfectants used was determined by stand counts

FIG. 11.—WINTER SURVIVAL OF WHEAT PLANTS GROWN FROM SCAB-INFECTED SEED

The plants at the left are from seed treated with formaldehyde by the dip method. In the center is a check plot; the seed planted here was soaked in water just before planting. The plants at the right are from seed soaked in Uspulun solution for two hours before planting (Table 5, Item 37). Some seed treatments have been of consistent benefit in increasing winter survival of plants grown from scab-infected seed, but the degree of benefit was not usually so conspicuous as that shown here.

and yield of grain. In earlier work the writer had found that some of the organic mercury disinfectants used as a wet treatment were very helpful in controlling the scab seedling-blight disease. An outstanding case of seed that was infected approximately 100 percent being treated effectively with Uspulun is shown in Fig. 11 and Table 5, Item 37.

TABLE 2.—WHEAT: EFFECT OF SEED TREATMENT ON SMUT DEVELOPMENT AND YIELD OF GRAIN WHEN SEED WAS INFECTED WITH STINKING SMUT
(Station farm, Urbana)

Item	Year	Variety	Amount of disinfectant per bushel	Storage of treated grain	Number of replications	Stinking-smut-infected heads		Acre-yield		Increase in acre-yield due to treatment		
						Check	Treated	Check	Treated			
Copper carbonate dust, 18 to 20 percent copper												
			oz.	*days*		*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
1	1931	Turkey	2	8	3	3.3	0	....	....	...	....	......
2	1931	Turkey	3	8	3	3.3	0	....	....	...	....	......
3	1932	Fulhio	2	0	4	9.4	.3	....	....	...	....	......
4	1932	Fulhio	3	0	4	9.4	tr.	....	....	...	....	......
5	1933	Fulhio	2	3	6	7.3	.1	26.0	31.7	5.7	21.9	56:1
6	1933	Fulhio	3	3	6	7.3	.2	26.0	31.1	5.1	19.6	34:1
7	1934	Fulhio	2½	0	12	4.8	.1	31.5	35.7	4.2	13.3	1666:1
8	1934	Fulhio	2½	365	12	4.8	.1	31.5	36.4	4.9	15.6	9999:1
Copper carbonate dust, 50 percent copper												
9	1931	Fulhio	2	8	3	3.3	0	....	....	...	....	......
10	1931	Fulhio	3	8	3	3.3	0	....	....	...	....	......
11	1932	Fulhio	2	0	4	9.4	0	....	....	...	....	......
12	1932	Fulhio	3	0	4	9.4	0	....	....	...	....	......
13	1933	Fulhio	2	3	6	7.3	0	26.0	29.0	3.0	11.5	34:1
14	1933	Fulhio	3	3	6	7.3	0	26.0	28.4	2.4	9.2	16:1
Copper, 20 percent, as copper sulfate dust (Dupont No. 68, DuBay No. 525)												
15	1931	Turkey	2	8	3	3.3	0	....	....	...	....	......
16	1931	Turkey	3	8	3	3.3	0	....	....	...	....	......
17	1932	Fulhio	2	0	4	9.4	.6	....	....	...	....	......
18	1932	Fulhio	3	0	4	9.4	.1	....	....	...	....	......

(Table is concluded on page 524)

TABLE 2.—EFFECT OF SEED TREATMENT FOR STINKING SMUT OF WHEAT—*Concluded*

Item	Year	Variety	Amount of disinfectant per bushel	Storage of treated grain	Number of replications	Stinking-smut-infected heads		Acre-yield		Increase in acre-yield due to treatment		
						Check	Treated	Check	Treated			
					Formaldehyde dust, 5 to 8 percent (Corona, Ansul)							
			oz.	*days*		*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
19	1931	Turkey	3	8	3	3.3	0	....	....	...	....	......
20	1933	Fulhio	3	3	6	7.3	7.5	26.0	27.6	1.6	6.2	8:1
					Iodin, 10 percent in carbon bisulfid							
21	1931	Turkey	6	8	3	3.3	2.2	....	....	...	....	......
					Ethanol mercury chlorid, .65 percent mercury (Sanoseed)							
22	1931	Turkey	3	8	3	3.3	0	....	....	...	....	......
23	1931	Turkey	3	8	3	3.3	0	....	....	...	....	......
					Ethyl mercury chlorid, 2 percent (Ceresan)							
4	1931	Turkey	2	8	3	3.3	0	....	....	...	....	......
25	1931	Turkey	3	8	3	3.3	0	....	....	...	....	......
26	1932	Fulhio	2	0	4	9.4	.1	....	....	...	....	......
27	1932	Fulhio	3	0	4	9.4	0	....	....	...	....	......
28	1933	Fulhio	2	3	6	7.3	.1	26.0	29.6	3.6	13.8	269:1
29	1933	Fulhio	3	3	6	7.3	0	26.0	30.6	4.6	17.7	587:1
30	1934	Fulhio	2	0	12	4.8	0	31.5	36.0	4.5	14.3	>9999:1
					Ethyl mercury phosphate: Items 31-33, 2 to 2½ percent; Items 34-35, 5 percent (New Ceresan)							
31	1932	Fulhio	1	0	4	9.4	0	....	....	...	....	......
32	1932	Fulhio	2	0	4	9.4	0	....	....	...	....	......
33	1933	Fulhio	1	3	6	7.3	.3	....	....	...	....	......
34	1933	Fulhio	½	3	6	7.3	.2	26.0	29.0	3.0	11.5	4999:1
35	1934	Fulhio	½	0	12	4.8	0	31.5	36.6	5.1	16.2	>9999:1

After going thru the winter, very few of the plants from untreated seed were alive. In all the tests, except for Item 37 just referred to, seed from a scabby crop, with infections averaging from 9 to 20 percent after recleaning, was used.

The dry organic mercury treatments, ethyl mercury chlorid and ethyl mercury phosphate, gave increases in field stand when used on scab-infected seed. The increases were especially outstanding in the spring plant counts (Table 5). Ethyl mercury chlorid also gave significant increases in yield in each test (Table 3). Sometimes a marked increase in vigor was observed, as shown in Fig. 12. Ethyl mercury

FIG. 12.—VIGOROUS WINTER WHEAT GROWN FROM TREATED SCAB-INFECTED SEED CONTRASTED WITH PLANTS FROM UNTREATED SEED

Certain treatments nearly always increased the yield of grain, and occasionally they caused a marked difference in vegetative vigor. At the center is a check row planted with untreated seed. The two adjacent rows were planted with seed treated with ethyl mercury chlorid.

phosphate was used in only a few yield tests. When used at the recommended rate of ½ ounce a bushel, it gave a significant increase in yield in one test but a slight decrease in another test (Table 3).

Copper carbonate also gave increases in stand and yield in most tests, but the increases in yield were small and the odds of probability in most tests were not significant. The results with formaldehyde dust show a slight decrease in stand (Table 5, Item 33) and an increase in yield in one test but not in another (Table 3, Items 10 and 11).

TABLE 3.—WHEAT: YIELDS OF GRAIN FROM TREATED AND UNTREATED SEED CARRYING SCAB

(Each yield test consisted of 12 rod-row replications, Station farm, Urbana)

Item	Year[a]	Variety	Anount of disin-fectant per bushel	Storage of treated grain	Acre-yield		Increase in acre-yield due to treatment		
					Check	Treated			
Copper carbonate, 18 to 20 percent copper									
			oz.	days	bu.	bu.	bu.	perct.	odds
1.......	1929	Ilred	3	1	29.7	34.2	4.5	15.1	196:1
2.......	1930	Ilred	2	2	34.8	37.3	2.5	7.1	3:1
3.......	1930	Ilred	3	2	34.8	37.2	2.4	6.8	3:1
4.......	1933	Turkey	2	3	35.4	36.2	.8	2.2	3:1
5.......	1933	Turkey	3	3	35.4	37.2	1.8	5.0	31:1
Copper carbonate, 50 percent copper									
6.......	1930	Ilred	2	2	34.8	36.7	1.9	5.4	3:1
7.......	1930	Ilred	3	2	34.8	38.1	3.3	9.4	8:1
8.......	1933	Turkey	2	3	35.4	35.8	.4	1.1	2:1
9.......	1933	Turkey	3	3	35.4	36.9	1.5	4.2	6:1
Formaldehyde dust, 5 to 8 percent (Smuttox, Ansul)									
10......	1929	Ilred	3	1	29.7	34.9	5.2	17.5	43:1
11......	1933	Turkey	3	3	35.4	35.7	.3	.8	2:1
Hydroxymercuricresol, 12 percent (Semesan Jr.)									
12......	1929	Ilred	2	1	29.7	36.9	7.2	24.2	1440:1
Phenyl mercury acetate (Bayer P. M. A.)									
13......	1929	Ilred	2	1	29.7	35.6	5.9	19.8	>9999:1
Ethyl mercury chlorid: Items 14-16, 1.6 percent; Items 17-19, 2 percent (Ceresan)									
14......	1929	Ilred	2	1	29.7	37.0	7.3	24.5	>9999:1
15......	1930	Ilred	2	2	34.8	45.4	10.6	30.4	293:1
16......	1930	Ilred	3	2	34.8	44.5	9.7	27.8	293:1
17......	1930	Ilred	2	2	34.8	45.1	10.3	29.5	4999:1
18......	1930	Ilred	3	2	34.8	46.5	11.7	33.6	1428:1
19......	1933	Turkey	2	3	35.4	38.7	3.3	9.3	88:1
Ethyl mercury phosphate, 5 percent (New Ceresan)									
20......	1933	Turkey	1[b]	3	35.4	33.4	−2.0[c]	−5.6[c]	51:1
21......	1933	Turkey	½	3	35.4	34.8	− .6[c]	−1.6[c]	2:1
22......	1933	Turkey	½	0	35.4	38.3	2.9	8.2	4999:1

[a]Year in which harvested, sown in previous fall. [b]Applied at twice the recommended rate. [c]Decrease in yield.

Nearly Disease-Free Wheat Seed

A number of experiments were made with noninfected seed in order to determine whether seed treatment may be of value in protecting the young plants from seedling diseases, or whether some treatments may have an injurious effect on growth. In commercial practice it often is not known whether a given lot of seed carries stinking smut infection, and it is therefore important to know whether treatments may be beneficial even in the absence of bunt or scab infection.

In twenty-six tests with copper carbonate and copper sulfate dusts (Table 4) no injury to yield resulted, and in five tests the increases in yield were statistically significant. The average increase in yield

TABLE 4.—WHEAT: YIELDS OF GRAIN FROM TREATED AND UNTREATED NEARLY DISEASE-FREE SEED
(Each yield test consisted of 12 rod-row replications, Station farm, Urbana)

Item	Year[a]	Variety	Amount of disinfectant per bushel	Storage of treated grain	Acre-yield		Increase in acre-yield due to treatment		
					Check	Treated			
Copper carbonate dust, 18 to 20 percent copper									
			oz.	*days*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
1......	1931	Fulhio	2	7	53.8	55.6	1.8	3.3	3:1
2......	1931	Fulhio	3	7	53.8	56.7	2.9	5.3	6:1
3......	1931	Ilred	2	8	47.4	48.2	.8	1.6	2:1
4......	1931	Ilred	3	8	47.4	49.5	2.1	4.4	4:1
5......	1932	Fulhio	2	0	41.6	42.8	1.2	2.8	32:1
6......	1932	Fulhio	3	0	41.6	42.4	.8	1.9	3:1
7......	1932	Ilred	2	0	41.4	42.7	1.3	3.1	27:1
8......	1932	Ilred	3	0	41.4	43.6	2.2	5.3	60:1
9......	1933	Turkey	2	3	42.3	44.3	2.0	4.7	8:1
10......	1933	Turkey	3	3	42.3	44.5	2.2	5.2	21:1
11......	1934	Turkey	2½	0	35.4	36.9	1.5	4.2	11:1
12......	1934	Turkey	2½	365	35.4	37.3	1.9	5.4	55:1
Copper carbonate dust, 50 percent copper									
13......	1932	Fulhio	2	0	41.6	42.6	1.0	2.4	4:1
14......	1932	Fulhio	3	0	41.6	42.3	.7	1.6	4:1
15......	1932	Ilred	2	0	41.4	43.3	1.9	4.5	28:1
16......	1932	Ilred	3	0	41.4	43.8	2.4	5.7	123:1
17......	1933	Turkey	2	3	42.3	43.1	.8	1.8	3:1
18......	1933	Turkey	3	3	42.3	44.3	2.0	4.7	14:1
Copper, 20 percent, as copper sulfate dust (Dupont No. 68, DuBay No. 525)									
19......	1931	Fulhio	2	7	53.8	54.2	.4	.7	2:1
20......	1931	Fulhio	3	7	53.8	54.9	1.1	2.0	2:1
21......	1931	Ilred	2	8	47.4	51.9	4.5	9.4	17:1
22......	1931	Ilred	3	8	47.4	49.3	1.9	4.0	5:1
23......	1932	Fulhio	2	0	41.6	42.4	.8	1.9	3:1
24......	1932	Fulhio	3	0	41.6	42.6	1.0	2.4	4:1
25......	1932	Ilred	2	0	41.4	43.6	2.2	5.3	35:1
26......	1932	Ilred	3	0	41.4	43.7	2.3	5.5	68:1

(Table is concluded on page 528)

TABLE 4.—TESTS WITH NEARLY DISEASE-FREE WHEAT SEED—*Concluded*

Item	Year[a]	Variety	Amount of disinfectant per bushel	Storage of treated grain	Acre-yield		Increase in acre-yield due to treatment		
					Check	Treated			
Formaldehyde dust, 5 to 8 percent (Smuttox, Corona, Ansul)									
			oz.	*days*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
27......	1931	Ilred	3	1	50.5	48.2	−2.3[b]	−4.5[b]	13:1
28......	1931	Ilred	3	8	47.4	32.0	−15.4[b]	−32.4[b]	1930:1
29......	1931	Fulhio	3	7	53.8	27.7	−26.1[b]	−48.5[b]	>9999:1
30......	1933	Turkey	3	1	42.3	42.5	.2	.5	1:1
31......	1933	Turkey	3	3	42.3	42.1	−.2[b]	−.5[b]	1:1
Ethanol mercury chlorid, .65 percent mercury (Sanoseed)									
32......	1931	Fulhio	3	7	53.8	55.0	1.2	2.2	1:1
33......	1931	Ilred	3	8	47.4	48.6	1.2	2.5	3:1
34......	1931	Fulhio	3	7	53.8	54.6	.8	1.4	2:1
35......	1931	Ilred	3	8	47.4	48.5	1.1	2.3	3:1
Ethyl mercury chlorid, 2 percent (Ceresan)									
36......	1931	Fulhio	2	7	53.8	53.2	−.6[b]	−1.1[b]	2:1
37......	1931	Fulhio	3	7	53.8	53.7	−.1[b]	−.2[b]	1:1
38......	1931	Ilred	2	1	45.4	47.8	2.4	5.2	4:1
39......	1931	Ilred	2	8	47.4	48.6	1.2	2.5	2:1
40......	1931	Ilred	3	8	47.4	48.8	1.4	2.9	1:1
41......	1932	Fulhio	2	0	41.6	42.1	.5	1.2	2:1
42......	1932	Fulhio	3	0	41.6	38.9	−2.7[b]	−6.5[b]	93:1
43......	1932	Ilred	2	0	41.4	43.1	1.7	4.1	54:1
44......	1932	Ilred	3	0	41.4	44.5	3.1	7.4	37:1
45......	1933	Turkey	2	3	42.3	43.1	.8	1.9	4:1
46......	1934	Turkey	2	0	35.4	37.2	1.8	5.1	612:1
Ethyl mercury phosphate: Items 47-50, 2 to 2½ percent, Items 51-53, 5 percent (New Ceresan)									
47......	1932	Fulhio	1	0	41.6	40.7	−.9[b]	−2.1[b]	4:1
48......	1932	Fulhio	2	0	41.6	41.9	.3	7.2	1:1
49......	1932	Ilred	1	0	41.4	42.1	.7	1.6	3:1
50......	1932	Ilred	2	0	41.4	43.4	2.0	4.8	28:1
51......	1933	Turkey	1	3	42.3	41.5	−.8[b]	−1.8[b]	2:1
52......	1933	Turkey	½	3	42.3	41.8	−.5[b]	−1.1[b]	2:1
53......	1934	Turkey	½	0	35.4	38.1	2.7	7.6	416:1

[a]Year in which harvested sown in previous fall. [b]Decrease in yield.

was 1.7 bushels, or 3.8 percent, with odds that were statistically significant. Formaldehyde dust on the other hand produced important decreases in yield. Bracken,[6*] in a ten-year seed treatment test with noninfected seed under dry-land conditions, found that copper carbonate caused no injury to yield but that formaldehyde did cause a depression in yield.

The organic mercury compounds—ethanol mercury chlorid, ethyl mercury chlorid, and ethyl mercury phosphate—gave somewhat variable results. Each compound averaged a slight increase in yield, but the increases were not significant. In a study of wheat-seedling diseases, caused by infection in the soil, Machacek and Greaney[49*] obtained better disease control with Semesan, Ceresan, and New Ceresan than with copper carbonate, altho all were beneficial. Formaldehyde, on the other hand, caused not only a decrease in stand but also an increase in damage from disease.

Winter Survival of Wheat Plants

As 94 percent of the wheat grown in Illinois is winter wheat,[a] a consideration of winter survival of treated seed is important.

In the winter of 1927-28 the wheat in the seed-treatment test plots at the Illinois Station, as well as the wheat in a large part of the state, was entirely killed. This was unusual, and the winter conditions since then have, on the whole, been considered favorable for winter wheat. Nevertheless in the spring of 1930 and 1933 (Table 5) nearly 50 percent of the plants were killed. Under the most favorable conditions during the five years in which these tests were made, the mortality was 6 percent in untreated seed. The average mortality during this period was 25.4 percent; that is, there was a survival of only 74.6 percent.

Winter survival was increased by certain seed disinfectants. In twenty-three tests with copper carbonate of low and high copper contents (Table 5) the winter survival was increased an average of 5.4 percent, with odds that were statistically significant. The two grades of copper carbonate were practically of equal benefit. More detailed analysis shows that when nearly disease-free seed was treated with copper carbonate, winter survival of plants was increased 4.1 percent by seed treatment. When scab-infected seed was used, the same seed treatment caused an 8.0-percent increase in winter survival.

The two organic mercury dusts—ethyl mercury chlorid and ethyl mercury phosphate (Ceresan and New Ceresan)—also increased winter survival significantly. They appeared to give nearly the same results. In twenty tests with these compounds winter survival was increased an average of 7.1 percent. When used with nearly disease-free seed, these organic mercury treatments increased winter survival of plants 4.1 percent. When used with scab-infected seed, winter survival was increased 12.1 percent. Thus with nearly disease-free seed the results with copper carbonate and Ceresan were identical, but with scab-infected seed Ceresan gave the better results.

Formaldehyde treatments (Table 5) caused a decrease in winter survival of plants when nearly disease-free seed was treated, but when scab-infected seed was treated some benefit was obtained. Ethanol

[a]Statistics for 1930-1932.

mercury chlorid and iodin were used only in a few tests with nearly disease-free seed, and the results were decreases in winter survival.

TABLE 5.—WHEAT: EFFECT OF SEED TREATMENT ON STAND AND WINTER SURVIVAL
(Station farm, Urbana)

Item	Year[a]	Variety	Seed infection	Amount of disinfectant per bushel	Storage of treated grain	Field stand from treated seed		Increase in field stand of treated over check		Winter survival[b]	
						Fall	Spring	Fall	Spring	Check	Treated
				Copper carbonate dust, 18 to 20 percent copper							
				oz.	*days*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
1...	1930	Ilred	Scab	2	2	52.7	24.2	13.3	23.5	42.2	45.9
2...	1930	Ilred	Scab	3	2	59.4	29.1	27.7	48.5	42.2	49.0
3...	1931	Ilred	N.D.F.[c]	2	8	91.4	83.8	8.8	9.0	91.5	91.7
4...	1931	Ilred	N.D.F.	3	8	89.6	82.8	6.7	7.7	91.5	92.4
5...	1932	Ilred	N.D.F.	2	0	91.6	79.0	6.1	4.8	87.4	86.2
6...	1932	Ilred	N.D.F.	3	0	86.4	79.0	.1	4.8	87.4	91.4
7...	1932	Fulhio	N.D.F.	2	0	86.4	81.8	1.5	2.4	93.9	94.7
8...	1932	Fulhio	N.D.F.	3	0	86.6	81.1	1.8	1.5	93.9	93.6
9...	1933	Turkey	Scab	2	3	83.1	59.1	1.8	13.4	63.8	71.1
10...	1933	Turkey	Scab	3	3	78.8	51.5	−3.4[d]	−1.2[d]	63.8	65.4
11...	1933	Turkey	N.D.F.	2	3	88.9	48.0	3.9	20.3	46.6	54.0
12...	1933	Turkey	N.D.F.	3	3	88.1	47.2	2.9	18.3	46.6	53.6
13...	1935	Michigan Amber	Scab	2	0	79.8	72.6	.6	11.7	81.9	91.0
				Copper carbonate dust, 50 percent copper							
14...	1930	Ilred	Scab	2	2	61.5	29.4	32.3	50.0	42.2	47.8
15...	1930	Ilred	Scab	3	2	55.7	27.3	19.8	39.3	42.2	49.0
16...	1932	Ilred	N.D.F.	2	0	87.9	78.5	1.9	4.1	87.4	89.3
17...	1932	Ilred	N.D.F.	3	0	85.9	80.0	− .5[d]	6.1	87.4	93.1
18...	1932	Fulhio	N.D.F.	2	0	89.7	82.8	5.4	3.6	93.9	92.3
19...	1932	Fulhio	N.D.F.	3	0	85.4	81.6	.4	2.1	93.9	95.6
20...	1933	Turkey	Scab	2	3	84.6	48.5	3.7	−6.9[d]	63.8	57.3
21...	1933	Turkey	Scab	3	3	81.6	57.1	0	9.6	63.8	70.0
22...	1933	Turkey	N.D.F.	2	3	89.4	50.5	4.4	26.6	46.6	56.5
23...	1933	Turkey	N.D.F.	3	3	88.1	48.9	2.9	22.6	46.6	55.5
				Copper, 20 percent, as copper sulfate dust (Dupont No. 68, DuBay No. 525)							
24...	1931	Ilred	N.D.F.	2	8	88.4	80.6	5.2	4.8	91.5	91.2
25...	1931	Ilred	N.D.F.	3	8	88.1	77.5	4.9	.8	91.5	88.0
26...	1932	Ilred	N.D.F.	2	0	93.2	80.6	8.0	6.9	87.4	86.5
27...	1932	Ilred	N.D.F.	3	0	87.9	78.8	1.9	4.5	87.4	89.6
28...	1932	Fulhio	N.D.F.	2	0	83.9	76.3	−1.4[d]	−4.5[d]	93.9	90.9
29...	1932	Fulhio	N.D.F.	3	0	88.2	83.6	3.6	4.6	93.9	94.8
				Formaldehyde dip, 1:320							
30...	1925	Turkey	Scab	..	¼	52.8	9.0	2.7	28.6	13.6	17.0
31...	1935	Michigan Amber	Scab	..	¼	78.5	76.2	−1.0[d]	14.1	81.9	94.5

TABLE 5.—*Concluded*

Item	Year[a]	Variety	Seed infection	Amount of disinfectant per bushel	Storage of treated grain	Field stand from treated seed		Increase in field stand of treated over check		Winter survival[b]	
						Fall	Spring	Fall	Spring	Check	Treated
Formaldehyde dust, 5 to 8 percent (Smuttox, Corona, Ansul)											
				oz.	*days*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
32...	1931	Ilred	N.D.F.	3	8	27.0	22.5	−67.9[d]	−70.7[d]	91.5	83.3
33...	1933	Turkey	Scab	3	3	77.8	51.1	−4.7[d]	−1.9[d]	63.8	65.7
34...	1933	Turkey	N.D.F.	3	1	87.9	36.8	2.7	−7.8[d]	46.6	41.9
35...	1933	Turkey	N.D.F.	3	3	86.5	37.4	1.1	−6.3[d]	46.6	43.2
Iodin, 10 percent in carbon bisulfid											
36...	1931	Ilred	N.D.F.	6	8	78.8	67.7	−6.2[d]	−12.0[d]	91.5	85.9
Chlorophenol mercury, .25-percent solution, seed soaked 2 hours (Uspulun)											
37...	1925	Turkey	Scab	..	..	78.6	44.5	53.0	416.7	13.6	56.7
Ethanol mercury chlorid (Sanoseed)											
38...	1931	Ilred	N.D.F.	3	8	90.0	81.3	7.1	5.7	91.5	90.3
39...	1931	Ilred	N.D.F.	3	8	87.9	79.0	4.6	2.7	91.5	89.9
Ethyl mercury chlorid, 2 percent (Ceresan)											
40...	1930	Ilred	Scab	2	2	68.8	33.9	48.0	73.0	42.2	49.3
41...	1930	Ilred	Scab	3	2	74.5	34.1	60.2	74.0	42.2	45.8
42...	1930	Ilred	Scab	2	2	70.0	36.7	50.5	87.2	42.2	52.4
43...	1930	Ilred	Scab	3	2	72.4	34.4	55.7	75.5	42.2	47.5
44...	1931	Ilred	N.D.F.	2	8	89.4	80.0	6.4	4.0	91.5	89.5
45...	1931	Ilred	N.D.F.	3	8	83.1	77.0	−1.1[d]	.1	91.5	92.7
46...	1932	Ilred	N.D.F.	2	0	91.2	85.4	5.7	13.3	87.4	93.6
47...	1932	Ilred	N.D.F.	3	0	91.2	87.1	5.7	15.5	87.4	95.5
48...	1932	Fulhio	N.D.F.	2	0	90.4	83.3	6.2	4.3	93.9	92.1
49...	1932	Fulhio	N.D.F.	3	0	90.4	85.1	6.2	6.5	93.9	94.1
50...	1933	Turkey	Scab	2	3	86.0	58.1	5.4	11.5	63.8	67.5
51...	1933	Turkey	N.D.F.	2	3	89.7	53.2	4.8	33.3	46.6	59.3
52...	1935	Michigan Amber	Scab	2	¼	82.9	76.8	4.5	18.2	81.9	92.7
Ethyl mercury phosphate: Items 53-54, 2 to 2½ percent; Items 55-59, 5 percent (New Ceresan)											
53...	1932	Fulhio	N.D.F.	1	0	86.9	80.6	2.1	.9	93.9	92.8
54...	1932	Ilred	N.D.F.	1	0	91.2	82.8	5.7	9.8	87.4	90.8
55...	1933	Turkey	Scab	1	3	83.6	56.8	2.5	9.0	63.8	67.9
56...	1933	Turkey	N.D.F.	1	3	88.6	46.5	3.5	16.5	46.6	52.5
57...	1933	Turkey	Scab	½	3	81.3	59.5	−.4[d]	14.2	63.8	73.2
58...	1933	Turkey	N.D.F.	½	3	88.9	43.9	3.9	10.0	46.6	49.4
59...	1935	Michigan Amber	Scab	½	0	82.9	75.6	4.5	16.3	81.9	91.2

[a]Year in which harvested, sown in preceding fall. [b]Winter survival percentages are based on spring count versus fall count. [c]Nearly disease-free. [d]Decrease.

Discussion of Wheat Seed Treatments

The data summarized in Table 13, page 553, show that no substantial increases in yield may be expected from treating seed wheat that is known to be free from seed infection. Scab infection is sporadic and may break out anywhere in the corn belt in severe form on wheat any season when weather conditions permit. Infected seed can be detected by a certain amount of bleached kernels (Fig. 3, page 508). When such infection occurs, seed treatment with certain organic mercury compounds is no doubt an economical procedure.

Heavy infections with stinking smut can be detected readily by a dark discoloration of the grain, especially in the brush, and a foul fishy odor. Light infections that cannot be detected readily in the seed may, however, still cause considerable loss, and the appearance of the seed alone cannot be taken as a criterion for judging whether the seed should be treated. In a large part of the state wheat is a minor crop grown in a rotation with other crops. Here the farmers usually grow considerable oats or barley or both. These crops may be threshed alternately with wheat, in which case there is no great danger of carrying the infection from one farm to another in threshing machines. Furthermore Turkey wheat, which is somewhat resistant to stinking smut, is the principal variety in a large part of this area. In this region it would seem wise to urge seed treatment only when the grain is known to carry infection.

In certain limited areas of the state wheat is the principal small grain crop. Furthermore soft wheats, which appear to be more susceptible to bunt than Turkey, are grown to a considerable extent in these locations. Intensive cropping favors the spread of infection from one farm to another, and here one seldom finds a field entirely free from stinking smut unless the seed has been properly treated. Intensive cropping also favors the spread of other diseases besides stinking smut, some of which are held in check by seed treatment. In this region, therefore, it seems advisable to recommend treating the seed every year. The odds that seed treatment will pay for itself even tho the seed appears clean are very good.

Favorable results have been obtained with copper carbonate as a treatment for stinking smut by a considerable number of investigators during the last fifteen years but the literature need not be reviewed here. In the tests here reported, the "extended," or 18-to-20 percent grade, was satisfactory and as efficient as the higher grade. As a general-purpose treatment for wheat, copper carbonate, according to the data obtained here, stands second to none if it is thoroly applied.

The results are summarized in Table 6. The copper carbonate treatment should not be attempted except with a good treating machine. Treatment with this compound has the advantage of not causing injury if an overdose is used, except as it may cause trouble in the drill hoppers; and if the treated wheat is stored in a dry place, length of storage does not cause any injury.

Some favorable reports have been made concerning some other copper compounds used as dust treatments, notably powdered or de-

TABLE 6.—WHEAT: SUMMARY OF STAND AND YIELD DATA IN COMPARABLE TESTS WITH INFECTED AND NONINFECTED TREATED AND UNTREATED SEED
(Average of 7 tests, Station farm, Urbana, 1933 and 1934)

Seed treatment	Field stand		Acre-yield	Increase in acre-yield		
	Fall	Spring				
	percl.	*percl.*	*bu.*	*bu.*	*percl.*	*odds*
None	84.7	61.8	36.2	...	...	.....
Copper carbonate[a]	86.4	65.9	38.5	2.3	6.4	768:1
Ethyl mercury chlorid[b]	89.3	70.0	38.6	2.4	6.6	290:1
Ethyl mercury phosphate[c]	86.3	64.6	38.3	2.1	5.8	700:1

[a]As the 20- and 50-percent grades gave similar results, they are summarized together. [b]Ceresan. [c]New Ceresan.

hydrated copper sulfate, either in the pure form or mixed half and half with finely ground limestone.[24, 25, 38, 41, 50, 68, 76, 85*] Both the pure form and the mixture were used at the rate of 2 ounces per bushel. The diluted form did not give satisfactory smut control in all the tests. A copper sulfate combination of unknown composition was used in the Illinois tests and gave about the same results as copper carbonate (Tables 2 and 4). Copper carbonate has an advantage over copper sulfate in that it is less soluble and does not take up much moisture from the air.

That formaldehyde in liquid form is not as safe for wheat as copper carbonate, from the standpoint of seed germination and yield of grain, is probably recognized by all investigators and was again demonstrated in these experiments. Formaldehyde dust also has given yields inferior to copper carbonate in the experiments here reported.

The organic mercury dusts used in these experiments, ethyl mercury chlorid (Ceresan) and ethyl mercury phosphate (New Ceresan), have given good results with wheat. In the control of stinking smut and their effect on yield they seem to be on a par with copper carbonate. When used on nearly disease-free seed, copper carbonate showed a slight advantage in yield. Other reports on the control of stinking smut with Ceresan are favorable.[17, 23, 55*] New Ceresan seems to be giving equally good results.[26, 53, 55, 65*]

A direct comparison between the results obtained with copper carbonate, ethyl mercury chlorid, and ethyl mercury phosphate is given in Table 6. Only those tests are included in which all of the seed disinfectants named were used, so that the data are directly comparable.

EXPERIMENTS WITH TREATED OATS

Smut-Infected Seed

Hulled Oats.—The seed of hulled oats treated with liquid formaldehyde was planted not more than one day after it was treated. It was well aired from the time the treatments were finished until it was planted. Thus perhaps there should have been less seed injury than would occur under ordinary farm conditions. Smut control with this material was good. Yields were increased whenever it was used on seed in which there was considerable smut infection (Table 7).

The formaldehyde dusts also gave good smut control, at least when the dusts were fresh. Old dust, even tho in unopened cans, may deteriorate badly. This was demonstrated by a test conducted in 1934 with Wolverine oats. Smut infection in the checks was 4.3 percent; in the oats treated with fresh formaldehyde dust, it was .1 percent; in the oats treated with formaldehyde dust stored one year unopened in the laboratory, 4.0 percent; and in the oats treated with formaldehyde dust stored one year in a mechanical refrigerator there was no smut. While this was only one test, the results nevertheless indicate the danger of using old dust. Whether the dust in the refrigerator retained its strength because the can happened to be gas-tight, or because it was kept cold, or because it was kept at nearly constant temperature, or whether there were other reasons, was not determined.

Copper carbonate eliminated four-fifths of the smut in six tests with hulled oats. Other investigators have obtained similar results. As more effective materials are available, this material should not be considered for hulled oats.

The mercury compound, "Abavit B," did not give entirely satisfactory smut control. "Wa-Wa Dust" was no better than wet formaldehyde with regard to smut control or its effect on yield of grain.

The organic mercury dusts, ethyl mercury chlorid (Ceresan) and ethyl mercury phosphate (New Ceresan) gave good smut control and yields were higher than with any other materials tried (Tables 7 and 8). The superiority of these materials probably is due to the fact that they do not injure the seed. These disinfectants appear to play a

TABLE 7.—OATS: EFFECT OF SEED TREATMENT ON STAND, SMUT DEVELOPMENT, AND YIELD OF GRAIN WHEN SEED WAS INFECTED WITH SMUT

(Each test consisted of 12 rod-row replications, Station farm, Urbana)

Item	Year	Variety	Amount of disinfectant per bushel	Storage of treated grain	Field stand		Smut-infected heads		Acre-yield		Increase in acre-yield due to treatment		
					Check	Treated	Check	Treated	Check	Treated			
Formaldehyde, liquid method, applied with sprinkling can or spray gun													
			oz.	*days*	*perct.*	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
1	1925	Big Four	(a)	1	95.7	91.0	20.3	.2	....	....	...	....	......
2	1926	Big Four	(a)	1	91.6	90.4	22.6	.1	62.8	66.1	3.3	5.3	8:1
3	1927	Big Four	(a)	1	88.3	88.6	9.1	0	22.0	22.1	.1	.4	1:1
4	1928	Big Four	(a)	1	80.6	80.4	15.0	0	78.1	84.0	5.9	7.6	11:1
5	1928	Sixty-Day	(a)	1	81.5	86.0	7.0	0	65.6	70.0	4.4	6.7	262:1
6	1929	Sixty-Day	(a)	1	86.7	88.8	4.9	0	79.2	78.3	−.9[b]	−1.1[b]	1:1
7	1929	Big Four	(a)	1	73.5	62.1	7.1	0	71.8	76.5	4.7	6.5	16:1
8	1930	Big Four	(a)	1	81.7	80.8	.1	0	64.1	63.8	−.3[b]	− .4[b]	8:1
9	1930	Sixty-Day	(a)	1	71.5	73.3	2.4	0	61.7	69.3	7.6	12.3	63:1
10	1931	Sixty-Day	(a)	1	82.1	82.7	4.2	0	50.0	52.2	2.2	4.4	2:1
11	1932	Sixty-Day	(a)	¼[c]	....	....	15.5	0	50.4	60.2	9.8	19.4	>9999:1
12	1933	Sixty-Day	(a)	1	75.0	75.7	1.7	0	37.9	37.6	−.3[b]	− .7[b]	1:1
13	1933	Big Four	(a)	1	78.5	83.3	8.7	0	25.0	32.5	7.5	30.0	>9999:1
14	1933	Quaker	(a)	1	....	....	23.8	0	28.4	38.5	10.1	35.5	>9999:1
15	1933	Sixty-Day	(d)	1	75.0	71.6	1.7	0	37.9	37.6	−.3[b]	− .8[b]	2:1
16	1933	Big Four	(d)	1	78.5	81.0	8.7	.1	25.0	32.1	7.1	28.4	>9999:1
17	1933	Quaker	(d)	1	....	....	23.8	0	28.4	38.3	9.9	34.8	>9999:1
Formaldehyde dust, 5 to 8 percent (Smuttox, Ansul, Corona)													
18	1928	Big Four	3	1	80.6	69.8	15.0	0	78.1	79.4	1.3	1.7	2:1
19	1928	Sixty-Day	3	1	81.5	72.0	7.0	0	65.6	69.8	4.2	6.4	9:1
20	1929	Big Four	3	1	73.5	64.3	7.1	0	71.8	77.2	5.4	7.5	106:1
21	1929	Sixty-Day	3	1	86.7	93.0	4.9	.1	79.2	84.7	5.5	6.9	243:1
22	1930	Big Four	3	1	81.7	88.7	.1	0	64.1	66.0	1.9	3.0	2:1
23	1930	Sixty-Day	3	6	71.5	88.7	2.4	1.8	61.7	72.4	10.7	17.3	1666:1
24	1931	Sixty-Day	3	1	82.1	73.0	4.2	.2	50.0	52.5	2.5	5.0	5:1
25	1931	Sixty-Day	2	1	82.1	77.8	4.2	.3	50.0	56.0	6.0	12.0	28:1
26	1931	Big Four	3	1	....	....	.9	0	67.3	66.6	−.7[b]	−1.1[b]	2:1
27	1931	Big Four	2	1	....	....	.9	0	67.3	66.1	−1.2[b]	−1.8[b]	2:1
28	1931	Hull-less	2	1	....	....	10.3	.5	47.0	58.6	11.6	24.6	858:1
29	1932	Sixty-Day	3	6	....	....	15.5	.4	50.4	60.3	9.9	19.6	>9999:1
30	1932	Big Four	3	6	....	....	14.4	0	53.8	60.2	6.4	11.9	208:1
31	1932	Hull-less	0	6	....	....	31.6	.3	18.2	39.1	20.9	114.8	1170:1
32	1933	Sixty-Day	3	1	....	....	1.7	.5	37.9	36.5	−1.4[b]	−3.7[b]	6:1
33	1933	Big Four	3	1	78.5	82.1	8.7	.1	25.0	31.8	6.8	27.2	4999:1
34	1933	Quaker	3	1	....	....	23.8	1.2	28.4	33.8	5.4	19.0	1726:1

(Table is continued on page 536)

TABLE 7.—EFFECT OF SEED TREATMENT FOR SMUT OF OATS—*Continued*

Item	Year	Variety	Amount of disin-fectant per bushel	Storage of treated grain	Field stand		Smut-infected heads		Acre-yield		Increase in acre-yield due to treatment		
					Check	Treated	Check	Treated	Check	Treated			
Copper carbonate dust, 18 to 20 percent copper													
			oz.	*days*	*perct.*	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
35	1925	Big Four	2	1	95.7	98.0	20.3	5.0	....	....	....	....	......
36	1925	Big Four	4	1	95.7	97.0	20.3	3.0	....	....	....	....	......
37	1926	Big Four	3	1	91.6	93.6	22.6	3.5	....	....	....	....	......
38	1927	Big Four	3	3	88.3	92.5	9.1	3.0	22.0	22.1	.1	.5	1:1
39	1928	Big Four	3	1	80.6	83.4	15.0	.6	78.1	78.3	.2	.3	1:1
40	1928	Sixty-Day	3	1	81.5	86.0	7.0	2.3	65.6	67.6	2.0	3.0	4:1
41	1931	Hull-less	2	1	....	....	10.3	1.0	47.0	57.1	10.1	21.4	3332:1
42	1931	Hull-less	3	1	....	....	10.3	.3	47.0	50.7	3.7	7.9	8:1
43	1932	Hull-less	2	0	....	....	31.6	.2	18.2	39.4	21.2	116.4	3332:1
44	1932	Hull-less	3	0	....	....	31.6	0	18.2	42.7	24.5	134.6	2499:1
A mercury compound, "Abavit-B"													
45	1925	Big Four	2	1	95.7	95.0	20.3	2.6	....	....	....	....	......
46	1925	Big Four	4	1	95.7	94.5	20.3	2.4	....	....	....	....	......
47	1926	Big Four	2	1	91.6	93.6	22.6	2.9	62.8	64.8	2.0	3.2	4:1
48	1926	Big Four	4	1	91.6	87.2	22.6	.5	62.8	65.5	2.7	4.3	4:1
49	1927	Big Four	2	3	88.3	90.0	9.1	1.6	22.0	22.1	.1	.5	1:1
50	1927	Big Four	4	3	88.3	90.2	9.1	.1	22.0	22.9	.9	4.1	8:1
51	1928	Big Four	3	1	80.6	75.4	15.0	.2	78.1	78.3	.2	.3	1:1
52	1928	Sixty-Day	3	1	81.5	82.0	7.0	.1	65.6	71.6	6.0	9.1	248:1
A mercury compound, "Wa-Wa Dust"													
53	1927	Big Four	2	3	88.3	87.1	9.1	.2	22.0	21.1	— .9[b]	—4.1[b]	5:1
54	1927	Big Four	4	3	88.3	83.2	9.1	0	22.0	20.0	—2.0[b]	—9.1[b]	4999:1
55	1928	Big Four	3	1	80.6	79.4	15.0	.1	78.1	77.7	— .4[b]	— .5[b]	1:1
56	1928	Sixty-Day	3	1	81.5	88.8	7.0	.3	65.6	70.7	5.1	7.8	8:1

TABLE 7.—*Concluded*

Item	Year	Variety	Amount of disinfectant per bushel	Storage of treated grain	Field stand		Smut-infected heads		Acre-yield		Increase in acre-yield due to treatment		
					Check	Treated	Check	Treated	Check	Treated			
Ethyl mercury chlorid: Items 57-61, 1.6 percent; Items 62-76, 2 percent (Ceresan)													
			oz.	*days*	*perct.*	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
57	1927	Sixty-Day	2	2	83.5	88.3	9.1	.4	19.7	22.0	2.3	11.7	37:1
58	1928	Sixty-Day	3	1	81.5	83.1	7.0	0	65.6	77.0	11.4	17.3	>9999:1
59	1928	Big Four	3	1	80.6	81.4	15.0	.2	78.1	86.8	8.7	11.1	118:1
60	1929	Sixty-Day	3	1	86.7	93.9	4.9	.2	79.2	88.8	9.6	12.1	9999:1
61	1929	Big Four	3	1	73.5	85.5	7.1	.1	71.8	82.1	10.3	14.3	3332:1
62	1928	Sixty-Day	3	1	81.5	86.7	7.0	0	65.6	78.1	12.5	19.0	3163:1
63	1928	Big Four	3	1	80.6	79.4	15.0	.1	78.1	88.7	10.6	13.5	9999:1
64	1930	Sixty-Day	3	1	71.5	89.6	2.4	0	61.7	76.4	14.7	23.8	4999:1
65	1930	Sixty-Day	2	1	71.5	85.4	2.4	.2	61.7	75.6	13.9	22.5	9999:1
66	1930	Sixty-Day	3	0	71.5	90.4	2.4	0	61.7	76.6	14.9	24.1	>9999:1
67	1931	Sixty-Day	3	1	82.1	83.0	4.2	0	50.0	54.3	4.3	8.6	43:1
68	1931	Sixty-Day	2	1	82.1	82.1	4.2	0	50.0	55.6	5.6	11.2	207:1
69	1931	Big Four	3	1	....	....	.9	0	67.3	71.0	3.7	5.5	19:1
70	1931	Big Four	2	1	....	....	.9	0	67.3	72.5	5.2	7.7	19:1
71	1931	Hull-less	2	1	....	....	10.3	0	47.0	61.4	14.4	31.0	4999:1
72	1932	Hull-less	2	0	....	....	31.6	.3	18.2	46.9	28.7	157.6	>9999:1
73	1932	Sixty-Day	3	0	....	....	15.5	.1	50.4	64.3	13.9	27.5	>9999:1
74	1932	Big Four	3	0	....	....	12.4	0	53.8	66.0	12.2	22.6	>9999:1
75	1933	Sixty-Day	3	1	75.0	81.9	1.7	0	37.9	43.8	5.9	15.5	4999:1
76	1933	Big Four	3	1	78.5	82.1	8.7	0	25.0	30.9	5.9	23.6	9999:1
Ethyl mercury phosphate: Items 77 to 81, 2½ percent; Items 82 to 86, 5 percent (New Ceresan)													
77	1932	Sixty-Day	1	0	....	....	15.5	.1	50.4	68.4	18.0	35.7	>9999:1
78	1932	Sixty-Day	1	6	....	....	15.5	0	50.4	65.5	15.1	29.9	>9999:1
79	1932	Big Four	1	0	....	....	12.4	.2	53.8	68.0	14.2	26.3	>9999:1
80	1932	Big Four	1	6	....	....	12.4	0	53.8	66.5	12.7	23.6	>9999:1
81	1932	Hull-less	1	0	....	....	31.6	.6	18.2	46.1	27.9	153.2	>9999:1
82	1933	Sixty-Day	½	0	75.0	81.1	1.7	0	37.9	41.0	3.1	8.2	12:1
83	1933	Sixty-Day	½	1	75.0	76.7	1.7	0	37.9	39.0	1.1	2.9	8:1
84	1933	Big Four	½	0	78.5	84.6	8.7	0	25.0	31.3	6.3	25.2	3332:1
85	1933	Big Four	½	1	78.5	82.1	8.7	0	25.0	30.4	5.4	21.6	9999:1
86	1933	Quaker	½	1	....	....	23.8	0	28.4	43.5	15.1	53.1	>9999:1

[a]Treatments made with a sprinkling can. [b]Decrease in yield. [c]Six hours. [d]Treatments made with a hand sprayer.

TABLE 8.—OATS: SUMMARY OF STAND AND YIELD DATA IN COMPARABLE SEED-TREATMENT TESTS IN WHICH ALL THE DISINFECTANTS NAMED WERE USED THRUOUT EACH TEST
(Several varieties were used in the tests; Station farm, Urbana)

Seed treatment	Stand	Smut-infected heads	Acre-yield	Increase in acre-yield		
Average of 10 tests, 1928-1933						
	perct.	*perct.*	*bu.*	*bu.*	*perct.*	*odds*
None	74.5	6.67	58.4	...	...	......
Formaldehyde, sprinkle	74.4	.01	62.4	4.0	6.8	255:1
Formaldehyde dust	74.0	.31	63.1	4.7	8.0	344:1
Ethyl mercury chlorid[a]	81.4	.06	67.2	8.8	15.1	>9999:1
Average of 6 tests, 1932-1933						
None	76.8	11.65	42.8	....	....	......
Formaldehyde dust	78.9	.22	49.9	7.1	16.6	23:1
Ethyl mercury chlorid[a]	82.0	.16	54.2	11.4	26.6	59:1
Ethyl mercury phosphate[b]	82.9	.15	54.7	11.9	27.8	59:1

[a]Ceresan. [b]New Ceresan.

double role in that they not only control smut but also protect the germinating kernel from molds in the soil.

In order to determine what success farmers would have with the use of dust fungicides, Ceresan and Corona Oat Dust (a formaldehyde dust) were furnished to a number of farmers in 1929, 1930, and 1931. The farmers were instructed to make the treatments with machines and store the grain over night in covered piles or in sacks. Some used homemade mixing machines, some used concrete mixers, a few had access to a commercial machine, and a few used tin cans. All of them applied the treatments and sowed the grain without supervision. Before harvest the writer visited all the fields and helped make the smut counts.

The average percentage smut (Table 9) was very close to what is considered the average annual smut loss in the state. The average control was not nearly so good as obtained in the experiments at the Station. This is accounted for largely by the fact that one particular farmer with badly infected oats failed to get control. The reason for this could not be determined. In the following year the same farmer did obtain fairly good control. These farmers averaged equally good smut control with the two treatments. Both the formaldehyde dust and the Ceresan were received fresh from the factory a short time before they were used. Yield determinations were not attempted.

Hull-less Oats.—Copper carbonate gave good smut control and

TABLE 9.—OATS: RESULTS OF SEED-TREATMENT TESTS CONDUCTED BY FARMERS IN SEVEN COUNTIES REPRESENTING CENTRAL AND NORTH-CENTRAL ILLINOIS

County	Cooperating farmer and year	Kind of oats	Smut-infected heads in the crop		
			No treatment	Ceresan[a] treatment	Corona oat dust[b] treatment
	1930		*perct.*	*perct.*	*perct.*
Champaign......	George Jelly.............	Big Four	4.6	.8	.6
	Roy Moody.............	(c)	2.3	.3	0
	C. N. Collins.............	Iowa 103	2.0	.3	.8
	A. E. Burwash............	Iowa 103	2.4	0	0
	1930				
Douglas........	A. E. Heath..............	(c)	4.3	.3	1.4
	Ward Maris..............	(c)	1.3	.6	.4
	George Consoer...........	(c)	2.2	.7	.3
	E. Frahm................	(c)	1.0	.5	.1
	C. McDonald.............	Burt	6.5	2.0	2.3
	1930				
Ford...........	C. Goodrich..............	Iowar	2.8	0	...
	Ray Green...............	Iowa 103	1.8	.7	...
	E. M. Fredrick............	(c)	4.9	.2	...
	1931				
	C. Goodrich..............	Hull-less	12.1	0	0
	C. Goodrich..............	Iowar	1.2	0	0
	A. Z. Fox................	Iowar	6.4	0	0
	Edward Lindholm.........	Big Four	3.2	Trace	Trace
	Dan Gentes...............	Big Four	6.9	0	0
	1929				
Iroquois........	M. Parker................	(c)	1.5	Trace	...
	C. Wienrank..............	(c)	1.0	.5	...
	1930				
	J. Benbow...............	Big Four	10.8	0	...
	A. J. Gillfillan............	(c)	4.3	1.1	.2
	R. F. Karr................	(c)	25.0	20.0	20.0
	H. D. Zum Mallen........	Black	8.1	0	0
	O. B. Koritz..............	(c)	2.6	0	0
	1931				
	R. F. Karr................	(c)	22.0	...	.5
	1929				
Livingston......	Charles Porter............	(c)	9.0	1.3	...
	W. H. Stuckemeyer........	Iowar	6.8	3.7	...
	W. H. Gentes.............	Iowar	4.2	3.2	...
	W. H. Gentes.............	Iowar	9.0	1.3	...
	1930				
	George Mies..............	Iowar	2.2	0	0
	W. C. Asper..............	(c)	9.8	...	5.5
	W. C. Asper..............	Iowar	5.5	2.0	...
	J. B. Eimann.............	Iowa 103	5.5	1.4	0
	A. B. Schubert............	Iowar	4.2	0	0
	L. Sellinger...............	Iowar	7.8	...	0
	1930				
McLean........	Floyd Carter..............	Silvermine	13.0	1.3	1.1
	Floyd Carter..............	Iowa 103	2.9	.6	.7
	1929				
Vermilion.......	G. M. Wright.............	Silvermine	1.0	Trace	...
	Guy Cunningham..........	Big Four	22.0	.6	8.4[d]
	H. G. Pendergrast.........	(c)	.5	0	...
	Hoopeston Canning Co.....	(c)	4.1	.5	...
	1930				
	J. Hart..................	(c)	.3	.1	.1
	A. Gunder................	(c)	4.3	.2	.2
	G. Cunningham...........	Big Four	13.4	.5	.2
	H. A. Anderson...........	(c)	1.9	.1	.1
Average of all fields....................................			6.2	1.1	1.1
Average of fields (27) in which Ceresan and Corona Oat Dust were both used....................................			5.3	1.1	1.1

[a]Ethyl mercury chlorid, 2 percent, used at the rate of 3 ounces per bushel. [b]Formaldehyde dust, 5 percent, used at the rate of 3 ounces per bushel. [c]Variety name not known. [d]Formaldehyde solution applied by the sprinkle method.

high increases in yield when applied to hull-less oats badly infected with smut (Table 7). Tests were made only in 1931 and 1932. Little difference was noted in the results with copper carbonate, formaldehyde dust, ethyl mercury chlorid, and ethyl mercury phosphate. In 1932, when smut infection in the checks was 31.6 percent, each one of these disinfectants more than doubled the yields of grain. The yields from untreated seed, which produced 31.6 percent smutty heads, was 56.4 percent below the average yield from the treated seed. In the previous year smut infection in hull-less oats was 10.3 percent, and the yield from untreated seed was cut 17.6 percent.

Smut-Free Oat Seed

In order to determine whether certain seed treatments might have beneficial effects other than thru smut control, experiments were started in 1930 in which treatments were made with smut-free seed. In 1931 and 1932 these experiments were carried on in cooperation with R. W. Leukel, U. S. Department of Agriculture. A report on these results, together with results from similar tests at five other stations, was published by Leukel and Stanton.[46*] These investigators found, during the two-year period of the experiment, a tendency for treatments to reduce yields at St. Paul, Minnesota; Madison, Wisconsin, and Ames, Iowa; and a tendency to increase yields at Urbana, Illinois; Lafayette, Indiana; and Ithaca, New York. Whether these differences were due to chance, method of handling, or natural local conditions could not be determined. The conclusion was that, on the whole, treatment of clean seed did not cause any consistently significant increase in yield.

At the Urbana Station care was taken never to apply the treatments more than one day before seeding. This eliminated the possible damage that might result from storing treated seed. That storage is an important factor in the results obtained with some disinfectants is shown elsewhere in this publication.

Briefly stated, the data show that formaldehyde dust, ethyl mercury chlorid, and ethyl mercury phosphate treatments all tended toward increasing the yield of clean seed (Tables 10, 13). With formaldehyde dust the increase obtained was not statistically significant, but with ethyl mercury chlorid a statistically significant increase was obtained. The tests with ethyl mercury phosphate were too few for drawing definite conclusions.

The increases in yield obtained with organic mercury dusts were very likely caused by the dusts protecting the seed from certain seedling diseases. This seems evident from the following facts: (1) field stands were increased when these dusts were used (Table 8); (2)

TABLE 10.—OATS: EFFECT OF SEED TREATMENT ON YIELD OF GRAIN WHEN THE SEED CARRIED NO SMUT INFECTION
(Station farm, Urbana)

Item	Year	Variety	Amount of disinfectant per bushel	Storage of treated grain	Replications	Acre-yield		Increase in acre-yield due to treatment		
						Check	Treated			
Formaldehyde, liquid method										
			oz.	*days*	*No.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
1.......	1931	Silvermine	(a)	1	5	66.1	72.4	6.3	9.5	65:1
2.......	1931	Iowar	(a)	1	6	75.3	69.7	−5.6[b]	−7.5[b]	26:1
3.......	1933	Sixty-Day	(a)	1	12	34.3	34.8	.5	1.4	2:1
4.......	1933	Sixty-Day	(c)	1	12	34.3	34.4	.1	2.9	1:1
Formaldehyde dust, 5 to 8 percent (Smuttox, Corona, Ansul)										
5.......	1930	Big Four	3	1	12	64.1	66.0	1.9	2.9	2:1
6.......	1931	Big Four	3	1	12	67.3	66.6	− .7[b]	−1.0[b]	2:1
7.......	1931	Big Four	2	1	12	67.3	66.1	−1.2[b]	−1.8[b]	2:1
8.......	1931	Sixty-Day	3	1	12	59.3	61.5	2.2	3.7	5:1
9[d].....	1931	Silvermine	3	1	5	66.1	71.1	5.0	7.0	4:1
10[d].....	1931	Iowar	3	1	6	75.3	77.2	1.9	2.5	2:1
11[d].....	1931	Silvermine	3	1	5	66.1	66.1	0	0	...
12[d].....	1931	Iowar	3	1	6	75.3	79.5	4.2	5.5	1:1
13[d].....	1932	Sixty-Day	3	¼[e]	10	71.6	69.3	−2.3[b]	−3.2[b]	7:1
14[d].....	1932	Sixty-Day	3	¼	10	71.6	73.1	1.5	2.0	5:1
15[d].....	1932	Sixty-Day	3	¼	10	71.6	72.8	1.2	16.7	2:1
16[d].....	1932	Iowar	3	¼	6	65.2	68.8	3.6	5.5	16:1
17[d].....	1932	Iowar	3	¼	6	65.2	65.3	.1	1.5	1:1
18[d].....	1932	Iowar	3	¼	6	65.2	65.5	.3	4.5	1:1
19[d].....	1932	Iomine	3	¼	6	59.3	60.3	1.0	16.8	2:1
20[d].....	1932	Iomine	3	¼	6	59.3	60.6	1.3	2.1	3:1
21[d].....	1932	Iomine	3	¼	6	59.3	60.8	1.5	2.5	3:1
Ethyl mercury chlorid, 2 percent (Ceresan)										
22.......	1930	Gopher	3	1	7	78.7	85.2	6.5	8.5	55:1
23.......	1930	Big Four	3	1	12	64.1	67.6	3.5	5.4	5:1
24.......	1930	Big Four	2	1	12	64.1	65.6	1.5	2.3	2:1
25.......	1930	Big Four	3	0	12	64.1	66.2	2.1	3.2	3:1
26.......	1931	Big Four	3	1	12	67.3	71.0	3.7	5.4	19:1
27.......	1931	Big Four	2	1	12	67.3	72.5	5.2	7.7	19:1
28.......	1931	Sixty-Day	3	1	12	59.3	69.1	9.8	16.5	714:1
29[d].....	1931	Silvermine	3	1	5	66.1	70.1	4.0	6.0	2:1
30[d].....	1931	Iowar	3	1	6	75.3	79.5	4.2	5.5	14:1
31[d].....	1932	Sixty-Day	3	¼[e]	10	71.6	73.1	1.5	2.0	7:1
32[d].....	1932	Iowar	3	¼	6	65.2	67.5	2.3	3.5	14:1
33[d].....	1932	Iomine	3	¼	6	59.3	65.2	5.9	9.9	130:1
34.......	1933	Sixty-Day	3	1	12	34.3	36.3	2.0	5.8	43:1
Ethyl mercury phosphate: Item 35, 2½ percent; Item 36, 5 percent (New Ceresan)										
35.......	1932	Sixty-Day	1	¼[e]	10	71.6	73.1	1.5	2.0	5:1
36.......	1933	Sixty-Day	½	1	12	34.3	38.8	4.5	13.1	1840:1

[a]Treatments made with a sprinkling can, see page 567. [b]Decrease in yield. [c]Treatments made with a hand sprayer by the mist method, see page 566. [d]Test conducted in cooperation with R. W. Leukel, Division of Cereal Crops and Diseases, U. S. Department of Agriculture, Washington, D. C. [e]Six hours.

when germinated on blotters, kernels treated with these compounds showed very little mold growth on them compared with those treated with formaldehyde or left untreated; and (3) under conditions where organic mercury dusts gave a marked improvement in field stand (Fig. 13) the seminal roots and subcoronal internodes of seedlings were

FIG. 13.—STAND AND VIGOR OF OATS INCREASED BY CERTAIN SEED TREATMENTS

The seed for this field was treated by a farmer and sown with an ordinary grain drill. In the rows to the left of the center, untreated seed was used; to the right, the seed was treated with Ceresan. Rows *a'* and *b'* were sown with the same drill shoes as rows *a* and *b* respectively and at the same rate of seeding. The differences exhibited here are due to the seed treatment.

much freer from discolorations. The discolorations were very evident in the checks in some seasons, notably in 1930.

The increases in yield were probably enough, on the average, to pay for the cost of the material and the labor of applying it, but not much more than that. Thus if one were certain that a given lot of seed oats contained no smut infection, he would hardly find it worth while to treat them. But when there is any possibility of smut infections being present, it is worth while to remove the risk of damage by treating them, for the cost of treatment is likely to be covered even if there is no smut infection present.

Discussion of Oat Seed Treatments

There are a number of methods of applying formaldehyde to oat seed, all of which work well so far as smut control is concerned.

The *steep* method—by which the grain is soaked in a formaldehyde solution, 1 pint to 40 gallons of water, for 10 minutes—adds considerable moisture, and so the grain does not flow thru the drill very well. This method is not recommended for that reason.

The *sprinkle* method, by which one pint of liquid is added per bushel of grain (page 567), does not swell the grain perceptibly; and the Haskell *spray* or mist method (page 566) adds practically no liquid. Both the sprinkle and spray methods are satisfactory if the oats are sown soon after the treatment is completed. In three tests in which these two methods were compared, no difference in smut control or yield of grain was noted (Table 7, Items 12-14 compared with Items 15-17). It is possible that some paraformaldehyde is formed when the sprinkle method is used.[29*] This substance is more toxic than formaldehyde, but as recommended in a former publication from the Illinois Station,[9*] the increased toxicity is offset by using 1 pint of formaldehyde to 80 bushels of grain instead of the customary 50 bushels. If the treated seed is to be stored, the spray method may have some advantage; but if it is used, the seed should either be aired thoroly after the treatment is completed or the dosage should be reduced to compensate for the longer time the seed is to remain in storage (page 561).

Churchill[11*] and Tapke[82*] obtained best smut control with liquid formaldehyde but obtained, respectively, better yield and better field stand with formaldehyde dust. At the Illinois Station, also, the dusts gave less perfect smut control but a little better yield of grain (Tables 7 and 8). Lehman and Fant[40*] obtained perfect smut control with both methods but secured better stand and vigor with the dust method. Young and McClelland[89*] obtained smut control with both methods and found little difference in yield. Pierstorff[59*] reported good smut control with both methods.

As a dry treatment, formaldehyde dust has a strong competitor in New Ceresan, which is less expensive and in some cases has a better effect on yield. Furthermore, formaldehyde dust often deteriorates rapidly, so that when it is bought at retail there is danger of obtaining a depleted dust. For these reasons, formaldehyde dust probably should not be included in the recommended list of seed disinfectants at the present time.

The ethyl mercury chlorid product (Ceresan) seems to have given quite generally good results wherever tested. Some investigators have reported better emergence from the soil,[82*] better vigor of seedlings,[40*] and better yield[11*] with Ceresan than with formaldehyde dust. Others have found Ceresan no better than formaldehyde dust in yields of grain obtained.[15, 46, 89*] In six years' experimentation at the Illinois Station ethyl mercury chlorid has fairly consistently given better stands and yields than have formaldehyde dusts (Table 8).

Ethyl mercury chlorid, the 2-percent product, is too expensive to be recommended as a treatment for oat seed. The newer and cheaper product, ethyl mercury phosphate (New Ceresan), has been available for only a few years and has not yet been tried very extensively. Tests conducted at this Station for two years indicate that it is on a par with ethyl mercury chlorid as a treatment for oats. Good results have also been reported from other places.[65, 82, 89*] So far as the writer can determine at the present time, this dust can safely be recommended.

To sum up the situation: For the treatment of ordinary hulled oats, ethyl mercury phosphate (New Ceresan) would seem to be first choice, formaldehyde spray second choice. The first is more expensive but simpler to apply and will probably give better yields of grain. Formaldehyde must be handled very carefully if satisfactory results are to be obtained. Hull-less oats should be treated with copper carbonate or New Ceresan; there seems to be little choice between the two. A number of investigators have reported that formaldehyde has caused more damage to hull-less than to hulled oats, and they do not recommend it for the hull-less varieties.

EXPERIMENTS WITH TREATED BARLEY

Stripe-Infected Barley Seed

Before stripe-resistant barleys came into use in Illinois, stripe was the most serious disease of barley. Until organic mercury seed-treating materials became available, no very satisfactory seed treatments were known for this disease. A brief review of the earlier investigations with seed treatments for this disease was given by Leukel, Dickson, and Johnson.[44*] Neither hot water nor solutions of copper sulfate or formaldehyde were very promising, seed injury resulting in most tests, and disease control was not always attained. It was found that by increasing the formaldehyde strength from the customary rate, 1 pint in 40 gallons water, to 1 pint in 30 gallons, better stripe control was secured, but more seed injury resulted. These same investigators found that certain organic mercury compounds in liquid and dust forms gave very good control of stripe, better germination, and better yields than materials previously in use.

Ethyl mercury chlorid was the first organic-mercury dry disinfectant to come into commercial use for barley in this country. Good control of stripe has been reported[12, 45, 66, 72*] as well as important increases in yield from treatment.[12, 66*]

The writer obtained very little control of stripe with formaldehyde dusts (Table 11). This is in agreement with results published by others.[12, 45*] Abavit "B" gave better but not quite satisfactory stripe control and did not give any decided increases in yield. Ethyl mercury chlorid, on the other hand, gave good stripe control and in the majority of tests caused significant increases in yield.

Ethyl mercury phosphate also is an apparently satisfactory disinfectant for stripe.[39, 45*] Stripe was perfectly controlled by this material in 1932 (Table 11), but no increase in yield was obtained. In 1933 stripe was not controlled quite so well, but a significant gain in yield was secured. A number of farmers conducted seed-treatment tests in 1932 and 1933 in cooperation with their county farm bureaus and the Agricultural Experiment Station (Table 12). The farmers applied the treatment themselves by such methods as they had available. Only three farmers who tested New Ceresan actually had stripe infection in their untreated barley. All three obtained perfect control by treatment. Of those who used ethyl mercury chlorid, 7 had stripe infection in the untreated strips on 5.3 percent of the plants, while only .8 percent of the plants in the treated strips were infected. Taken altogether, in 14 tests in which susceptible barley varieties were used, stripe infection was found on 4.0 percent of the plants grown from untreated seed and on only .4 percent of the plants grown from treated seed.

Smut-Infected Barley Seed

There are several smuts of barley, and they do not respond equally well to seed treatment. That the covered smut can be controlled to a large extent by chemical seed treatment has been recognized for some time. Leukel[42*] gave a good review of the earlier work on control methods. He found[41, 42*] that covered smut could be controlled by formaldehyde, but when the dosage was sufficient to control the smut, there was considerable injury to seed germination. Formaldehyde in dust form, Smuttox, gave better results. Some organic mercury compounds in both liquid and dust forms gave good smut control and caused no injury to germination. Only one of the organic mercury dusts mentioned, Ceresan, is commercially available. Copper carbonate

TABLE 11.—BARLEY: EFFECT OF SEED TREATMENT ON DEVELOPMENT OF STRIPE INFECTION AND YIELD OF GRAIN
(Each test consisted of 12 rod-row replications. Treatments applied in nearly all cases one day before planting. Station farm, Urbana)

Seed infection	Year	Variety	Amount of disinfectant per bushel	Field stand		Stripe-infected plants		Acre-yield		Increase in acre-yield due to treatment		
				Check	Treated	Check	Treated	Check	Treated			
Formaldehyde dust treatments, 5 to 8 percent (Smuttox, Corona Oat Dust)												
			oz.	perct.	perct.	perct.	perct.	bu.	bu.	bu.	perct.	odds
Stripe	1928	Oderbrucker	3	....	....	10.6	11.0	....	....	....	....	......
Stripe	1932	Oderbrucker	2	....	....	4.0	3.5	39.4	41.0	1.6	4.0	5:1
Stripe	1932	Oderbrucker	3	....	....	4.0	1.5	39.4	38.8	— .6[a]	—1.5[a]	2:1
Stripe	1933	Oderbrucker	3	65.7	62.9	2.3	2.0	20.6	19.6	—1.0[a]	—4.9[a]	10:1
Scab	1933	Wisconsin Pedigree 38	3	57.8	55.1	0	0	14.9	15.4	.5	3.4	5:1
Scab and blight	1934[b]	Wisconsin Pedigree 38	3	72.6	71.3	0	0	20.8	20.0	— .8[a]	—3.8[a]	9:1
Nearly disease-free	1933	Wisconsin Pedigree 38	3	80.1	80.8	0	0	15.2	16.5	1.3	8.6	60:1
Nearly disease-free	1934[b]	Wisconsin Pedigree 38	3	92.3	94.6	0	0	22.4	22.3	— .1[a]	— .4[a]	1:1
A mercury compound, "Abavit-B"												
Stripe	1928	Oderbrucker	3	....	....	10.6	0.6	....	....	...	...	......
Stripe	1929	Stavropol	3	90.3	89.1	9.6	0.8	36.2	36.9	.7	1.9	2:1
Stripe and scab	1929	Velvet	3	45.6	40.8	11.8	2.4	40.5	44.2	3.7	9.1	21:1
Scab	1929	Oderbrucker	3	74.7	78.0	.3	0	36.7	37.7	1.0	2.7	3:1

TABLE 11.—*Concluded*

Seed infection	Year	Variety	Amount of disinfectant per bushel	Field stand		Stripe-infected plants		Acre-yield		Increase in acre-yield due to treatment		
				Check	Treated	Check	Treated	Check	Treated			
			oz.	*perct.*	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*odds*
Ethyl mercury chlorid, 1.5 to 2.0 percent (Ceresan)												
Stripe	1928	Oderbrucker	3[c]	....	....	10.6	.4	....	....	....	....	......
Stripe	1928	Oderbrucker	3	....	....	10.6	.2	....	....	....	....	......
Stripe	1929	Stavropol	3[c]	90.3	91.5	9.6	.2	36.2	38.5	2.3	6.3	294:1
Stripe	1931	Oderbrucker	2	....	....	5.1	0	40.6	48.6	8.0	19.7	1933:1
Stripe	1931	Oderbrucker	3	....	....	5.1	0	40.6	46.4	5.8	14.2	78:1
Stripe	1932	Oderbrucker	2	....	....	4.0	0	39.4	41.2	1.8	4.5	8:1
Stripe	1932	Oderbrucker	3	....	....	4.0	0	39.4	41.4	2.0	5.1	9:1
Stripe	1933	Velvet	3	65.7	81.6	2.3	.3	20.6	23.9	3.3	16.0	369:1
Stripe and scab	1929	Velvet	3[c]	45.6	47.4	11.8	0	40.5	43.5	3.0	7.4	8:1
Stripe and scab	1930	Wisconsin Pedigree 38	2	53.3	58.7	7.1	1.3	35.8	46.6	10.8	30.4	4999:1
Stripe and scab	1930	Wisconsin Pedigree 38	3	53.3	64.7	7.1	0	35.8	44.6	8.8	24.0	4999:1
Stripe and scab	1930	Velvet	2	61.3	69.3	25.9	0	38.8	45.3	7.5	19.3	60:1
Stripe and scab	1930	Velvet	3	61.3	72.0	25.9	0	38.8	47.3	9.5	24.4	216:1
Scab	1929	Oderbrucker	3[c]	74.7	78.9	.3	0	36.7	43.4	6.7	18.3	174:1
Scab	1933	Wisconsin Pedigree 38	3	57.8	63.6	0	0	14.9	17.0	2.1	14.1	4999:1
Scab and blight	1934[b]	Wisconsin Pedigree 38	3	72.6	87.3	0	0	20.8	22.5	1.7	8.2	56:1
Nearly disease-free	1933	Wisconsin Pedigree 38	3	80.1	83.6	0	0	15.2	17.9	2.7	17.8	4340:1
Nearly disease-free	1934[b]	Wisconsin Pedigree 38	3	92.3	94.6	0	0	22.4	22.7	.3	1.3	2:1
Ethyl mercury phosphate, 2½ to 5 percent (New Ceresan)												
Stripe	1932	Oderbrucker	1[d]	....	....	4.0	0	39.4	39.3	— .1[a]	— .3[a]	1:1
Stripe	1933	Oderbrucker	½[e]	65.7	71.2	2.3	.4	20.6	23.9	3.3	16.0	78:1
Scab	1933	Wisconsin Pedigree 38	½[e]	57.8	66.6	0	0	14.9	18.0	3.1	20.8	1732:1
Scab and blight	1934[b]	Wisconsin Pedigree 38	½[e]	72.6	88.0	0	0	20.8	23.4	2.6	12.5	570:1
Nearly disease-free	1933	Wisconsin Pedigree 38	½[e]	80.1	82.6	0	0	15.2	19.3	4.1	27.0	9999:1
Nearly disease-free	1934[b]	Wisconsin Pedigree 38	½[e]	92.3	96.0	0	0	22.4	22.9	.5	2.2	5:1

[a]Decrease in yield. [b]Experiment conducted in Stephenson county in cooperation with V. J. Banter, farm adviser, and G. Ackerman, farmer. [c]Ethyl mercury chlorid 1.5 to 1.6 percent; others, 2 percent. [d]Ethyl mercury phosphate, 2½ percent, DuBay No. 1134. [e]Ethyl mercury phosphate, 5 percent, DuBay, No. 1153.

has not given satisfactory control of covered smut, loose smut, or stripe in barley.[86*]

For control of loose smut of barley, the hot-water treatment has usually been recommended. A number of investigators, however, have obtained partial to complete control with such chemical treatments as formaldehyde or organic mercury compounds. Some of the literature on this subject also has been reviewed by Leukel.[43*] After four years of experimentation he came to the conclusion that loose smut can be

TABLE 12.—BARLEY: RESULTS OF SEED-TREATMENT TESTS CONDUCTED BY FARMERS IN THREE COUNTIES IN NORTHERN ILLINOIS

County	Year	Cooperating farmer	Seed treatment	Disease in crop: Loose smut	Disease in crop: Covered smut	Disease in crop: Stripe
			Oderbrucker			
				perct.	perct.	perct.
DeKalb	1932	Carl Peterson..........	None	1.4	0	.2
			Ceresan[a]	0	0	0
DeKalb	1933	George Piggot..........	None	1.0	0	0
			New Ceresan[b]	0	0	0
DuPage	1932	C. Mack..............	None	.8	.2	.6
			Ceresan	.6	0	0
DuPage	1933	W. D. Fiene..........	None	3.8	3.7	.7
			Ceresan	0	0	0
			New Ceresan	0	0	0
			Glabron			
DeKalb	1932	Lee Mosher...........	None	4.6	0	.6
			Ceresan	4.6	0	0
			Velvet			
DeKalb	1933	J. W. Cory............	Formaldehyde	1.4	0	7.9
			New Ceresan	1.2	0	0
DuPage	1932	A. Schillinger..........	None	1.4	1.0	25.2
			Ceresan	.4	0	4.6
DuPage	1933	L. H. Book............	None	6.0	.9	4.3
			New Ceresan	.4	0	0
Stephenson	1932	G. Ackerman..........	None	3.1	.1	.5
			Ceresan	3.4	0	0
Stephenson	1932	George Riess..........	None	.5	0	4.1
			Ceresan	.4	0	.1
Stephenson	1933	G. Ackerman..........	None	4.0	0	0
			New Ceresan	2.0	0	0
			Wisconsin Pedigree 37			
DeKalb	1932	C. M. Johnson.........	None	5.0	.2	0
			Ceresan	.6	0	0
DeKalb	1933	E. J. Hipple...........	None	1.1	0	0
			New Ceresan	1.0	0	0
DeKalb	1933	W. F. Leifhart.........	None	1.0	0	0
			New Ceresan	0	0	0

TABLE 12.—*Concluded*

County	Year	Cooperating farmer	Seed treatment	Disease in crop: Loose smut	Covered smut	Stripe
Wisconsin Pedigree 38						
				perct.	*perct.*	*perct.*
DeKalb	1933	George Piggot..........	None	2.4	0	0
			New Ceresan	.1	0	0
DeKalb	1933	W. F. Leifhart.........	None	.8	0	0
			New Ceresan	.8	0	0
DeKalb	1933	W. Hammett..........	None	1.8	0	0
			Ceresan	.1	0	0
			New Ceresan	.1	0	0
DeKalb	1933	E. E. Hipple...........	Formaldehyde	.3	0	0
			New Ceresan	.4	0	0
DuPage	1933	A. Schillinger..........	None	.5	0	0
			New Ceresan	.3	0	0
DuPage	1933	E. Schuetze............	None	2.4	0	.2
			New Ceresan	1.0	0	0
Stephenson	1932	A. C. Baumgartner.....	None	1.3	0	0
			Ceresan	1.5	0	0
Stephenson	1932	W. Noltemeyer.........	None	.8	0	0
			Ceresan	.8	0	0
Stephenson	1933	G. Ackerman..........	None	0	0	0
			New Ceresan	0	0	0
Stephenson	1933	A. C. Baumgartner.....	None	1.0	0	0
			Ceresan	.3	0	0
			New Ceresan	.8	0	0
Stephenson	1933	George Riess...........	None	Trace	0	0
			New Ceresan	Trace	0	0
Average for Oderbrucker, Glabron, and Velvet.....			Not treated	2.5	.5	4.0
			Treated	1.2	0	.4
Average for Wisconsin Pedigree Nos. 37 and 38....			Not treated	1.3	Trace	Trace
			Treated	.5	0	0

[a]Ethyl mercury chlorid. [b]Ethyl mercury phosphate.

controlled in certain varieties by chemical disinfectants, while in other varieties only the hot-water treatment is effective. A short time later Tapke[83]* pointed out that there are two kinds of loose smut, and that one can and the other cannot be controlled by chemical means. It now appears that it is not so much the variety of barley, but the variety of loose smut, that determines what kind of seed treatment is needed.

In twenty-five tests conducted by farmers in northern Illinois in 1932 and 1933 (Table 12) covered smut of barley was of small importance; what occurred was controlled perfectly by ethyl mercury chlorid and ethyl mercury phosphate. Loose smut occurred much more generally than covered smut. On a few farms it also was completely controlled by these two disinfectants; but, taking all the tests together, it was decreased to just a little less than half that on the untreated strips.

The two kinds of loose smut are difficult to distinguish one from the other in the field. Judging from the results from these seed-treatment tests, the intermediate type, which can be controlled by the disinfectants used, accounted for about half the loose smut. If these tests are a fair representation of what may be expected under average conditions, then organic mercury disinfectants are of value in reducing the losses from loose and covered smut of barley. Occasionally, however, farmers will no doubt find heavy smut losses in spite of treatment with a material like New Ceresan. When this happens it is advisable either to exchange grain with someone known to have barley that is free from smut or to treat the seed with hot water.

Scab- and Blight-Infected Barley Seed

Barley seed-treatment experiments were conducted in 1929 and 1933 with seed infected primarily with scab caused by *Gibberella saubinetii*. Seed infected primarily with blight caused by *Helminthosporium sativum* was used in 1934. In some other years (Table 11) seed infected with both scab and stripe was used. Results must be judged from field stands and yields of grain.

Formaldehyde dust treatment of scab-infected seed gave no increases in stand or yield (Table 11). Ethyl mercury chlorid and ethyl mercury phosphate both gave decided increases in field stand and in most cases caused statistically significant increases in yield. Porter, Brown, and King[62*] also obtained decided increases in stand and yield for blight-infected barley when the seed was treated with these mercurials. Christensen and Stakman[10*] found that Ceresan treatment increased the stand, vigor of seedlings, and yield of grain in proportion to the amount of blight infection in the seed, when Velvet, Manchuria, and some other varieties were used, but the Glabron variety did not respond beneficially to seed treatment.

Nearly Disease-Free Barley Seed

Good healthy seed of Wisconsin Pedigree 38 variety was used in tests in 1933 and 1934. The results obtained in 1933 were especially interesting (Table 11).

The two organic mercury compounds caused some increase in stand, but the conspicuous thing was an increase in vigor. The improvement was similar to that sometimes observed in wheat (Fig. 12, page 525). Later in the season (1933) the crop suffered from drouth and chinch bugs, so that the yields of grain were low, but the difference in vigor was maintained and resulted in marked increases in yield from seed treatment.

Three kinds of seed were used in this season—healthy Wisconsin Pedigree 38, scab-infected Wisconsin Pedigree 38, and stripe-infected

Oderbrucker. Only 2.3 percent of the plants produced from the infected seed were infected with stripe. It is of special interest that in the crop from healthy seed the increases in yield from treatment were as great as or greater than from infected seed. This must have been an unusual situation, and is one for which the writer has no explanation. In 1934, on the other hand, significant increases in yield were obtained by treating scab- and blight-infected Wisconsin Pedigree 38 barley but not by treating healthy seed of the same variety.

Discussion of Barley Seed Treatments

Formaldehyde dust did not control the stripe disease, and in seven tests (Table 11) it more frequently caused decreases in yield than increases. Similar results were obtained in a three-year test in Michigan.[12*] Formaldehyde used in liquid form has given still less satisfactory results.[12*] Formaldehyde in either form should not be recommended, therefore, as a seed treatment for barley.

Ethyl mercury chlorid (Ceresan) and ethyl mercury phosphate (New Ceresan) controlled stripe, covered smut, half of the loose smut, and in nearly all tests caused increases in yield. In most of the tests the increases in yield were statistically significant.

There is no doubt that seed treatment of barley with Ceresan or New Ceresan has paid very well in tests, made with a considerable number of different varieties in Illinois and elsewhere. However, when Wisconsin Pedigree 38 is used, a new variety which is increasing rapidly in popularity, is outstanding for high yield, quality of grain, resistance to the stripe disease, and has the desirable smooth awns, it is still an open question whether seed treatment as a regular practice is worth the trouble and expense. But when the barley seed of this or any other variety is infected with scab, blight, or smut, seed treatment is a paying procedure. When the chemical dust treatment fails to check severe smut infection, it may be necessary to resort to the hot-water method the next year or else secure seed that is not infected.

YIELD INCREASES ANALYZED

When smut-infected seed of wheat and oats was treated with copper carbonate, ethyl mercury chlorid, or ethyl mercury phosphate, the increase in yield could not be explained by the prevention of smutty heads alone. The percentage decrease in yield in untreated checks compared with yields from the treated plots was approximately twice as great as the percentage of smutty heads in the untreated checks (Table 13 and Fig. 14). With the formaldehyde treatments, on the other hand, the percentage loss in yield that resulted from not treating the seed was approximately equal to the percentage of smutty heads. The formaldehyde-treated grain, it will be observed, did not yield as well as the grain treated by the other methods mentioned above, probably because of injury caused by the formaldehyde. Injury to germination, vigor, or yield by formaldehyde treatments has frequently been reported. It has also been shown[20*] that the chemotherapeutic index of formaldehyde is higher than that of some organic mercury products, and thus more injury may be expected.

Smut-free seed also was used in a number of experiments in which the same disinfectants were used as those indicated above. A summary of the results of these tests is given in Table 13 and Fig. 14.

TABLE 13.—SMUT OF WHEAT AND OATS: EFFECT OF CERTAIN SEED DISINFECTANTS ON YIELDS OF GRAIN WHEN SEED WAS INFECTED AND WHEN IT WAS NEARLY DISEASE-FREE

(Data are summarized from Tables 2, 4, 8, and 9)

Seed treatment	Disease infection in seed planted	Number of tests	Smutty heads in untreated checks	Decrease in yield from untreated seed (treated seed = 100)	
			perct.	*perct.*	*odds*
Wheat					
Copper carbonate	Bunt	6	6.5	13.4	3332:1
	None	18	0	3.8	>9999:1
Ethyl mercury chlorid	Bunt	3	6.5	13.4	>9999:1
	None	11	0	1.8	17:1
Ethyl mercury phosphate	Bunt	2	6.1	12.2	295:1
	None	8	0	1.2	4:1
Oats					
Formaldehyde sprinkle	Smut	16	9.8	8.2	3332:1
	None	4	0	.6	1:1
Formaldehyde dust	Smut	17	9.6	9.4	2250:1
	None	17	0	1.8	143:1
Ethyl mercury chlorid	Smut	20	8.1	15.8	>9999:1
	None	13	0	5.8	>9999:1
Ethyl mercury phosphate	Smut	10	13.2	23.8	1666:1
	None	2	0	5.4	243:1

Not all these tests are directly comparable with those made with smut-infected seed, with regard to varieties, years tested, and other factors. A number of tests, however, are comparable, and if these were analyzed separately, the situation would not be altered materially. Incidentally the organic mercury compounds had a more beneficial effect on smut-free oats than on smut-free wheat.

The results of yield tests with nearly disease-free seed have been discussed to some extent earlier in this bulletin. Some evidence of disease control in the seedling stage has been pointed out. The increases in yield obtained from treatment must be explained either on the basis of the control of seedling disease caused by infection carried on the seed or in the soil, or the control of other disease infections not yet understood, or else on the basis of a chemical stimulation of the seedling of a physiological nature. Many writers have used the term

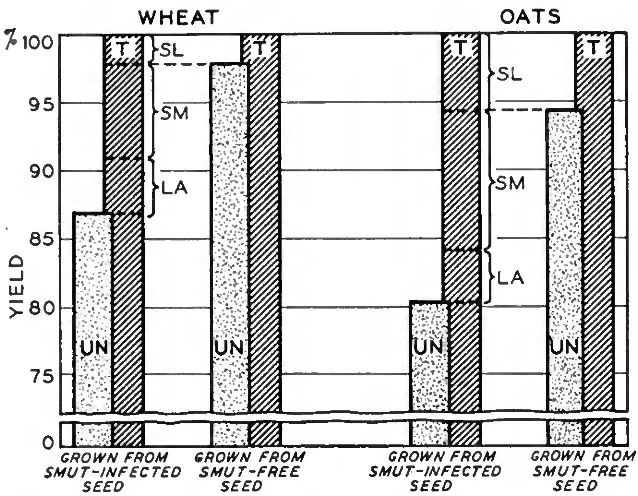

FIG. 14.—LOSSES IN WHEAT AND OATS RESULTING FROM OMISSION OF SEED TREATMENT

The yield from untreated seed is represented by UN, while T represents the yield from treated seed. The difference between the yields from treated and untreated seed can be accounted for by the control of seedling diseases (SL), by the substitution of sound heads for smutty ones (SM), and the remainder presumably by the control of latent smut infection (LA). These graphical data are summarized from Table 13, the formaldehyde treatments being omitted here.

"stimulation" to describe the effect of treatment but some doubtless used the word loosely and simply meant increased germination, vigor, or yield without necessarily implying physiological stimulation. The effect of removing inhibitory factors such as disease germs can hardly be considered as true stimulation.

The question of seed stimulation was discussed some years ago by Klages,[34*] who pointed out that there was no good proof that seed treatments have caused stimulation. Since that time a number of writers have taken the stand that such a thing as seed stimulation does actually occur. Niethammer,[57, 58*] for instance, in the absence of any recognized disease infection, secured better germination of wheat seed treated with Uspulun than with untreated seed. Increased germination was not observed in all seed lots, but occurred especially in those in which germination was not up to the standard for high-class seed. He suggested that the effect was caused by physiologic stimulation, which is limited to the seedling stage. Popoff[61*] makes more sweeping statements and claims that the stimulation may have an effect on yields of grain. Sampson and Davies[78*] were unable to find evidence of stimulation.

The writer feels that it is still an open question whether chemicals may cause physiologic seed stimulation which influences the plant thruout its life and results in increased yields of grain, aside from that caused by materials which serve a nutritional function. Seed stimulation, if it has occurred at all, certainly has not occurred regularly in the experiments conducted at this Station and, to a large extent, if not entirely, the effects probably can be ascribed to disease control.

An explanation is still needed for the excessive increases in yield from treated smut-infected seed. As early as 1897 it was pointed out by Bolley[3*] that in a field of wheat having 10 to 30 percent bunt-infected heads, scarcely a stool was free from smut fungus in the lower parts of the plant. Zade[91*] made similar observations and called this situation "latent infection." A number of investigators have reported decreased yields from smut infection that could not be accounted for by smutty heads alone.[18, 54, 76, 88, 90, 91*] Some have pointed out that when wheat plants were grown from the same lot of seed—part of the seed inoculated with stinking smut, the other free—plants in the first group were shorter and less thrifty even tho they did not have smutty heads.[52, 77*] The same situation was found to be true for the smuts of oats.[27, 88, 91*] It seems evident, therefore, that smut may cause damage from latent infection that is not indicated by smut development in the heads. Fortunately the total effect may be controlled by seed disinfection. In Fig. 14 the areas marked LA indicate the percentage loss from latent smut infection.

MACHINE VERSUS SHOVEL MIXING

When recommending seed treatments with chemical dust, most investigators have emphasized the need of applying the dust thoroly with a mixing machine.

In order to determine what success farmers are having in the control of stinking smut of wheat with various materials and methods, a survey of wheat fields was made by federal pathologists in various areas from Iowa and Minnesota to Idaho and Montana in 1930[23*] and 1931.[17*] Some of the conclusions from these reports are: "The dust treatments gave the best control of any of the treatments when applied with good commercial machines or home mixers." "Dust treatments cannot be made successfully by the sprinkle and shovel method."[23*] In summarizing the results from a survey of 202 fields in Minnesota, R. C. Rose[17*] states: "Machine treated seed gave most satisfactory results with both formaldehyde and copper carbonate. The formaldehyde spray and the copper carbonate shovel mix methods were the least effective."

Thus there seems to be general agreement that copper carbonate cannot be applied satisfactorily by mixing with a shovel or rake.

In recent years formaldehyde dusts and ethyl mercury phosphate (New Ceresan) have appeared on the market, and the statements have been made that these materials can be applied successfully by mixing with a shovel and then covering the pile of grain and letting it stand overnight or for 24 hours. Formaldehyde dust is recommended primarily for oats. It is a gas treatment and therefore very different from copper carbonate in its action. Ethyl mercury phosphate is a combined gas and contact disinfectant.

In order to compare the shovel and machine methods of applying these two materials, an experiment was conducted with oats that were heavily but naturally infected with smut. The oats were poured on a floor, and the required amount of disinfectant added after each bushel of grain was added to the pile until the pile contained 6 bushels. This pile was then shoveled into another pile, and then sacked and labeled "turned twice." Another lot was shoveled three times into piles and then sacked and labeled "turned four times." After standing in closed sacks for 24 hours, samples for planting were taken with a grain sampler thruout the length of the center of each sack.

The shovel method of applying formaldehyde dust did not give as good control as the machine method, altho the amount of smut was greatly diminished when mixing had been done by shoveling four times (Table 14). Smut was controlled satisfactorily with ethyl mercury phosphate when the scoop-shovel method was used, but the yields of grain were inferior in comparison with yields from machine-treated seed. The decreases in yield resulting from the shovel method compared with the machine method were as follows: turned 4 times with a shovel, 2.7 bushels decrease, with odds that the decrease was significant; turned only twice, 4.2 bushels decrease, with high odds. Evidently there was a real tendency for lack of thoro mixing to cause a decrease in yield. The probable explanation for this effect is that by the shovel method the chemical was left in too concentrated form on

TABLE 14.—METHOD OF APPLICATION: EFFECTIVENESS OF SHOVEL AND MACHINE METHODS WHEN APPLYING TWO KINDS OF SEED DISINFECTANTS ON OATS

(Treated seed was sacked and stored for 24 hours before seeding
Station farm, Urbana, 1933)

Disinfectant and method of application	Smut-infected heads	Acre-yield	*Increase* in acre-yield due to seed treatment		*Decrease* in acre-yield due to shovel method	
	perct.	*bu.*	*bu.*	*odds*	*bu.*	*odds*
None	23.8	28.4	....	......	...	......
Formaldehyde dust, 3 ounces per bushel (Corona Oat Dust)						
Treating machine, 3 minutes	1.2	34.8	6.4	9999:1	...	......
Scoop shovel, turned 4 times	2.8	35.0	6.6	9999:1	...	......
Scoop shovel, turned 2 times	9.8	32.4	4.0	4999:1	2.4	27:1
Ethyl mercury phosphate 5 percent, ½ ounce per bushel (New Ceresan)						
Treating machine, 3 minutes	0	43.5	15.1	>9999:1	...	......
Scoop shovel, turned 4 times	.1	40.8	12.4	>9999:1	2.7	555:1
Scoop shovel, turned 2 times	.2	39.3	10.9	>9999:1	4.2	1730:1

some of the grain and caused injury. Ethyl mercury phosphate at its worst gave better yields than formaldehyde dust at its best.

It seems advisable, judging from the data available at the present time, to use a suitable treating machine, whenever possible, for applying the dry treatments. Such a machine does a better job than can be done with a shovel, and the operators are not so exposed to the fumes and poisonous dust. Many farmers, however, do not have machines and do not see immediate prospects of obtaining them. If the operator will protect himself properly with a dust mask (respirator) or wet sponge over the nose, the scoop-shovel method, if the seed is shoveled about four times, may be used as second choice for applying formaldehyde dust or New Ceresan.

DOSAGE AND LENGTH OF TIME IN STORAGE BEFORE SEEDING

That the dosage of formaldehyde must be gaged closely is well known, the aim being to obtain maximum smut control with minimum damage to the seed. The safety margin is very small.

Investigating the chemotherapeutic index[a] of several seed disinfectants, Gässner and Rabien[20*] found that smut spores (bunt) could

[a]c/t (c = *dosis curativa*, t = *dosis toxica*), a mathematical ratio taking into account the relative injury caused by a disinfectant or drug to a given germ, on the one hand, and to an animal or plant subject to infection by this germ, on the other. The lower the index the more valuable, theoretically, is the disinfectant.

be killed equally well by immersing them for a short time in a strong solution of organic mercuries or formaldehyde or for a longer time in a weaker solution. Six hours was the longest duration tested, and for wet treatments this probably is as long as would be practical. When using formaldehyde on wheat seed, the therapeutic index was lowered very materially by decreasing the strength and increasing the time; in fact the *dosis curativa* was less than the *dosis toxica* only in the long-time treatments. If the same tendency holds for a still longer time of treatment, that fact may explain why formaldehyde dusts have

TABLE 15.—LENGTH OF STORAGE: EFFECT OF DIFFERENT PERIODS OF STORAGE ON YIELD OF THREE VARIETIES OF OATS TREATED WITH FORMALDEHYDE BY THE SPRAY METHOD
(Station farm, Urbana, 1933)

Days storage after treating and before seeding	Smut-infected heads	Acre-yield	*Increase* in acre-yield due to treatment			*Decrease* in acre-yield due to storage	
	perct.	*bu.*	*bu.*	*perct.*	*odds*	*perct.*	*odds*
Sixty-Day							
Untreated check	1.7	37.9	...	....	......	...	......
1 day	0	37.6	− .3	− .8	2:1	...	......
12 days	0	32.4	−5.5	−14.5	192:1	13.8	908:1
Big Four							
Untreated check	8.7	25.0	...	....	......	...	......
1 day	0	32.1	7.1	28.4	>9999:1	...	......
12 days	0	31.3	6.3	25.2	>9999:1	2.5	4:1
Quaker							
Untreated check	23.8	28.4	...	....	......	...	......
1 day	0	38.3	9.9	34.9	9999:1	...	......
7 days	0	36.4	8.0	28.2	9999:1	4.9	49:1
Average							
Untreated check	11.4	30.4	...	....	......	...	......
1 day	0	36.0	5.6	18.4	>9999:1	...	......
7 to 12 days	0	33.4	3.0	9.9	32:1	7.2	1100:1

usually given better results in yield tests than have liquid formaldehyde treatments. Formaldehyde dusts, as ordinarily used, are weaker in action than liquid formaldehyde and require a longer time in which to act. Seed treated with them should stand overnight or for 24 hours before being sown, if satisfactory smut control is to be obtained. Liquid formaldehyde as ordinarily used gives good control if the treated seed is permitted to stand only two or three hours.

In case of a dry disinfectant of a volatile nature like formaldehyde dust or ethyl mercury phosphate it seems obvious that the effective dosage is governed not only by the amount of disinfectant applied but also by the length of time it is allowed to act before the seed is planted or aerated. When the Haskell spray method is used[22*] it has been assumed that the treated grain may be stored for a few hours or for a much longer time with equally good results. Perhaps this is true if the grain can be aired thoroly after it has been subjected to the treatment for the minimum effective time.

Formaldehyde Treated Oats Stored for Different Periods

In order to determine what would happen if oats treated with formaldehyde applied by the spray method were stored for different numbers of days in regular 2-bushel grain sacks tied shut, an experiment was made with three varieties of oats. Samples for planting were taken from the center of the sack with a grain sampler. Compared with yields from treated seed stored only one day, storage for 7 to 12 days caused a decrease in yield of 7.2 percent, with high odds of probability that the decrease was significant (Table 15).

Seed treated with formaldehyde dust and stored in grain sacks suffered deterioration similar to that caused by the spray method (Table 17).

Organic Mercury Treatments

Ethyl mercury phosphate (New Ceresan) is another material that has a small safety margin. The danger from injury is not so great as with formaldehyde but is of importance nevertheless. The 5-percent product now on the market is recommended for use at the rate of ½ ounce per bushel.

In a test with two varieties of wheat involving 12 rod-row replications of each treatment, applications were made at the recommended rate and at 4 times this rate. The excessive rate, as compared with the recommended amount, caused a reduction in yield of 17.5 percent in Cheyenne wheat and 24.4 percent in Turkey. Data given in Table 3, page 526, Items 20 to 22, show that when New Ceresan was applied at the normal rate and stored 3 days, it had little effect on yield. When the dosage was doubled, there was a significant decrease in yield. When the dosage was normal and the seed was sown the same day as treated, there was a significant increase in yield from treatment. Neill[56*] found in experiments with dust disinfectants applied at 40 times the normal rate that Ceresan gave very poor germination, and New Ceresan also caused poor germination but better than Ceresan. He reports, however, that the injury from New Ceresan was entirely avoided by sowing the seed with superphosphate fertilizer when the fertilizer was placed in the drill rows. Macdonald[48*] applied Ceresan and Agrosan to wheat at 3, 6, and 42 times the recommended amounts, and immediately planted the seed in a field test. Only Ceresan at the

42x rate caused injury to germination. Machacek and Greaney[49*] found that when Ceresan and New Ceresan were used in excess as a steep, they caused severe seed injury.

As these organic mercury compounds cause damage when applied in excess, and as they act partly as gas disinfectants in stored grain, damage in storage, as might be expected, was found to occur. Leukel[42*] stored treated barley seed for different periods of time in closed tin cans and in cotton sacks and observed the germination of the seed on a greenhouse bench after storage was completed. When stored in the cans, decreases in germination occurred after treatment with Smuttox, Corona 80-B, and P. M. A.; when stored in cloth sacks, injury occurred only with Smuttox and P. M. A. His tests did not show injury from storing grain treated with Ceresan, and in that respect his results with barley are not in agreement with those the writer obtained with wheat and oats. Crosier[13*] reported abnormal and stunted germination from wheat treated with Ceresan and stored for some time.

In experiments by the writer, treated and untreated samples of two varieties of wheat were stored for one year, similar treatments

TABLE 16.—LENGTH OF STORAGE: EFFECT OF DIFFERENT PERIODS OF STORAGE ON YIELD OF TWO VARIETIES OF WHEAT TREATED WITH COPPER CARBONATE AND ETHYL MERCURY PHOSPHATE
(Station farm, Urbana, 1934)

Days storage after treating and before seeding	Stinking smut heads	Acre-yield	*Increase* in acre-yield due to treatment			*Decrease* in acre-yield due to storage	
Treated with copper carbonate, 18 to 20 percent copper, 2½ ounces per bushel							
	perct.	*bu.*	*bu.*	*perct.*	*odds*	*perct.*	*odds*
Fulhio							
Untreated check	4.8	31.5	...	....	......	....	......
4 to 6 hours	.1	35.7	4.2	13.3	1666:1	....	......
365 days	.1	36.4	4.9	15.6	9999:1	None	......
Turkey							
Untreated check	0	35.4	...	....	......	....	......
4 to 6 hours	0	36.9	1.5	4.2	11:1	....	......
365 days	0	37.3	1.9	5.4	55:1	None	......
Treated with ethyl mercury phosphate 5 percent (New Ceresan) ½ ounce per bushel							
Fulhio							
Untreated check	4.8	31.5	...	....	......	....	......
4 to 6 hours	0	36.6	5.1	16.2	>9999:1	....	......
365 days	0	26.6	−5.4[a]	−17.1[a]	>9999:1	31.7	>9999:1
Turkey							
Untreated check	0	35.4	...	....	......	....	......
4 to 6 hours	0	38.1	2.7	7.6	416:1	....	......
365 days	0	32.2	−3.2[a]	− 9.0[a]	416:1	16.6	>9999:1

[a]Decrease in yield.

TABLE 17.—LENGTH OF STORAGE: EFFECT OF DIFFERENT PERIODS OF STORAGE ON YIELD OF OATS TREATED WITH FORMALDEHYDE DUST AND WITH ETHYL MERCURY CHLORID

(Average of 6 tests with Sixty-Day and Big Four varieties, Station farm, Urbana, 1930, 1931, 1932)

Seed treatment and days storage after treating and before seeding	Field stand	Acre-yield	*Increase* in acre-yield due to treatment		*Decrease* in acre-yield due to storage		
	perct.	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*	*odds*
None (5.9 percent smut)	78.4	58.6	...	...	...	...	....
Formaldehyde dust, 3 ounces per bushel							
0 to 1 day	82.4	63.4	4.8	8.2	...	...	....
6 to 7 days	81.6	62.6	4.0	6.8	.8	1.3	3:1
26 to 54 days	77.8	59.1	.5	.9	4.3	6.8	138:1
Ethyl mercury chlorid (Ceresan) 3 ounces per bushel							
0 to 1 day	86.7	66.4	7.8	13.3	...	...	......
6 to 7 days	83.3	64.3	5.7	9.7	2.1	3.2	20:1
26 to 54 days	80.6	61.2	2.6	4.4	5.2	7.8	230:1

TABLE 18.—LENGTH OF STORAGE: EFFECT OF DIFFERENT PERIODS OF STORAGE ON YIELD OF OATS TREATED WITH ETHYL MERCURY PHOSPHATE (NEW CERESAN) AT THE RATE OF ½ OUNCE PER BUSHEL

(Station farm, Urbana)

Days storage after treating and before seeding	Smut-infected heads	Acre-yield	*Increase* in acre-yield due to treatment		*Decrease* in acre-yield due to storage		
	perct.	*bu.*	*bu.*	*odds*	*bu.*	*perct.*	*odds*
Sixty-Day, 1932							
Untreated check	15.5	50.4	....	......	...	....	......
0 days	.1	68.4	18.0	>9999:1	...	....	......
6 days	0	65.5	15.1	>9999:1	2.9	4.2	4:1
54 days	0	62.3	11.9	4999:1	6.1	8.9	53:1
Big Four, 1932							
Untreated check	12.4	53.8	....	......	...	....	......
0 days	.2	68.0	14.2	>9999:1	...	....	......
6 days	0	66.5	12.7	>9999:1	1.5	2.2	3:1
54 days	0	57.4	3.6	11:1	10.6	15.6	1999:1
Sixty-Day, 1933							
Untreated check	1.7	37.9	....	......	...	....	......
0 days	0	41.0	3.1	12:1	...	....	......
1 day	0	39.0	1.1	8:1	2.0	4.9	53:1
6 days	0	37.8	— .1	1:1	3.2	7.8	160:1
70 days	0	35.8	—2.1	10:1	5.2	12.7	714:1
Big Four, 1933							
Untreated check	8.7	25.0	....	......	...	....	......
0 days	0	31.3	6.3	3332:1	...	....	......
1 day	0	30.4	5.4	9999:1	.9	2.9	3:1
6 days	0	29.0	4.0	293:1	2.3	7.3	11:1
70 days	0	27.8	2.8	81:1	3.5	11.2	28:1
Average							
Untreated check	9.6	41.8	....	......	...	....	......
0 days	.1	52.2	10.4	......	...	....	......
6 days	0	49.7	7.9	......	2.5	4.8	434:1
54 to 70 days	0	45.8	4.0	......	6.4	12.2	78:1

being made also a few hours before seeding. One-year storage with ethyl mercury phosphate reduced the yield of the two varieties 31.7 and 16.6 percent respectively. The results are shown in Table 16. Treated oats were stored for various lengths of time before they were seeded (Tables 17 and 18). Formaldehyde dusts, ethyl mercury chlorid, and ethyl mercury phosphate all caused a progressive decrease in yield with length of time in storage.

The writer is willing to concede that damage does not always take place when grain treated with formaldehyde or ethyl mercury phosphate is stored for some time before planting. Published as well as unpublished data from other investigators made available to the writer would indicate this. However, the conditions under which damage may or may not occur are not understood; and since it has been shown definitely that there is danger of reducing yields when treated seed is stored for prolonged periods before it is planted, it would seem inadvisable to take the risk. The question is whether the dosage can be reduced to a point where it will do no damage under prolonged storage and still remain effective.

Reducing the Dosage

As formaldehyde and the organic mercury compounds can be used satisfactorily when the dosage is gaged properly and the seed is sown soon thereafter, it seems logical to believe that the damage that may occur during storage is due to excessive treatment. In other words, when damage has occurred, more disinfectant has been used than was necessary for smut control. To test out this assumption, an experiment was conducted in 1934 with oat seed treated with formaldehyde and ethyl mercury phosphate at ¼, ½, ¾, and normal rates of application, stored 65 days before seeding. A similar set of treatments was made one day before seeding. Altho the test was severely injured by dry weather and chinch bugs, the indications were that if treatments are made a week or more before sowing, the rate of application of formaldehyde (spray method) or ethyl mercury phosphate may be cut to one half the amount that is usually recommended and still obtain good smut control.

The above experiment was repeated in 1935 in two locations, Urbana and Stockton. Growing conditions were good in both locations, but smut development was not high, averaging only about 4 percent of the heads of the check rows (Tables 19 and 20). Again the indications were that if the treatments are made in advance before sowing, perhaps only a week, the dosage can be cut in half. It seems probable that such a reduction in dosage will prevent a great deal, if not all, the damage that otherwise might result from storage.

If further tests prove this procedure sound, it will have great

TABLE 19.—RATE AND TIME OF SEED TREATMENT WITH FORMALDEHYDE: EFFECT ON SMUT CONTROL WHEN FORMALDEHYDE WAS APPLIED BY THE SPRAY METHOD AT DIFFERENT RATES AND THE SEED STORED FOR DIFFERENT PERIODS OF TIME BEFORE SOWING
(Grown at Urbana and Stockton, Illinois, 1935)

Days storage after treating and before seeding	Percentage of smut-infected heads in the crop				
	Untreated check	1 pint formaldehyde to 50 bushels oats	1 pint formaldehyde to 75 bushels oats	1 pint formaldehyde to 100 bushels oats	1 pint formaldehyde to 150 bushels oats
Wolverine, Urbana					
3 to 4 hours	4.1	.3	.7	1.7	2.7
5 days	4.1	0	0	0	0
23 days	4.1	0	0	0	0
Wolverine, Stockton					
3 to 4 hours	4.8	0	1.3	1.8	...
7 days	4.8	0	0	.2	...
43 days	4.8	0	0	0	...
Kanota, Stockton					
3 to 4 hours	3.8	.2	.2	.8	...
7 days	3.8	0	0	0	...
43 days	3.8	0	0	0	...

TABLE 20.—RATE AND TIME OF SEED TREATMENT WITH CERESAN: EFFECT ON SMUT CONTROL WHEN ETHYL MERCURY PHOSPHATE (NEW CERESAN) WAS APPLIED AT DIFFERENT RATES AND THE SEED STORED FOR DIFFERENT PERIODS OF TIME BEFORE SOWING
(Grown at Urbana and Stockton, Illinois, 1935)

Days storage after treating and before seeding	Percentage of smut-infected heads in the crop				
	Untreated check	½ ounce Ceresan per bushel oats	⅜ ounce Ceresan per bushel oats	¼ ounce Ceresan per bushel oats	⅛ ounce Ceresan per bushel oats
Wolverine, Urbana					
2 to 3 hours	4.1	0	0	1.3	1.8
5 days	4.1	0	0	0	0
23 days	4.1	0	0	0	.2
72 days	4.1	0	0	0	0
Wolverine, Stockton					
2 to 3 hours	4.8	0	.2	.3	...
7 days	4.8	0	0	0	...
43 days	4.8	0	0	0	...
Kanota, Stockton					
2 to 3 hours	3.8	0	.2	.5	...
5 days	3.8	0	0	0	...
43 days	3.8	0	0	0	...

importance. The error in estimating a long-time storage period is likely to be less than in estimating a short-time period. Treatments could be made early in winter and the dosage adjusted to the length of time intervening until seeding. Seedsmen would be able to treat their seed before sale, and thus insure the very best results. Portable power seed-treating machines would be able to operate whenever convenient. Slack periods could be utilized for treating seed. Making treatments early would result in a substantial saving of money since less disinfectant would be needed.

Copper Carbonate Treatments

The foregoing comments concerning damage to treated seed in storage and the advisability of reducing the dosage when treated seed is to be stored do not apply to copper carbonate. Copper carbonate is an inert material when dry and has no effect during storage[68*] (Table 16), nor does an excessive amount cause harm to the grain.[56*] The dosage is the same regardless of the length of the storage period, and treated grain can be held over until the following season if a good dry storage place is provided.

DIRECTIONS FOR APPLYING DISINFECTANTS

Copper Carbonate

(For Stinking Smut of Wheat)

To apply copper carbonate properly to wheat seed for the control of stinking smut, a machine is necessary. One made from an oil drum (Fig. 15) is very satisfactory if the drum is filled one-third full and is revolved thirty or more times. A power cement mixer is good if the opening can be closed tightly. For large amounts of seed a commercial machine thru which the wheat passes in a steady stream saves time. A number of such machines are on the market. One type employs a mixing drum with a power drive, another is equipped with a series of baffle plates over which the grain and dust flow by gravity. Both types, when properly constructed, give good results. A combined cleaning and treating machine is shown in Fig. 16.

Repeated observations have demonstrated that a good job of mixing cannot be done with a shovel. Shovel-treated grain may look to the naked eye as tho well treated but smut control is less apt to be satisfactory. In fact, the copper carbonate treatment should not be a mixing process only, but the copper carbonate should be rubbed into the entire seed coat of every kernel if it is to be most effective.

Use 2 to 3 ounces of 18- to 20-percent dilute copper carbonate to each bushel of seed, or 2 ounces of the concentrated 50-percent grade. The dilute grade has proved very satisfactory in Illinois.

Grain treated with copper carbonate can be stored from one year to the next in a dry place without harm. It has been said that insects and mice do not attack treated grain so readily as they do untreated grain. The cost of copper carbonate is 2 to 3 cents a bushel of grain.

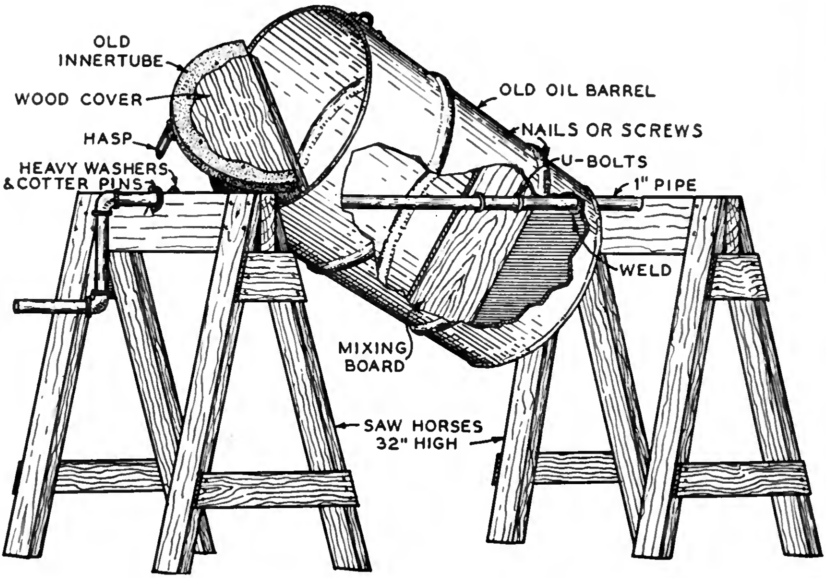

FIG. 15.—A SEED-TREATING MACHINE SUITABLE FOR APPLYING DRY DISINFECTANTS

A machine like this can be made from a 30-gallon oil drum. The lid should fit dust-tight. One bushel is treated at a time. This style of machine originated at the Pennsylvania State College. Larger machines can be built if a power drive can be arranged, or power machines with a continuous action may be purchased.

When working with copper carbonate, care should be taken not to inhale the dust. It is best to work in the open or in a drafty place. If this is impossible, a respirator should be worn. *Breathing very much of the dust will cause illness.*

After treated wheat has stood in the drill hoppers over night or longer, it is safest to make sure the cylinders are loose before using the machine again. This can be done by turning the drive rod back and forth with a wrench. Otherwise, especially if the weather has been damp, the cylinders may stick and injure the drill.

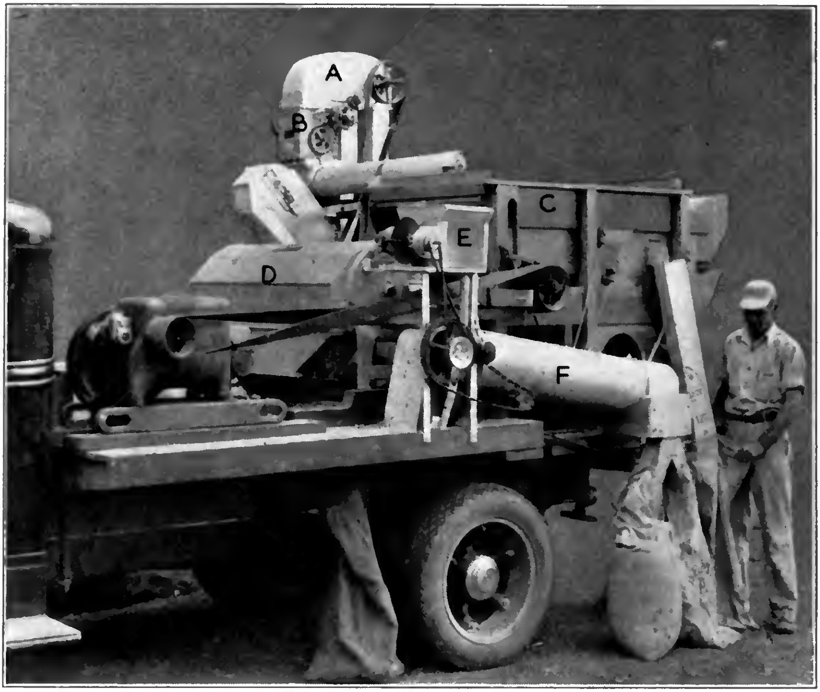

FIG. 16.—PORTABLE SEED CLEANING AND TREATING MACHINE

Some of the essential features of this machine are: (A) an elevator which raises the grain from a hopper near the ground; (B) a weighing device; (C) fanning mill; (D) disk cleaner; (E) an adjustable positive feed for delivering the disinfectant to the treating drum; (F) a revolving treating drum with baffle plates on the inside. A number of machines of this type are rendering valuable custom service on farms in the soft-wheat belt of Illinois. Very good preparation of seed for planting is done quickly with little labor and at low cost.

Ceresan Treatment

(For Stinking Smut of Wheat, Smuts of Oats, Smuts of Barley, Scab or Blight of Wheat and Barley, Stripe Disease of Barley)

Ceresan is a patented commercial compound that is sold widely. The new product, containing 5 percent ethyl mercury phosphate, is used at the rate of only ½ ounce per bushel.[a] This is sufficient for disease control; if more is used, yields are likely to be lowered.

It is best to apply Ceresan with a treating machine such as de-

[a]The earlier Ceresan product (ethyl mercury chlorid) the author understands is no longer marketed extensively for wheat, oats, and barley, being superseded by the "new improved" Ceresan. All directions for treatment therefor refer to the later product.

scribed for the copper carbonate treatment. If the mixing has been thoro, the seed may be sown at once. For best results, it should be sown within a day or two. If no treating machine is available, this compound can be mixed with a shovel. The shovel method is more successful with Ceresan than with copper carbonate, because Ceresan works not only by contact but also as a gas. When shovel-treated, the grain must be sacked or left in a pile and covered for about 24 hours.

If it is desired to store the grain for a week or longer, the dosage should be reduced to three-fourths or one-half the amount specified above, that is, ⅜ or ¼ ounce per bushel. This will be sufficient for smut control and will tend to avoid damage from storage. When such small amounts are used, it becomes increasingly necessary to do the mixing thoroly with a good mixing machine.

Do the treating out-of-doors where there is some air movement, or do it in a drafty place under a roof. *Do not inhale this dust, for it is poisonous.*

Formaldehyde Spray Treatment

(For Oat Smuts)

To treat oats for smut by the formaldehyde spray method a quart-size spray gun (Fig. 17) and ordinary commercial formaldehyde are needed. Both can be purchased cheaply at most drug stores.

If the oats are to be sown the same day or the next day, mix 1 pint of formaldehyde with 1 pint of water. This quart of half-strength solution is sufficient for 50 bushels of oats. One man scoops the oats from one pile to another while another man shoots 3 or 4 full strokes on each shovelful as it is picked up. The number of shots depends on the sprayer as well as the size of the shovel. After this has been done, turn the pile at least once more by shoveling it into another pile or into sacks or a wagon box. If the seed is not sacked, cover it with blankets or canvas for 5 hours or overnight before seeding.

If, after this treatment, the oats should have to be stored several days or a week before being planted, no great harm will be done; but the seed will suffer least damage if sown as soon as possible after the treatment is completed. Spreading the grain out thin and airing it will help to prevent damage in storage.

If to be stored 2 to 5 days before sowing, use less formaldehyde. Mix 1 part formaldehyde with 2 parts water and apply 1 quart of the mixture to 50 bushels of oats as directed above.

If to be stored longer than 5 days, mix 1 part formaldehyde with 3 parts water and apply 1 quart of the mixture to 50 bushels of oats. Shovel from one pile to another two or three times, then put into sacks

FIG. 17.—TREATING OATS WITH FORMALDEHYDE BY THE SPRAY METHOD

The spray method is one of the most effective methods of applying formaldehyde to oats. The work should be done in a ventilated place, otherwise the fumes become obnoxious.

or cover with canvas. These reduced dosages, recommended when oats are to be stored before seeding, are sufficient for smut control if the mixing is done properly. If more formaldehyde is used, there is danger of reducing the yield of the crop.

The approximate cost of the formaldehyde is ½ to ⅔ cent a bushel. The formaldehyde should be kept tightly corked.

Formaldehyde-treated oats may be fed to animals if the oats are first thoroly aired.

Formaldehyde Sprinkle Treatment

(For Oat Smuts)

The formaldehyde sprinkle method, as developed in Illinois,[9*] calls for 1 pint of formaldehyde to 80 bushels of oats. This treatment controls the smut well if the solution is thoroly mixed with the grain and the pile is tightly covered for about three hours. The more usual recommendation is to use 1 pint of formaldehyde to 50 bushels of oats. In the hands of the average user, this greater concentration is surer to control smut but it is also more apt to cause injury to the seed. It is best to apply the treatment at a temperature of 60° F. or warmer.

Mix 1 pint of formaldehyde with 10 gallons of water for each 80 bushels of seed to be treated. Make up immediately before use, or keep tightly corked.

Sprinkle the solution over the oats with a sprinkling can, using 1 pint to each bushel, and mix thoroly. Pile the oats up and cover with blankets, canvas, or sacks which have been moistened with the same solution.

After about three hours uncover the oats. If they have been thoroly mixed they will have absorbed the moisture so well that they will be dry enough to sow at once in a broadcast seeder or drill. If the oats cannot be seeded at once, they should be spread out in a thin layer and stirred occasionally to allow the formaldehyde gas to escape.

Hot-Water Treatment

(For Loose Smuts of Wheat and Barley)

The hot-water treatment applied for the control of loose smuts of wheat and barley kills other seed infections besides the loose smuts but, as it causes some seed injury and the method is exacting, it is not recommended except for loose smuts that are not controlled by chemical treatments. An accurate thermometer is necessary.

Place the grain in loosely woven sacks, half a bushel to each sack, and tie the sacks at the top so as to leave plenty of room for expansion and for the agitation of the grain.

Soak in cold water for 4 to 5 hours.

Dip for a minute or two in water at about 120° F. to warm the grain so it will not lower the temperature of the final treating solution so much.

Plunge wheat into water at 129° F., and barley into water at 127° F., and allow to remain 10 minutes. Agitate the grain in the sacks during this time.

Spread out the grain to cool quickly and to dry.

Before the next sack is treated, restore the correct temperature by adding boiling water.

Sow the seed as soon as it is dry enough to be run thru a drill. Allow for the swollen condition of the grain and probable injury to germination. In certain tests involving 33 samples of machine-threshed grain, the average germination before treatment was 87.6 percent, after treatment it was only 52.7 percent.[81*]

Because of the tediousness of this process it is commonly used only to obtain smut-free grain for a small plot from which sound healthy seed may be taken for the general seeding the following year. One of the worst difficulties with this method is to get the heat to penetrate quickly and thoroly into the grain mass within the sacks. Suitably constructed wire baskets are better than sacks. Special revolving wire-covered drums, chain hoists, and live steam for heat control make treatment on a large scale practical.[60*]

GENERAL SUMMARY AND CONCLUSIONS

Major diseases of wheat, oats, and barley that can be wholly or partially controlled by seed treatment are described herein. These include stinking smut, loose smut, and scab of wheat; loose smuts, covered smut, stripe, scab, and blight of barley; and smuts of oats.

Early in the past decade a number of new organic mercury disinfectants became available for experimental use, which gave special promise for the control of certain seed-borne diseases without causing seed injury. Still better disinfectants of this type, which could be used in dry form for dusting the grain, became available a little later.

Experiments to determine the value of these new materials and some of the older ones were conducted over a period of twelve years. Some of the materials tested were worthless, and some others which were used in wet form are now obsolete. Two of the dry disinfectants —copper carbonate and ethyl mercury phosphate—are filling a real need at the present time.

Yield tests with treated grain were conducted by the rod-row method at the Station farm at Urbana and at a few other places in the state. Seventy cooperative tests also were made with oats and barley by farmers on a larger scale under practical farm conditions.

Wheat stinking smut was controlled and good increases in yield from infected seed were obtained with copper carbonate, ethyl mercury chlorid (Ceresan), and ethyl mercury phosphate (New Ceresan). The 18-to-20-percent copper carbonate apparently was as effective as that with a higher copper content. For the control of the seedling disease caused by *scab,* the organic mercury compounds gave best results. When treatments were made on nearly disease-free wheat seed, copper carbonate gave best increases in yield. All three of these disinfectants caused an increase in the winter survival of winter wheat plants.

The benefits derived from treating *noninfected wheat seed,* however, were not always enough to warrant the trouble and expense of treatment. In areas where wheat is not a major crop but is grown in rotation with a number of other crops, it is recommended that the seed be treated only when stinking smut or scab infection occurs. In areas where wheat is grown more extensively, the seed should be treated every year.

Oat smuts were well controlled with formaldehyde treatments applied by several methods and with Ceresan and New Ceresan. New Ceresan has resulted in better yields than formaldehyde, the increase being more than enough to pay for the difference in cost. Formaldehyde applied by the spray or sprinkle methods is the cheapest treatment and is recommended as second choice. Formaldehyde dust was found to deteriorate rapidly in storage. Unless a farmer can be very sure that the material he buys is fresh, formaldehyde dust is not recommended. While Ceresan and New Ceresan have given significant increases in yield when smut-free seed was used, it is questionable whether treatment every year should be recommended. However, smut is blown for miles and a smut-free field gradually becomes reinfected. Treatment at least every second year would therefore seem to be well worth while.

The *barley diseases* considered in these experiments were *stripe, scab,* and *three kinds of smut.* Ceresan and New Ceresan proved outstanding in controlling these diseases and increasing the yields of grain. An objectionable amount of smut may sometimes persist after seed is treated with New Ceresan, for one of the three kinds of smut that cause trouble can be controlled only by the hot-water method. The variety Wisconsin Pedigree 38 is highly resistant to stripe disease and so far has not shown much smut infection. When this variety is used, seed treatment is recommended only when the seed is infected with scab or if smut infection should become important.

Some *seedling diseases,* as well as *latent smut infection,* were doubtless controlled by the better seed disinfectants. At least certain treatments applied to smut-infected wheat and oat seed caused much larger increases in yield than could be accounted for by the substitution of sound heads for smutty heads.

The *machine method* of applying formaldehyde dust or New Ceresan to oats was much more effective than the shovel method both in smut control and in yield of grain.

No damage resulted from *storing seed* treated with copper carbonate, for a year before it was sowed. On the other hand, when seed treated with formaldehyde dust, Ceresan, and New Ceresan respectively was stored for a week, some depression in yields resulted, and when the treated seed was stored for a longer period still greater damage resulted. Since a smaller dosage of formaldehyde or New Ceresan than customary has been shown to be satisfactory for smut control when the treated oats are stored for some time after treatment, it is believed that if the approximate period of storage is known, a dosage can be determined that will give as satisfactory results as the fresh treatment.

All comments made concerning the commercial disinfectants mentioned herein under their trade names must be understood as applying strictly to the chemical compounds sold under those names at the time of these experiments.

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