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COVER ILLUSTRATION

Shows value of treating seed to control pre-emergence damping-off. In the flat at the right, where untreated cucumber seeds were planted, damping-off killed all but 9 of the seedlings before they reached the surface of the ground. The same number of seeds, treated with copper oxid, were planted at the left, and nearly all produced healthy, vigorous seedlings.

The complete report of the study on which this circular is based—Bulletin 439, "Control of Damping-Off: An Evaluation of Seed and Soil Treatments"—can be obtained on request.

Urbana, Illinois
November, 1937

Printed in furtherance of the Agricultural Extension Act approved by Congress May 8, 1914.
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Damping-Off Control in Illinois

Recommendations for Seed and Soil Treatment

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Though recognized as a disease of vegetables for more than a century, it is doubtful if even today many vegetable growers are aware of the true nature of damping-off or of its wide prevalence.

In all vegetable-producing areas of Illinois, according to special surveys, the fungi that cause the disease, principally Pythium and Rhizoctonia species, are present in the soil. And whether the disease is serious or not in any one season or locality depends almost entirely upon the temperature and the amount of moisture in the air and in the soil from the time the seeds are sown until the seedlings are well hardened. When the temperature is moderate (60° to 80° F.), the soil moisture medium to high, and the humidity high, the disease is likely to be most severe.

When conditions are favorable for the development of the disease, damping-off is often responsible for as much as 90-percent kill of seedlings. In especially susceptible varieties seedling losses of 25 to 75 percent occur yearly. In flats and cold frames damping-off usually gets started at a few infection points, from which it spreads, causing large spots or areas in which nearly all the seedlings are killed. Occasionally damping-off spreads in this manner in the field also, though usually in the field the infection points are more numerous but the spread to adjacent plants is more limited.

GREATEST LOSSES OCCUR BEFORE EMERGENCE

Pre-emergence phase. The main reason that many growers are not aware of the true prevalence of damping-off is that the most important phase of the disease, the pre-emergence phase, is inconspicuous and therefore likely not to be recognized. The young seedlings are killed before they reach the surface of the ground and sometimes even before the sprout emerges from the seed. A grower usually attributes the failure of the seed to poor germination or to low vitality when, as a matter of fact, germination tests usually bear out the seedsman's claims of quality, and it becomes evident that disease existed where the poor stands were obtained.
Post-emergence phase. Practically everyone who has grown plants from seed is familiar with the post-emergence phase of damping-off. The infected seedlings topple over any time after they have emerged from the ground and until the stems have "hardened" sufficiently to resist invasion. Infection usually occurs at or below the ground level, and the infected tissues appear soft and water-soaked. As the disease advances, the stems become constricted and the plants collapse. Seedlings that were apparently healthy one day may have collapsed by the next morning. Usually the cotyledons and leaves wilt slightly before the seedlings are prostrated, tho frequently they stay green and turgid until collapse occurs.

Other diseases caused by damping-off fungi. There are other recognized diseases caused by various damping-off fungi. Sometimes these occur entirely separate from damping-off; sometimes they are additional phases of the general damping-off problem. For example, if crucifer seedlings are attacked when still succulent, the young plants

Typical post-emergence damping-off

The center plant is healthy, the other two diseased. Tho better known to most growers, this phase of the disease is less common than the pre-emergence phase.
soon collapse and die. If, on the other hand, infection occurs after the seedlings have begun to “harden,” the infected plants do not topple over—in fact, they are seldom actually killed, but instead they become stunted and are of little commercial value. The invaded regions of the stem become constricted, dry, and hard. In humid weather this “wire-stem” condition may develop further into diseases recognized as stem rot and bottom rot. In many tho by no means in all cases these diseases are traceable to seedbed infections.

These interrelations between damping-off and other diseases serve to emphasize further the scope and complexity of the damping-off problem as well as the importance of producing healthy seedlings.

**CONTROL MEASURES NEEDED**

To offset poor stands growers usually plant much more seed than would be required for a normal crop were the seedlings to remain healthy. This means added expense for seed; and if a better stand is obtained than was expected, the plants must be thinned. If the disease is more severe than was anticipated, the method is of little value.

Cuprocide and Metrox gave equally satisfactory control

The results of planting untreated seed may be seen in the two checks. The lower check was a flat of river sand, from which only one seedling of the 250 seeds planted came up. Some growers have erroneously believed that damping-off is never severe in sandy soil.
A better way to reduce the losses from damping-off is to treat the seed or the seedbed with appropriate materials, tho seedbed treatment is practical only in the greenhouse or cold frame.

Unfortunately not all the materials and methods of treatment that have been offered for the control of damping-off have been both efficient and practical. Some injure the plants; others fail to control the disease. Since the disease itself is highly complex, being caused by several different species of fungi each of which may act differently on different plants and under different conditions of moisture, temperature, aeration, or cultural practices, it is not strange that difficulty has been experienced in finding effective treatments.

In order to determine which of the many materials and methods of controlling the disease are commercially the most satisfactory and adaptable for Illinois growers, the entire problem of damping-off and its control was subjected to extensive study at the Illinois Agricultural Experiment Station from 1932 to 1935. It is from the tests and observations made in that study that most of the recommendations in this circular have been formulated.

**CULTURAL MEASURES ARE PART OF CONTROL**

The control of damping-off in commercial plantings calls for several important measures, among which are certain cultural practices. One of the principal cultural measures that will help to protect plants against this disease is to avoid rotations in which crops that are especially susceptible follow each other. Such crops as beets, spinach, cucumbers, and peas, which are very susceptible to damping-off, should not follow each other but should be interplanted with such crops as corn, onions, radishes, turnips, carrots, or beans, which are not very susceptible.

When seedlings are grown in greenhouses, considerable protection against damping-off can be obtained by seeing that both house and soil are well aerated and the humidity kept low. This is especially important if the temperature rises above 70° F. The seed and seedlings should be watered as little as is compatible with good growth until after the seedlings have hardened off. At no time should heavy watering be practiced. The temperature of the house should of course be maintained at a level most satisfactory for the particular crop being grown.

These general cultural practices, however, will not alone solve all phases of the damping-off problem. When seedlings are grown out-of-doors the grower has no control over the most important factors in the
occurrence and severity of damping-off,—namely, temperature, soil moisture, and humidity. It is usually advisable, therefore, both in the greenhouse and out-of-doors, to supplement the cultural practices with either seed or soil treatments. Soil sterilization is of course not a practical treatment for use out-of-doors.

Thus it is clear that the seeds of all vegetables generally susceptible to damping-off should be chemically treated (unless the soil is sterilized—see page 10) if the best protection is to be assured, and they should be treated with the chemicals specifically adapted to them.

SEED TREATMENTS GIVE BEST PROTECTION

Treatment of the seed of crops susceptible to damping-off should be regarded as an inexpensive type of crop insurance. The cost is extremely low compared with the benefits—increased yields, savings of time, labor, and seed by avoiding the replanting that is often necessary when untreated seed is used. In some seasons, when the weather does not favor the development of the disease, the seed treat-

Effect of treating cabbage seed with Semesan

Of 250 seeds treated with Semesan and planted in unsterilized soil, 213 emerged and 4 were later attacked by post-emergence damping-off. Only 74 of the 250 untreated seeds planted in the unsterilized soil emerged, and of these 8 later damped off. Practically identical results were obtained with Vasco 4.
ments may prove to have been not so much needed as in others; but
often the treatment of the seed with the proper chemicals is the means
of saving entire plantings of crops susceptible to damping-off.

Compared with soil treatment, seed treatments are less expensive
and less troublesome to apply. They are fully as effective as soil treat­
ments under nearly all conditions, and furthermore they are adapted
to outdoor as well as to greenhouse and cold-frame culture. If, how­
ever, soil treatments are used for the control of other diseases and
insects, as they often are in greenhouses and cold frames, it is neither
necessary nor advisable to treat the seed for the control of damping-off.

Treating the seed of some varieties of peas (Surprise and Wiscon­
sin Early Sweet) not only helps to control damping-off, but brings
about a more vigorous growth of the plant by preventing the prematur­
eture rotting of the cotyledons and reducing stem infections. Treat­
ments to increase the stands should not be made, however, if the seed
has been inoculated with nitrogen-fixing bacteria. The application of
either Semesan or cuprous oxid to inoculated seed so reduces the
nodulation as to render the inoculation of limited value to the crop.1

The seeds of some vegetables, such as peas, spinach, and crucifers,
have a tendency to clog drills when treated with chemicals. The clog­
gging often results in cracking the seed and in irregular sowing. The
clogging can be largely prevented by adding small amounts of special
flake graphite (No. 0607) at the time of treatment.

GOOD SEED COVERAGE ESSENTIAL

The effectiveness of the various chemicals that have been used for
seed treatments for the control of damping-off depends to a large
extent upon the type of coverage obtained on the seeds. Of those
tested at the Illinois Station, Semesan, Metrox, and Cuprocide stuck
uniformly and well on practically all seeds tested. Vasco 4 gave the
best coverage of all the zinc oxids tested, altho there was not a great
deal of difference between it and Leafox or AAZ Special on the crops
which responded favorably to treatment with zinc. The other mate­
rials tested gave rather spotty, uneven coverage on most seed.

Obviously materials that do not cover the seed uniformly will not
give satisfactory control. Moreover, materials must be ruled out that
cause more injury by stunting and leaf burning than is offset by the
protection they give against damping-off. These limitations have been
given full consideration in the recommendations that follow.

Seed on Nodulation by Rhizobium leguminosarum.”
SEED TREATMENTS FOR DAMPING-OFF

All the following treatments gave commercially satisfactory control, tho some were more effective than others. The order in which the treatments are listed indicates the order of their effectiveness in the Illinois tests.

**Lettuce, endive, beet, Swiss chard, carrots, muskmelon, watermelon, cucumber, tomato, pepper, eggplant**

1. **Cuprous oxid** (Cuprocide or Metrox). Follow instructions of manufacturers.
2. **Copper sulfate soak**. Dissolve 11/2 ounces of copper sulfate in 1 gallon of water; soak seed at least 1 hour in twice their volume of liquid.
3. **Semesan** is a very good treatment if crops are grown under glass and are watered lightly.

**Squash**

1. **Copper sulfate soak**. See No. 2 above for lettuce.
2. **Cuprous oxid** (Cuprocide or Metrox). Follow instructions of manufacturers.

**Cabbage, kale, kohlrabi**

1. **Zinc oxid** especially prepared for seed treatments, such as Vasco 4, Leafox, or AAZ Special. Use an amount equal to 2 to 21/2 percent of weight of seed.
2. **Semesan** is even better than the foregoing treatment, if the crops are grown under glass and watered lightly.

**Radish, turnip**

Treatments are of doubtful value, but if applied, use those recommended for cabbage and other crucifers.

**Pea (Surprise and Wisconsin Early Sweet)**

**Cuprous oxid** (Cuprocide or Metrox). Follow instructions of manufacturers.

*(Peas that have been treated with nodule-producing bacteria should not be treated with chemicals—see p. 8.)*

**Spinach**

1. **Cuprous oxid** (Cuprocide or Metrox). Follow instructions of manufacturers.
2. **Zinc oxid**. See No. 1 above for cabbage.
3. **Copper sulfate soak**. See No. 2 above for lettuce.
4. **Semesan** is a very good treatment if the crop is grown under glass and is watered lightly.

**Bean, leek, onion, parsnip**

No treatments recommended.

Several vegetable crops of only minor importance in Illinois have not been included in the above list. Such crops may, as a rule, be treated similarly to the botanically related crops which are listed.
SOIL TREATMENT NOT GENERALLY RECOMMENDED

In greenhouses and cold frames it is sometimes necessary to sterilize the soil in order to control damping-off and other diseases adequately. Of a number of soil-treatment methods tried at the Illinois Station, steaming the soil or treating it with liquid or dust formaldehyde has given the most satisfactory results. But if soil-sterilization methods are used to control damping-off, it is imperative that conditions of temperature, soil moisture, and humidity that are favorable to the disease be changed, and that extra precautions be taken to prevent recontamination with the damping-off fungi. When recontaminations occur, the disease is often more serious than it would have been had the seed been planted in unsterilized soil. As a matter of fact, if damping-off is the only control problem involved, it is doubtful, except in unusual circumstances, whether the output of time and expense necessary for effective soil treatment is justified.

Details of soil-treatment methods are given in Illinois Circular 454, "Disease and Insect Pests of Cabbage and Related Plants."

SPRAYING FOR POST-EMERGENCE DAMPING-OFF

After post-emergence damping-off has made its appearance, and if humidity is high and temperature 60° F. or above, one of the following mixtures should be applied at the rate of 2 gallons per square yard, or about 1/2 gallon per flat (15 by 20 inches). Two or three applications, made with a sprinkling can at three- or four-day intervals, will be sufficient. Unless post-emergence damping-off does appear in a planting, there is nothing to be gained by spraying for its control.

Bordeaux mixture
3 ounces copper sulfate and 1 1/2 ounces hydrated lime in 5 gallons of water. (Do not use within five days previous to transplanting.)

Cuprous oxid
1 ounce in 3 gallons of water.

Cheshunt solution
Powdered copper sulfate 2 parts, mixed thoroughly with 11 parts fresh, finely ground ammonium carbonate. Set mixture aside for 24 hours in a tightly stoppered bottle. Use 1 ounce of mixture in 2 gallons of water.

Semesan drench
1 ounce in 3 gallons of water.

Copper carbonate
1 ounce in 3 gallons of water.
Of the above treatments, the bordeaux mixture has given the best control in the Illinois tests. All have caused some injury to the plants, tho the injury has been of little significance compared with the losses that result when treatment is needed but is not applied. Further investigation will be needed before a perfectly satisfactory treatment for the control of post-emergence damping-off can be formulated.

OTHER SEED-BORNE DISEASES

Some diseases of vegetable crops, such as black rot and blackleg of crucifers and bacterial spot of tomatoes, are frequently spread by the planting of infected seed. To reduce the contamination of clean ground that otherwise results, the seed of susceptible crops should be treated with bichlorid of mercury if any infection is suspected or if the source of the seed is unknown. When this treatment is used, it should be applied ahead of the damping-off treatment.

For cabbage, kale, kohlrabi, cauliflower
Use 1 part bichlorid of mercury in 1,000 parts of water (or 1 tablet in 1 pint of water, or 1 ounce in 7½ gallons of water). Leave seed in solution for 30 minutes.

For cucumber and watermelon
Use bichlorid of mercury solution of the same strength as for cabbage. Leave seed in solution for 10 minutes.

For tomatoes and peppers
Use 1 part bichlorid of mercury in 3,000 parts of water. Leave seed in solution for 5 minutes.

After the seed has been in the solution for the required length of time, rinse and thoroly dry it before treating it with other chemicals for the control of damping-off.

Sources of Treatment Materials. The trade materials used in these experiments were manufactured and furnished by the following companies:

Cuproide (cuprous oxid) and AAZ Special (zinc oxid). Rohm and Haas Chemical Co., 222 W. Washington Square, Philadelphia, Pennsylvania.
Semesan (organic mercury 30 percent). Bayer-Semesan Co., 105 Hudson Street, New York City.
PRECAUTIONS

1. All chemical treatments used in Illinois on the crops listed herein should be used *exactly* as recommended by the manu­facturers.

2. Use treatments only for those crops for which they are *specifically* recommended.

3. No chemical treatment can be depended upon that does not *cover the seed* uniformly and well at the recommended strengths.

4. Semesan, altho an excellent treatment for damping-off, will not give adequate protection to seedlings if heavy rains follow soon after the plantings are made.

5. Never use copper treatments on the seed of crucifers, for such treatments are almost certain to cause injury.

6. Cuprous oxids which contain more than 5 percent inert ingredients are of doubtful value as seed treatments.

7. Cuprous oxids should not be used in soil more acid than pH 5. If such condition exists, the soil should be limed to lower the acidity.

8. Keep chemicals in air-tight containers and apply to seed as near planting time as possible.

9. If soil-sterilization methods are used, extra precaution must be taken to prevent recontamination of the soil.

10. For practical control of damping-off *under glass*, seed treatments must be supplemented by proper cultural practices. Watering should be held at a minimum after the seed are planted. Good aeration and low humidity should be provided. The temperature should be maintained at a level most favorable to the crop which is being produced.

ALL CHEMICALS recommended for treatment for the control of damping-off are POISON. BICHLORID OF MERCURY IS A DEADLY POISON. Keep all these materials completely away from children and animals.