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Seminar Paper

THE DAMPING-OFF OF CONIFEROUS SEEDLINGS

Submitted by:

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PREFACE

It has been the writer's aim to review the literature on damping-off of coniferous seedlings and to give in a non-techinical way the importance of the disease; the damage done; what the disease is and the different types in which the disease makes an appearance; the enviromental factors effecting the damage done by the disease; and finally, the means of control, both cultural and by soil sterilization.

This paper is not, nor any part of it, presented as original work. The writer has taken freely from the list of references at the end of the paper and, where the results of an experiment is given or the reference is quoted, authority is shown by name and number of the ref- as given for the publication in the reference list.

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DAMPING-OFF OF CONIFEROUS SEEDLINGS

With the present widespread interest in reforestation and in methods of forest reproduction, there has been an increase in the number, size, and exent of forest nurseries. In 1927 it required over 10,000,000 seedlings for the reforestation operations on the National Forests alone. Besides the national reforestation program, many private forest land holders have become interested in forest nursery operation and are growing seedlings for forest planting. Many states are operationg forest nurseries on a 'cost only' basis to supply farmers with seedlings to plant wind-breaks and farm woodlots. Also some states own forest lands which they are planting with nursery stock to form State Forests. With these many interests combined, the number of forest tree seedlings grown in nurseries annually is great.

With this great number of seedlings to be grown annually in a relatively small area under intensive cultivation, the importance of soil organisms in relation to plant growth has gained full recognition from the nureseryman. How to treat the soil in such a way as to destroy the harmful soil organisms without injuring the productiveness of the soil is one of the great problems of the plant propagator. The subject is complicated by the fact that, in addition to the harmful organisms, the soil contains organisms which are desirable or even essential to the productiveness of the

soil. All soils harbor fungi, insects, bacteria, and other forms of living organisms which may or may not be injurious to plant life. Some of these pest organisms are dependent on a particular plant as a host, in which circumstance crop rotation, in most cases, is a remedy. However, some of the organisms are parasitic upon a wide range of hosts, besides being capable of existing saprophytically upon vegetative matter in the soil. Such is the activity of the common damping-off fungi.

Damping-off is a term commonly used to describe the disease causing the death of very young seedlings and succulent plants due to various parasitic fungi. While for convenience, the trouble is spoken here as a single disease, it is really a series of diseases caused by a large number of distinct types of fungi. So far as investigative work has been carried on, all control methods effect the causal fungi the same. Also, the nurseryman is not always in a position to identify the causal fungi. So that in order to simplify the discussion, I have not distinguished between the various causal fungi.

Damping-off has been a handicap to nearly all nurseryman who raise conifers from seed. L.R.Jones (16) states, "This malady is the most serious hinderance to success in rearing seedlings of pine or other conifers in the nursery". In most nurseries a large number of seedlings are lost every year. The loss is ordinarily considerably heavier than the nurseryman realizes. Young seedlings decay and disappear so

soon after infection that the number of dead seedlings visible at any one time is but a small part of the total loss. Also many seedlings are killed after the seed sprouts and before the seedlings appear above ground. This loss previously attributed to poor germination is in reality due to the work of the damping-off fungi underground. Mrs.Rathbun-Gravatt (23) found that poor germination of pine, as a result of the work of the damping-off parasites, is mainly due to the destruction of radicles after they have emerged from the seed coat but before the seedlings are large enough to break through the soil. It was also found that the same parasites may cause the decay of unruptured seeds although the loss from this is less important.

The economic importance of the disease in conifers is due in part to the heavy average losses experienced at many nurseries and in part to the irregular character of the losses. In one season the losses may be negligible, while the next season the beds of certain species may be practically wiped out. This uncertainty, where orders are placed in advance for the nursery stock, makes it necessary that a very large margin be allowed for loss in the nursery. Even without this element of uncertainty, the losses experienced are expensive due to the high cost of seed and the expense of cultivation without a crop. The cost of seed (10) ranges from a minimum price of 50 cents per pound for western yellow pine (Pinus poderosa) collected by the Forest Service to $5 and $10 per pound for Norway pine (Pinus resinosa)

quoted by commercial seedmen.

However, the loss from damping-off can not be figured merely on a basis of the number of the seedlings destroyed. The most serious aspect of the disease is the extent to which planting is discouraged by it. When interest on the cost of a forest plantation is compounded for the great length of time which must elapse between forest planting and cutting, a very slight initial increase in the cost of planting stock becomes a heavy charge against the ultimate value. Both the average loss and the irregularity in production due to damping-off are reflected in the prices of coniferous planting stock, so that the disease must be controlled to give the maximum opportunity for profitable reforestation.

There is considerable literature on the damping-off disease, both in connection with forest tree seedlings and with truck crops. The early literature, because of the extensive early development of plant pathology and forest planting in Germany, is written in German. These early articles are based on work of the reconnaissance type. Therefore, although the disease was noticed in Europe as early as the eighteenth century, most of the European data available is observational with a relatively small amount of actual investigational work as to the causes of the disease reported.

With the awakening of interest in reforestation in the United States at the beginning of this century and the first effots to grow coniferous seedlings in quantity for

forestry purposes, attempts were made to determine the cause of the disease in this country and to develop direct-control methods. Thus modern investigations have centered largely about problems of etiology and control.

As a result of the recent investigational work as to the cause of damping-off, nurserymen and pathologists have determined that there are a great number of causal fungi connected with the disease. Nine different geni of the class of Thallus plants, Phycomycetes, have been reported as attacking young seedlings (11,12,14,18,29). These are Pythium, Coticium, Fusarium, Phytophthora, Rhizoctonia, Trichoderma, Pestalozzia, Botrytis, and Alternavia.

Although damping-off may be caused by a large number of distinct types of fungi, for convenience, the trouble is spoken of here as a single disease. The great number of causal fungi which may cause infection is illustrated by the indefinite number of species of Fusarium that are capable of causing the disease. Greenhouse tests (26) show that all of 44 different strains and species of Fusarium are capable of attacking young pine seedlings.

Hartley (12) in summarizing his own work and the work of others on damping-off states,"It is belived that of the various organisms which have been connected with damping-off in coniferous seed beds, Pythium debaryanum, Corticium vagum, and Fysarium spp. include all of importance. The others either because of low indicated virulence or infrequent occurrence, and in most cases both, do not seem to merit ex-

tensive consideration."

The old conception of damping-off seems to have been the death of seedlings as the result of the attack of a parasitic fungus at the soil surface, causing a local constriction of the stem at that point, followed by the fall and wilting of the seedling. Seedlings may be attacked in this manner, but they are also very frequently attacked in other ways. Hartley (11) distinguishes the following different types of damping-off:

(1) Normal damping-off: The still succulent seedlings are invaded by the parasites at any point on the root or lower part of the stem, ordinarily a short distance below the ground surface. The fungus spreads rapidly and the seedlings fall over. The fall of the seedlings is not usually due to stoppage of water supply and the consequent wilting, but occurs when the tissues of the hypocotyl just above the soil surface becomes involved in decay and while the rest of the stem is still green and turgid.

(2) Germination loss: In this type of damping-off the radicles are killed soon after emerging from the seed coats and before the seedlings appear above the ground. There is no essential difference between this type and the normal type except that this type occurs earlier in the life of the seedling and is not ordinarily detected. A poor initial stand of seedlings due to this type of damping-off is commonly attributed by the nurseryman, not to damping-off, but to poor germinative capacity of the seed.

(3) Late damping-off: The term "late damping-off" is ordinarily used for the damping-off as a result of root infection of seedlings several weeks old whose stems have developed strong supporting tissues. Damping-off is usually restricted to include only the cases of death and early decay of seedlings less than two months old, resulting primarily from fungus invasion. This type of damping-off differs from the normal type only by the age of the seedlings concerned. The symptoms of late damping-off show that the seedlings remain erect, dry up and turn brown, and in some cases shed their leaves before the stem falls over.

The death of seedlings due to root killing by damping-off parasites may continue throughout the season and probably even into the second year. Seedlings attacked after they have reached the age of two months will usually recover if transplanted in sterile soil. Death from paraistic attack after the seedlings are two months old is commonly classed as rootrot.

(4) Top damping-off: A type of damping-off involving parts of the cotyledons or the upper stem, while the lower stem and root remain sound until after death of the parts above. It is fairly common in moist atmospheric conditions, as in greenhouses, although seldom as prevalent in open seed beds as the normal type of damping-off.

A special case of damping-off of tops is found in cases in which the tips of all the cotyledons are simultaneously killed. Infection occurs in such cases while the tips

are still inclosed in the persistent seed coat. This type of damping-off is not always fatal although it commonly kills the affected seedlings.

Blacktop is a special type of damping-off of the tops distinguished from the other types by the dark color of the tissues decayed.

(5) Decay of dormant seed: It is undoubtedly true that dormant seed are sometimes killed by micro-organisms. Under seed-bed conditions, some of the damping-off fungi probably kill some coniferous seed before the coats are split. It is also probable that considerable quantities of seed are destroyed by ordinary saprophytic molds.

Of the types of damping-off described in the foregoing paragraphs, the first two, normal damping-off and germination loss, are ordinarily the most important. However, there are so many different factors effecting the amount of damage from parasites, that under given conditions any one of the various types of damping-off may cause the most damage in the seed beds.

Environmental factors and nursery methods that favor damping-off are many. The more important will be reviewed briefly:

(1) Density of sowing: Is is found that conifers suffer most from damping-off when sown too closely. A bed containing a stand of seedlings which is too dense will not only lose more seedlings than a less crowded bed, but it will lose a higher persentage of its seedlings. This is due

to the ease with which the parasites spread from one seedling to another in dense stands. Tests at two different nurseries with jack pine showed that the damping-off loss in seedlings sown broadcast was only four-fifths as great as in adjacent plats sown in drills. Thus the tendency among nurserymen is to sow the seeds braadcast in the seed bed and not to strive for such a dense stand.

(2) Moisture and temperature factors: Experiments carried on by Hartley (12) showed that the rate of damping-off varies directly as the temperature. High temperatures favor damping-off. Hartley found that temperature is even more important then moisture. Excessive moisture may hinder the growth of soil fungi by decreasing its air supply. It is also true that a wet soil is a cold soil. This explains the drop in damping-off following an increase in soil moisture from rain.

Nursery practice favors having the beds raised from 2 to 3 inches above the paths to secure drainage, and at some nurseries the surface of the bed is arched to increase run-off. At nurseries with heavy soils and excessive rains this is probably good practice, but on very sandy soils in dry climates there is a danger of having the seed beds too dry so that large numbers of seedlings are killed by drought or from "white spot" injury.

To secure aeration the eastern nurseries leave their beds entirely open to the wind, or, if side walls are needed to exclude seed-eating animals, they use wire netting only.

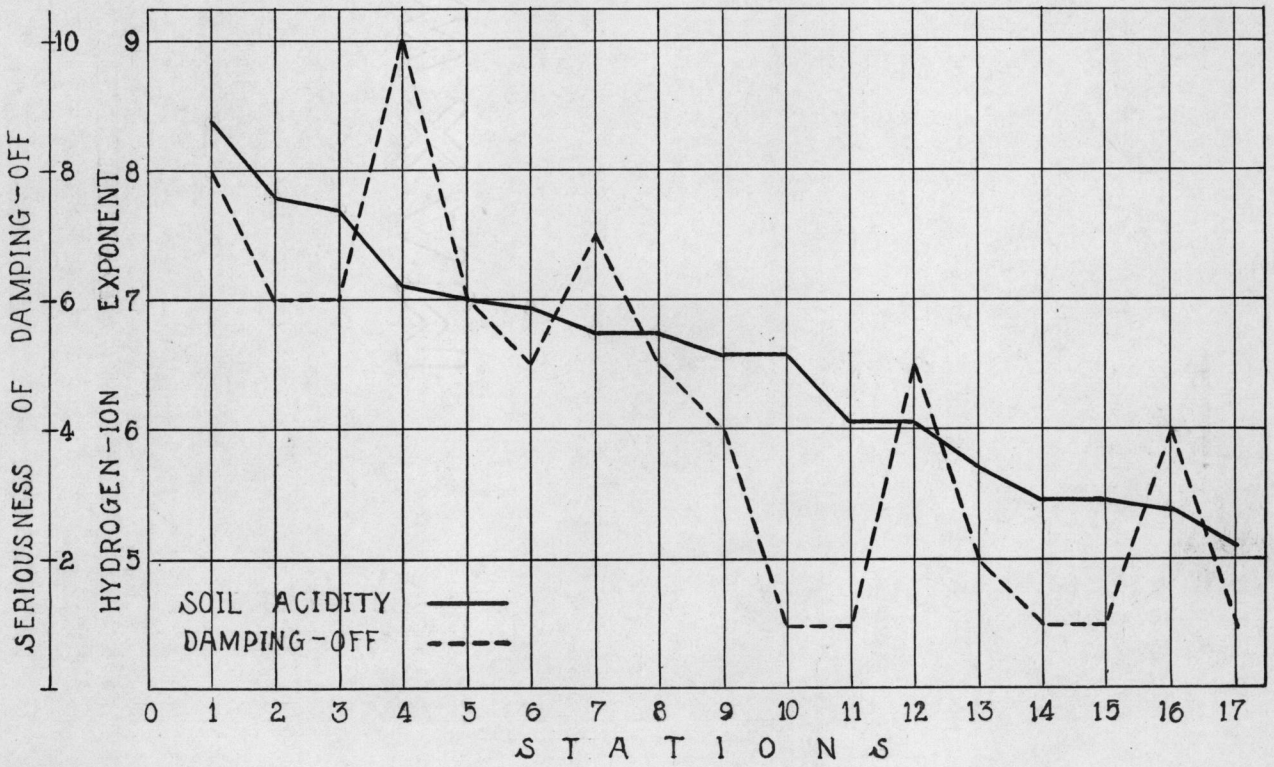
Yet, it has been found at the mid-western nurseries that tight board sides gave better results. Here there is as much danger of keeping the beds too dry as too wet.

(3) Chemical factors: The chemical factor for which there is the most evidence of a relation to damping-off of conifers is soil acidity. The fact that sulphuric-acid soil treatment has been found to be an effective means of controlling the disease, that its value is lost if lime is later added to the soil, that soil treatment with sulphur has seemed to decrease the disease, and that lime alone and wood ashes have increased the damping-off when applied, all suggest that soil acidity is not favorable to the disease. Additional evidence of this appear in figure I. Alkaline soils are thus beleived to favor damping-off. If this is true, it may explain the fact the some of the heaviest losses from damping-off occur in Nebraska and Kansas rather than in the more humid Eastern States.

It appears that plants on a soil rich in nitrogen are especially susceptible to disease. Experience indicates increased disease as a result of the addition of inorganic nitrogenous substances. Sodium nitrate and sodium nitrite have both given indication of increased damping-off. Organic nitrogenous substances also favor the work of the fungi. E.B.Fred in studying the relation of green manures to seedling growth, found that green manures recently plowed under favored the growth of damping-off fungi. The addition of dried blood at two nurseries in Kansas caused a very much heavier loss.

Figure I.

From Hartley - U.S.D.A.Bul.No.934



RELATION BETWEEN

DAMPING-OFF & SOIL ACIDITY

NOTE: The acidity of the soil is reported as Ph7, indicating approximate neutrality, while Ph6 indicates ten and Ph5 one-hundred times as great a hydrogen-ion concentration as Ph7; therefore the lower the hydrogen-ion exponent line, the greater the acidity. The seriousness of damping-off is on an arbitrary scale in which the nurseries with negligible loss are rated as 1 and the nursery which suffered the most is rated as 10.

(4) Soil types: Certain types of soil are particularly favorable for the damping-off fungi. Such are the soils containing a high percentage of undecomposed vegetable matter. As the fungus lives on the organic matter of the soil in the absence of the host plant, it is reasonalbe to suppose that the fungus content of soils rich in organic matter is greater than that in soils poor in organic matter.

The growth of the fungus in acid vs. alkaline soils and dry vs. moist soils has already been discussed. Thus sandy soil is usually the safest for seed-bed sites from the standpoint of damping-off control. This is because such soils are better drained and because they contain less organic matter for the fungi to exist on.

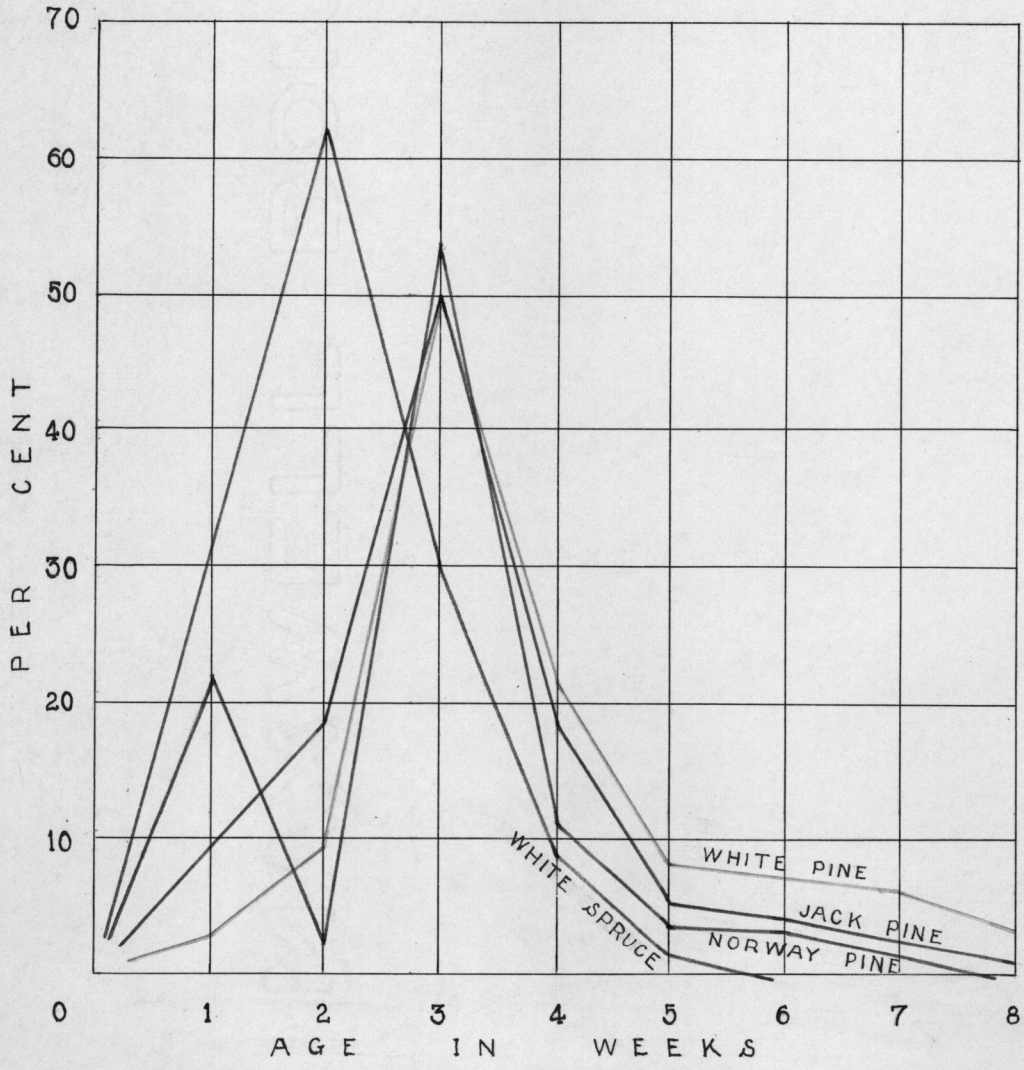
(5) Fertilizers: The relation between the nitrogen content of the soil and damping-off damage has been mentioned. Undecomposed organic, nitrogenous fertilizers as well as inorganic nitrogenous fertilizers have proven to favor the growth of the disease.

Fertilizers such as lime or wood ashes which have a basic or alkaline reaction favor the growth of the fungi while acid fertilizers such as ammonium sulphate decrease the damage from damping-off.

(6) Biological factors: The relation between the damping-off parasites and other micro-organisms in the soil is a matter of some interest. Hartley (7) found that competition of other soil micro-organisms is the greatest factor limiting the damage from the fungi in untreated beds. Exper-

Figure II.

From Hansen - U.of Minn.Exp.Sta.Tech.Bul.15



AVERAGE RATE DAMPING-OFF

NO TREATMENT TO SOIL

iments in autoclaved soil by Hartley (12) and in nursery seed-beds in Kansas (12) as well as observations of the growth of the fungus in cultures with other parasites prove this statement.

(7) Time of sowing: At some nurseries it makes little difference when the seed is sown. In one season beds sown in early spring suffer least from the disease. The next season the latest soen beds may come out the best. However, at some nurseries it is found that there is a best time and a worst time for seed sowing. The Forest Service (10) has found that at two western nurseries (in Nebraska and Colorado) yellow-pine seed-beds sown in late autumn are comparatively free from damping-off. Repeated tests during two or three successive seasons are necessary to determine for any particular nursery whether or not damping-off losses are regularly less in beds sown at a particular time.

(8) Age of seedlings: There is no great loss from damping-off after the seedlings are four weeks old. This is clearly illustrated in figure II taken from Hansen (4). However, it must be borne in mind that this damage does not include germination loss but only the loss from damping-off fungi after the seedlings are above the ground.

CONTROL METHODS

During recent years a great deal has been written on the methods best calculated to prevent damage to plants from damping-off parasites. Many state and national nurseries as well as commercial nurseries have been experimenting with different control methods under varing conditions. Contrary results have often been obtained for the same method due to different enviromental factors such as soil, density of the plants, moisture, and temperature. All the methods of control so far advanced may be grouped under one of two general methods: (1) cultural means of control, by maintaining enviramental conditions which interfere with the growth of the fungi; or (2) eradication of the fungi by means of disinfectant or sterilization of the soil.

CULTURAL MEANS

Every investigator or propagator agrees that much can be accomplished in the control of damping-off by giving careful attention to soil moisture, temperature, and atmospheric humidity. These factors are relatively easily controlled in the greenhouse but in the open seed-bed in the nursery as forest tree seedlings are grown, they present a more difficult problem.

Temperature and moisture of both the seed-bed and

and the atmosphere surrounding the young seedlings may be controlled to a certain extent by regulated irrigation and by the use of shade screens constructed of lath so as to give the desired degree of shade and closed or open sides around the seed-bed. Experience in dealing with the particular soil under the varying conditions of climate are necessary for successful control.

Surface soil moisture can be controlled by raising the beds or crowning them to aid run off and by facing the beds with gravel, coarse sand, or even heated sand has been recommended. However, the seed should not be covered too deeply. Hansen (4) has pointed out that increased depth of cover over the seeds decreases germination and increases damping-off.

Although damping-off is capable of attacking plants standing singly, no method of culture is more conducive to damping-off in the seed-beds than thick sowing of seed with the resultant crowding of the plants. In experiments carried on by Johnson (16) with tobacco in flats in the greenhouse where conditions favorable to damping-off were maintained, he found that the percent of plants diseased by damping-off fungi varied from 0 percent for flats sown with 0.1 and 0.2 grams seed increasingly up to 96 percent for flats sown with 1.0 grams seed. The results of this experiment as well as similiar results obtained by Hartley (12) working with pine seedlings illustrates quite conclusively that the amount

of damping-off varies directly with the thickness of sowing. This is due to the increased humidity resulting from increased shading and lessened circulation around the base of the plants and also crowding affords easier transfer of the fungus from one plant to another as well as making the plants more tender and succulent and therefore more susceptible to attack.

Certain types of soil are particularly favorable to the growth of the damping-off fungi. Soils which contain a high percent of undecomposed vegetable matter are such. Johnson (16) found that in sterilized and latter inoculated soils that the most rapid spread and prolific growth of the fungi was obtained in a mixture of 50 percent manure and 50 percent garden loam, and the least growth in garden loam and pure sand. Since the fungus growth lives on organic matter present in the soil in the absence of the host plant, the soils rich in organic matter would have a greater fungus content than soils low in organic matter.

It appears that alkaline soils favor the disease while acid soils tend to prevent the rapid development of the fungus. Thus basic fertilizers are not as favorable as acid fertilizers for use in coniferous nurseries where the danger from damage by damping-off is great. Experience has also indicated that nitrogenous fertilizers increase the damage from damping-off and therefore should be avoided.

The seed used also has much to do with damping-off.

Spaulding (26) has found that seeds which are light in weight and poorly filled produce weak seedlings which are longer in germinating and are more subject to disease than seedlings from heavier, better filled seeds.

All of these cultural measures have value, but all have their limitations. These measure seek to control the disease only by making the enviromental conditions such that they interfere with the growth of and spread of the fungus. They do not destroy the fungi that is already present in the soil nor do they prevent the future infection of the soil with the parasite as do the more successful of the soil disinfecting methods. Therefore, where the damage from damping-off is great, methods other than cultural must be resorted to.

SOIL STERILIZATION

The only hope of preventing a heavy loss of seedlings from damping-off in a seed bed that has been previously infected with the damping-off fungus is to destroy the organisms that are present in the soil. At present, adherence to the best known nusery practice will not avoid considerable annual losses at most nurseries or prevent epidemic years in which the beds of certain species are entire failures. The multiplicity of the parasites and the different conditions of soil and climate to be met so complicate the problem that it has been found most profitable to make a direct attack on the parasites by the use of disinfectants.

Definite and satisfactory control of the disease by soil disinfection by chemicals or heat presents many problems. A successful method must be comparatively simple of application, inexpensive, destroy all the undesirable organisms in the soil and yet leave the soil in a good condition for plant growth, and leave in the soil a residue that will prevent reinfection with the parasite for the next four or five weeks and yet not injure the seedling.

Many treatments have been advocated by different experimentors and nurserymen, many of them with contrary results. The more important of these treatments are described in the following pages with their results besed on the requirements of a satisfactory treatment.

STEAM STERILIZATION

The sterilization of the soil by the use of live steam has been rather widely advocated (3, 15, 24) for killing undesirable soil organisms. It has been used with special success in the treatment of tobacco beds for root-rot by W.W.Gilbert (U.S.D.A.Bur.Pl.Ind.Bul.158) who states that its advantages consist in killing weed seeds, altering the physical texture of the soil making it more suitable for root development, and rendering considerable plant food directly available to the seedlings.

The method of steam sterilization most widely recommended is called the "inverted-pan method". This method consists of the use of a galvanized-iron steam pan which is set over the bed to be treated in an inverted position, the edges sunk down to form a tight compartment over the bed. At the Wisconsin nursery (15) live steam is run under the pan from a boiler at a pressure of 80 to 150 pounds for a period of 30 to 60 minutes, while a higher pressure but a shorter time is used at the Kansas State nursery. With this treatment, a soil temperature of 94°C to 98°C was secured to a depth of eight inches.

The Kansas State nursery (24) reports that the cost of the treatment without the cost of the steam pan or boiler totaled $1.65 per bed for 16 beds and at a later trial $1.69 per bed for 23 seed-beds which was a reasonable estimate of weeding an untreated seed-bed throughout the first season.

Results at the Vermont Experiment Station (3) with steam sterilization of the soil indicate:

(1) That it is not as successful as some of the chemical treatments because it does not prevent the reinfection of the soil after the treatment.

(2) That steam lessens the amount of capillary moisture in the upper layers of the soil during the ensuing growing season.

(3) That it kills nearly all the organisms in the soil including weed-seeds as well as micro-organisms. Thus weeding is practically eliminated the first season; but it provides for an excellent opportunity for growth of the first fungus which is introduced into the seed-bed. Under ordinary nursery conditions it is almost impossible to prevent the introduction of the spores of the damping-off fungus after disinfection.

DISINFECTION WITH FORMALIN

Formalin has proven to be one of the most valuable of a number of chemicals as a fungicide against damping-off. (3,10,15,17,18,25,26). However, treatment of the soil with formalin at strengths of 1-100 or less as is frequently recommended does not kill the fungus according to Johnson (5) but may hold the parasite in check until the plants are sufficiently developed to withstand the attack of the fungi. Johnson found that treatment of the soil with a 1-50 solution of 40 persent formalin at the rate of two quarts per

square foot of seed-bed will kill the fungi which causes damping-off, and will effectively prevent damage under the most favorable weather conditions for fungus growth.

Rankin (18) recommends the following procedure for treating the soil with the formalin solution in the same strength as Johnson recommends. After the soil is prepared by forking or raking and the solution is applied by means of a sprinkling can, the seed-beds should be covered as securely as possible with heavy paper or other impervious material for forty-eight hours. The active substance in the fomalin solution is liberated as a gas, formaldehyde. Three or four days after the cover is removed, the soil should be loosened and allowed to stand for a day or two after which the bed may be prepared and the seed sown.

The chief objections to the formalin treatment are the cost and the time required for it to act. The treatment has been found to be somewhat more expensive than the other chemical treatments. It is also much more difficult to apply, having to be applied five or six days before the seeds are sown. There has also been a complaint that the formalin gas remaining in the soil damages the young seedling roots as well as reducing the germination percent by killing dormant seeds. Gifford (3) found that in no case did the reduction in germination exceed 14 percent. while t the loss from damping-off in adjacent check plots ranged from 25 percent to 75 percent and may reach a maximum of damage of 90 percent of the plot.

DISINFECTION WITH SULPHURIC ACID

The application of sulphuric acid to the soil at the time of sowing the seed has been used successfully (4,7,8,10,12,18,25,26,27) for several years on coniferous seedlings as they are apparently especially tolerant of acid soil. Acid is not recommended, however, for dicotyledonous plants as they are very intolerant of acid. Rankin (7) recommends as the average amount of sulphuric acid, three-sixteenth of a fluid ounce of clear commercial sulphuric acid to each square fool of soil treated. However, this should vary considerably with the natural acidity of the soil treated. The acid should be applied in solution when the seed is sown, three-sixteenth fluid ounce acid to one quart of water. Light watering should be made until aft after the seeds have germinated so as to prevent acid injury to the seedlings.

The results from the numerous nurseries would indicate that for preventing the damping-off of conifers, sulphuric acid is the best disinfecting agent on most soils, as regards convenience, economy, and effectiveness. The acid treatment when applied in the proper strength meets all the requirements of a satisfactory treatment. It is camparatively cheap, often more than paying for itself in its secondary advantages. It destroys the harmful organisms present in the soil without destroying the tilth of the soil. It leaves a residue in the soil which if properly handled is not harmful to the seedlings. It is very easily applied, being only

necessary to sprinkle the seed-bed after the seed is sown with the solution. Besides it has several secondary advantages which make it even more desirable.

Hartley (7) found that the acid treatment gave the following results: (1) 65 percent higher germination, (2) 45 percent less damping-off than in adjacent check plots, (3) the final stand was over 4½ times as great as the untreated stand, and (4) the increased size of the seedlings varied from 37 percent to 750 percent.

At nurseries where weeds are troublesome in the seed-beds, the effect of the disinfectants on the weeds is probably the most important of the secondary results of the treatment. The economic value of this weed-control feature varies with the different nurseries. At the Bessey Nurseries (10) during 1912 the total cost of the acid treatment and the weeding of treated beds was $0.0094 per square foot as compared to $0.0125 for weeding only in the untreated beds. In such cases the control of damping-off secured by the treatment will be clear gain.

It is interesting to note that in the seed-beds of the Feather River Forest Experiment Station, California, a light sulphuric-acid treatment is in regular use simply on account of its value as a weed killer, entirely irrespective of any effect on damping-off.

MISCELLANEOUS CHEMICAL SOIL TREATMENT

The corrosive qualities of sulphuric acid are in-

convenient and its effects are not as lasting as might be desired. Aluminum sulphate as an acidifying material is recommended by Hartley (13). While aluminum sulphate is irritating if inhaled, it is not corrosive. For conifers it is applied at the time of sowing at the rate of ½ ounce per square foot of seed-bed. It may be dissolved in water or put on the beds dry and then washed in by sprinkling. It has proved by test equal or superior in the control of damping-off and like sulphuric acid, it helps to control weeds.

Hartley (8) also recommends that for soils on which sulphuric acid is not an efficient disinfectant, copper sulfate and zinc chloride have indicated greater efficiency against parasites than formalin. Copper sulfate 1/4 ounce per square foot of seed-bed or zinc chloride 3/8 ounce per square foot is applied in solution.

SUMMARY

(1) By damping-off is meant the killing of very young seedlings by parasitic fungi. It is the most serious dicease of very young seedlings in coniferous nurseries.

(2) There are a large number of fungi that may cause damping-off. These fungi are capable of attacking a large variety of different plants, including all the coniferous forest seedlings, as well as living upon the dead organic matter in the soil.

(3) The fungi may cause five different types of damage: 1. normal damping-off, 2. germination loss, 3. late damping-off, 4. top damping, and 5. decay of dormant seeds.

(4) The disease is favored particularly by certain weather conditions, such as excessive moisture and high temperature, and certain soil conditions such as an alkali reaction, nitrogenous fertilizers, or a large amount of organic matter.

(5) Much can be accomplished in the control of damping-off by giving careful attention to soil maisture, temperature, and atmospheric humidity.

(6) Soil disinfection has so far proved the best method of combating damping-off. Of many methods recommended by investigators, treatment with sulphuric acid has proven to be the most widely successful. Other treatments that have been reported as being successful are with live steam, formalin, aluminum sulphate, copper sulphate, and zinc chloride.

(7) In addition to decreasing damping-off, the chemical disinfectants, when properly used, cause an increase in the apparent germination and are helphful in controlling weeds. This latter effect alone at some nurseries pays the entire expense of the treatment.

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