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SUGAR BEET DISEASES
AND THEIR CONTROL

by

Norman R. Gerhold

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Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

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INTRODUCTION

The production and processing of sugar beets (*Beta vulgaris* L.) is one of the leading agricultural industries in Colorado. During the past ten years approximately 132,000 acres of irrigated land have been devoted to the growing of sugar beets each year. This acreage produced an average of 2,000,000 tons of high-quality beets valued at $22,000,000. The crop is not only important from the standpoint of sugar production, but it is also profitable because of the high cash value of the beets, excellent value of the tops and pulp, and the encouragement of good farming practices which maintain the soil fertility level.

Certain diseases are responsible for losses in the beet sugar industry in Colorado each year. Cercospora leaf spot caused by the parasitic fungus *Cercospora beticola* Sacc. is normally of little importance in Colorado due to the dry weather conditions that prevail in the sugar-beet-growing areas. However, in those years which are favorable for the development of *Cercospora beticola*, losses can be held to a minimum by the resistant germ plasm now incorporated in many of the commercial varieties. Gaskill (15) has shown that commercial varieties now grown in Colorado are moderately resistant, even under high relative humidity conditions in the field. Variety U. S. 201 has shown almost complete resistance when grown under epiphytotic conditions.

Virus yellows, a disease that is considered one of the limiting factors of sugar beet production in Europe, has become important in the different sugar-beet-growing areas of the United States. In Colorado, yellowing of the foliage of mature sugar beets has been observed for many years. Until 1952, this condition was attributed to nitrogen deficiency. With the use of serological tests, Coons (8) demonstrated that the yellowing of foliage on mature beets, as observed in Colorado, was due to a virus which is very similar in nature to the one that occurs in Europe. Field trials were conducted by Gaskill (15) in Colorado in 1954 to determine the effect of virus yellows on yield and sugar content. Viruliferous aphids (Myzus persicae (Sulzer) were placed on each plant in a randomized plot containing three varieties of sugar beets. Results of these trials showed a decrease of 12.6 per cent in tons per acre, and 14.0 per cent in gross sucrose per acre compared with the non-infested check. In a separate trial, U. S. Inbred 52-353 (Deming), showed a high degree of resistance.

The curly top disease of sugar beets is caused by a virus that is transmitted by the beet leafhopper, Circulifer tenellus (Baker). Prior to 1934 no practical control of this disease was known. At that time the United States Department of Agriculture introduced a variety, U. S. Number 1, which was resistant to the curly top virus. Since that time other resistant varieties have been introduced, so that a large part of the total acreage on the Western Slope of Colorado, where curly top is severe, is now planted with resistant varieties. The beet leafhopper migrates to the cultivated districts of Utah, western Colorado, southern Nevada, central Arizona, and southeastern California, from semi-desert breeding areas in southern Utah, southern Nevada, and western Arizona. Due to the small populations of the leafhopper in eastern Colorado, where 95 per cent of the beets are grown, curly top is not of economic importance.

Other virus diseases, such as savoy and mosaic, occur in the State each year, but they appear to be of slight economic importance.

Sugar beets require a considerable amount of readily available phosphate and nitrogen for their best development. Soils that are deficient in available phosphate produce a physiogenic disease of sugar beets known as "black heart". A slight deficiency may not produce symptoms that can be readily recognized, but it can be observed that the beet

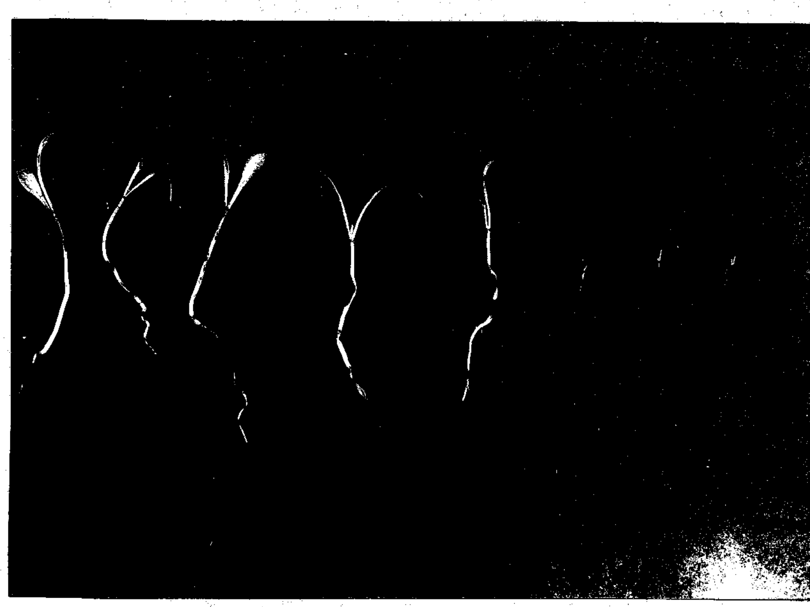


Figure 1. Typical symptom expression of damping-off of sugar beets as incited by *Rhizoctonia solani* and *Pythium ultimum*. The tissue of the hypocotyl may collapse or the entire root system may show necrosis.

roots are small and the tops remain green up to harvest. In case of a severe phosphate deficiency, leaves curl upward and the tissue between the veins of the leaves turns black. This disease can be prevented by timely applications of 150-200 pounds of treble superphosphate per acre. There are many degrees of symptom manifestations of nitrogen deficiency in sugar beet plants. A slight deficiency may cause early yellowing of the tops. Severe nitrogen deficiency produces small tops, low yield of roots, and no significant response to a phosphate fertilizer. It has been shown that a liberal application of manure, supplemented by nitrogenous fertilizer, will correct this deficiency in beets.

In summary, it can be said that fungi, viruses, and certain physiogenic conditions are responsible each year for losses in the sugar beet crop. However, at the present time, root rot is the most widespread and economically significant pathological condition in the Colorado sugar beet crop.

The average annual loss caused by all diseases of sugar beets in Colorado is very difficult to determine. It has, however, been conservatively estimated that the annual loss for seedling diseases alone has averaged 4 per cent. This estimate is especially low for the Fountain Valley, Arkansas Valley, and the irrigated areas in the northern and eastern parts of the State.

Figure 2. Advance stage of Rhizoctonia root rot showing foliage symptoms. Note the wilting and death of the leaves.

The prevalence of pre- and post-emergence damping-off is a determining factor in obtaining adequate and uniform stands of seedlings in these areas. Isolations from diseased beets, collected from these areas, yielded pure cultures of Pythium ultimum Trow, and Rhizoctonia solani Kuhn (Pellicularia filamentosa (Pat.) Rogers). In many instances only one of these organisms could be isolated from individual seedlings in a single field, while in other cases both were readily isolated.

Pythium ultimum attacks the seedling during its primary development and may cause either pre- or post-emergence damping-off. The embryo may be invaded before it has time to germinate, or the seedling may be attacked before the cotyledons emerge from the soil. Post-emergence damping-off develops very rapidly, Figure 1. In 24 hours after the first indication of wilting, the affected seedling is almost completely decayed. Infection begins in the roots or near the soil line and advances up the hypocotyl. The seedling soon shrivels so completely that it is often difficult to find any remnant of it.

Rhizoctonia solani is a fungus known to be responsible for pre- and post-emergence damping-off of seedlings, Figure 1, as well as decay and death of older sugar beets. Due to the similarity of the symptoms caused by Pythium and Rhizoctonia on sugar beet seedlings, it has been the writer's

Figure 3. Longitudinal section of a sugar beet infected with *Rhizoctonia solani*.

experience that isolations and identification of the causal agency from diseased tissues is necessary in order to diagnose the disease involved.

Mature beets infected with Rhizoctonia solani show a blackening of the petioles of the outer leaves. The affected leaves often fall to the ground when still green, and later turn brown, Figure 2. The crown of severely infected beet roots usually has many brown to dark-brown cracks. Rhizoctonia may also produce irregular brown lesions on the beet root, Figure 3. These lesions usually occur near the crown region, but sometimes occur below the soil line. In many of the sugar-beet-growing areas of Colorado, the occurrence of diseased beets incited by Rhizoctonia, varies from a trace to severe, thus resulting in reduced stands and beet yields of poor market value.

Fusarium yellows of sugar beet is caused by a soil-borne organism, Fusarium oxysporum f. betae, Snyd. and Hans. Stewart (42) was first to describe the disease in Colorado in 1931. Since that time the disease has become a problem of considerable importance in the production of sugar beets in the Arkansas Valley and in the Brush-Sterling district of Colorado. The disease usually appears about the middle of July and becomes more severe as the season advances. The disease is characterized by a yellowing of leaf tissues between the veins of the larger leaves. Very often only

Figure 4. Foliage symptoms of a sugar beet infected with Fusarium oxysporum f. betae. Note the curling and twisting of the leaves.

one-half of the leaf blade is affected while the other half remains normal. The large veins of the leaf usually remain green for a longer period than the other tissue of the leaf, but finally the whole leaf dies. The younger leaves, in the crown region, usually show a distortion in the form of rolling and twisting, Figure 4. The root of a diseased plant often fails to show any external symptom other than a decrease in size. Internally, however, longitudinal root sections exhibit a brown discoloration in the vascular system, Figure 5. Losses from this disease are due to a reduction in stand and size of roots, and to low sugar content of affected beets. Prior to this study the only practical control for this disease was crop rotation. It was shown by Morris and Afanasiev (37) that the disease was always present with continuous beets as well as in two- and three-year rotations. Sugar beets planted in four- or six-year rotations with, respectively, two or three years of alfalfa, were practically free of Fusarium Yellows.

The importance of obtaining adequate and uniform pre-thinning stands of beets has received considerable attention during the past few years because more emphasis is being placed on mechanical thinning and harvesting. Any information that contributes to the effective control of soil-borne organisms by seed treatment, soil treatment, resistant varieties, or other agronomic practices, is of significant value to the beet sugar industry.

Figure 5. Longitudinal section of a sugar beet infected with Fusarium oxysporum f. betae.

A portion of the data presented in this thesis involves (1) the testing of different isolates of _Rhizoctonia solani_ for pathogenicity; (2) the effect of different fungicides on the growth of _Pythium ultimum_ and _Rhizoctonia solani_ on artificial media; (3) improved methods of testing seed- and soil-treatment fungicides; (4) greenhouse and field observations on the response of sugar beets to seed- and soil-treatments; and (5) the response of different varieties of sugar beets to _Fusarium oxysporum_ f. _betae_.

LITERATURE REVIEW

The organism now known as *Rhizoctonia solani* Kuhn was reported for the first time in 1728 by Du Hamel who observed it causing a disease on saffron (*Crocus sativus*). He called the fungus *Tuberoides* after noting knot-like swellings scattered irregularly in the mycelial network. In 1791 Bulliard classified it among the truffles, and in 1801 Persoon named it *Sclerotinium crocorum*. De Candolle, in 1818, gave the fungus the name "*Rhizoctonia*". Kuhn, in 1858, described a new disease on potatoes for which he gave as the causative agent, *Rhizoctonia solani*. This pathogen also had in its early history a number of names such as *R. betae*; *R. napaeae* (West, 1846); *R. rapae* (West 1852); and *Hypochnus solani* (Prillieux and Delacroix, 1891). In 1903 Rolfs isolated single spores of *Corticum vagum* and obtained cultures of *Rhizoctonia solani* (14).

Several workers have determined and compared the rate of growth for numerous isolates at the same and different temperatures. Le Clerg's work (30, 31) showed that the rate of growth for different isolates varied tremendously at a given temperature. The results, furthermore, gave strong indication that the isolates differed as to temperature optima. He found that the optimum temperature for potato isolates was between 20° and 30° C. His isolate R-53 grew about twice as fast as R-63 at 15° C., but at 30° C. their rates of growth were the same. Le Clerg (31) tested 116 isolates obtained chiefly from sclerotia formed on potato tubers and from the lesions on stems of older plants. Among these isolates he did not find any that were pathogenic to half-grown or mature sugar beets. On the other hand, Rhizoctonia isolates obtained from sugar beets were pathogenic to potatoes.

Matsumoto (33) explained that among his isolates, B-1 grew most rapidly at 31° C., while P-1, P-4, and H had about the same optimum temperature for growth, which was somewhat lower (24° C.) than that for B-1. P-7 seemed to have no well-defined optimum since there was no difference in growth rate between 24° and 33° C.

In 1916 Peltier (39) reported that 165 species of plants were subject to attack by Rhizoctonia. Included in these species were all the more important families of dicotyledons as well as a number of monocotyledons and several gymnosperms. He reported that most of the floricultural plants, vegetable and field crops, herbaceous plants, and many weeds were susceptible to attacks by Rhizoctonia.

In addition to its occurrence on many different hosts, Rhizoctonia also forms specialized races or strains, some of which differ morphologically as studied by Matsumoto (33) and Le Clerg (31). They have shown that there may be a slight or occasional morphological difference between isolates. More recently, Exner and Chilton (13) found as many as 29 distinct cultural types differing in rate of growth, color, size, and position of sclerotia occurring among isolates from a single basidial mat.

Houston (23) made additional studies on 260 isolates of Rhizoctonia from 15 different crop plants. He classified the isolates into cultural types. Type C was essentially non-pathogenic to sugar beet roots, while Type B was, from a practical standpoint, non-pathogenic on sugar beet seedlings, but was highly pathogenic on older beet roots.

A strain of Rhizoctonia was reported by Kotila (25) to be pathogenic to the foliage of sugar beets and did not cause any damage to the older roots, but was capable of causing both pre- and post-emergence damping-off of sugar beet seedlings.

Leach (26) reported that the three most common fungi to cause damping-off of sugar beets in California were Rhizoctonia solani, Pythium ultimum, and Phoma betae. The first two were common in field soils, while Phoma appeared to originate only from imported seed. Tilford and Young (43) stated that Aphanomyces cochlioides was responsible for the major part of losses in Ohio from seedling diseases, but that R. solani, although less common, may cause severe damage. Afanasiev (2) discussed the relationship of six groups of fungi to seedling diseases of sugar beets in Montana. Fusarium, Macrosporium, and Rhizoctonia were only slightly pathogenic, Phoma and Pythium were moderately so, and Aphanomyces cochlioides was the most pathogenic on sugar beet seedlings.

Buchholtz (6) studied the factors influencing the pathogenicity of Pythium debaryanum on sugar beet seedlings. Field trials revealed that the application of hydrated lime slightly increased the number of emerging seedlings and increased the percentage survival. It was shown from date of planting tests that early planting increased emergence and survival. Seed treatment (5 per cent ethyl mercury phosphate) was found to be effective in increasing the emergence and survival of sugar beet seedlings. Tests in the greenhouse showed that Pythium debaryanum, Phoma betae, and Rhizoctonia were pathogenic to sugar beet seedlings. Rhizoctonia was very seldom isolated from field-grown sugar beet seedlings, but was found to produce lesions on young seedlings when grown in infested soil in the greenhouse. Isolations from diseased beets in the field showed that Pythium debaryanum caused over 95 per cent of the damage to germinating and emerging seedlings. A correlation of 0.745 was found between pH and percentage stand. Areas in which

Pythium brought about poor stands were found generally to be more acid, e.g., below a pH of 6.5.

McKeen (36) made a study of sugar beet root rot in southern Ontario. Isolations made from diseased beet seedlings in the field and in greenhouse soil yielded pure cultures of *Aphanomyces cochlioides*, *Pythium aphanidermatum*, *Pythium ultimum*, *Rhizoctonia solani*, *Fusarium spp.*, *Penicillium spp.*, *Actinomyces spp.*, and *Mucor spp.* Pathogenicity tests were conducted by growing sugar beet seedlings in sterile soil inoculated with cornmeal cultures of all the above organisms. In these tests only *A. cochlioides*, *P. aphanidermatum*, *P. ultimum*, and *R. solani* proved to be pathogenic. Microbiological studies were conducted in the rhizosphere of diseased and healthy sugar beet roots. It was found that the number of organisms in the rhizosphere of diseased sugar beet roots was much larger than in that of healthy beet roots. This increase in number of organisms was believed to be due, at least in part, to the utilization of necrotic tissues or substances released on their breakdown. In order to determine the effect of fungicides on the microbiological balance in soil, Arasan was applied to air-dried soil at the rate of four pounds per acre, and placed in open flasks. Water was added, and at weekly intervals dilution plates were poured, and counts of bacteria and fungi were taken. The results showed that the number of fungi in the Arasan-treated soil was reduced within two days to about one-fourth of that in the check, and that this relationship persisted for 67 days. In the case of the bacteria, however, the Arasan treatment stimulated development initially, the number reaching a maximum in about 15 days. By the 67th day the number had returned to normal. It was concluded from these studies that control with Arasan may be achieved, in part, through a direct fungicidal action and in part to a shift in the microbiological balance of the soil flora unfavorable to the pathogen.

In 1913 Edson (11) reported that damping-off and root rot of sugar beets were found to be associated with four organisms: *Pythium debaryanum*, *Aphanomyces levis*, *Phoma betae*, and a species of *Rhizoctonia*. It was determined that *Phoma* was invariably present on beet seed. The other species mentioned were found to be soil-borne and were not associated with the seed. Partial control of the seed-borne phase of *Phoma* was accomplished by soaking the seed in water at 60° C. for ten minutes. After an interval of 24 hours the process was again repeated. The seed was planted immediately after cooling.

In 1924 Rumbold (41) reported exposing sugar beet seed balls for 20 minutes to a mixture of formaldehyde vapor and steam at a temperature of 140° F. It was found that under these conditions most bacteria and fungus spores were killed. It was further noted that the outermost tissue of the seed balls became impregnated with formaldehyde, which gave further protection to the seeds when planted.

Coons and Stewart (9) reported in 1927 on a series of greenhouse and field tests that had been conducted over a five-year period. _Phoma betae_, _Pythium debaryanum_, and _Rhizoctonia_ were reported to be the chief causal agents of sugar beet seedling diseases in Michigan. It was concluded from these studies that dusting sugar beet seed with a suitable disinfectant held considerable promise for the beet sugar industry. It was shown that it was possible, by the use of disinfectants, to prevent a serious reduction in stand from seed- and soil-borne pathogens.

From 1927 to 1937 considerable emphasis was placed on the evaluation of copper sulphate, red cuprous oxide, yellow cuprous oxide, zinc oxide, and various mercuric compounds (32). It was determined that red cuprous oxide was more effective against _Pythium spp._, while the mercury compounds were best against _Rhizoctonia_ and _Phoma_.

Replicated seed treatment studies conducted by Gaskill and Kreutzer (16) from 1943 to 1945 showed that Arasan, New Improved Ceresan, 2 per cent Ceresan, Du Pont 1452-F, and yellow cuprocide were effective in improving seedling survival in fields where damping-off was an important factor.

The chief cause of damping-off was determined to be Pythium ultimum. Isaksson, Brewbaker, and Bush (24) confirmed these results in seed treatment trials conducted in Colorado in 1944 and 1945.

Seed treatment trials were conducted in 1942 by Leach and Bainer (28), showing the effect of different compounds on segmented and non-segmented seed. It was found from these studies that segmented seed responded in much the same manner as whole seed to the protective effects of fungicides. Due to the greater surface area and its increase in susceptibility to infection, a somewhat higher dosage was required for segmented seed. A 1.5 per cent dosage of Ceresan or 0.5 per cent of New Improved Ceresan proved to give adequate protection against severe infestation. Red copper oxide and Spergon offered some protection but was less effective than the organic mercuries.

In 1947 Afanasiev (1) evaluated the effect of seed treatments on seedling diseases of beets planted in the greenhouse in soil infested with Aphenomyces cochlioides. Beet seed was treated with New Improved Ceresan, Phygon, yellow cuprocide, and Arasan. The fungicides were used alone and in combination with an 8 per cent methocel sticker. The treatments were evaluated in fertilized and non-fertilized soil. The following fertilizers were added to one of the check flats: 15.7 grams of sodium nitrate, 1.8 grams of treble-superphosphate, and 1/5 manure on the basis of soil volume. The results showed that the effect of all seed treatments used in controlling seedling diseases of sugar beets was very small. Non-treated beet seed planted at the same time in fertilized soil produced a large number of healthy seedlings. It was concluded that any fertilization which produced vigorous, fast-growing beets was more important in controlling seedling diseases of beets than the different seed treatments.

Leach (27) found that good coverage and complete elimination of dustiness could be obtained by spraying soluble fungicides or water suspensions of wettable fungicides with a suitable binder through nozzles onto seed during agitation in a rotating container. Sugar beet seed treated in this manner was protected against damping-off as effectively as by the same materials in dust form. In moderately infested soil, seed treated by the spray method with either Arasan SF, wettable Phygon, or Ceresan M was adequately protected.

Among the relatively new organic fungicides, the nature and uses which have been summarized by McCallan (34), are such well-known materials as Thiram, Ferbam, Zineb, Phygon, and Spergon. Some of these have been used, at least experimentally, for the treatment of soil. For example, McKeen (35) found that greenhouse soil treated with Thiram and artificially inoculated with Pythium ultimum and Rhizoctonia solani was effective against damping-off of cucumber, pepper, spinach, and tomato. It was further determined that control was more complete when seed and soil treatments with this fungicide were combined. With the use of seed and soil treatments, the pre-emergence phase of the disease was reduced to a very low level, and post-emergence damping-off rarely exceeded 5 per cent up to 16 days after emergence.

Paraformaldehyde, P-162 (hexachlorocyclopentadiene), OPP (orthophenylphenate), sulfur, and PCNB (pentachloronitrobenzene) were evaluated in field trials by Houghland and Cash (22) for the control of Streptomyces scabies. The soil fungicides were applied broadcast to the entire plot area, but only the two center rows were harvested for plot records. Water emulsions of P-162 were applied with a small motor-driven sprayer equipped with a T-jet nozzle for hand application. Paraformaldehyde in flake form was applied broadcast by hand, and sulfur was applied in finely ground form as "flowers". PCNB was mixed with sand and applied by hand in the row and then mixed with the surface soil. PCNB at 150 pounds per acre was effective in controlling scab, but was phytotoxic to potatoes. OPP had no effect on potato yields, but the material as used was not effective in the control of potato scab. Paraformaldehyde was not effective as a soil fumigant for controlling scab, and the test with P-162 was inconclusive. Sulfur reduced the percentage of scabby potatoes at 400 pounds per acre, but was not as effective as PCNB in reducing the percentage of scab. Hooker (20) also found PCNB to be an effective control measure for scab and Rhinzoctonia solani when broadcast and disked into the soil.

Hildebrand, McKeen, and Koch (18) evaluated the effectiveness of Arasan applied into the row at the time of planting for the control of blackroot of sugar beets. Arasan at rates of 3 and 4 pounds per acre was mixed with a 2-16-6 commercial fertilizer, and the fungicide-fertilizer mixture was applied into the row at the time of planting by means of an Oliver-Superior drill at rates of 300 to 400 pounds per acre. Field trials were conducted in soil known to have a definite blackroot history. Non-thinned stands of seedlings receiving the fungicide-fertilizer mixture exceeded those receiving fertilizer alone by 34.7 to 61.3 per cent. Counts made subsequent to blocking and thinning showed gains for the treated rows over non-treated rows from 8 to 35 per cent.

Leach and Snyder (29) evaluated the effect of Dithane D-14 when applied into the row at time of planting for control of Rhizoctonia solani, Fusarium solani f. phaseoli on beans, and Rhizoctonia solani, Fusarium solani f. pisi, and Ascochyta spp. on peas. The fungicide was applied by the drip method very similar to the method used for the control of onion smut by formaldehyde. A marked reduction in the severity of root rots was obtained when Dithane D-14, at the rate of one gallon per acre, was applied as a soil treatment in the planted row at the time of seeding.

Hooker and Peterson (21) controlled Streptomyces ipomoea on sweet potatoes with an application of 800 pounds of sulfur per acre. Sulfur was broadcast by hand and thoroughly disked into the soil.

Exploratory tests were conducted in 1952 by Holton and Jackson (19) for the control of dwarf bunt due to soil-infestation in the Pacific Northwest by the application of fungicides to the soil at the time of seeding winter wheat. Fungicides were applied with a conventional-type duster powered by a gasoline motor and mounted on a four-row custom-built seeder. Each of the four dust-delivering tubes were attached to a drill spout so that the fungicide was blown into the drill opening simultaneously with seed delivery. Of the fungicides tested, only Anticarie gave significant control of dwarf bunt.

Brinkerhoff, Brodie, and Korsten (5) compared several seed treatment fungicides at different rates by mixing with sand and applying in the drill row in flats of soil that had been artificially inoculated with Rhizoctonia solani. In tests in which the soil was treated, it was found that

Mathieson 275 caused the least injury to cotton seedlings and was fairly consistent in controlling Rhizoctonia solani. Two tests indicated that Mathieson 275 had a longer residual effect than Thiram.

Hildebrand, McKeen, and Koch (17) evaluated the effectiveness of different compounds for the control of blackroot of sugar beets caused by the organism Aphanomyces cochlioides. The chemicals under test and a fertilizer, 2-16-8, were thoroughly mixed together in a flask. The mixture, having been uniformly spread over the surface of the soil in bands 2 inches wide where the seed was to be planted, was then worked thoroughly into the top 1 1/4 inches of soil. The seeds were planted in the center of the treated bands at a depth of about 1/2 inch. Arasan, when applied at the rate of 3 to 4 pounds per acre, consistently proved to be the most effective of the chemicals tested in reducing pre- and post-emergence damping-off of sugar beets. Arasan, which was investigated more intensively than any of the other chemicals, was found to retain its fungicidal capability after being mixed for as long as 14 months with the commercial fertilizer. The effects of temperature were also studied. It was found that up to 21° C., Arasan, at the rate of 4 pounds per acre in a moderately wet soil, effectively controlled the disease without injury to the seedlings. At 27° to 29° C., moderate injury to roots and lower hypocotyl resulted from a 3-pound-per-acre application of the chemical, and following a 4-pound application, root and hypocotyl injury was evident.

Doran (10), working with club root of cabbage, reduced the number of infected plants by the application of mercurous chloride and hydrated lime to the soil. The mercurous chloride was mixed with a 5-8-7 fertilizer, used at the rate of 16.0 grams per square foot. The fungicide-fertilizer mixture plus hydrated lime at the rate of 20 grams per square foot, was mixed with greenhouse soil and planted to cabbage. The degree of control of club root by mercurous chloride and hydrated lime was found to be affected by the moisture content of the soil. "The combination treatment of a soil in which, non-treated, there was 100 per cent club root, reduced the number of infected plants to 20 per cent in soil 80 per cent saturated, to 3.3 per cent in soil 50 per cent saturated." Doran also found that onion smut was controlled by 2.75 grams (per square foot) of sodium nitrate applied three days before seeding, or by 3.0 grams of calcium or potassium nitrate ten days before seeding. Ferbam, 0.5 to 1.0 grams, controlled onion smut when applied to soil two or ten days before seeding. For the prevention of damping-off, Phygon applied to the soil in fertilizer gave good results with eggplant, pepper, beet, cucumber, and tomato. Stands of beet, cucumber, and tomato were also improved by Dithane D-14.

Afanasiev and Morris (3) investigated diseases of sugar beets in twenty rotations at the Huntley Branch Station in Montana between 1936 and 1941. From different rotation studies it was shown that sugar beets grown in a manured rotation had a relatively small amount of seedling disease. On the other hand, the occurrence of high amounts of seedling diseases and a considerable amount of phosphorus deficiency in sugar beets maintained in the non-manured rotation indicated that the depletion of the soil was mainly responsible for the prevalence of seedling diseases. These results were confirmed by greenhouse studies (4) in which it was shown that plants grown from non-treated beet seed in soil fertilized with complete fertilizers had only a small amount of seedling disease. It was further demonstrated that sodium nitrate and treble superphosphate applied to the surface of sugar beet seed failed to produce a beneficial effect, either on the reduction of seedling diseases, or on the promotion of more rapid development of beet seedlings.

METHODS AND MATERIALS

During the summers of 1950 and 1951 isolations were made from diseased beets collected throughout the eastern part of Colorado. Pure cultures of *Rhizoctonia solani*, *Pythium ultimum*, and *Fusarium oxysporum* f. *betae* were obtained by excising a single hyphal tip from each of these organisms. Cultures were maintained on potato dextrose agar.

From preliminary tests in the greenhouse, five isolates of *Rhizoctonia* and one isolate of *Pythium* were selected on the basis of their pathogenicity for these studies. The five different isolates of *Rhizoctonia* were designated by the numbers 1, 50, 10A, 53, and 11A.

To determine the differences in pathogenicity among the five isolates of *Rhizoctonia*, giant cultures were made by inoculating sterilized barley in quart milk bottles. The bottles were stored at room temperature for a period of two weeks. The contents of each bottle was then ground and mixed with pasteurized soil. Two flats of soil were inoculated for each isolate. Approximately one quart of inoculum was used to inoculate two flats. Each flat was planted with four rows, 50 seeds per row. Stand counts and the number of surviving seedlings were taken from the two center rows of each flat.

The effect of temperature on the diameter of growth of Rhizoctonia on artificial media was determined by removing discs from five-day old cultures by means of a Number 11 cork borer, 1.7 centimeters in diameter, and placing them in the center of a potato dextrose agar plate. Five replications of each isolate were prepared for each temperature. The plates were incubated for four days at eight different temperatures. The average daily growth was obtained by measuring the diameter of the colony in centimeters at two locations on the plate.

Fungicides were evaluated for their effectiveness in inhibiting mycelial growth of Rhizoctonia and Pythium on potato dextrose agar in petri dishes. Fungicides were added at different concentrations (ppm) to warm agar (approximately 45° C.) in 250 milliliter flasks. The fungicide and agar were thoroughly mixed and then poured into petri dishes and allowed to solidify. The plates were inoculated by removing discs from five-day-old cultures of Rhizoctonia and Pythium with a Number 11 cork borer, 1.7 centimeters in diameter. The discs were then placed in the center of the agar plates containing the fungicides. Plates were stored at 28° C. and readings made at the end of 96 hours. The effectiveness of the fungicides was determined by measuring the growth of the colonies in centimeters.

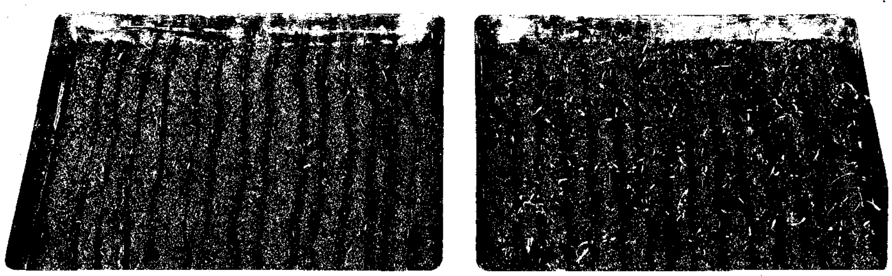


Figure 6. View of aluminum pans used for the evaluation of seed and soil treatments in the laboratory.

Soil-treatment materials were evaluated in infested and non-infested soil in aluminum pans 13 inches long, 8 inches wide, and 2 inches deep. Partitions were made in the pans by folding an 8 x 2 inch blotter to form two sides and a bottom. Fifteen partitions were fitted into each pan, Figure 6. Six grams of the fungicide to be tested were mixed with one liter of vermiculite (plaster aggregate) which was used as a carrier for bulking purposes. The fungicide-vermiculite mixture was then mixed with infested and non-infested soil at different concentrations (ppm). Twenty-five sugar beet seeds were placed in the bottom of each partitioned space, and 50 grams of experimental mixture added to each space. Each row was then watered with 20 cubic centimeters of tap water. The pans were covered and left at room temperature. Emergence and number of surviving seedlings were determined by stand counts taken every second day.

In 1952 fungicides were applied to the soil with a hand planter (Planet, Jr.) equipped with a modified fertilizer attachment, Figure 7. The fungicides to be applied were thoroughly mixed with a given amount of finely screened sand for bulking purposes. At the time of application the fungicide and sand mixture was placed in hopper (A) at the back of the planter. A mechanical device, operated by an off-set cam on the rear wheel (B), produced a shaking motion to the

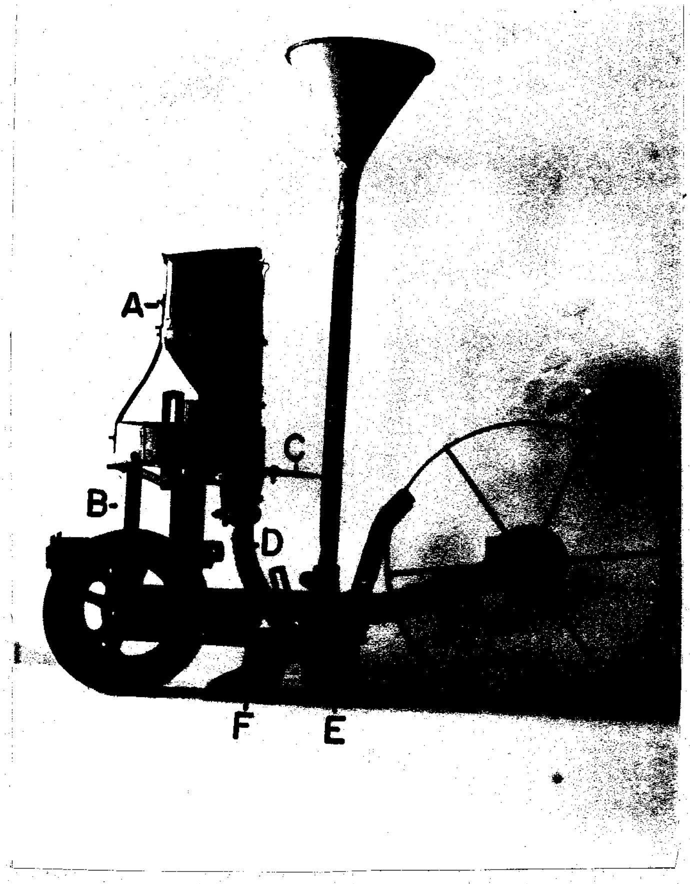


Figure 7. Planet Jr. equipped with modified fertilizer attachment.

Legend:
A. Hopper
B. Shaking device
C. Adjustable vent
D. Flexible metal tube
E. Planter shoe
F. Covering device

hopper. This insured an even flow of the fungicide through an adjustable vent at the bottom of the hopper (C), into two flexible metal tubes (D), which directed the flow of material into the soil directly behind the seed applicator spout in the planter shoe (E). The fungicide was mixed with the soil as the soil pushed over the top and sides of the planting shoe. The covering device (F) behind the planting shoe also mixed the fungicidal material with the soil. This method of applying the fungicides to the soil provided a protective band approximately 2 1/2 to 3 inches wide and 1 1/2 to 2 inches deep around the germinating seedling.

In the summer of 1952 a 10 per cent Thiram dust was applied to the soil at the time of planting. A four-row conventional crop duster, operated by a gasoline motor, was placed in a one-wheel trailer and attached to the back of a sugar beet planter, Figure 8. Each of the four dust-delivering tubes were attached to a drill spout so that the fungicide was blown into the drill opening simultaneously with seed delivery.

Copper sulfate was applied into the irrigation water at the rate of 25 pounds per acre. A pre-determined amount of copper sulfate was placed in cloth bags. One cloth bag containing copper sulfate was placed between each of the rows to be treated. The rows were then irrigated until all the copper sulfate was dissolved from each of the cloth bags.

Figure 8. Four-row duster attached to the back of a sugar beet planter for row applications of fungicides into the soil.

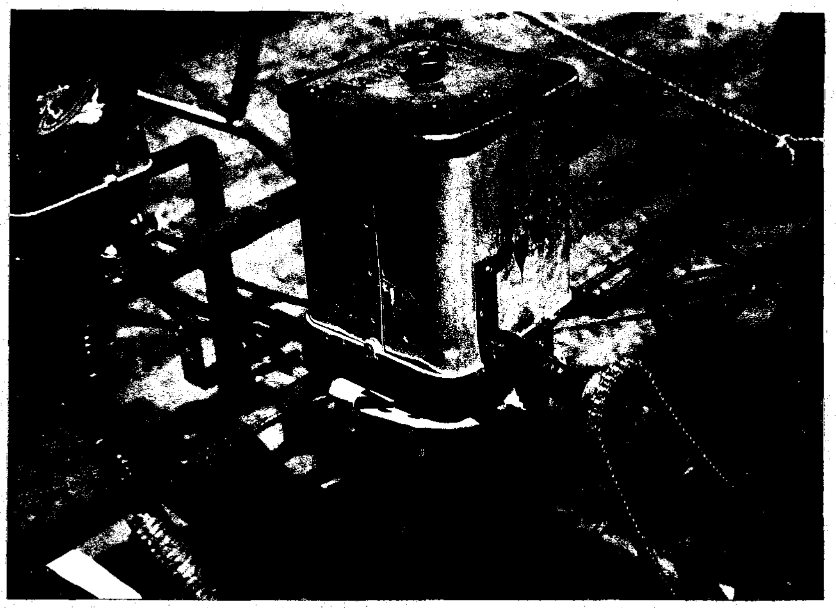
Back View

Side View

Figure 9. Milton drill equipped for the application of fungicides into the soil at time of planting.

In 1953 and 1954 fungicides were applied into the row at the time of planting with a modified four-row Milton drill, Figure 9. Seed boxes were mounted on a metal frame immediately above the two center planters of the drill, Figure 10. These boxes served as a hopper for the fungicide. The fungicide hoppers were attached to the metal frame in such a manner that they could be easily turned over for emptying and cleaning purposes, Figure 10. A metal seed gate with different sized openings was attached to the bottom of the fungicide hopper to regulate the flow of the fungicide. To further facilitate an even flow of the fungicide through the opening in the bottom of the hopper, a chain-driven agitator was installed. From the fungicide hopper the fungicide dropped through a flexible metal tube. Thus it was distributed in the soil behind the furrow opener, Figure 11. The furrow opener could be regulated to any depth or any position in front of the planter. The fungicide became mixed with the soil as the soil flowed around the furrow opener.

A measuring device, Figure 12, was used to apply CBP and P-162 into the row at the time of planting. A capillary tube was attached to the bottom of the measuring device which was used to regulate the flow of the chemical. From the capillary tube, the chemical flowed down a neoprene tube into a copper tube which was inserted between the

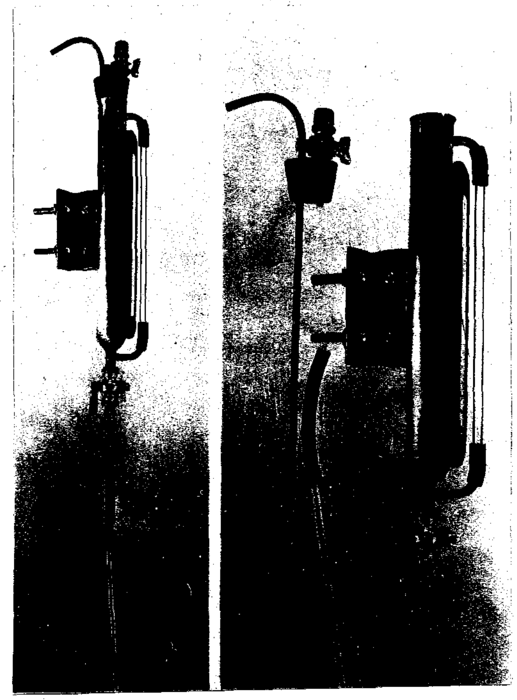


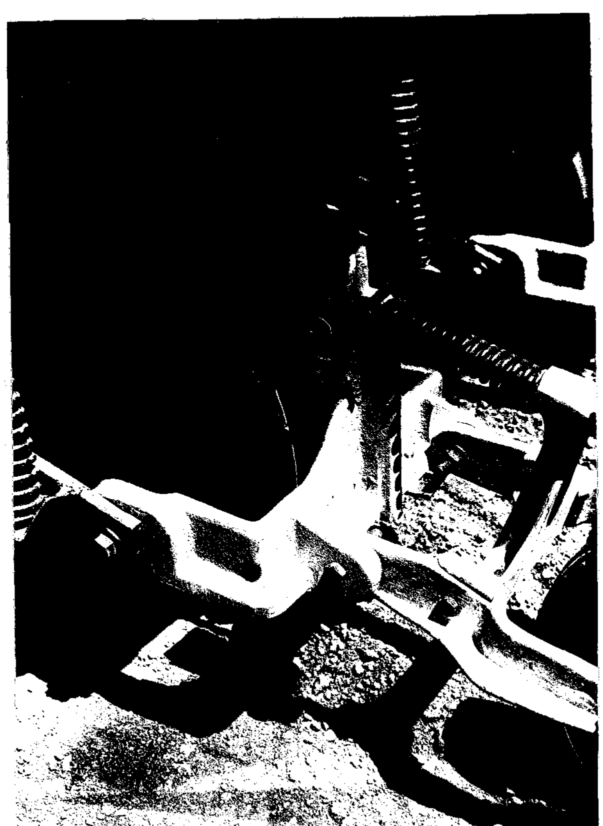
Upright Position

Tilted Position

Figure 10. Fungicide hopper in upright and tilted positions. Tilted position shows the metal seed gate used for regulating the flow of the fungicide. Note the attachment of the grain spout to the fungicide hopper which extends down into a flexible metal tube.

Figure 11. Side view of the furrow opener showing the location of the flexible metal tube with the attached dust nozzle.





planting disks, Figure 13. By regulating the speed of the drill and the size of the capillary tube, it was possible to apply chemicals at a rate of .5 milliliter per foot of row.

Fungicides were also applied to the soil under pressure at time of planting in the form of a spray. A spray nozzle, Figure 14, was attached immediately behind the planting disk in such a manner that the fungicide was applied into the row with the seed. The fungicide was further mixed with the soil as it closed behind the planting disks. In the 1954 tests, a spray nozzle was attached to the furrow opener in front of the planter, as well as a spray behind the planter as described above. By this method of application, the fungicide was applied before and after planting. A Wisconsin gasoline engine mounted on a metal frame above the planter was used as a source of power for a "Hypro" centrifugal pump, Figure 15. The fungicides were applied at the rate of 10 gallons per acre and at 30 pounds pressure. For bulking purposes, the fungicides were mixed with finely screened sand in the 1953 tests, and the finish grade aggregate of Vermiculite in the 1954 tests.

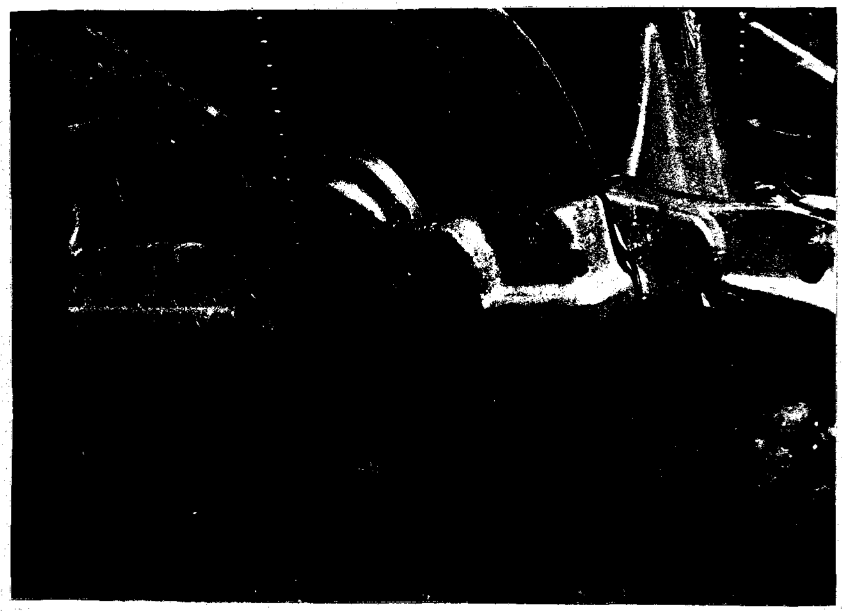


Figure 14. Side view of the planting disk showing the location of the spray nozzle.

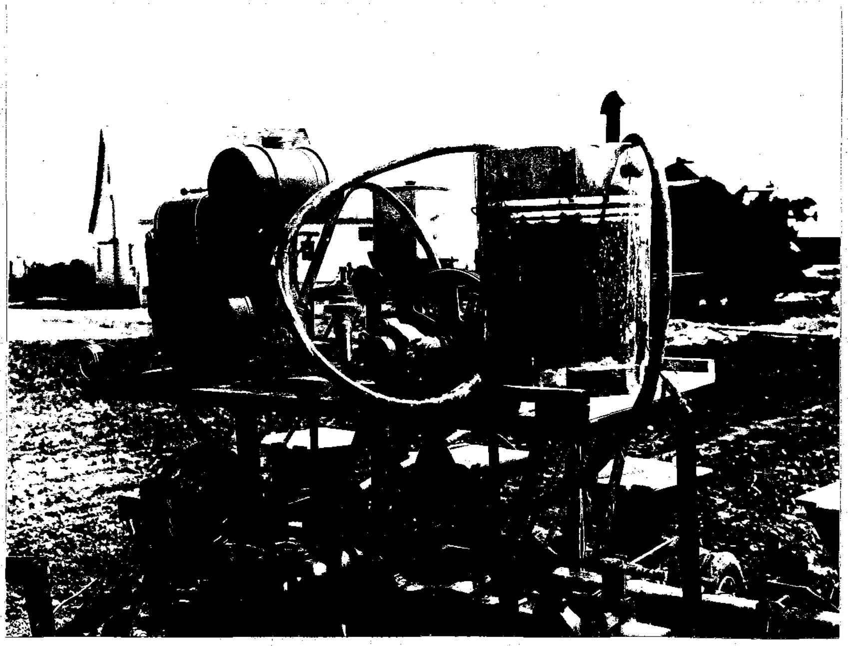


Figure 15. General view of the spraying equipment used for the application of fungicides into the soil at time of planting.

The following fungicides, hereafter referred to by their trade names, used in this work are mentioned below.

Agrox - 6.7 per cent phenyl mercury urea.

Cadminate - 60 per cent cadmium succinate.

Captan - 75 per cent N. trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide.

CBP - chlorobromopropene.

Ceresan M - 7.7 per cent ethyl mercury p-toluene sulfonanilide.

Copper sulphate - 25 per cent metallic copper.

Crag 658 - 95 per cent copper zinc chromate complex.

Dow 9-B - 50 per cent zinc trichlorophenate.

Maneb - 70 per cent manganese ethylene bisdithiocarbamate.

P-162 - 95 per cent hexachlorocyclopentadiene.

Phygon - 50 per cent dichloronaphthoquinone.

Spergon - 98 per cent tetrachloro para benzoquinone.

Thiram - 50 and 75 per cent tetramethyl thiuramdisulfide.

Vancide 51 - sodium salt of dimethyl dithiocarbamic acid, sodium salt of 2-mercaptobenzothiazule.

XP-47 - Experimental.

Yellow cuprocide - yellow cuprous oxide containing 47 per cent metallic copper.

ZAC - zinc dimethyl dithiocarbamate/cyclohexylamine complex.

Zineb - 65 per cent zinc ethylene bisdithiocarbgmate.

Sugar beet seed of commercial variety G. W. 304 was used in all the seed- and soil-treatment studies in this investigation. The seed was processed, decorticated, and sized to 7/64 to 9/64 inch. Other varieties used are listed as follows:

C 455 - LSVR, Milpitas hybrid.

G. W. 359 - LSVR, commercial variety.

B 626 - Fusarium resistant selection from G. W. 359.

B 525 - Rhizoctonia resistant selection from Scottsbluff, Nebraska, and extremely susceptible to _Fusarium oxysporum_ f. _betae_.

B 593 - LSVR, sugar selection from G. W. 305.

B 630 - LSVR, selection from C 455.

B 544 - LSVR, _Betae patellaris_ hybrid.

G. W. 529 - LSVR, commercial variety.

G. W. 589 - Fusarium resistant selection from G. W. 529.

EXPERIMENTAL RESULTS

Laboratory Investigations

Pathogenicity tests

The pathogenicity of five isolates of *Rhizoctonia* was determined in pasteurized greenhouse soil which had been artificially infested with each isolate. Seed of variety G. W. 304 was planted in the infested flats as previously described. Stand counts were taken one week and two weeks after emergence. The average number of seedlings per replication from these tests are recorded in Table 1.

Table 1. The results of testing the pathogenicity of five isolates of *Rhizoctonia solani* on a susceptible sugar beet variety, G. W. 304.

Isolate No.	Ave. number seedlings per replication[1]		Pathogenicity ranking
	1st week after emergence	2nd week after emergence	
1	74.0	96.3	5
50	24.7	37.0	3
10A	5.0	15.0	1
53	25.5	45.7	4
11A	32.5	36.7	2
Check (Non-inoculated soil)	79.7	117.5	-

[1]Results of two separate trials.

Isolate Number 10A was found to be the most pathogenic, as determined by stand counts taken after the second week of emergence. An average number of 15 seedlings emerged as compared to 117.5 in the non-infested check. Isolates Number 11A, 50, and 3 were less pathogenic, but apparent differences were evident among them. Isolate Number 1 proved to be the least pathogenic with an average number of 96.3 seedlings per replication.

During the past two years approximately 150 varieties and inbred lines of sugar beets have been evaluated for their resistance or susceptibility to Rhizoctonia in the seedling stage in greenhouse soil infested with a mixed culture of the five isolates. None of the varieties or inbred lines showed any marked degree of resistance to Rhizoctonia in the seedling stage.

Effect of temperature on diameter of growth of five isolates of Rhizoctonia solani

Pathogenicity tests in Table 1 showed differences in pre-emergence damping-off of sugar beets in soils artificially infested with five isolates of Rhizoctonia. In order to determine if there was a correlation between the pathogenicity tests and the rate of growth of the five isolates on artificial media, five potato dextrose agar plates of each isolate were prepared as previously described and stored at eight different temperatures. The average daily growth was obtained by measuring the diameter of the colony in centimeters at two locations on the plate. The results are presented in Table 2. These data, illustrated in Figure 16, show that the optimum temperature for each of the five isolates was 28° C. Isolate Number 1, which was the least pathogenic, grew more rapidly at 10° and 22° C. than any of the other isolates. The growth rate of isolate 10A was slower than any of the other isolates at 35° C. and at 10° C. For some unknown reason all the isolates grew more slowly at 15° C. than at 10° C. There appeared to be very little difference in the growth rates of the isolates at any of the other temperatures.

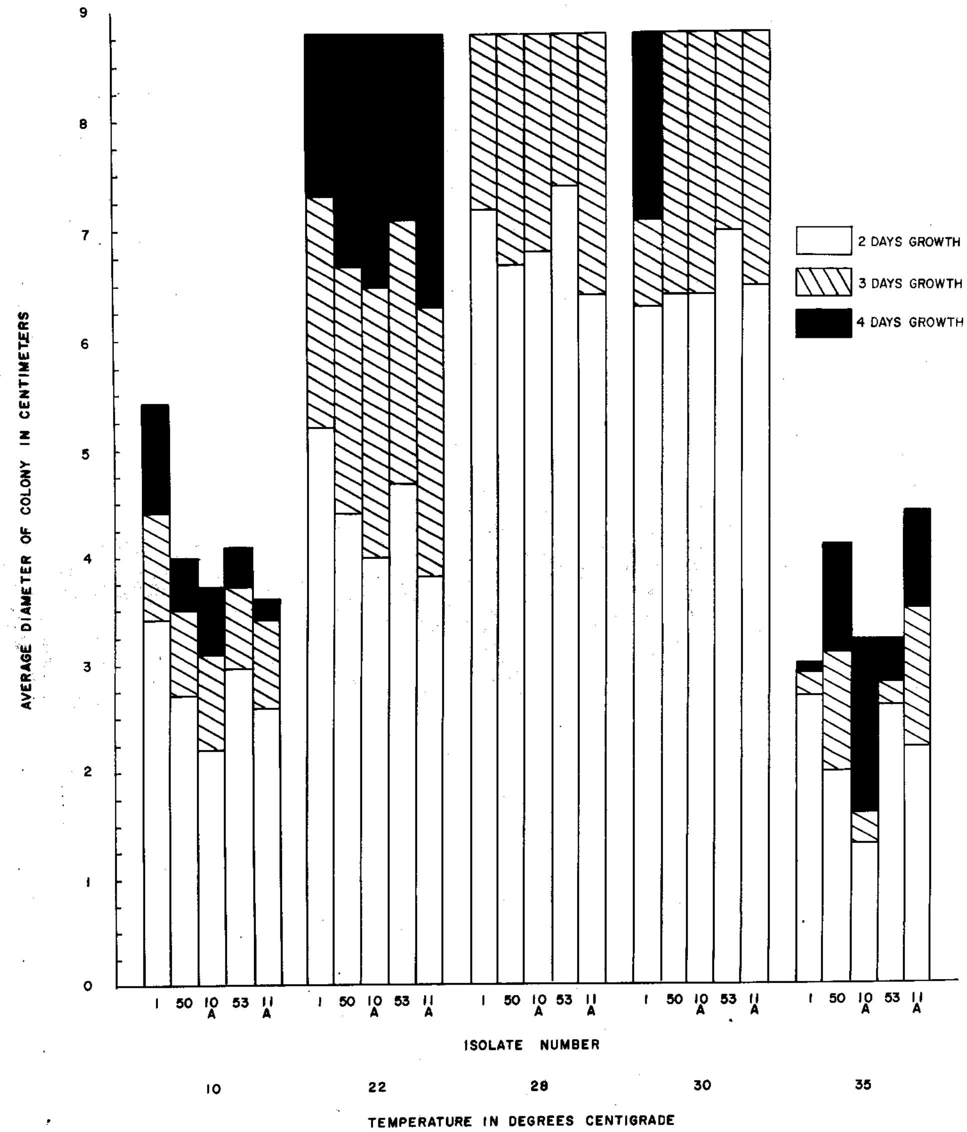
Effect of certain fungicides on the growth of five isolates of *Rhizoctonia solani*

Fungicides were evaluated for their effectiveness in inhibiting mycelial growth of the five isolates of *Rhizoctonia* by incorporating certain fungicides into warm agar at different parts per million. Three replications were prepared for each isolate at each concentration and inoculated with agar discs, 1.7 centimeters in diameter, removed from five-day-old cultures. Plates were held at 28° C. for four days. The initial diameter of the inoculum disc was subtracted from the final diameter of the colony

Table 2. The effect of temperature on the diameter of growth of five isolates of Rhizoctonia solani on artificial media.

Isolate No.	No. days of growth	Average diameter of colony in cm. Degrees centigrade 10	15	22	28	30	32	35	38
	2	3.4	2.4	5.2	7.2	6.3	5.4	2.7	0.9
1	3	4.4	2.7	7.3	9.0	7.1	8.6	2.9	1.0
	4	5.4	3.0	8.8	8.8	8.8	8.6	3.0	0.8
	2	2.7	1.3	4.4	6.7	6.4	5.9	2.0	0.7
50	3	3.5	1.9	6.7	8.8	8.8	8.0	3.1	0.7
	4	4.0	1.9	8.8	8.8	8.8	8.8	4.1	0.8
	2	2.2	1.7	4.0	6.8	6.4	5.4	1.3	0.7
10A	3	3.1	2.2	6.5	8.8	8.8	7.3	1.6	0.7
	4	3.7	2.3	8.8	8.8	8.8	8.8	3.2	0.9
	2	2.9	1.5	4.7	7.4	7.0	5.6	2.6	0.7
53	3	3.7	2.1	7.1	8.8	8.8	7.6	2.8	0.9
	4	4.1	2.4	8.8	8.8	8.8	8.8	3.2	0.9
	2	2.6	1.4	3.8	6.4	6.5	5.8	2.2	0.7
11A	3	3.4	2.1	6.3	8.8	8.8	8.2	3.5	0.7
	4	3.6	2.5	8.8	8.8	8.8	8.8	4.4	0.7

Figure 16. The effect of temperature on the diameter of growth of five isolates of *Rhizoctonia solani* on artificial media.


AVERAGE DIAMETER OF COLONY IN CENTIMETERS
0
1
2
3
4
5
6
7
8
9
2 DAYS GROWTH
3 DAYS GROWTH
4 DAYS GROWTH
1 50 10A 53 11A
ISOLATE NUMBER
10
22
28
30
35
TEMPERATURE IN DEGREES CENTIGRADE

to determine the rate of growth. Table 3 shows that at the end of four days, the mycelium of each of the isolates grown on non-treated agar, had completely covered the plate. Maneb at 150 ppm was the most consistent in inhibiting mycelial growth of each of the five isolates. Zineb at all concentrations was the least toxic. Thiram at 30 ppm was more toxic than Maneb at 30 ppm, although at 75 ppm the difference between the two compounds was negligible. Captan was more toxic than Zineb, but was not as effective in controlling mycelial growth as Maneb or Thiram. Isolate Number 1 appears to be more sensitive to Maneb and Thiram than to either Captan or Zineb. Isolate 10A, which was proven to be the most pathogenic of the five isolates, was shown to respond in the same manner as isolates 50, 53, and 11A to each of the four fungicides.

Effect of certain fungicides on the growth of *Rhizoctonia* and *Pythium*

Maneb, Thiram, Captan, and Zineb were mixed with warm agar in petri dishes at different parts per million, as previously described, and inoculated with *Rhizoctonia* (Isolate 10A) and *Pythium*. Two replications were prepared for each treatment at each concentration and stored for four days at 28° C. Readings were taken as described previously. Table 4 shows that Maneb at 100 ppm completely inhibited the growth of *Pythium*. Zineb at all

Table 3. The effect of certain fungicides on the growth of five isolates of *Rhizoctonia solani* on artificial media.

Treatment	Concentration ppm	Average diameter of colonies in cm.[1] Isolate number 1	50	10A	53	11A
Maneb	30	2.9	4.3	4.0	5.1	4.6
	75	1.5	2.1	2.6	3.3	2.2
	150	0.7	1.0	1.2	1.7	0.6
Thiram	30	3.2	3.9	3.5	4.6	4.1
	75	1.1	2.5	2.0	2.9	2.5
	150	0.9	2.3	1.9	2.3	2.2
Captan	30	5.8	5.0	4.0	5.5	5.2
	75	2.6	2.5	2.5	2.1	2.5
	150	1.5	2.0	1.5	1.7	2.0
Zineb	30	7.1	6.6	7.1	7.1	7.1
	75	6.5	5.5	5.6	6.0	5.9
	150	3.9	4.3	4.1	5.5	5.0
Check	--	7.1	7.1	7.1	7.1	7.1

[1]Average diameter of colony minus the diameter of inoculum disc.

Table 4. Effect of certain fungicides on the growth of *Rhizoctonia solani* and *Pythium ultimum* on artificial media.

Concentration ppm	Average diameter of colonies in cm.[1]							
	Pythium inoculated				Rhizoctonia inoculated[2]			
	Treatment				Treatment			
	Maneb	Thiram	Captan	Zineb	Maneb	Thiram	Captan	Zineb
0	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
10	7.1	7.1	7.1	7.1	3.4	6.6	6.8	7.1
30	6.8	5.8	7.1	7.1	2.0	3.0	5.6	6.2
50	6.2	4.0	7.1	7.1	1.4	3.0	3.4	6.2
75	5.4	2.4	7.1	7.1	1.0	2.6	2.4	3.6
100	0.0	1.4	6.2	7.1	0.8	1.8	2.4	3.6
150	0.0	0.0	5.6	7.1	0.8	1.5	1.8	3.4
200	0.0	0.0	4.4	7.1	0.6	1.5	1.4	3.0
400	0.0	0.0	1.8	7.1	0.4	0.8	1.0	1.8

[1]Average diameter of colony minus the diameter of inoculum disc.

[2]Isolate 10A.

concentrations was not toxic to *Pythium*. *Rhizoctonia* growth was best controlled with 400 ppm of Maneb. Zineb proved to be more toxic to *Rhizoctonia* than to *Pythium*. Captan was more effective in controlling the mycelial growth of *Rhizoctonia* than of *Pythium*. Mycelial growth of *Pythium* was also inhibited by 150 ppm of Thiram.

Comparative effectiveness of seed treatment and soil treatment

Rhizoctonia-infested soil. Seed- and soil-treatment trials were conducted in soil artificially infested with *Rhizoctonia* (Isolate 10A). Infested and non-infested soil was thoroughly mixed with a Maneb-vermiculite mixture at different ppm. The fungicide-soil mixture was placed in aluminum pans as previously described and planted with non-treated beet seed. Beet seed was also treated with Maneb at different dosage rates and planted in infested and non-infested soil in aluminum pans. Data are presented in Table 5 showing the effectiveness of Maneb in controlling pre- and post-emergence damping-off of sugar beet seedlings. Maneb, as a soil treatment, controlled post-emergence damping-off at 300 ppm. The average number of seedlings per replication 14 days after emergence was 28.0 as compared to 3.3 in the infested check. Soil treatments at rates of 500, 800, and 1000 ppm proved to be phytotoxic to the emerging seedlings. Emergence was not delayed in the

Table 5. Comparative effectiveness of seed treatment and soil treatment in soil artificially infested with *Rhizoctonia solani*.

Treatment		Average number of seedlings per replication											
		Infested soil						Non-infested soil					
Soil treatment	Seed treatment	Soil treatment			Seed treatment			Soil treatment			Seed treatment		
		Maneb			Maneb			Maneb			Maneb		
ppm	Oz. per 100 lbs.	1[1]	7	14	1	7	14	1	7	14	1	7	14
100	—	6.4	21.5	14.9				8.0	22.7	27.3			
—	0				0.3	5.3	3.3				20.0	22.0	18.6
300	—	10.8	30.8	28.0				10.0	31.0	25.6			
—	6				7.3	14.6	4.6				12.7	20.0	16.6
500	—	4.0	31.8	29.9				12.7	32.7	33.3			
—	8				4.3	14.6	13.3				20.0	22.7	18.3
800	—	2.2	26.3	26.2				10.7	29.7	29.0			
—	10				8.0	18.3	15.3				17.0	25.0	24.6
1000	—	0.6	16.2	16.0				7.3	24.7	26.0			
—	12				9.7	22.0	13.3				21.0	30.0	28.0

[1]Number of days after emergence.

non-infested soil-treatment plots, but the young seedlings were definitely stunted in growth. Seed treatment partially controlled pre-emergence damping-off at 6, 8, 10, and 12 ounces per 100 pounds of seed. The average number of emerging seedlings on the seventh day was 14.6, 14.6, 18.3, and 22.0, respectively. However, counts made on the fourteenth day after emergence showed a reduction in stand. A reduction of stand was not evident in the soil-treatment plots. Seed treatment tests in the non-infested plots showed that the pasteurized soil was not completely sterilized. Damping-off was evident in these plots when counts were made on the fourteenth day after emergence.

Pythium-infested soil. Seed and soil treatment trials were conducted in soil artificially infested with Pythium ultimum. The same procedure was followed as in the preceding test. Table 6 shows that soil treated with Maneb at 300 ppm was more effective in controlling post-emergence damping-off than seed treatment. Stand counts taken on the seventh day after emergence in the soil-treated plots showed an average of 26.5 seedlings per replication in soil which had been treated with Maneb at 300 ppm. Seed treatment studies showed that Maneb at 6, 8, 10, and 12 ounces per 100 pounds of seed gave good control of pre-emergence damping-off. Seedlings grown in soil which had been treated with Maneb at rates of 500, 800, and 1000 ppm were stunted upon

Table 6. Comparative effectiveness of seed treatment and soil treatment in soil artificially infested with *Pythium ultimum*.

Treatment		Average number of seedlings per replication											
Soil treatment	Seed treatment	Infested soil						Non-infested soil					
		Soil treatment			Seed treatment			Soil treatment			Seed treatment		
ppm	Oz. per 100 lbs.	Maneb 1[1]	7	14	Maneb 1	7	14	Maneb 1	7	14	Maneb 1	7	14
100	—	13.9	18.3	24.1				8.0	22.7	27.3			
—	0				8.0	12.0	9.0				20.0	22.0	18.6
300	—	20.0	26.5	23.6				10.0	31.0	25.6			
—	6				20.0	26.3	19.7				12.7	20.0	16.6
500	—	1.6	20.0	25.9				12.7	32.7	33.3			
—	8				22.0	26.3	19.3				20.0	22.7	18.3
800	—	1.5	19.0	24.4				10.7	29.7	29.0			
—	10				24.0	30.0	19.3				17.0	25.0	24.6
1000	—	0.6	18.0	30.2				7.3	24.7	26.0			
—	12				50.0	24.3	15.3				21.0	30.0	28.0

[1] Number of days after emergence.

emergence. Seedlings grown in these soils were approximately one-half the size of those seedlings grown in non-treated soil.

Greenhouse Investigations

Seed treatment studies

Rhizoctonia-infested soil. Seed treatment trials were conducted in ground benches in the greenhouse in soil artificially infested with Rhizoctonia solani. Giant cultures of the five isolates of Rhizoctonia were prepared as previously described and mixed thoroughly with pasteurized soil in the benches. Treated and non-treated seed was planted 50 seeds per row with five replications of each treatment. The results of these trials are presented in Table 7. Stand counts taken the second day after emergence showed that Captan and Maneb significantly increased the stand over the non-treated check, with an average of 41.2 and 45.0 seedlings, respectively, per replication. The differences between Thiram and Zineb were negligible. Post-emergence damping-off was evident when stand counts were taken on the seventh and eleventh days after emergence. The protective effect of Maneb and Captan was much greater than either Thiram or Zineb.

Pythium-infested soil. Seed treatment trials were conducted in ground benches in the greenhouse in soil

Table 7. Emergence and survival of sugar beet seed at five dates after planting seed treated with different chemicals and tested in pasteurized soil and soil artificially infested with mixed isolates of <u>Rhizoctonia solani</u>.

Treatment	Rate of application oz. per 100 lbs. seed	Average number of seedlings per replication									
		Inoculated soil					Pasteurized soil				
		12/4	12/6	12/8	12/10	12/14	12/4	12/6	12/8	12/10	12/14
Maneb	8	34.0	45.0	45.0	43.0	42.4	51.2	58.6	59.2	64.4	64.6
Captan	12	31.2	41.2	38.8	38.2	35.4	54.0	59.6	59.0	63.3	63.3
Thiram	6	16.2	19.6	15.4	14.2	13.8	51.4	54.0	55.4	60.2	61.4
Zineb	8	16.2	18.2	13.6	14.0	12.8	54.2	59.2	59.2	63.4	63.4
Non-treated check	--	13.6	17.4	15.0	13.4	13.6	52.8	58.4	58.6	59.6	60.2

Table 8. Emergence and survival of sugar beet seed at five dates after planting seed treated with different chemicals and tested in pasteurized soil and soil artificially infested with mixed isolates of *Pythium ultimum*.

Treatment	Rate of application oz. per 100 lbs. seed	Average number of seedlings per replication									
		Inoculated soil					Pasteurized soil				
		12/4	12/6	12/8	12/10	12/14	12/4	12/6	12/8	12/10	12/14
Maneb	8	13.4	43.6	43.8	44.2	42.0	51.2	58.6	59.2	64.4	64.6
Captan	12	17.2	43.2	38.4	37.2	35.4	54.0	59.6	59.0	63.3	63.3
Thiram	6	14.2	36.0	35.0	33.0	32.2	51.4	54.0	55.4	60.2	61.4
Zineb	8	10.4	29.4	25.2	24.8	22.8	54.2	59.2	59.2	63.4	63.4
Non-treated check	--	2.2	10.8	7.8	7.6	7.0	52.8	58.4	58.6	59.6	60.2

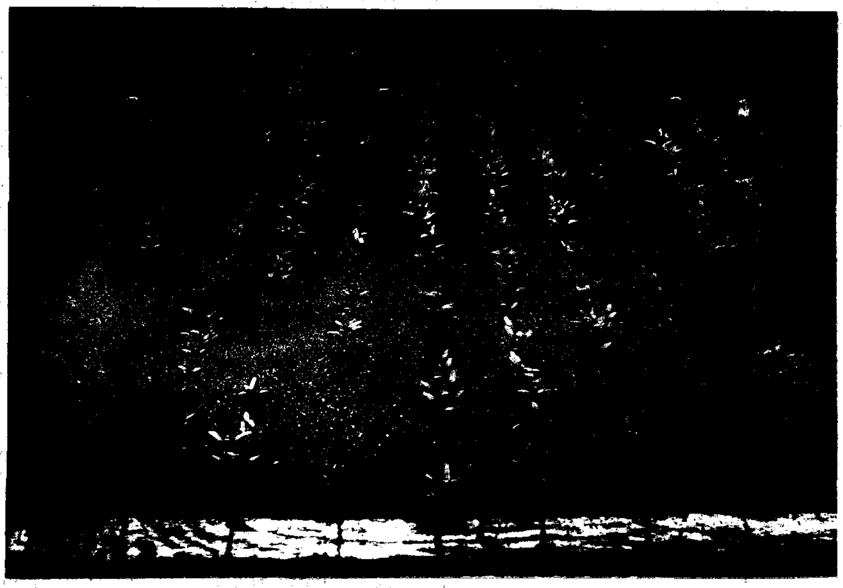


Figure 17. Comparative effectiveness of seed-treatment materials for the control of pre-emergence damping-off of sugar beet seedlings in soil artificially infested with Pythium ultimum.

Legend:
NT - Non-treated
M9 - Maneb 9 oz.
M6 - Maneb 6 oz.
A - Thiram 8 oz.
M8 - Maneb 8 oz.
C - Ceresan M 6 oz.
A-C- Thiram - Ceresan M.

artificially infested with Pythium ultimum. The same procedure was followed as in the preceding test. The effect of four fungicides on the control of pre-emergence damping-off of sugar beet seedling is presented in Table 8. Thiram and Zineb were less effective in controlling pre-emergence damping-off than Maneb or Captan. An average of 43.6 and 43.2 seedlings per replication were recorded on the third day after emergence for Maneb and Captan. These figures compared with an average of 10.8 seedlings per replication for the non-treated checks show an increase in stand of over 300 per cent. Post-emergence damping-off was evident when stand counts were made on the seventh and eleventh days after emergence. Figure 17 shows the effectiveness of certain seed-treatment materials for the control of pre-emergence damping-off of sugar beet seedlings as incited by Pythium ultimum.

Field Investigations - 1952

Seed treatment studies

In 1952 seed treatment trials were conducted in a field at Sterling, Colorado, known for its high incidence of disease. Treated and non-treated seed was planted in a randomized block with four-row plots. Each treatment was replicated three times in rows 30 feet long. Seed was planted by means of a hand planter on April 29, and stand counts on the two center rows of each plot were recorded on May 26. These data are presented in Table 9. Manzate-treated seed, at the rate of 8 ounces per 100 pounds of seed, showed a 215.7 per cent increase in stand over the non-treated check. Ceresan M and Agrox showed a 169.4 and 157.9 per cent increase, respectively, in stand over the non-treated check. Isolations from diseased beets taken from these plots revealed pure cultures of Pythium ultimum.

Table 9. Comparative effectiveness of seed-treatment materials for the control of pre-emergence damping-off of sugar beets. Field trial - 1952.

Treatments	Oz. per 100 lbs. seed	Average number seedlings per replication	Increase in stand over check (per cent)
Check	0	170.6	-
Manzate	8	538.6	215.7
Spergon	8	286.0	67.6
Agrox	4	440.0	158.9
Ceresan M	4	459.6	169.4
Phygon	6	396.0	132.1
Thiram	8	349.6	104.9

Soil treatment studies

Soil treatment plots of a triple-lattice design were employed in the field in 1952 to evaluate the comparative effectiveness of different soil-fungicidal materials. Nine replications of three 25-feet rows were made for each of the soil-fungicidal materials, and also the non-treated check. Each quantity of the different fungicidal material used per linear foot of row was thoroughly mixed with a given amount of finely screened sand for bulking purposes. The required amount of bulked material was applied to each 25 feet of row by means of a modified hand planter (Planet, Jr.) previously described in Chapter III. Stand counts were made prior to thinning. The differences in stand counts of seedlings for the non-treated soil check and the treated soil were an indication of the comparative effectiveness in the control of damping-off by the different soil-fungicidal materials employed in the experiment.

The data compiled in Table 10 show that Arasan and Zineb, at rates of four pounds per acre, significantly increased the stand of sugar beet seedlings over the non-treated check. Both *Pythium* and *Rhizoctonia* were isolated from diseased seedlings taken from the non-treated soil plots. The frequency with which the two organisms occurred was not recorded.

Application of a 10 per cent Thiram dust with a crop duster. A dust containing 10 per cent Thiram was applied at the rate of 20 pounds per acre to the soil at time of planting by means of a four-row conventional crop duster. Tests were conducted at three locations on farms in eastern

Table 10. Effectiveness of different soil-treatment compounds in the control of pre- and post-emergence damping-off of sugar beet seedlings.

Treatment[1]	Rate[2] pounds per acre	Average number plants per plot
Check	-	62.20
Fertilizer	75	61.62
Thiram	3	73.63
Thiram	4	86.34
Ceresan M	½	55.46
Ceresan M	1	72.26
Dow 9-B	4	56.12
Captan	4	71.73
Yellow cuprocide	4	66.44
Zineb	4	79.23
Phygon	2	67.44
Spergon	4	59.94
Crag 658	4	70.49
Dow D.H.A.	4	80.20
Cadminate	4	73.80

L.S.D. 5% = 13.12
L.S.D. 1% = 17.31

[1]Fertilizer, 12-24-0, at the rate of 75 pounds per acre, was added to each treatment with the exception of the check.

[2]Based on linear feet of row.

Colorado. Two four-row plots were treated the entire length of the field. The rows adjacent to the treated plots were considered as check plots. Prior to thinning, stand counts were taken on 100 inches of row at ten locations in each field. The average number of seedlings per 100 inches of row is tabulated in Table 11. On the Davis farm an 18.4 per cent increase in stand over the non-treated check was obtained. At the two other locations disease was not present, and, as a result, there was no difference between the treated and non-treated rows.

Table 11. The effect of a 10 per cent Thiram dust applied at the rate of 20 pounds per acre into the row at time of planting. 1952.

Treatment	Average number of seedlings per plot		
	Wolfe farm*	Kauffman farm**	Davis farm**
Check	319.6	100.5	115.3
Treated	312.5	108.6	136.6

* = 10 replications.
** = 5 replications.

<u>The effect of copper sulfate in the irrigation water</u>. Copper sulfate, at 25 pounds per acre, was applied into the irrigation water in a field known for its high incidence of Fusarium yellows. The experiment consisted of six-row plots, each row 150 feet long. Each treated and non-treated plot was replicated four times. Stand counts were taken on

50 feet of row from the four center rows of each plot. Copper sulfate was applied on May 28, at which time the first stand count was made. The final stand count was made just prior to harvest on September 20. Table 12 shows that copper sulfate at the rate used had no effect in reducing the loss caused by Fusarium oxysporum f. betae.

Table 12. The effect of copper sulfate in the irrigation water on the incidence of Fusarium yellows.

Treatment	Rate pounds per acre	Average number plants per replication		Per cent decrease in stand
		1st stand count	2nd stand count	
Copper sulfate	25	221.75	110.00	50.4
Check	0	211.75	110.75	47.7

Evaluation of sugar beet varieties

In 1951 a survey was begun to determine the resistance or susceptibility of commercial varieties and inbred lines of sugar beets to Fusarium oxysporum f. betae. A field was chosen near Sterling, Colorado, because its past history had shown losses ranging from 50 to 75 per cent. Different varieties of beets were planted for observation purposes in strips throughout a three-acre plot. Prior to harvest, mass selections were made from those varieties showing resistance.

In these tests, Variety G. W. 359 showed a high degree of resistance to *Fusarium oxysporum* f. *betae*.

In 1952 a more intensive study was made concerning the resistance of G. W. 359. Experimental plots were established in the same field as those conducted in 1951. Variety G. W. 359 was grown along with other varieties and inbred lines in strip plantings. Stand counts of 800 feet of row for each variety were made just after thinning and every month thereafter until harvest. The results of the stand counts are summarized in Table 13. The results of these trials showed that G. W. 359 and B 626, the Fusarium-resistant selection from G. W. 359, were the outstanding varieties. The total number of plants diseased in varieties G. W. 359 and B 626 was 44 and 38 per cent respectively. B 544 suffered the greatest loss during the season of any variety. However, the percentage of those beets alive on September 29 was about equal to other varieties tested. This may indicate that the variety was made up of susceptible and resistant individuals. Relatively few plants of B 525, the susceptible check, were lost during the growing season, but few healthy plants were found at harvest. C 455, B 630, and G. W. 329 were about equal as to stand loss and total diseased beets. Although these varieties did not approach G. W. 359 in resistance, it is believed that there were enough resistant beets in these varieties that improvement could be made by selection.

Table 13. Stand loss and percentage diseased beets in certain lines of sugar beets grown in a field naturally infested with *Fusarium oxysporum* f. *betae*.

Variety	Per cent lost beets 6/9-7/2	Per cent lost beets 6/9-8/5	Per cent lost beets 6/9-9/29	per cent[1] healthy beets 9/29	per cent[2] total diseased 6/9-9/29
C455	23	37	41	59	65
GW359	11	20	26	77	44
GW329	25	37	42	51	70
B626	11	20	26	84	38
B525	15	30	39	48	71
B593	24	38	45	64	65
B630	27	38	45	66	64
B544	37	51	60	66	74

[1]Percentage of live beets remaining 9/29 which were healthy as ascertained by top symptoms.

[2]Percentage of initial post-thinning stand, 6/9, which died during the season or were infected at the end of the season.

In order to obtain yield of roots, sugar content, and total sugars of the varieties known to be resistant to *Fusarium oxysporum* f. *betae*, a plot was established in the same field as the strip test. The test was a randomized complete block design with nine replications. Stand counts were taken on all plots after thinning and every month thereafter until harvest. Stand figures were based on a total of 1268 feet of row. Stand counts and disease incidence are summarized in Table 14. There appears to be little difference in stand loss between C359 with 28 per

Table 14. Stand loss and incidence of disease under a severe epiphytotic of Fusarium yellows in a variety test at Sterling, Colorado. 1952.

Variety	Per cent lost beets			Per cent[1] healthy beets	Per cent[2] diseased beets
	6/9-7/2	6/9-8/5	6/9-9/29	9/29	6/9-9/29
C359	11	18	21	72	43
B626	8	14	15	74	38
B589	6	13	16	69	42
GW529	12	22	25	51	63
B525	12	23	29	36	74

[1]Percentage of live beets remaining 9/29 which were healthy as ascertained by top symptoms.

[2]Percentage of initial post-thinning stand, 6/9, which died during the season or were infected at the end of the season.

cent, B 626 with 26 per cent, and B 589 with 31 per cent. Stand loss and total diseased beets are in the same magnitude for B 626 and C 359 as they were in the strip test. Variety B 525, the susceptible check, produced the largest number of diseased beets.

The desirability of a variety of sugar beets, as determined by stand counts, is often correlated with its desirability as determined by yield and sugar tests under disease conditions. In order to determine the effect of Fusarium oxysporum f. betae on yield and sugar content, the above-mentioned plots were trimmed approximately to stand prior to harvest. The harvested area of each plot was six rows 22 inches wide and 18 feet long. Sugar analysis was made on two samples per plot. The performance of the varieties is tabulated in Table 15. Varieties B 626, C 359, and B 589 were found not to differ significantly in the amount of sugar produced per acre. B 626 was found to produce more tons per acre than any of the other varieties, although there was no significant difference between B 626, C 359, B 589, and G. W. 529.

Varieties C 359, B 626, and B 589 were tested under Fusarium-free conditions in supplemental variety tests at three locations, the results of which are summarized in Table 16. In sugar per acre, C 359 was significantly higher than B 589, but was not significantly higher than B 626 in total sugar per acre. There was a significant drop in tonnage of Variety B 626 from its parent, C 359, however there was no significant difference in sugar content. Figure 18 shows a view of the field at Sterling, Colorado, in which the above tests were conducted.

Table 15. Yield of roots, sugar content, and total sugars of five varieties of sugar beets harvested from a field naturally infested with <u>Fusarium oxysporum</u> f. <u>betae</u>. 1952.

Variety	Yield of roots (tons per acre)	Sugar content (per cent)	Total sugar (pounds per acre)	Stand harvested (per cent)
B626	16.52	16.40	5419	87.0
C359	16.41	16.10	5285	83.0
B589	16.39	15.59	5109	84.0
GW529	14.83	14.66	4349	77.0
B525	12.24	13.68	3348	72.0
L.S.D. 5%	1.78	0.47	563	8.7
L.S.D. 1%	2.40	0.63	757	11.7

Table 16. Tons of beets per acre, percentage sugar content, and pounds of sugar per acre of three varieties of beets under Fusarium-free conditions. 1952.

Variety	Tons beets per acre	Sugar content (per cent)	Pounds sugar per acre
C359	21.82	15.13	6663
B626	20.69	15.11	6311
B589	21.05	14.78	6289
L.S.D. 5%	1.03	0.57	375

Figure 18. Resistance and susceptibility of different sugar beet varieties to _Fusarium oxysporum_ f. _betae_ as shown in the test plot at Sterling, Colorado. Variety G. W. 359 is in the center of the photograph.

Field Investigations - 1953

Soil treatment studies

In 1953 certain fungicides were applied into the row at the time of planting by means of a four-row Milton drill designed for the specific purpose of applying fungicides into the soil. Each of the materials used was thoroughly mixed with a given amount of finely screened sand for bulking purposes. At the time of planting, the furrow openers were adjusted to a depth of 1 1/2 inches and placed immediately in front of the planters. The fungicide and sand mixture fell through a flexible metal tube, as previously described, and was mixed with a band of soil approximately 3 inches wide and 1 1/2 inches deep. As the planter moved forward, seed was planted in the treated row.

An experimental plot was established in the same field in which the variety tests were conducted. A randomized complete block design was employed which consisted of 12 treatments with 6 replications, 4-row plots, each row 30 feet long. Only the two center rows of each plot were treated. Planting was completed on April 21, and the first stand count on the center 15 feet of row was made on May 21. The first stand count after thinning was made on May 25, and the second was made just prior to harvest. Counts were made on 30 feet of row.

Table 17 shows the results of these trials. Statistical analysis of the data was not determined because there were no apparent differences in stand counts taken before thinning. However, the results show that CBP-55 and P-162, as applied by the drip method, suppressed the growth of the emerging seedlings. Z.A.C. and Vancide 51, at the rates of 4 pounds per acre, also were injurious to the beet seedlings. Stand counts taken prior to harvest showed that a commercial fertilizer, 12-24-0, applied at the rate of 75 pounds per acre in the row at time of planting reduced the incidence of Fusarium yellows as incited by _Fusarium oxysporum_ f. _betae_. The reduction in stand loss from the use of the fertilizer was 28.5 per cent as compared to a loss of 46.8 per cent in the non-treated check.

Field Investigations - 1954

Seed treatment studies

To further evaluate Maneb and Captan as fungicides for sugar beet seed treatment, extensive field trials were conducted during the spring of 1954. In cooperation with the field men of the Great Western Sugar Company, seed treatment trials were conducted at 31 locations throughout the Great Western Sugar Company territory. Treated and non-treated seed was planted in strips the entire length of each field. Stand counts were made on 100 inches of row at

Table 17. Comparative effectiveness of fungicides applied to the row at time of planting for the control of pre- and post-emergence damping-off of sugar beets. 1953.

Treatment	Pounds per acre	Average number plants per plot: Stand count before thinning[1]	1st stand count after thinning[1]	2nd stand count after thinning[1]	Decrease in stand[2] Per cent
Check		258.2	75.5	40.2	46.8
Thiram	4	254.0	86.3	50.5	41.5
Zineb	4	246.5	76.5	45.8	40.1
Captan	4	241.3	85.7	52.0	39.3
Vancide Z. W.	4	254.8	82.8	49.0	40.8
Z.A.C.	4	143.5	47.8	25.0	47.6
Vancide 51	4	187.0	62.0	31.5	49.2
Ceresan M	1	215.0	66.3	34.0	48.7
XP-47	3	240.0	84.1	54.2	35.6
Fertilizer 12-24-0	75	231.8	79.3	56.7	28.5
CBP-55	**	229.6	71.5	31.0	56.6
P-162	**	171.3	58.7	30.3	41.6

**Applied at rate of 0.5 ml. per foot.
[1]Average of two center rows of 4-row plot.
[2]Determined from 1st and 2nd stand counts after thinning.

twenty locations in the field. Seed treated with Phygon and Thiram was included in the tests because 95 per cent of the beet seed used in the Great Western Sugar Company territory is treated with either of the two fungicides.

The results of these tests, as tabulated in Table 18, show that Maneb increased the stand at Brush, Fort Morgan, Eaton, Billings, and Lovell, with increases in stand over the non-treated check of 10.2, 33.8, 23.9, 42.6, and 9.9 per cent, respectively. At Sterling, Maneb was equal to Captan and Thiram. Phygon, Maneb, and Thiram produced the greatest percentage increase in stand at Greeley. In Nebraska, Phygon and Captan were the outstanding treatments.

At the time the results of the seed treatment tests were being compiled, each field man was requested to include, in addition to the results of the seed treatment tests, a past history of the crop sequence in the field in which the seed treatment tests were conducted. It is of interest to note from Table 19 that the greatest per cent increase in stand was obtained by a Maneb seed treatment following corn. Furthermore, it was shown that Maneb offered more protection, or equal protection, to the germinating seed than any of the other treatments following beans, beets, or potatoes. Thiram appeared to be the best treatment following small grain.

Table 18. Results of 31 seed-treatment trials at 12 locations. 1954.

Location	Number of trials	Percentage of check[1]			
		Treatment and dosage			
		Captan 12 oz.	Phygon 6 oz.	Maneb 10 oz.	Thiram 6 oz.
Colorado					
Brush	3	103.3	105.5	110.2	109.6
Windsor	3	94.5	116.7	99.1	126.4
Fort Collins	2	97.5	109.4	103.9	104.6
Fort Morgan	3	112.7	112.4	133.8	98.7
Brighton	2	120.6	130.2	111.5	118.4
Sterling	2	127.4	116.7	129.2	131.4
Eaton	3	108.5	98.2	123.9	114.6
Greeley	4	111.1	121.3	120.1	117.6
Montana					
Billings	2	126.1	101.5	142.6	140.1
Nebraska					
Scottsbluff	3	135.9	109.1	109.9	113.7
Lyman	2	137.1	148.6	127.2	127.7
Wyoming					
Lovell	2	99.8	109.3	109.9	102.6

[1]Check equals 100 per cent.

Table 19. The results of previous cropping on the effect of seed treatment of sugar beets.

Previous crop	Number of tests	Per cent increase in stand over check Treatment			
		Captan	Phygon	Maneb	Thiram
Corn	2	6.55	25.93	29.99	13.92
Beans	16	19.26	9.06	21.91	15.48
Beets	7	8.12	10.18	11.23	12.32
Small grain	3	11.55	15.03	10.44	20.34
Potatoes	3	0.32	12.06	11.92	8.32

In order to further evaluate the testing procedures used in the laboratory and greenhouse studies, a seed treatment trial was conducted in a field known for its high incidence of disease at Sterling, Colorado. The four fungicides used in the laboratory and greenhouse studies were evaluated in a complete randomized block design with six replications. Each plot consisted of four rows 30 feet long. Planting was completed on April 6, and stand counts on the middle 20 feet of the two center rows of each plot were taken on May 20.

The average number of seedlings per replication resulting from these tests is shown in Table 20. Captan, Maneb, and Zineb were significant over Thiram at the 5 per cent level, but only Captan was significant at the 1 per cent level. There was no significant difference between Maneb and Zineb.

Table 20. Relative value of four chemical seed treatments as measured by emergence and by control of pre-emergence damping-off of sugar beet seedlings in the field. 1954.

Treatment	Ounces per 100 pounds of seed	Average number seedlings per replication
Captan	12	549.00
Maneb	8	480.00
Thiram	6	410.16
Zineb	10	489.50
Check	0	356.16

L.S.D. 5% - 60.70
L.S.D. 1% - 82.78

Soil treatment studies

It was shown in Tables 5 and 6 that Maneb as a soil treatment was more effective in controlling post-emergence damping-off of sugar beets than seed treatment. In order to gain more information concerning the effectiveness of soil treatment for the control of pre- and post-emergence damping-off of sugar beets, a 7 x 7 latin square design was employed for the field evaluation of the four fungicides evaluated in the laboratory and greenhouse. Each plot consisted of four rows, each row 30 feet long. Fungicides were applied into the row at the time of planting by means of a Milton drill designed for the specific purpose of applying fungicides into the soil. Beets were planted on

April 6, and stand counts of emerged and surviving seedlings were recorded on May 20. These results are presented in Table 21. Even though these results show an increase in stand with the use of Captan at the rate of 4 pounds per acre, the differences were not significant statistically.

Table 21. Comparative effectiveness of fungicides applied to the row at time of planting for the control of pre- and post-emergence damping-off of sugar beets. 1954.

Materials	Rates pounds per acre	Average number seedlings per replication
Thiram	4	144.14
Maneb	4	164.71
Captan	4	192.14
Captan	6	182.00
Zineb	5	148.42
Vermiculite	*	161.29
Check	-	152.14
F-value	1.14	
5%	2.42	
1%	3.47	

*Applied at same rate as mixed with fungicides.

Evaluation of control measures

Seed treatments, soil treatments, commercial fertilizers and green manures, liming, cultivation, and various cropping practices, have been recommended for the control of pre- and post-emergence damping-off of sugar beet seedlings. The results of the above tests show that seed and soil treatments are beneficial in reducing the incidence of disease of sugar beet seedlings. In order to obtain further information concerning the effect of seed and soil treatment and other agronomic practices on the incidence of seedling diseases of sugar beets, an experimental plot was established on the Colorado Agricultural Experiment Station farm at Fort Collins, Colorado. The experiment consisted of seven treatments and a non-treated check, each replicated four times in four-row plots. Each row was 50 feet long. Beets were planted on August 10 with the Milton planter. The plot was sprinkled every evening by means of an overhead sprinkling system. The first stand count after emergence was made on August 18, and final counts were taken on September 3.

Statistical analysis of the data obtained from the first stand count after emergence showed that Maneb-treated seed, plus the application of Maneb into the soil at the time of planting, significantly increased the stand of sugar beet seedlings over the non-treated check, Table 22.

Table 22. Field evaluation of control measures for pre- and post-emergence damping-off of sugar beets.

Treatment	Average number seedlings per replication	
	1st reading	2nd reading
Maneb-treated vermiculite 4 lbs./acre	385.50	464.25
Maneb spray 4 lbs./acre	287.50	336.00
Maneb-treated seed 10 oz./100 lbs. seed	371.75	432.00
Maneb-treated seed plus Maneb-treated vermiculite 4 lbs./acre	425.50	534.00
Maneb-treated seed plus Maneb spray 4 lbs./acre	371.50	452.00
Maneb-treated seed plus cultivation upon emergence	322.75	398.75
Maneb-treated seed plus Maneb spray upon emergence	399.75	460.25
Non-treated check	321.25	372.50

1st reading L.S.D. 5% = 80.00; 1% = 110.13
2nd reading L.S.D. 5% = 90.00; 1% = 122.68

The results obtained from the second stand count after emergence show that Maneb-treated seed plus Maneb as a soil treatment significantly increased the stand over the non-treated check at both the 5 and 1 per cent level. Maneb as a soil treatment alone showed significance over the non-treated check at the 5 per cent level, but not at the 1 per cent point. Maneb in the form of a spray was not as effective as Maneb applied with vermiculite. Cultivation had little, if any, effect on the number of emerging seedlings. Post-emergence damping-off was not evident in the field as indicated by the difference in the first and second stand counts.

DISCUSSION

During the past three years (1952-1954) seed- and soil-treatment trials have been conducted in fields known to have a past history of pre- and post-emergence damping-off of sugar beet seedlings. In many of the strip tests conducted at different locations, the results were erratic. In order to determine if different races or strains of the organisms responsible for damping-off were present, pathogenicity tests were conducted in the greenhouse in steamed soil artificially inoculated with the causal agents. From preliminary tests, five isolates of Rhizoctonia solani and one isolate of Pythium ultimum were selected for further study.

Based on culture characteristics, there appears to be two distinct strains of Rhizoctonia solani used in these studies. The mycelium of isolate Number 1, when grown on potato dextrose agar, appears whitish to cream color. Isolates Numbers 50, 10A, 53, and 11A each have the characteristic light brown color when grown on potato dextrose agar. However, when pathogenicity tests were conducted with the five isolates of Rhizoctonia, large differences among the isolates resulted. Isolate Number 10A was found to be extremely pathogenic to sugar beet seedlings. The difference in the average number of seedlings per replication resulting from these studies indicated that there was no difference in degree of pathogenicity among isolates Numbers 50, 53, and 11A. On the basis of the pathogenicity tests, there appears to be three distinct strains of Rhizoctonia: (1) Isolate Number 1; (2) isolates Numbers 50, 53, and 11A; (3) and isolate Number 10A.

Temperature studies with the five isolates of Rhizoctonia showed that isolate Number 1 grew more rapidly at 10° and 22° C. than any of the other isolates. The growth rate of Isolate 10A was slower than any of the other isolates at 10° and 35° C.

The effect of certain fungicides on the growth of the five isolates of Rhizoctonia solani was studied on artificial media. The results of these trials showed that isolate Number 1 was more sensitive to Maneb and Thiram at all concentrations than to either Captan or Zineb. The differences among the other isolates were negligible.

It appears, therefore, from these studies that three strains of Rhizoctonia are present among the five isolates. When subjected to various chemical compounds, there appeared to be no differences in resistance of the three strains to the chemical compounds employed, except for that noted above.

Another study was undertaken but was not reported in the chapter on experimental results. Seeds treated with different fungicides were evaluated in soil which had been artificially infested with each of the five isolates of *Rhizoctonia*. The experiment was repeated three times, but due to the variability among trials, no definite conclusions could be drawn. It was evident from these studies, however, that Isolate 10A, as well as the other isolates, was capable of causing post-emergence damping-off of sugar beet seedlings 14 or more days after emergence.

It was shown from the seed- and soil-treatment studies in aluminum pans in the laboratory that Maneb as a soil treatment was more effective than seed treatment in controlling pre- and post-emergence damping-off of sugar beet seedlings. Maneb at 100 ppm was found to be very effective in inhibiting the mycelial growth when incorporated into potato dextrose agar plates. However, when Maneb was incorporated into *Pythium*- and *Rhizoctonia*-infested soil at 100 ppm, only partial control was obtained. The best results were obtained from the soil treatment studies at 300 ppm. Concentrations of 500, 800, and 1000 ppm of Maneb were phytotoxic to the emerging sugar beet seedlings. The differences in emergence counts among plants grown in inoculated and non-inoculated soils which had been treated with Maneb at 500, 800, and 1000 ppm may be attributed to the effect of adverse growing conditions of the suscept. Any injury or adverse condition which delays the germination of sugar beet seed increases the susceptibility of the emerging seedling to pre- and post-emergence damping-off.

The results obtained from the seed treatment studies conducted in infested soil show that both Pythium and Rhizoctonia are responsible for pre- and post-emergence damping-off of sugar beet seedlings. These data indicate little difference in the incidence of pre-emergence damping-off as incited by either Pythium or Rhizoctonia. The data presented in Tables 5 and 6 show that the incidence of post-emergence damping-off was greater in Rhizoctonia-infested soil than in Pythium-infested soil when the seed was treated at the rate of 6 ounces per 100 pounds. At this dosage only partial control was obtained. However, at the higher dosage rates there appeared to be little difference in the incidence of post-emergence damping-off. These results were further substantiated by greenhouse tests (Tables 7 and 8) in soil artificially infested with Pythium and Rhizoctonia. Post-emergence damping-off was negligible when seed was treated with Maneb at 8 ounces per 100 pounds and planted in soil infested with Rhizoctonia and Pythium. If seeds were treated with a fungicide which offered only partial control, post-emergence damping-off was evident. There appeared to be a general trend for seedlings growing in Rhizoctonia-infested soil to have a higher degree of post-emergence damping-off than in Pythium-infested soil.

although the differences in many cases were small. It is believed that if the different tests had been extended to a longer growing period, the differences would have been even greater.

The evaluation of seed- and soil-treatment fungicides on a field basis always constitutes a problem so far as dosage rates are concerned. The establishment of soil- and seed-treatment experimental plots are not only time consuming but very costly. It is always advantageous to keep the number of compounds and their dosage rates to a minimum in field testing. There appears to be a great need for laboratory and greenhouse techniques for the screening of seed- and soil-treatment fungicides.

An attempt was made in these studies to correlate different testing methods in the laboratory with greenhouse and field data. Table 4 shows that Maneb incorporated into potato dextrose agar at 100 ppm completely inhibited the growth of Pythium. Tests were conducted, which are not reported in this thesis, in which analytical filter papers, 1/2 inch in diameter, were soaked in different concentrations of Maneb and then placed in the center of potato dextrose agar plates. The plates were then inoculated at two separate locations with Pythium. Concentrations as high as 1000 ppm failed to inhibit the growth of mycelium. Additional tests were conducted in small glass vials in which *Pythium*-infested soil was mixed with a Maneb-vermiculite mixture. Small agar discs, 1.0 cm. in diameter, were removed from five-day-old cultures of *Pythium* and placed one inch deep in the treated soil. The vials were watered and left at room temperature for two days, after which time the agar discs were removed from the soil and planted on potato dextrose agar plates. Concentrations of Maneb up to 1000 ppm failed to inhibit the growth from the agar discs. The most consistent results were obtained by incorporating the fungicide into warm potato dextrose agar. When these data (Table 4) were compared with the results obtained in the tests in which beet seed was planted in soil treated with a Maneb-vermiculite mixture in the aluminum pans (Tables 5 and 6), it was shown that partial control was obtained at 100 ppm, and almost complete control was obtained at 300 ppm.

In order to compare the results obtained in the laboratory and greenhouse with field results, it was assumed that an acre of soil 6 inches deep weighs 2,000,000 pounds. A band of soil 3 inches wide, 1 inch deep, and 12 inches long would then contain 867.74 grams of soil. An application of a fungicide into the soil at the time of planting at the rate of 4 pounds per acre per linear foot of row 22 inches wide, would be equal to an application of approximately 86.6 ppm. This figure approximates the rates of control obtained in the laboratory and greenhouse.

Even though significant differences have been obtained with the application of fungicides into the row at the time of planting, the results have been discouraging. At the present time, soil treatment of sugar beets in Colorado is not being practiced due to the added cost of applying the fungicide. At the present prices, the cost of treating an acre of soil approximates four dollars. The cost of seed treatment is about 2 cents an acre.

Seed treatment of sugar beets has long been recognized as a control measure for pre-emergence damping-off of sugar beets. However, relatively little is known concerning the extent of the protection offered by a seed treatment around a germinating beet seed. Preliminary trials were conducted in the greenhouse in order to determine the effectiveness of seed and soil treatments at different depths of planting in pasteurized soil artificially infested with _Pythium ultimum_. A portion of the infested soil was treated with Maneb at the rate of 300 ppm and placed in paraffin-impregnated cups (cottage cheese cups). Sugar beet seed was also treated with Maneb at the rate of 8 ounces per 100 pounds and planted at different depths in the treated- and non-treated infested soil. Stand counts taken after emergence showed that seed treatment was as effective as soil treatment in controlling pre- and post-emergence damping-off when beet seed was planted at a depth of 1/4 inch. However, when seed was planted at depths of 1/2, 1, and 1 1/2 inches, the effectiveness of soil treatment was much greater than seed treatment.

Seed treatment studies conducted at 31 locations throughout the Great Western Sugar Company territory showed that Maneb increased the stand more consistently than any of the other compounds. In Nebraska, Phygon and Captan were the outstanding treatments. A test of this kind is always difficult to evaluate. Different planting rates, types of planters used, soil types, environmental factors, etc., play an important role in the evaluation of such a test. Unfortunately, it was impossible to make isolations from diseased beets at each of the locations. It may have helped to explain the differences obtained at the different locations.

Under extreme epiphytotic conditions, Variety G. W. 359 was found to be the most resistant commercial variety tested when grown in a field naturally infested with *Fusarium oxysporum* f. *betae*. There appeared to be little difference in stand loss between G. W. 359 and B 589. It was shown from Table 14 that there was little difference between G. W. 359 and B 626, which indicates that resistance was not stepped up by one year of selection. However, the difference between B 589 and its parent, G. W. 529, was striking. The step-up in resistance of B 589 over its parent, G. W.

529, would indicate that where the frequency of resistant beets is low in a variety, one generation of selection makes a great improvement. It was shown that B 626, C 359, and B 589 were statistically equal in sugar production per acre. B 626 was the highest yielding selection and had the highest sugar content of the three. G. W. 359, without selection, performed well under severe *Fusarium* conditions, and as well as or even better than B 589, which is a *Fusarium*-resistant selection from a susceptible variety. A comparison of the performance of G. W. 529 and B 589 indicates that progress can be made by selecting for resistance in a variety initially low in resistance. The performances of B 525 and G. W. 529 emphasize the effects of *Fusarium oxysporum* f. *betae* on a susceptible variety. Yield loss may be considered the result of stand loss. On the other hand, the great reduction in sugar content is probably caused by the presence of the organism in the plant.

SUMMARY

Tests were conducted in the laboratory, greenhouse, and in the field to show the effect of seed and soil treatments on the control of pre- and post-emergence damping-off of sugar beets incited by five isolates of *Rhizoctonia solani* and one isolate of *Pythium ultimum*. Different varieties of sugar beets were evaluated in the field for their resistance or susceptibility to *Fusarium oxysporum* f. *betae*. The results may be summarized as follows:

1. Three separate strains of *Rhizoctonia solani* were identified on the basis of pathogenicity, cultural characteristics, and rate of growth at different temperatures.
2. When subjected to various chemical compounds, there appeared to be no differences in resistance of the three strains to the chemical compounds employed. However, isolate Number 1 was more sensitive to Maneb and Thiram, at all concentrations, than to either Captan or Zineb.
3. Maneb incorporated into warm potato dextrose agar plates at 100 ppm inhibited the mycelial growth of *Rhizoctonia solani* and *Pythium ultimum* when they were transferred to the plates by small agar

discs removed from five-day-old cultures.

4. Maneb was evaluated as a seed- and soil-treatment fungicide in infested and non-infested soil in the laboratory. The results showed that a Maneb-vermiculite mixture applied to the soil at 100 ppm was more effective in controlling post-emergence damping-off than seed treatment. A method of evaluating seed- and soil-treatment fungicides in aluminum pans was described.
5. Laboratory and greenhouse studies showed that Rhizoctonia solani and Pythium ultimum were both responsible for pre-emergence damping-off of sugar beets. There appeared to be a general trend for seedlings growing in Rhizoctonia-infested soil to have a higher degree of post-emergence damping-off than in Pythium-infested soil, although the differences in many cases were small.
6. Screening tests in greenhouse soil artificially infested with Rhizoctonia and Pythium showed that Maneb, as a seed treatment, 8 ounces per 100 pounds of seed, controlled pre-emergence damping-off very effectively.
7. Maneb was evaluated as a seed- and soil-treatment fungicide at different depths of planting in

soil artificially infested with *Pythium ultimum*. There were no apparent differences in the amount of pre- and post-emergence damping-off between seed and soil treatment when seed was planted 1/4 inch deep. At depths of 1/2, 1, and 1 1/2 inches, soil treatment was more effective in controlling pre- and post-emergence damping-off than seed treatment.

8. Maneb incorporated in warm potato dextrose agar was found to be the most satisfactory laboratory test for the evaluation of seed- and soil-treatment fungicides against *Rhizoctonia* and *Pythium*. Dosage response in laboratory testing was in close agreement with greenhouse and field results.

9. Applications of fungicides into the row at the time of planting with a modified hand planter (Planet Jr.), showed that Thiram and Zineb at 4 pounds per acre significantly increased the stand of sugar beet seedlings over the non-treated check.

10. Consistent results were not obtained by the application of a 10 per cent Thiram dust into the row at the time of planting with a four-row crop duster.

11. Copper sulfate, at 25 pounds per acre, applied into the irrigation water was not effective in controlling Fusarium yellows of sugar beets.

12. Under extreme epiphytotic conditions, Variety G. W. 359 was found to be the most resistant commercial variety tested when grown in a field naturally infested with Fusarium oxysporum f. betae. Selections were made from resistant and susceptible beet varieties. It was shown that where the frequency of resistant beets was low in a variety, one generation of selection makes a great improvement. Variety B 626 was highest in acre yields of beets and in sugar content, but not significantly higher than its parent variety C 359 or B 589.

13. Seed treatment trials conducted at 31 locations showed that Maneb increased the stand more consistently than any of the other compounds employed.

14. Field tests conducted in 1954 showed that Maneb-treated seed plus the application of a Maneb-vermiculite mixture into the soil at time of planting, significantly increased the stand of sugar beet seedlings over the non-treated check. Maneb as a soil treatment alone showed signifi-

cance over the non-treated check at the 5 per cent level but not at the 1 per cent level. Cultivation had little, if any, effect on the number of surviving seedlings.

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