THE INFLUENCE OF SOME AGRONOMIC PRACTICES ON THE PREVENTION OF BLACK-ROOT OF SUGAR BEETS

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Grant Elwyn Nichol

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THESIS

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by

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Introduction

Damping-off of sugar beet seedlings is a condition apparently caused by the action of certain organisms, resulting in the death of the plants about the time that they emerge from the soil. It is a source of loss well-known to beet growers throughout the world.

Losses from damping-off generally occur when the beets are in the seedling stage; sometimes before the seedlings are out of the ground, generally before they have developed their first pair of true leaves, but sometimes even after the crop has been blocked and thinned.

Damping-off has also been commonly called: black-root, black-rot, black-leg, and root disease, descriptive of the appearance of the injury which it produces on the roots of the seedlings.

Damping-off varies from year to year, between localities, and between fields in a given locality. Losses from it are unpredictable, and may range from a trace up to the destruction of the entire crop in a field. Many experimenters think that the condition may be correlated with unfavorable growing conditions in the spring, such as heavy rainfall, long periods of rainfall, poor drainage, and low temperature. The impression is that losses are usually greater on heavy soils.

During some seasons, it is quite general over a beet growing area. In other years it may be confined to one or two factory districts in a beet growing region. It may almost completely destroy a stand of beets in one field, while an adjoining field may be free from the condition. In other cases, it has been known to destroy parts of a field of beets, killing the beets in one or more irregular patches in the field, or sometimes killing most of the beets up to some clearly defined line across the field and doing no damage in the remainder of the field. It has been known to wipe out a stand of beet seedlings, but the same land when replanted showed no sign of damage from damping-off.

Damping-off is apparently caused by fungi organisms which are present in varying numbers on beet seed and in all soils, but which do not always affect the beet crop. Three organisms are responsible for most of the losses from damping-off of sugar beet seedlings. They are: Phoma betae, Phythium spp., and Rhizoctonia spp.

Phoma betae is always present on shipments of European-grown beet seed, and is sometimes present on American-grown seed. This organism does not live over winter in the soil, except on beet refuse, so the source of infection is always from the use of infected seed, providing a normal crop rotation is followed. Species of Phythium and Rhizoctonia are found living saprophytically in varying numbers in almost all soils.

Coons and Stewart (1) describe the effects of the above-mentioned organisms on sugar beet seedlings as follows: With Phoma betae infection "the seedling shows a browning and blackening of the hypocotyl and root. The discoloration usually shows above the surface of the ground before the seedling topples over. The killing may be fairly rapid or take place so slowly that the seedling seems almost ready to outgrow the disease. Plants are frequently found with hypocotyl completely blackened as far as the cotyledon, which remains turgid and green. Examination of such plants shows the vascular region as the only part not affected. The general impression one has from the examination of such a seedling is that the attack has been made by a moderately rapidly growing organism, which produces a dry type of decay".

Infection from Pythium spp. causes a type of disease "in which rapid wilting occurs, usually unaccompanied by marked discoloration. Such plants have a brown decayed region in the root, and the central vascular region is discolored far in advance of the external lesions. The lesions have a water-soaked appearance as compared with the dry, black lesions characteristic of the Phoma type of attack. Twenty-four hours after the first indications of wilting the seedling is almost completely decayed."

With Rhizoctonia infection, "which is not so distinctive in appearance as the others, the color of the young leaves gives the first indication of disease. The leaves may be merely deeper green in color, but occasionally they are blue green. Associated with this sign, one finds often a lemon-yellow color of the stem. The seedlings grow slowly and, in general, show evidence of malnutrition. On removing the seedlings from the soil, the tap-root is found decayed at the tip and the rootlets above the decayed region are developing, apparently attempting to replace the primary root. No doubt, many of the seedlings thus affected develop into marketable mature beets, but of poor type." This disease is commonly known as "root rot" or "tap root tip rot". It is first noted as a wilting of the leaves of certain plants in a field during the hot days of mid-summer. If these plants are pulled up it is found that the extreme ends of the tap-roots are rotted off. Many of them have just enough root system to keep the plant alive during the growing season. Such plants do not develop roots of marketable size.

Nuchols and Tompkins (23) described healthy beet seedlings as having erect straight petioles; while beets affected by damping-off organisms had petioles which were distinctly bowed at the base, leaving the plant with an open type of top which was vase-like in appearance. Associated with this was a pale leaf color of the diseased plants. They advocated the educating of beet workers to recognize the symptoms so that they could remove diseased plants and leave healthy ones, at the time of thinning.

Most of the experimenters working with this problem have attempted to control damping-off by the use of fungicidal dusts on the seed. Results from this work have varied a great deal and usually no definite conclusions were reached.

Some experimental workers have attempted to prove that good cultural practices will reduce losses from damping-off. They have been somewhat successful in that any practice which will enable air to get into the soil will make conditions more unfavorable for the growth of damping-off organisms. This is well demonstrated by ridge planting, which allows a maximum of air to get into the surface of the soil.

There has been an impression that legumes, such as alfalfa and sweet clover maintain some of the damping-off organisms in the soil, and that cultivated crops, especially corn, present a condition which is not so favorable for the maintenance of these organisms. A limited amount of experimental work has shown this to be true. This fact may have some practical application in the planning of crop rotations which include sugar beets.

It has been noted that when beet seedlings were very thick in the rows, it resulted in heavy losses of the plants. This suggested that possibly overcrowding caused a weakening of the plants, and has resulted in some experimental work with heavy rates of fertilization. The results from this work show, in general, that the use of fertilizers, especially those carrying sodium, results in a smaller percentage of loss from damping-off.

Present Status of the Problem

Damping-off of sugar beet seedlings has been recognized for many years as one of the factors which has retarded the development of the sugar beet industry. While considerable research has been made on the problem, many of the findings are contradictory, and as a result, no definite control measures have been recommended.

It is quite generally agreed that the three organisms; *Phoma betae*, *Pythium* spp., and *Rhizoctonia* spp. are responsible for most of the losses from damping-off of sugar beet seedlings; the *Phoma betae* being carried on the seed, while *Pythium* and *Rhizoctonia* are present in the soil.

Dusting of the seed with fungicidal dusts usually will cut down on losses from *Phoma betae*, but will not eliminate these losses entirely. Seed dusting apparently has little, if any, effect in controlling *Pythium* and *Rhizoctonia*.

Good cultural practices, meant to increase aeration of the surface soil, works out nicely in the armchair, but unfavorable weather conditions may make it impossible to carry out these plans in the field.

The problem seems to be one of making conditions as favorable as possible for the germination and growth of the beet seedlings, and at the same time making conditions unfavorable for the development of the organisms causing losses from damping-off.

Purpose of Problem

The purpose of this work was to attempt to find some control measure, or measures, which a beet grower could apply as insurance that his sugar beet seedlings would not be destroyed by damping-off. No attempt was made to isolate and study the fungi organisms which are ordinarily held responsible for causing this disease.

Review of Literature

Due to inaccessibility of many references, the following review of literature made by Coons and Stewart (1) in 1927, is given.

"Root disease, black-rot, or black-leg has long been known as a sugar beet disease problem. In the old literature, insects and soil factors were believed responsible. Hellriegel (7) first called attention to the fungous and bacterial factors involved when by a 20-hour soaking of the seed in one per cent carbolic acid solution he lessened the root-rot. He attributed this effect to the disinfection of the seed ball. The work of Wimmer (16), Wilfarth (17), and Karlson (9), substantiated this viewpoint. Frank (6) and Kruger (10), later demonstrated the seriousness of *Phoma betae*, but the tendency of nearly all of the older research work was to look upon root disease as an indication of some defect in cultural conditions rather than a parasitic relation influenced by environmental conditions.

Duggar and Stewart (4) in 1901, proved that *Corticium vagum* B. and C. *solani* Burt. (called by them *Rhizoctonia*) was capable of killing sugar beet seedlings. Pammel (11), Selby (15), and Duggar (3) had previously reported *Rhizoctonia* as causing root-rot in fields of mature beets.

European literature for many years has had numerous, more or less intensive studies on sugar-beet root diseases called "Wurzelbrand". In a series of reports between 1906 and 1911, Peters and his associates (12) went over the voluminous literature and from this and their own experiments concluded that Pythium *debaryanum* Hesse, *Phoma betae* (Oud.) Fr., Aphanomyces laevis de By. were the organisms concerned in the production of seedling diseases of sugar beets in Germany. The German investigators were unable to produce damping-off with Rhizoctonia violocea Tul.

In 1915, Edson (5) working at Madison, Wisconsin, found that Phoma betae, Pythium debaryanum and Rhizoctonia spp. as well as an organism which he later named Rheosporangium aphanidermatum[1], were the principal organisms concerned in the seedling diseases of sugar beets in the United States. Each organism produced a high percentage of diseased plants when introduced into the seed bed. Edson also found Phoma betae present in all lots of seed balls from Europe or America examined, thus confirming the previous results of Peters.

Although Phoma is constantly being introduced into sugar beet fields, Pool and McKay (13) have shown that it does not live from year to year in the soil except on fragments of sugar beet tissues. However, Rhizoctonia, and the Phycomycetes, Pythium debaryanum, Aphanomyces laevis, and Pythium aphanidermatum, are common soil organisms (Jensen (8); Drechsler (2) widely distributed in nature.

The problem of controlling sugar beet seedling diseases is, therefore, concerned with the seed-borne fungus, Phoma betae, and the numerous soil inhabiting fungi capable of attacking beets. It is obvious that since non-infested soil cannot be found for use with disinfected seed, seed treatment at best can be only partially effective.

Besides this difficulty, it has been found by several experimenters that treatment of seed to eliminate Phoma betae was not possible. Edson (5), in an attempt to free seeds from Phoma betae, tried three different treatments: (a) strong solution of hydrochloric acid, (b) concentrated

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1. Now known as Pythium aphanidermatum (Edson) Fitp.

sulphuric acid for one hour, and (c) two per cent formaldehyde solution. Each treatment was used for periods sufficient to injure the seedling without materially reducing the subsequent development of Phoma.

However, Peters' method of pasteurization at 60°F, for ten minutes on two successive days gave one Phoma-diseased plant in about three or four hundred. Edson (5, p. 138) states that this method is not practical for field use, as the germination is reduced. In 1924, Miss Rumbold (14) reported favorable results in sugar beet seed disinfection using formaldehyde and steam in a sort of combination pasteurization and disinfection system. This method has not come into general use."

Coons and Stewart (1) considered that damping-off was of importance to the sugar beet industry in that it caused immediate loss of seedlings, resulting in a reduced stand; and that it was the cause of root-rot which appeared in partially grown beets later in the season. Their investigations consisted of seed treatments with various materials. Wet treatment of beet seed was considered impracticable from a commercial standpoint, because of the impossibility of handling large quantities of seed in this manner. Dusting of the seed, while entirely possible from the handling standpoint, frequently was too expensive because of the lack of assurance that treatment was always necessary to prevent damping-off. Mercury dusts were considered to be especially expensive. They concluded that a mixture of copper and mercury compounds would make a dust which had fair fungicidal properties combined with low cost. They felt that seed treatment might have commercial possibilities after further investigations.

LeClerg (21) found that beet seed treatment with Ceresan seed disinfectant in Minnesota not only increased the number of seedlings per 100 feet of row, but increased the percentage stand before harvest and the final yield in tons.

Leach and Houston (20) state that soil-borne *Pythium* sp. and *Rhizoctonia solani* are the most important organisms causing damping-off of sugar beets in Northern California, and that *Phoma betae* is frequently destructive on seedlings from European grown seed, but has not been observed on seedlings from domestically produced seed.

They found that cuprous oxide is an effective seed treatment where damping-off is caused by *Pythium* sp; but that organic mercury compounds (Ceresan and New Improved Ceresan) were more effective when *Rhizoctonia* and *Phoma* are involved. This somewhat confirms the observations of Coons and Stewart in 1927, when they recommended that a mixture of copper oxide and the mercury compounds be used for commercial beet seed treatments.

Influence of Cultural Practices

Coons and Kotila (19) made studies on the influence of preceding crops on damping-off of sugar beets. They found that the amount of damping-off of a beet crop was greatly increased when the beet crop was immediately preceded by a crop of sweet clover or alfalfa.

The growing of corn before beets resulted in significantly less damping-off of the following beet crop. A preceding crop of beans did not greatly alter the amount of damping-off. They concluded that "arrangement of crop rotations to avoid intensification of damping-off by alfalfa or the clovers, and to take advantage of its' reduction by corn should lead to improved sugar beet stands".

Influence of Fertilizers

A very limited amount of published material was found which stated that certain fertilizing elements had an effect on the amount of damping-off of sugar beet seedlings.

One of these articles was published in "Facts About Sugar" (18) from information given out by Dr. J. A. Brock and Col. Gallagher of the Continental Sugar Company. They stated that the addition of NaCl to "diseased soils" resulted in a marked decrease in the amount of damping-off of sugar beet seedlings grown on that soil, and also gave increased yields of beets. No explanation for the decrease in damping-off was given.

Lill, et al, (22) in experiments carried on in Michigan, demonstrated that the application of NaCl to beets resulted in larger numbers of commercial roots per acre, larger yields, and more sugar per acre. Chemical analyses of the roots showed that the addition of salt to the soil gave beets with a slightly higher potash content. Considering the higher yield, this resulted in a large increase in the amount of potash taken from an acre of soil. This is apparently true even when there is plenty of available potash in the soil.

There is an impression among some research workers that beet seedlings with a high potash content are more resistant to seedling diseases than those with a lower potash content.

Experimental Results

Muntz Farm - 1938

In this problem, the first attempt to control damping-off was made during the summer of 1938 on the Muntz farm at Holgate, Ohio. This was in a field which had been rented by the Farmers and Manufacturers Beet Sugar Association for experimental and demonstrational purposes. One part of the field had already been planted twice, and the stand was destroyed both times by damping-off. A third planting was made on July 7, using untreated commercial seed and using various soil amendments, as shown in the following outline.

Table 1 - Plot treatment and rate of application of Soil Amendments at Muntz Farm in 1938.

Plot	Fertilizer	Rate per Acre
1	Sodium Bicarbonate	700 lbs.
2	Muriate of Potash	300 lbs.
3	None (check)	---
4	Sodium Chloride	500 lbs.
5	Sodium Sulfate	600 lbs.
6	Di-calcium Phosphate	300 lbs.

The plots were 50 feet long and wide enough to accommodate 76 rows of beets. Fertilizer was applied crosswise of the rows of beets, the materials being broadcast on top of the ground after the seed bed had been prepared and before the seed was planted. None of the plots were replicated.

A small amount of damping-off was noted, there being no outstanding differences in the amount of damping off with the different treatments. The check plot was just as good as those which had received fertilizer. In all cases, plenty of healthy beets were present to leave a perfect stand after blocking and thinning.

At harvest time, the fertilized plots yielded more than the check plot, even though the entire field had received a total of 585 lbs. of complete fertilizer per acre in the previous plantings.

Greenhouse Work - 1938-1939

In the late fall of 1938, surface soil from the previously described plots at Holgate, Ohio, was sacked and taken to East Lansing for greenhouse work. This soil was selected because it was known to be thoroughly infested with the organisms causing damping-off.

In all greenhouse work, 10-inch pots were used. Each pot was planted with 75 seed balls which had been graded to remove the small seed.

The first greenhouse experiment was an attempt to demonstrate the effect of excess water on damping-off. Three pots of soil were made up from each of the previously mentioned plots at Holgate. These 18 pots were divided into three series, each series containing one pot from every plot. One of these series was kept excessively wet, another was kept in a wetter than normal condition, and the third series was kept at about optimum. This experiment was repeated three times, using the same soil. The following averages indicate the number of plants which had survived at the time the beets had developed the first pair of true leaves.

Table 2 - The number of seedlings which reached the two-leaved stage under three different moisture conditions.

	Replication of Pots						
Treatment	1	2	3	4	5	6	Average
Optimum Moisture	91	89	72	85	83	77	83
Above Opt. "	89	82	68	63	71	62	73
Excessive "	85	57	58	40	56	55	59

It is believed that this experiment demonstrates the value of good drainage in attempting to obtain a satisfactory stand of sugar beets.

In another experiment, limed soil was compared with unlimed soil. Soil from the Muntz farm was used in this experiment. The soil was placed in 10" pots and 75 graded seed balls were planted in each. Nine pots received calcium carbonate at the rate of 2,000 lbs. per acre and nine pots were untreated. The experiment was repeated on the same soil, so the averages shown below are for 18 pots of beets.

Table 3 - The average number of beets which reached the two-leaved stage on limed vs. unlimed soil.

Soil Treatment	Av. No. Two-leaved Beets
2,000 lbs. $CaCO_3$ / acre	97
No lime	29

It is possible that the amount of lime added to the soil was sufficient to raise the pH of the soil above the point which was optimum for the development of the damping-off organisms.

An experiment was conducted, using lime and sodium sulfate in various combinations. The soil was a uniform mixture taken from the Muntz farm plots at Holgate, Ohio.

One hundred seed balls were planted per pot.

The following tables show the results of the experiment.

Table 4 - The effect of lime on total number of beets, total weight of beets, and average weight of beets in a total of four pots.

Lime Application Pounds per acre	Total Number of Beets	Total Weight (Grams)	Average Weight (Grams)
None	904	45.48	.0503
200	895	54.65	.0611
400	840	52.75	.0628
600	620	53.38	.0861

Table 5 - The effect of lime on total number of beets, diseased beets, and per cent of diseased beets in a total of four pots.

Lime Application Pounds per acre	Total Number of Beets	Diseased Beets	Per Cent Diseased
None	904	740	82
200	895	396	44
400	840	441	53
600	620	110	18

Table 6 - The effect of sodium sulfate on total number of beets, total weight of beets, and average weight of beets in a total of four pots.

Sodium Sulfate Application Pounds per acre	Total Beets	Total Weight (Grams)	Average Weight (Grams)
None	631	39.94	.0633
200	819	52.68	.0643
400	892	58.40	.0655
600	917	55.24	.0602

Table 7 - The effect of sodium sulfate on total number of beets, diseased beets, and per cent of diseased beets in a total of four pots.

Sodium Sulfate Application Pounds per acre	Total Beets	Diseased Beets	Per cent Diseased
None	631	413	65
200	819	398	49
400	892	485	54
600	917	391	43

The results of this experiment show that the addition of lime was somewhat more beneficial in reducing damping-off than was the addition of the sodium sulfate.

As lime applications increased, the total number of beets decreased, and the weight per beet increased. The higher average weight is probably due to the fact that each beet had more plant food available for its use.

As sodium sulfate applications increased, the total number of beets also increased. This would indicate that the sodium compounds had probably reduced damping-off of the seedlings while they were yet very small and enabled larger numbers of them to survive.

An attempt to repeat this experiment on the same soil resulted in no differences between treatments and since it could not be repeated, the value of the results is not too great.

Holgate

An experiment, combining salt and lime, was carried out during the season of 1939 in the Northwest Test farm of the Ohio Agricultural

Experiment Station at Holgate, Ohio.

Four-row plots were used throughout the experiment. Salt and lime were applied at the rates of 0, 300# and 600# per acre in all possible combinations. This test was replicated twice.

The second part of the test combined sodium sulfate and lime, the sodium sulfate being substituted for salt and applied at the same rate per acre. This experiment was also replicated twice.

The following tables summarize the results of the experiment.

Table 8 - Showing the stand after thinning on plots receiving salt and lime treatments.

Salt Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	18277	19060	19908	19082
300#	19583	20104	18799	19495
600#	18669	20235	19844	19583
Average	18843	19800	19517	19387

Table 9 - Showing the stand after thinning on plots receiving sodium sulfate and lime treatments.

Sodium Sulfate Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	20431	18995	19647	19691
300#	19779	18473	20301	19518
600#	19126	20105	19648	19626
Average	19779	19191	19865	19612

Table 10 - Effect of salt and lime applications on the <u>number of beets</u> lost between thinning time and harvest time.

Salt Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	9857	10183	11031	10357
300#	9008	7441	5418	7289
600#	5222	5940	7311	6158
Average	8029	7855	7920	7935

Salt applications significant to the 1% point with a difference of 1653 beets.

Lime applications not significant.

Table 11 - Effect of sodium sulfate and lime applications on the number of beets lost between thinning time and harvest time.

Sodium Sulfate Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	10313	10052	8877	9748
300#	7768	8225	9139	8377
600#	8029	4896	6462	6462
Average	8703	7742	8159	8196

Sodium sulfate applications significant to the 5% point with a difference of 1633 beets.

Lime applications not significant.

Table 12 - Effect of salt and lime treatments on the number of marketable beets per acre at harvest time.

Salt Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	8420	8877	8877	8725
300#	10575	12663	13381	12206
600#	13447	14295	12533	13425
Average	10814	11945	11597	11452

Salt applications are significant to the 1% point with a difference of 806 beets.

Lime applications are not significant.

Table 13 - Effect of sodium sulfate and lime treatments on the number of marketable beets per acre at harvest time.

Sodium Sulfate Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	10118	8943	10770	9943
300#	12011	10248	11162	11140
600#	11097	15209	13186	13164
Average	11075	11466	11706	11416

Sodium sulfate applications are significant to the 5% point with a difference of 1557 beets.

Lime applications are not significant.

Table 14 - Effect of salt and lime treatment on the tons of beets per acre.

Salt Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	1.50	1.66	1.83	1.66
300#	2.38	3.43	3.62	3.14
600#	4.90	4.86	3.95	4.57
Average	2.93	3.32	3.13	3.13

Salt applications significant to the 1% point with a difference of .27 tons.

Lime applications not significant.

Table 15 - Effect of sodium sulfate and lime treatments on the tons of beets per acre.

Sodium Sulfate Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	2.77	1.99	2.28	2.35
300#	3.04	2.55	3.00	2.86
600#	2.90	4.54	4.47	3.97
Average	2.90	3.02	3.25	3.06

Sodium sulfate applications significant to the 5% point with a difference of .81 tons.

Lime applications not significant.

Table 16 - Effect of salt and lime treatments on the sucrose percentage of the beets.

Salt Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	14.61	14.88	14.86	14.78
300#	15.69	15.55	15.98	15.74
600#	16.08	17.00	16.56	16.55
Average	15.46	15.81	15.80	15.69

Salt applications significant to the 1% point with a difference of 1.09%.

Lime applications not significant.

Table 17 - Effect of sodium sulfate and lime treatments on the sucrose percentage of the beets.

Sodium Sulfate Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	15.35	14.58	14.74	14.89
300#	15.46	15.31	15.71	15.49
600#	15.98	15.76	16.02	15.92
Average	15.60	15.22	15.49	15.43

Salt applications significant to the 5% point with a difference of 1.00%.

Lime applications not significant.

Table 18 - Effect of salt and lime treatments on the purity coefficient of extracted juice of beets from the treated plots.

Salt Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	88.57	87.53	87.08	87.72
300#	89.21	87.68	89.83	88.91
600#	88.79	88.97	87.79	88.52
Average	88.86	88.06	88.23	88.38

Salt applications not significant.

Lime applications not significant.

Table 19 - Effect of sodium sulfate and lime treatments on the purity coefficient of extracted juice of beets from the treated plots.

Sodium Sulfate Applications Per Acre	Lime Applications in Pounds Per Acre			Average
	None	300#	600#	
None	87.63	87.15	86.97	87.25
300#	88.58	88.43	89.13	88.71
600#	89.31	87.62	88.72	88.55
Average	88.50	87.73	88.27	88.17

Sodium sulfate applications significant to the 5% point with a difference of 1.54%.

Lime applications not significant,

The above tables show that both salt and sodium sulfate gave more beets per acre, higher yields per acre, smaller losses of beets between thinning time and harvest time and higher sugar content. Only sodium sulfate gave a higher purity coefficient of the samples taken at harvest time. Salt did not lower the purity coefficient of the beets.

Merrill Experiment

A planting of "muck beets" was made in 1939, on the Merrill farm of the Lake Shore Sugar Company for the purpose of producing stecklings.

Permission was obtained to apply various soil amendments in an attempt to find their value in reducing damping-off of the seedling beets.

The area planted consisted of twelve rows of beets, each one-half mile long. They were planted in 24" rows on June 20, at the rate of eighteen pounds of seed per acre.

Soil amendments were placed on top of the row after the beets were planted. The materials were distributed as evenly as possible, but since each row was a half-mile long, a perfect job of distribution was not accomplished.

After the seedlings had reached the two-leaved stage, stand counts were made on them. In making this count, a stake 42.5" long was placed beside the row. The number of diseased beets in this space was counted as well as the total number of beets. Ten counts were made at regular intervals in each row.

Table 20 gives an outline of the experiment, and shows the results of the stand counts.

Due to variations in the application of the soil amendments, no definite conclusions are drawn. It appears that the application of salt reduced the amount of damping-off but also reduced the number of seedlings which emerged from the ground. This was especially true of the 300# application. If rainfall had been more plentiful at the time of germination and emergence, it is possible that the heavy applications of salt would have been diluted to the point where they would not have been injurious.

Table 20 - Showing the soil amendments used, the rate of application, total number of beets in 425" of row, number of diseased beets in this area, and per cent of disease.

Row	Lime	Salt	Magnesium Sulfate	Total	Diseased	Per Cent Diseased
	Lbs. per Acre			Beets in 425" of row		
Buffer	500	100	50	479	4	0.8
1	1500	0	0	322	32	9.9
2	1000	100	0	358	31	8.7
3	1000	0	50	399	82	20.6
4	500	200	0	261	11	4.2
5	500	100	50	319	49	15.4
6	500	0	100	393	80	20.4
7	0	300	0	54	1	1.9
8	0	200	50	217	16	7.4
9	0	100	100	460	28	6.1
10	0	0	150	465	141	30.3
Buffer	500	100	50	337	23	6.8

Results of Fertilizer and Seed Treatment Trials -1939

A combination of fertilizer and seed treatment trials were carried out on the Experiment Station farm at East Lansing during the summer of 1939.

Fifteen five-row plots, each 336 feet long, were laid out on soil which had previously received a blanket application of 400# of a 4-16-4 fertilizer per acre:

These plots received additional fertilizer and seed treatments as follows:

Table 21 - Outline of plots used for fertilizer and seed treatment work at East Lansing in 1939.

Plot	Seed Treatment	Fertilizer per Acre
1	Treated	50# Borax
2	"	None
3	"	"
4	"	"
5	Not treated	"
6	Treated	400# Muriate of Potash
7	"	" " " " + 500# Lime
8	"	500# Lime
9	"	400# 44% Super Phosphate
10	Not treated	None
11	Treated	400# 44% Super Phosphate + 500# Lime
12	"	500# Lime
13	"	400# Muriate of Potash
14	"	" " " " + 500# Lime
15	Not treated	None

Each plot consisted of five rows, and with the exception of the checks, (plots 5, 10 and 15) each individual row of the plot was planted with seed which had been dusted with a different seed treatment according to the following plan.

	Seed Treatment	Rate of Application to Seed
North row	Cuprocide	1:50
Second row	Copper carbonate	1:50
Middle row	2% Ceresan	1:50
Fourth row	Vasco - 4	1:25
South row	New Improved Ceresan	1:100

The rate of application and sequence of seed treatments were followed uniformly on all treated plots.

A variety of Danish seed was used on all plots at the rate of fifteen pounds per acre, and was planted on May 19.

The fertilizer was applied on top of the row after the seed had been planted, the idea being to have a fairly high concentration of fertilizer near the seedlings at the time they emerged from the soil. The purpose of this was to determine whether different fertilizers had an effect on the amount of damping-off of the seedlings.

Stand counts were made on the seedlings as soon as it was thought they had all emerged from the soil and also after blocking and thinning. A final stand count was made at harvest time. The figures from this count were used to compute the number of beets per acre as shown in Table 3. While greater differences were shown in the original stand count, it was felt that the final stand count was the better measure of the true worth of the various treatments.

At harvest time, all the beets were weighed to determine the exact yield resulting from each of the various treatments.

Four samples, each consisting of fifteen average-sized beets, were taken from each row and analyzed in the laboratory for sugar and purity.

A summary of the results is given in the following tables.

Table 22 - Effect of Fertilizer and Seed Treatments on the Calculated Number of Seedling Beets Per Acre Before Thinning.

Number of Seedling Beets Per Acre

Fertilizer Per Acre	No. of Plots	No Treatment	SEED TREATMENTS					Average
			Cupro-cide	Copper Carbonate	2% Ceresan	Vasco-4	New Improved Ceresan	
None	3	40720						40720
None	3		74131	32826	76568	34641	111235	65880
50# Borax	1		134959	78408	120335	113023	134959	116337
400# Muriate of Potash	2		61995	82959	177780	75686	115784	102841
400# Muriate of Potash 500# Lime	2		113956	102094	125819	64718	88404	98998
500# Lime	2		100266	46516	185053	41032	171363	108846
400# 44% Super Phosphate	1		105789	51028	116679	40138	125780	87883
400# 44% Super Phosphate 500# Lime	1		109367	71096	187775	30959	200532	119946
Average		40720	93745	63512	135983	54243	128840	84356

The above figures were calculated from counts made at four places in each 336' row. A 43" stake was placed beside the row and counts were made of the number of beet seedlings in this space. The figures are not considered to be entirely valid, due to the fact that all the seedlings were not actually counted. The indicated tendencies, however, are worthy of consideration.

Table 23 - Effect of Fertilizer and Seed Treatments on the Calculated Number of Beets per Acre After Thinning.

Fertilizer Per Acre	No. of Plots	No Treatment	Number of Beets Per Acre — SEED TREATMENTS: Cuprocide	Copper Carbonate	2% Ceresan	Vasco-4	New Improved Ceresan	Average
None	3	14002						14002
None	3		18695	13042	18773	12109	22117	16947
50# Borax	1		21547	18046	21391	23569	21625	21236
400# Muriate of Potash	2		21274	21897	22208	20205	20924	21302
400# Muriate of Potash 500# Lime	2		24230	22091	23297	18224	21897	21948
500# Lime	2		20963	17152	22519	14157	23997	19758
400# 44% Super Phosphate	1		21702	17813	23080	14235	20458	19458
400# 44% Super Phosphate 500# Lime	1		22869	17282	21313	13846	22791	19620
Average		14002	21261	17879	21513	16096	22072	18612

Table 24 - Effect of Fertilizer and Seed Treatments on the Calculated Number of Beets Per Acre At Harvest Time.

Fertilizer Per Acre	No. of Plots	No Treatment	Number of Beets Per Acre — SEED TREATMENTS: Cupro-cide	Copper Carbonate	2% Ceresan	Vasco-4	New Improved Ceresan	Average
None	3	13261						13261
None	3		17450	13016	16932	11564	20951	15983
50# Borax	1		21002	16802	20536	22402	19680	20084
400# Muriate of Potash	2		20730	21313	21352	20185	20691	20854
400# Muriate of Potash 500# Lime	2		24036	20808	22558	18163	21508	21415
500# Lime	2		20147	16530	21274	13846	22558	18871
400# 44% Super Phosphate	1		20924	16802	22714	14157	19758	18871
400# 44% Super Phosphate 500# Lime	1		22480	17268	20924	13613	20769	19011
Average		13261	20549	17269	20445	15771	21048	17865

Table 25 - Effect of Fertilizer and Seed Treatments on the Calculated Tons of Beets Per Acre.

Fertilizer Per Acre	No. of Plots	No Treatment	SEED TREATMENTS					Average
			Cuprocide	Copper Carbonate	2% Ceresan	Vasco-4	New Improved Ceresan	
None	3	10.99						10.99
None	3		12.66	9.84	12.69	8.39	13.20	11.36
50# Borax	1		12.68	11.12	12.21	13.53	10.97	12.10
400# Muriate of Potash	2		13.75	13.61	12.99	13.18	11.30	12.97
400# Muriate of Potash 500# Lime	2		13.83	13.32	13.30	11.81	13.17	13.09
500# Lime	2		12.95	11.19	13.03	9.80	13.09	12.01
400# 44% Super Phosphate	1		13.07	10.89	13.26	9.65	13.53	12.08
400# 44% Super Phosphate 500# Lime	1		14.86	11.98	14.04	10.35	13.42	12.93
Averages		10.99	13.30	11.65	13.02	10.69	12.72	12.02 +

Table 26 - Effect of Fertilizer and Seed Treatments on the Calculated Amount of Recoverable Sugar Per Acre.

Fertilizer Per Acre	No. of Plots	No Treatment	SEED TREATMENTS					Average
			Cupro-cide	Copper Carbonate	2% Ceresan	Vasco-4	New Improved Ceresan	
None	3	3358						3358
None	3		3896	3063	3920	2564	4157	3520
50# Borax	1		4311	3603	3832	4311	3606	3933
400# Muriate of Potash	2		4377	4455	4384	4264	3668	4230
400# Muriate of Potash 500# Lime	2		4546	4419	4456	3896	4153	4294
500# Lime	2		4183	3711	4166	3082	4337	3896
400# 44% Super Phosphate	1		4224	3416	4242	3122	4271	3855
400# 44% Super Phosphate 500# Lime	1		4801	3747	4593	3357	4372	4174
Average		3358	4270	3760	4203	3414	4086	3829

The experimental data show that the following seed treatments decreased disease losses at East Lansing in 1939: Cuprocide (Red Copper Oxide); 2 per cent Ceresan (organic mercury compounds). Treatment with Copper Carbonate gave results intermediate between those of the above-mentioned seed treatments and the check. Vasco-4 (a zinc compound) was about equal to the non-treated plots.

Plots receiving fertilizer in addition to the general application were better than those which did not receive the extra fertilizer. Borax appeared to give very good results under the conditions which existed at East Lansing. In combination with Vasco-4 it resulted in almost twice as many beets per acre at harvest time as the plots treated with Vasco-4 without the additional borax.

The addition of lime to plots fertilized with either potash or phosphorus resulted in an increase in beets per acre and recoverable sugar over the plots which received potash or phosphorus alone.

Tonnage of beets and recoverable sugar per acre were closely correlated.

The percentage of sucrose and per cent purity showed very slight variations. The plots receiving fertilizer were slightly higher in quality than those which received no fertilizer.

Summary

Some general conclusions may be drawn from the experimental work which was carried out on this problem.

The addition of sodium compounds (salt and sodium sulfate) to the soil, in these experiments resulted in fewer seedlings being lost by damping-off; and gave increased tonnage and recoverable sugar per acre without a decrease in sucrose percentage or a decrease in the purity coefficient.

Seed treatments with copper and mercury compounds cut down on seedling losses at East Lansing in 1939.

The application of borax to the soil at East Lansing indicates that boron deficiency may reduce beet yields very materially on some of our beet growing soils in the state.

Lime applications seemed to be slightly beneficial on soil from Ohio which was used in the greenhouse. This seemed to hold true, even though the soil did not show an acid reaction.

Conclusions

Experience has shown experimental workers that there is no "cure-all" which will prevent the loss of beet-seedlings from damping-off. Control of the disease can apparently be accomplished by the adoption of good cultural practices.

Proper drainage is one of the first essentials. (Page 12). Damping-off organisms thrive under wet conditions, therefore it is necessary that the beet grower have facilities for getting excess water from his fields as soon as possible.

Crop rotation is another important factor. (Coons and Kotila, Page 9). The rotation should be long enough to allow all beet refuse to decay in the soil, since this refuse may carry the organisms which cause damping-off and other diseases. The recommended length of rotation is from four to five years.

Fertilization is another essential (Brock and Gallagher, Page 10; Lill, et al, Page 10). While most beet soils are naturally fertile, it is profitable to supplement this with additional fertilizing materials. Commercial fertilizers, barnyard manure, green manure and the plowing down of plant refuse are all valuable for adding plant-food elements and humus to the soil. The addition of sodium compounds (Page 14) helps to reduce damping-off but seems to give best results when plenty of other plant food elements are present.

Early cultivation, for the purpose of getting air into the surface of the soil, is oftentimes very valuable in reducing losses from damping-off.

The dusting of seed probably should be regarded as a form of insurance. As yet it cannot be recommended for commercial use, due to the great variations in the results it has given.

Summarizing the above conclusions, we note that they are the practices normally followed by good farmers. While these practices may not give absolute control of damping-off in all cases, yet they will reduce it to a minimum. In addition, the adopting of these practices will probably increase yields and net profits sufficiently to more than pay for the extra labor which their adoption may require.

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